15 | EXECUTIVE FUNCTIONS

SUSAN M. FITZPATRICK and CAROLYN M. BAUM

15.1 STROKE REHABILITATION: THE ROLE OF EXECUTIVE FUNCTIONS

Rehabilitation for people recovering from stroke focuses on restoring the ability to perform the activities required for living independently. For the most part, clinical neu­rehabilitation concentrates on interventions designed to treat motor and language impairments. The difficulties an individual may experience from impairments of high-level cognitive functions, typically labeled executive functions, are often apparent in clinical settings and are often not the focus of therapy. Part of the reason executive functions may be somewhat overlooked in clinical care is that executive functions have been defined in a number of contexts ranging from experiential cognitive studies to neuropsychological assessments. There is no commonly agreed set of cognitive abilities or neural structures uniquely identified as supporting executive functions. Rebecca Elliot (2003) provides a good summary of why the term executive functions is not a unitary concept. In this chapter, we will attempt to integrate across the behavioral, cognitive, and neural descriptions of executive functions in an effort to identify gaps in our knowledge that, if filled, could be helpful in translating research findings into clinical practice.

In general, cognitive psychologists describe executive functions as (i) the ability to exhibit flexible adaptive behavior, (ii) the use of appropriate problem-solving strategies as required for maintaining and updating goals, (iii) the capacity to monitor the consequences of actions, and (iv) the ability to use prior knowledge to correctly interpret future events (Miyake & Shah, 1999). Cognitively, the term executive functions also derives from the idea of top-down control by a central executive, as proposed in models of working memory (Baddeley, 2001) or of attentional control (Lezak, 1982, 2004; Prigatano, 1999; Dosenbach et al., 2008). Their difficulties may not become apparent until they attempt to resume unstructured activities at home, work, or in social situations. Chan et al. (2008) provide a comprehensive review of the various cognitive neuroscience models proposed for executive functioning and discuss some of the difficulties with assessing cognitive contributions to complex behaviors in the laboratory, in clinical settings, and in everyday life. Brain injury as a result of stroke is a leading cause of individuals becoming unable to carry out the activities central to their daily life (Cardol et al., 2002). Considering the impact of stroke on everyday functioning, it is unsurprising that 85% of people who survive a stroke return home (Reuter-Bernays & Rentsch, 1993). Stroke can result in a wide range of deficits, including executive function deficits. When not identified and managed, these functional deficits lead to restrictions in home, work, and community activities, even if by clinical assessment the deficits are considered "mild" (Pujol et al., 2007; Roach et al., 2007). The cognitive deficits associated with stroke vary in type and severity from individual to individual, based on site and lesion (s) location, but Zinn, Bosworth, Hoening, and Swartzwelder (2007) found that nearly 50% of individuals show deficits in executive function. We suspect this number underestimates the true incidence of high-level cognitive difficulties.

The Cognitive Rehabilitation Research Group (CRRG) at Washington University in St. Louis maintains a large database of information regarding stroke patients admitted to Barnes-Jewish Hospital. As of December 2009, the CRRG research team had evaluated 9,000 patients hospitalized for stroke. Although stroke is often associated with elderly populations, nearly half of the patients (46%) were younger than 65. About 95% patients (50%), were classified as having mild stroke (National Institute of Health Stroke Scale score = 0 to 5). In a subsample of 110 patients, 69% were found to have executive dysfunction as measured on behavior and performance tests (Baum, 2009; Wolf et al., 2009). The demographics of stroke evidence in the Washington University database—younger and with milder disability—presents an eye-opening challenge for rehabilitation professionals. Younger stroke survivors may be conversant with special forms of returning to work and to the myriad demands of active family and social life. Unlike older stroke survivors, whose lives may be more structured and thus more readily routinized, younger individuals were engaged in more demanding forms of work. Such dependency on the flexibility provided by intact executive functioning (Wolf et al., 2009; O'Brien & Wolf, 2010). To meet the needs and expectations of younger stroke patients, neu­rehabilitation approaches must be prepared to address deficits in executive functions.

In this chapter, our performance-based definition of executive functions and executive dysfunction overlaps with but is not ably by

executive dysfunction

equivalent to, neuropsychological tasks primarily reliant on cognitive neuro­science, and cognitive neuroscience (Elliot, 2003). Rather than exhaustively review the decades of research pertinent to executive functions, including the large bodies of research carried out on working memory and attention, we decided to use this chapter as an opportu­nity to explore how the concept “executive function” is used by different disciplines, in what ways the uses of the concept are similar or different, and the opportunities and challenges are to be met when integrating findings from across the disciplines to yield a coherent understanding at the neural, cognitive, and behavioral/ performance levels, so that research findings can be used to inform clinical practice aimed at ameliorating executive dysfunction. It is our goal to identify the language and knowledge gaps that could be hindering the successful translation of experimen­tal knowledge into practical applications for individuals recovering from stroke. It is not possible to overemphasize how difficult such integrative work can be. For the past several years, the James S. McDonnell Foundation has been encouraging working groups composed of basic cognitive neuroscientists and academic clinicians to develop consensus reviews for diagnosis and treatment based on a cognitive neuroscience model called CAP (computation­anatomy-­psychology; Corbett & Fitzpatrick, 2011). The first series of papers, on action rehabilitation, recently appeared as a special issue to Neurorehabilitation and Repair (Frey et al., 2011; Pomeroy et al., 2011; Sathian et al., 2011) and serves as one model for developing mutually agreed-upon language and concepts.

In this chapter, we review not only the measures used to identify executive dysfunction and the interventions targeted to executive dysfunction at the neural, behavior, and performance levels. For the purposes of this chapter, only key findings from the cited papers pertinent to the chapter’s goals are provided; readers are encouraged to consult the original papers for more complete details. The approach we’ve selected begins with examining the current understand­ing of executive function at the multiple levels of analysis we call Brain (including neural and cognitive systems), Behavior, and Performance. Figure 15.1 provides a

Figure 15.1 The Language of Executive Function At Multiple Levels

<table>
<thead>
<tr>
<th>BRAIN</th>
<th>BEHAVIOR</th>
<th>PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nervous System</td>
<td>Brain Behavior</td>
<td>Rewidth Consequences</td>
</tr>
<tr>
<td>Motor</td>
<td>Working memory</td>
<td>Initiation</td>
</tr>
<tr>
<td>Sensory</td>
<td>Attention</td>
<td>Risk-taking</td>
</tr>
<tr>
<td>Inte­gration</td>
<td>Awareness</td>
<td>Reaction time</td>
</tr>
<tr>
<td>Multisensory</td>
<td>Autonomy</td>
<td>Change sets</td>
</tr>
<tr>
<td>Regional specializations</td>
<td>Fatigue</td>
<td>False to inhibit</td>
</tr>
</tbody>
</table>

Figure 15.1 The Language of Executive Function At Multiple Levels

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Executive functions are required to perform complex tasks. Complex tasks require goals to be formulated, and performance is a particular sequence of actions. In carrying out complex tasks, the task rules or contexts can change, and there is often competing stimuli that must be ignored to accomplish the task (Jonides & Shallice, 1996; Kaplan & Berman, 2010). When considering performance, at least five cognitive constructs have empirical support as major components of executive functioning: (i) inhibition, (ii) working memory, (iii) set-shifting, (iv) set shifting, and (v) emotional regulation (Norman & Shallice, 1986; Shallice, Levin, Eisenberg, & Benton, 1991; Baddeley, 1996; Goldman-Rakic, 1986; Smith & Jones, 1999; Jonides & Smith, 1997; Miyake et al., 2000; Brauer, Cohen, & Barch, 2002; Diamond, 2000). In essence, executive functions make it possible for humans to successfully encounter novelty. Executive functions rely on connections to other areas throughout the brain. Executive functions are among the most complex functions of the human brain and are central to being able to perform activities at home, work, and in community life.

Both experimental and clinical studies support the theory that executive dysfunction only to frontal lobe injury; however, we now recognize that individuals can experience executive dysfunction even in absence of frontal lobe injury (Tranel, Anderson, & Benton, 1994; Manchester et al., 2004). In fact, there has been some evidence to support the theory that executive dysfunction is more likely attributed to diffuse lesions in the brain (Stein & Levine, 2002; Pessin, 2008). Almost any brain injury disrupting the networks supporting executive function can be expected to lead to cognitive, behavioral, and performance problems to a greater or lesser extent. Being able to identify patterns of neural injury predictive of the extent and nature of executive dysfunction is central to creating a feasible post-stroke treatment plan. If, as we discuss above, the concept of "executive functions" does not neatly map onto identifiable cognitive operations, it is even more difficult to map the disruptions of executive functions suspected of supporting complex human behaviors onto discrete neural structures. In part, the difficulty derives from the observation that executive functions are behaviorally context-dependent, and are characterized as the dynamic deployment of cognitive resources. Although published more than 2 decades ago, a review by Posner and Petersen (1990) provides a cogent discussion of the challenges inherent in the attempts to map processes described at the cognitive level of analysis onto neural substrates. Posner and Petersen's concepts remain relevant today and should guide practical interpretation of research findings.

Neurorehabilitation researchers and clinicians should be cautious of overgeneralizing from brain models of executive functions proposed by cognitive neuroscientists, particularly if based primarily on functional imaging studies, because imaging research can be performed with the task performed during data acquisition and on the experimental context. Cognitive neuroscience studies of attention, working memory, or set-shifting with experimental tasks designed to probe specific cognitive processes (e.g., Stroop task, N-back test, or Wisconsin card sorting task) should not be taken as complete proxies for complex more for real-world performances (see discussion in Chan et al., 2008).

Translating from cognitive neuroscience to neurorehabilitation is also complicated by the presence of posture. Cognitive neuroscience studies of attention, working memory, or set-shifting with experimental tasks designed to probe specific cognitive processes (e.g., Stroop task, N-back test, or Wisconsin card sorting task) should not be taken as complete proxies for complex more for real-world performances (see discussion in Chan et al., 2008).

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15.3 NEURAL SUBSTRATES OF EXECUTIVE FUNCTIONS

Much of what is known about the neural systems supporting executive functions has been derived from neuropsychological studies. The frontal cortex is also central to being able to perform activities at home, work, and in community life.

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Figure 15.3 Neurons of Executive Function at Multiple Levels. Note: This list is not exhaustive but is meant to introduce interventions at different levels.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefrontal Cortex</td>
<td>Executive Function</td>
</tr>
<tr>
<td>Motor Cortex</td>
<td>Motor Function</td>
</tr>
<tr>
<td>Limbic System</td>
<td>Emotion Regulation</td>
</tr>
<tr>
<td>Default Mode Network</td>
<td>Perception</td>
</tr>
</tbody>
</table>

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Evidence is accumulating on how neuromodulatory neurotransmitters influence activity in cortical-striatal circuits implicated for working memory deficits responsible for performance of cognitive tasks, such as those known to rely on working memory, a key component of executive functions (for reviews see Cool & D’Esposito, 2009; Robbins & Arntsen, 2009). In particular, converging evidence from cognitive neuroimaging studies carried out with rodents, nonhuman primates, and human subjects underscores the importance of dopamine neuro-modulation on performance of working memory dependent tasks.

Although most of the functional imaging studies reporting results on the role of neurotransmitters and neuromodulators during performance of cognitive tasks are typically carried out with healthy participants without neuromodulatory deficits, a few studies have also been carried out with patient populations. People with Parkinson’s disease are, not surprisingly, important for studies looking at the effects of dopamine on cognitive function. The results of such studies taken together with theoretical models describing how different brain regions interact to accomplish complex tasks are intriguing enough to encourage further experimental studies and are of potential interest to rehabilitation. Before pharmacological interventions can be used effectively, much remains to be learned from studies with defined patient populations with an eye toward delineating how pharmacological approaches may or may not be helpful with individuals with compromised neurological function and difficulties performing complex working-memory dependent tasks.

The current understanding is that neurons in the prefrontal cortex, an area known to be important in the performance of working-memory-dependent tasks, receive modulatory input from ascending dopaminergic midbrain neurons (i.e., the striatum) for review see Cool & D’Esposito, 2009). Communication between the prefrontal cortex (PFC) and the striatum is important for optimal working memory performance. In contrast, a role of these ascending fibers is to stabilize task-relevant working memory representations or, in other words, to decrease an individual’s susceptibility to distractions during task performance. It can be tempting in light of the experimental evidence to consider the possibility that neuromodulatory processes may be leveraged to enhance recovery from working memory deficits could be helped by the administration of dopamine agonists, either alone or in conjunction with rehabilitation. However, a series of publications from Mark D’Esposito’s laboratory, reviewed below, provide a cautionary note in need of further clarification. When rehabilitation practitioners look to translate experimental results. Attempting to modulate cognitive performance by tinkering with the complex, dynamic, and adaptive nature of chemical neurotransmission requires detailed understanding.

Wallace et al. (2011) evaluated the influence of dopaminergic modulation on measures of prefrontal cortex-striatal functional connectivity by reanalyzing data from a study with human subjects (Gibbs & D’Esposito, 2005) that reported the effects of the dopamine D2 receptor agonist bromocriptine in conjunction with a functional neuroimaging study during performance on verbal delayed-recognition tasks. The principle finding was that bromocriptine appeared to modulate the putative PFC-dependent retrieval rate, but not the encoding or retention stages of the task.

Following up the previous findings, Wallace et al. (2011) reanalyzed the neuroimaging data obtained from subjects in the Gibbs and D’Esposito (2005) study in an effort to tease out the effects of bromocriptine on the functional connectivity of the prefrontal cortex and the striatum during working memory tasks. Before exploring the neuroimaging results, it is critical to note the behavioral observation that dopamine augmentation yields an inverted U-shaped curve with respect to task performance. Too little or too much dopamine appears to negatively influence behavior (see discussion in Gjedde et al., 2010). Behaviorally, individuals can be characterized as belonging to either a high-span working memory group or a low-span working memory group. Interestingly, bromocriptine administration improved task-related speed and accuracy only in low working memory span individuals. High working memory span individuals trended toward a decrement in performance. Importantly, the effects are not explained by changes in either motor speed or vigilance. The findings raise important implications for dopamine augmentation in rehabilitation, as discussed below.

When Wallace et al. (2011) analyzed the imaging data to obtain a measure of fronto-striatal connectivity, the principle finding was that bromocriptine administration increased the measured connectivity in low working memory span individuals and was positively correlated with the improved behavioral performance on the experimental task. Similarly, bromocriptine exerted a negative effect on fronto-striatal connectivity in the high working memory span individuals, again correlating with the behavioral performance through both the imaging and the performance data failed to reach statistical significance, possibly due to the small sample size. The findings, albeit obtained from healthy young participants in a carefully controlled experimental setting, still offer some intriguing implications for additional research.

15.1. NEURAL MEASURES AND INTERVENTIONS

It is important that stroke patients be assessed with structural neural imaging methods to determine the full extent of their injuries. Refer to Figure 15.2 and 15.3. It is useful to have anatomical imaging (CT or MRI) to make a determination of the structural integrity of the brain, and diffusion tensor or diffusion weight imaging to assess white matter integrity. Ramirez, Gao, and Black (2008) provide a detailed overview of clinical brain imaging methods and how these tools can contribute to a neuroanatomical/neuropsychological disorder for neurorehabilitation (see also Chapter 4). Increasingly, resting state functional connectivity blood oxygenation level dependent (BOLD) processing techniques are being used to provide a case study underscoring the need that these methods specifically address the needs of clinical populations with neurological insults affecting large neural networks and multiple neurotransmitter systems. Some of the questions that will need to be answered include the following:

- Could dopamine augmentation help individuals demonstrate post-stroke deficits dependent on working memory functions?
- Are there diagnostic measurements that could reliably ascertain which patients are likely to benefit?
- Knowing that understimulation or overtreatment could result in negative effects, how will the optimal dose be determined for individual patients?
- How could dopamine augmentation be optimally paired with behavioral interventions?
- Will pharmacological resistance develop over time as part of an adaptive response?
- What are the unwanted effects?
- Will dopamine augmentation yield behaviorally meaningful improvement?

Answering these questions, and the myriad others expected to arise in the clinical setting, suggests some general translational research principles regarding what needs to be determined prior to adoption of neuromedical adjunctions to behavioral rehabilitation interventions. This will be the case whether the neuromodulation is obtained via pharmacological treatments or by the application of electrical stimulation (for further discussion see Botezich, 2004, and Chapter 10). Carrying out such research will require the infrastructure and resources needed to support multidisciplinary teams with expertise in neuroscience, computational modeling, imaging, cognitive psychology, neurology, and rehabilitation.
research and clinicians interested in considering how neuropsychopharmacology could influence the behaviour of post-stroke dysfunction or recovery. Narushima and colleagues also suggest that antidepressant therapy may aid recovery of executive functions by upregulating neurotransmitters and thereby enhancing neuroplasticity (Narushima et al., 2007). A similar mechanism of action has been suggested, based on experimental studies with murine brain slices, as contributing to the action of cortical stimulation techniques (Fritzen et al., 2010).

We admit that it is appealing to consider the use of pharmacological agents to alter plasticity and network reorganization to make the state of the system more responsive to rehabilitation. Mind the cautionary "case study" provided in Box 1 explaining how knowledge gaps that must be bridged if the field of neurorehabilitation is to translate experimental findings into clinical applications. The challenge for any intervention directed at the neuroplasticity level is demonstrating that the resulting changes are confined to the neural level but can yield or enable changes and meaningful improvements at higher levels of analysis.

If an intervention is to be useful in rehabilitation, it is not enough to demonstrate that a pharmacological agent may increase, for example, long-term potentiation (LTP) as a proxy for synaptic plasticity unless there is also evidence that alterations in synaptic plasticity allows for meaningful behavioral changes and that the changes are not confined to the neural level but can yield or enable changes and meaningful improvements at higher levels of analysis. Although interventions that target neuroplasticity have been proposed, it is still not known whether these interventions can be translated into clinical applications. This is particularly true for interventions that target neuroplasticity in chronic stroke patients, where the evidence is still limited.

Nevertheless, the evidence that antidepressant therapy can have a positive effect on executive functioning post-stroke (Narushima et al., 2007). The authors propose that the effect could be mediated via a monoaminergic modulation of frontal-striatal networks. Robbins and Aronson (2009) have published an authoritative and comprehensive review of experimental and clinical evidence for the role of monoaminergic modulation of executive functions in the context of mental disorders that is recommended for all researchers and clinicians interested in considering how neuropsychopharmacology could influence the behaviour of post-stroke dysfunction or recovery. Narushima and colleagues also suggest that antidepressant therapy may aid recovery of executive functions by upregulating neurotransmitters and thereby enhancing neuroplasticity (Narushima et al., 2007). A similar mechanism of action has been suggested, based on experimental studies with murine brain slices, as contributing to the action of cortical stimulation techniques (Fritzen et al., 2010).
appraise one's strengths and weaknesses in activities of daily living, behavioral and emotional function, and cognitive and physical function following brain injury. The respondent's responses are compared to a relative's or therapist's observations. Awareness is a serious problem when a person has executive dysfunction, since the first step in learning new strategies to manage an executive function deficit is to know that you have a problem that needs new strategies.

15.4.3 PERFORMANCE-BASED TESTS

Neuropsychological tests are designed to document the relationship between brain function and behavior. The finding of neuropsychological assessment is to provide an accurate depiction of an individual's specific cognitive impairments (e.g., working memory deficit), as well as assessing how well component cognitive processes work together to accomplish a task. However, these tasks tend to ignore the person-environment interaction. The natural and built environment can both support and hinder performance in ways that might not be obvious in the absence of a complete understanding of what cognitive resources are actually required. Clarity in the task demands and the available affordances are critical in planning interventions and working with patients and their families to help them learn to manage the consequences of executive dysfunction. Performance-based tasks, primarily developed by occupational therapists, take a different approach from what we have described for neuropsychological tests and seek to answer a different question about executive function. "How does the brain and cognition support the everyday performance of tasks necessary to live independently, be safe, to manage daily affairs?" Using a performance approach, executive function is examined as a person performs an actual task, an actual task that is necessary in everyday life. Clearly, linking performance to the underlying neural structures supporting performance requires intermediate cognitive models. A discussion of this distinction in levels of analysis carries important lessons for rehabilitation (Breuer, 1997).

It should not be assumed that impairment in a cognitive process will result in impairments in overall functional capacity, because activities can be accomplished by employing different strategies and by different levels of motivation, interest, and different environments. For example, there are many ways individuals can navigate a grocery store even if the end goal, buying all the items on a list as quickly as possible, is identical. By conceptualizing the task differently, different cognitive resources and brain networks are brought to the goal. It is, however, important to learn how it is that a person plans and executes a task. For example, whether a great meal is provided by selecting and buying all the items on a list or whether a great meal is provided by selecting and buying a great deal of food is not the same task. It is possible to assess the sequence and activities over many days until the task is mastered. The EFPT provides a record of executive functions serving in the perfor-

15.5 BEHAVIORAL AND PERFORMANCE INTERVENTIONS

Throughout this chapter we have made the point that executive functions serves as an "umbrella term" for a constellation of cognitive processes supporting complex behaviors (Elliott, 2003). It should not come as a surprise that, as a result of this complexity, individuals with executive function impairment are somewhat resistant to rehabilitative efforts. There are some promising strategies addressing the rehabilitation of executive functions that deserve further study. Of course, rehabilitation interventions for executive dysfunction can share many of the problems encountered in rehabilitation more generally, including lack of well-designed intervention trials with outcome measures linked to the stated goals. Thus, in planning intervention strategies will be presented, two at the behavioral level and two at the performance level. Refer to Figure 15.3.

15.5.1 INTERVENTIONS AT THE BEHAVIORAL LEVEL

Goal Management Training (GMT) is a neuropsychological intervention developed to teach patients with brain injury a strategy for planning and implementing activities and to structure their intentions. It is based on Duncan's theory of goal neglect. The theory states that any activity requires the person to establish goals and/or task requirements to create the structure to guide the actions that will lead to the goals being achieved. While performing a task, the current state of affairs and the goal state are compared, and actions or mental operations are selected to help bring the current state toward the goal state. The clinician can use to help individuals either learn new strategies or learn comprehension strategies to help them function to the goals being achieved. Performance-based measures can be used in both the clinic and the wider range of abilities, previously thought to be untestable, because the EFPT can be used in both the clinic and the home, it is a bridge linking the data obtained in controlled research studies with the rehabilitation goal of assessing an individual's ability to perform in everyday life. The Rehearsal Test (Hartman-Maeir et al., 2009) is designed to indicate one's ability to perform daily tasks. The patient's task is to prepare two hot drinks, one for the clinician and one for the patient. The clinician and patient must make the decisions about the details of the task to be completed from some options of coffee, tea, hot chocolate; and the clinician observes while the patient completes the task. The task is scored for each element of the task, and the patient obtains the ingredients, puts the ingredients into the cup, and serves the beverage (a 12-step task). Each of the steps is scored based upon the speed, receipt of cues, incomplete performance, and necessity of assistance. Following completion of the task performance, the therapist engages the client in a debriefing that focuses on the client's evaluation of the performance.

The Grownd Test by Shallice and Burgess (1991), which was adapted and studied in clients with traumatic brain injury (Knight et al., 2002; Alderman et al., 2003) and following stroke (Dawson et al., 2009), is a multi-sub-goal task performed in a real-world situation, a supermarket or a health facility. It is a clinician tool to provide a representation of coffee, tea, or hot chocolate; and the clinician observes while the patient completes the task. The task is scored for each element of the task, and the patient obtains the ingredients, puts the ingredients into the cup, and serves the beverage (a 12-step task). Each of the steps is scored based upon the speed, receipt of cues, incomplete performance, and necessity of assistance. Following completion of the task performance, the therapist engages the client in a debriefing that focuses on the client's evaluation of the performance. The test can be used in both the clinic and in the wider range of abilities, previously thought to be untestable, because the EFPT can be used in both the clinic and the home, it is a bridge linking the data obtained in controlled research studies with the rehabilitation goal of assessing an individual's ability to perform in everyday life. The Rehearsal Test (Hartman-Maeir et al., 2009) is designed to indicate one's ability to perform daily tasks. The patient's task is to prepare two hot drinks, one for the clinician and one for the patient. The clinician and patient must make the decisions about the details of the task to be completed from some options of coffee, tea, hot chocolate; and the clinician observes while the patient completes the task. The task is scored for each element of the task, and the patient obtains the ingredients, puts the ingredients into the cup, and serves the beverage (a 12-step task). Each of the steps is scored based upon the speed, receipt of cues, incomplete performance, and necessity of assistance. Following completion of the task performance, the therapist engages the client in a debriefing that focuses on the client's evaluation of the performance.

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for a circumstance encountered in everyday life would be
training a person to use the same restaurant on the
same route with specific instructions of where to turn, how
To look before crossing a street, how to obey street lights,
etc. Training would also cover what the individual should
do upon arrival to the restaurant, how to become familiar
with the staff and the menu, and how to use the menu
and order a dish. The aim is to maintain a schedule that can
become routine, doing the same activities in the same
sequence each day.

Neurofunctional retraining considers the person's
learning capacity in the design and implementation of
programs. The specific cognitive capacities are not the
target of the intervention. Rather, the person's capacity—attending,
memory, attention, and executive function—must
be considered in the design of functional skills training.
The person's capacity may differ from day to day, as
may the individual's strategy to accommodate the
person's use of strategies and level of awareness (Bass
Katz, 2009).

Cognitive Orientation to Daily Occupational Performance
(CO-OP), also developed by occupational therapists, is a
client-centered, performance-based, problem-
solving approach that enables the person to acquire
skills through a process of strategy use and guided discov­
y (Polatjajo & Mandich, 2004, 2005; see also Chapter 2).
CO-OP fosters skill acquisition, cognitive strategy
use, generalization, and transfer of learning. The founda­
tional theories are drawn from behavioral and cognitive
neuroscience, motor control, and occupational therapy.
Behavioral theories focus on the relationship between stimu­
lus, response, and consequence. Learning is viewed as a
permanent change in the form, duration, or frequency of a
behavior. Reinforcement is seen as an integral component
of learning. Cognitive theories emphasize the individu­
al's role in understanding and making sense of the enviroment.
Shaping, prompting, fading, and chaining techniques to support
skill acquisition (Polatjajo & Mandich, 2004). CO-OP
requires the mental organization of knowledge (prob­
lem solving, reasoning, and thinking) in the acquisition
and performance of skills (Schunk, 2000). The problem-
solving strategy used in CO-OP is “GOAL, PLAN, DO,
CHECK.” It was adopted from Meichenbaum (1977; 1994)a
framework for guiding the discovery of self-generated
strategies. Although there is a fixed or structural limit in the
individual's capacity to understand the task and how to perform it; the
associative stage is where the individual focuses attention and performs
the process. The associative stage is the part of the process in which the
strategy is where the skill is performed consistently and in a
coordinated pattern. CO-OP is based on a learning para­
digm that acknowledges that new skills emerge from an
interaction between the person and the environment. This interaction
supports the learning environment to support optimal learning. In
this approach, cognitive acts as the mediator between the
individual's ability and the performance that is the goal of
the intervention; as such, a certain level of cognitive abilities is
required in order to develop the new desirable skills.
CO-OP creates a learning paradigm that helps individuals
develop skills to support their daily life activities (Baum
Katz, 2009).

The following reflect the gaps we identified that can be addressed:

- Cognitive and rehabilitation scientists need to develop
  a shared language that will allow cross-level validation of
  the interventions; however, the person's capacities-par­
tial efficiency and environmental support.

- What is task set maintained over an entire task epoch? How
  many questions would one have to answer to complete a task?
  At the cognitive and neural levels, are different strate­
gies truly independent?

- We need to develop and maintain shared database of
  patients that include comprehensive clinical evalu­
  ations, results from neuropsychological tests, perfor­
  mance-based tests, and self and caregiver reports. These
  databases must be maintained over time to begin
  to understand the consequences of aging with a
  brain injury. Such information is necessary to guide inter­
  ventions and anticipate outcomes.

- Patient-centered outcomes will always rely on the inter­
  actions among the nature of the injury, the recovery
  processes, patients' expectations, their life demands, and
  their environments. Each will make contributions to actual and perceived outcomes. This is the complex­
  ity of neuromodification and the challenges to those
  who study executive function. In Figure 15.4 we have
  made an attempt to capture the complexity of these
  interactions and demonstrate the importance of social
  and environmental support.

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15.6 CONCLUSIONS

The executive dysfunction difficulties faced by individuals who
have a stroke requires the continued work and communication of
cognitive and rehabilitation scientists.

15.7 EXECUTIVE FUNCTIONS | 219