Abstract

RULE-BASED CATEGORY LEARNING: AN EFFECTIVE TREATMENT OPTION IN TRAUMATIC BRAIN INJURY

By Suchita Gaitonde

Traumatic Brain Injury (TBI) can cause changes in the physical, emotional, cognitive, and psychosocial functioning of the individual. Most of the cognitive rehabilitation programs treating patients with TBI focus on attention and memory retraining. Categorization is one of the most fundamental cognitive processes. Yet research in the area of TBI and categorization is limited. This study investigated one specific aspect, category learning in patients who sustained TBI. The performance of normal subjects was compared to the performance of the TBI subjects on three category-learning tasks. The results of the study indicated that subjects with TBI received more trials and made more errors during spontaneous categorization of stimuli across the 3 levels as compared to the normal subjects. Normal subjects delineated the rules spontaneously more frequently than TBI subjects who required cueing more frequently. In regards to the hierarchical structure of the rules, the number of trials received for spontaneous categorization of stimuli across the 3 levels increased as a function of the steps (1-5) for both the TBI and the normal subjects.
RULE-BASED CATEGORY LEARNING: AN EFFECTIVE TREATMENT OPTION

IN TRAUMATIC BRAIN INJURY

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Traumatic Brain Injury (TBI) is one of the leading causes of death and disability in people ages 15-24 years. It is estimated that nearly 2 million people in the United States suffer from Traumatic brain injury each year (Youse, Le, Canizzaro & Coelho, 2002). Of those about 50,000 die and another 80,000 have brain injury related disabilities. Approximately 5.3 million people in the United States live with a disability that was caused by traumatic brain injury. Males are more than twice as likely than females to experience TBI.

Motor vehicle accidents are by far the most common cause of TBI, accounting for approximately 50% of all head injuries, followed by motorcycle and bicycle accidents (Constantinidou, 1995). Injuries inflicted as a result of fall from heights, pedestrian injuries, and assaults are some of the other common causes of TBI. Child abuse, particularly the type that involves violent shaking, along with motor vehicle accidents and falls are significant causes of cerebral injury in the pediatric population.

Traumatic Brain Injury can be defined as an insult to the brain not of the degenerative or congenital nature but caused by an external force that may produce a diminished or altered state of consciousness. It implies damage to the brain as a result of external forces impinging on the head and the brain. It excludes insults to the brain
resulting from other neurological conditions such as cerebrovascular accidents, tumors, or degenerative diseases. There are two basic types of traumatic brain injuries-open head injury or the penetrating type and the closed head injury (CHI) or the non-penetrating type.

Open-head or penetrating head injury connotes that the meninges are ruptured as a result of the tearing of the dura mater by the skull fragments (Brookshire, 1992). It is usually caused by high-velocity impacts such as bullets or projectiles. Closed-head injury (CHI) is described as a blunt blow to the head associated with acceleration or deceleration forces applied to the skull that result in generalized cerebral dysfunction (Adamovich, Henderson & Auerbach, 1985). Though the meninges remain intact, the damage is caused due to abrasions, lacerations, contusions, and shearing of the brain tissue. The two main mechanical phenomena, responsible for brain damage in CHI are contact and inertial loading or acceleration forces (Constantinidou, 1995; Katz, 1992).

**Severity Rating in Traumatic Brain Injury**

The brain, like all other organs in our body has an inherent tendency to withstand a minor infection or trauma. The minor blows to the head, which everyone experiences as toddlers, are sufficient enough to prove this point. However, a major impact to the head due to a vehicular accident or as a result of fall may produce a significant modification of the brain function with potential for permanent sequelae (Bigler, 1990).

The severity rating in TBI is based on several factors, the significant amongst which are the duration of loss of consciousness (LOC), the duration of posttraumatic amnesia (PTA) and the initial Glasgow coma score (GCS). Loss of consciousness refers to the initial effect or the initial response of the brain to trauma and can range from a few
seconds to more than 24 hours in case of severe TBI (Constantinidou, 1995). The length of Post Traumatic Amnesia (PTA) is another measure used to classify the severity of brain injury. PTA includes the period of retrograde and the anterograde amnesia. PTA should not be confused with coma and recovery from coma (Bigler, 1990). PTA usually exists even when the patient is alert and functioning. A patient in the PTA stage experiences difficulty in retaining new information. PTA durations of 5 minutes to a day signify mild injury. PTA period greater than 24 hours is indicative of moderate to severe injury.

Level of consciousness provides important information to establish the magnitude and the degree of initial brain injury. The level of consciousness is quantified using the Glasgow Coma Scale (GCS), developed by Teasdale and Jennett in 1974. The GCS assesses three components of wakefulness—the stimulus required to induce eye opening, the best motor response, and the best verbal response. The scores on the GCS range from 3-15. A rating of eight or less signifies severe brain injury and the patient is often in a state of coma. GCS ratings of 9-12 indicate a moderate injury; scores above 13 imply a mild traumatic brain injury (Brookshire, 1992).

Traumatic Brain Injury causes a wide range of alterations in the physical, emotional, cognitive, behavioral, and psychosocial functioning of the individual. TBI is generally accompanied by loss of consciousness, PTA, and alterations in the mental status such as confusion or feeling of disorientation. Other common symptoms include physical symptoms such as fatigue, dizziness, sleep disturbances, blurred vision, hearing problems, and headaches. The individuals often seem to be distractible, depressed and
demonstrate slow thinking. Feelings of helplessness, explosive temper, agitation, and irritability are not unusual.

Recovery from severe brain injury is a lengthy process and often requires several months to years. It has been reported that the severe TBI survivor faces 5-10 years of intensive services at an estimated 4 million dollars. The lifetime cost of all brain injuries in the United States is approximately 37.8 million dollars. Most persons surviving a severe head injury require intensive treatment following hospital care in order to reach their maximum level of functioning in independent living and functional pursuits.

There has been a steady increase in the number of treatment options available for the post medical cognitive rehabilitation of the traumatically brain injured patients. Most of the therapies, which are used for treatment of TBI, focus on some form of cognitive retraining for memory and attention. The Memory Retraining (Parente’ & DiCesare, 1991) and Attention Process Training (Sohlberg & Mateer, 1987) are two such examples of cognitive retraining programs. While memory and attention have been explored to a great degree in the literature, categorization a very fundamental cognitive process has not been thoroughly investigated The present study will focus on the categorization and category-learning ability in brain injured individuals and investigate its potential as a suitable treatment option for the rehabilitation of individuals with brain injury.

Categorization

Categorization is a very complex task and is basic to all our intellectual abilities. It can be simply defined as the ability to classify objects in a particular group or category. (Estes, 1994). Individuals classify objects into various categories consciously or unconsciously on the basis of various perceptual features such as size, shape, color,
texture, weight, detail, texture, or construction. Research had demonstrated that both infants and adults form some type of central representation or summary of the categories, which reflects the central tendency of the category instances. This central tendency that can be referred to as the mean or the mode of features within the category is referred to as the schema or the prototype (Younger & Gotlieb, 1988). The various processes involved in perceptual categorization include perceptual processing, memory access and category decision.

*Category Learning*

An individual classifies an object as belonging to a particular category on the basis of some features that are common between the object and the category to which it belongs. The higher the number of features that the object possesses that is in common with the category, the more likely that the object will be assigned to that category (Lamberts, 1997). The process of categorizing stimuli is carried out on the basis of a set of rules that define category membership or knowledge of what a particular good example of the category might look like. Category learning takes place through rule-based category tasks, information integration tasks or through prototype distortion learning tasks (Ashby & Ell, 2001).

Rule Based category learning involves learning through explicit memory process. In most instances, the subject is presented with a stimulus that has only one relevant stimulus dimension. The subject’s task is to discover this relevant dimension and then assign the stimulus to an appropriate category based on the relevant perceptual dimension. Most of the neuropsychological tests including the Wisconsin Card Sorting Test are created based on the principle of Rule Based category learning. Another theory of category learning caters to information-integration. This theory proposes that accuracy of categorizing is maximized if the information from two or more stimulus components is
integrated at some predecisional stage. The optimal rule in information integration tasks is difficult or impossible to describe verbally. Another aspect of category learning is through Prototype Distortion in which the category is created by first defining the category prototype and then creating the category members by randomly distorting these prototypes (Ashby & Ell, 2001).

The present study is a part of a larger project, which tests the effectiveness of a Categorization Program (CP) developed by Constantinidou, Thomas, Scharp, Hammerly & Best in 2001. This study will utilize the rule-based category learning incorporated in the Categorization Program, in order to determine its efficacy as an appropriate training tool in patients with brain injury. The Categorization Program (CP) developed at the Neurocognitive Disorders Lab at Miami University, Ohio integrates current cognitive theory from various disciplines and is built on a theoretical model proposed by Constantinidou, Thomas, and Best (in press).

The CP is currently tested at five brain injury rehabilitation sites in the United States. The testing of non-injured subjects is conducted at Miami University. The present study will compare the category learning abilities of individuals with TBI who receive the Categorization Program training with the normal subjects. This study will focus specifically on the Part B of the Categorization Program, which involves Category learning and consists of 3 levels. Each level consists of 5 steps that are arranged in an increasing order of difficulty.

This study will test the assumption that the 3 levels of the Part B are hierarchically more difficult. In addition it will determine whether the five steps within each level are built hierarchically with step 1 being the easiest and step 5 being the most difficult.
Significance of the Problem

Progress has been made in the area of brain injury research in the last two decades. However, research is mostly directed towards surgical procedures designed to minimize secondary neuropathology and in TBI models that emphasize the complex interactions among pathology, impairment, disability, and handicap. Far less research is targeted towards efficacy of the different cognitive treatments or rehabilitation procedures currently used in patients with TBI.

Thus the present study will compare the category learning abilities in patients with TBI and normal subjects. Research from this study will provide further information on the effects of TBI on categorization abilities. In addition the present results will help in the development of a treatment protocol designed to improve categorization following TBI.

Purpose

The purpose of this study is to compare the performance of the TBI group with the normals in order to estimate the efficacy of the category learning protocol as an effective tool for cognitive rehabilitation. Another purpose of the study is to test the hierarchical structure of the 3 levels of the protocol by counterbalancing the presentation of the levels (1-3) within a group of normal subjects.
CHAPTER II
Review of the Literature

Cognitive Processes Involved in Traumatic Brain Injury

Human Cognitive processes can be divided into basic and complex. Attention, memory and learning are considered as the basic processes, which are prerequisites for the accurate functioning and execution of the complex processes such as categorization, perception, analytical reasoning and abstract thought processing. Cognition includes the use of these processes and the knowledge base to make decisions to interact with the environment in the most appropriate way to execute these decisions, monitor responses to determine the appropriateness of these decisions and adjust behavior if it is determined to be inappropriate and/or inaccurate (Adamovich, 1995),

Traumatic Brain injury results in the disruption of the cognitive processes and brings about significant changes in the functioning of an individual. The extent to which the various cognitive processes are involved depends on the severity of the injury and also on the site of lesion. However, the basic cognitive processes such as attention, memory, and learning are compromised to a certain degree even in case of a mild injury and the change in function is noticed.

In addition to the above processes categorization is often affected after TBI. Infact categorization deficits may interfere with performance on attention and learning tasks. There seems to be an interdependence of functions such as attention, learning, memory and categorization in the normal adult brain. Given this relationship among various cognitive processes, this literature review will begin with a discussion on attention and memory, and will conclude with a presentation of categorization and category learning.

Attention

Shiffrin (1988) defined attention as ‘that process that has been used to refer to all those aspects of human cognition that the individual can voluntarily control and those
that deal with limited resources or capacity and methods of dealing with such constraints’ (p739). Attention deficits result in significant disruptions in the completion of activities of daily living. Activities such as taking a message over the phone, making a grocery list, crossing the street, taking down notes in a class etc. require various levels of attention.

Sohlberg and Mateer (2001) presented a clinical model of attention and treatment, which defined a hierarchy of 5 levels of attention. The 5 levels of attention include focused attention, sustained attention, selective attention, alternating attention, and divided attention. The basic level of attention or ‘focused attention’ refers to the ability to respond discreetly to a specific visual or an auditory stimulus. The next level of attention in the hierarchy corresponds to the ability to maintain responses or focus on a particular task for a brief period of time and is called as ‘sustained attention.’ We exercise sustained attention when taking notes in a class. The next level is ‘selective attention’ and corresponds to the ability to maintain a behavioral or cognitive set in the face of distracting or competing stimuli. ‘Alternating attention’ is the fourth level in the hierarchy and refers to the ability to focus attention and move between tasks that require different cognitive subsystems such as the ability to watch a football game while having a conversation on the phone. The last stage in the hierarchy i.e. ‘divided attention’ involves the ability to respond simultaneously to multiple task demands such as driving a car.

Deficits in attention disrupt analytical reasoning, problem solving, and task-completion in general (Ben-Yishay, 1978). Attentional problems sometimes show up on the surface in the form of behavioral issues. Individuals functioning at a higher cognitive level sometimes display egocentric, rude, impulsive, disinhibited, denying or in general incoherent behavior (Adamovich, 1995). Geschwind (1982) referred to the attentional problems following a closed head injury as “global” disorders of attention or “confusional states.” The salient features of these disorders include lack of coherence, paramnesia, inappropriate social judgment, impulsivity, lack of insight, literal interpretations and denial of illness.
Several cognitive rehabilitational programs emphasize on remediation of attentional deficits. They generally focus on multimodality stimulation such as tactile, auditory, visual, gustatory, vestibular, and oral-verbal in case of low-level attention remediation. Most of the studies involving treatment of attentional disorders involve repetition of specific activities or tasks that provide opportunity to exercise attentional skills (Mateer, Sohlberg, & Youngman, 1996). The Attention Process Training (APT) program designed by Sohlberg and Mateer (1987) focused on a broad range of attentional deficits combined with selective workbook or computer based programs. The APT program was based on the five-level model of attention including focused, sustained, selective, alternating and divided attention. Improvement in attention was indicated on the Paced Auditory Addition Task following the attention training and gains on a visual task were observed during and after visual-process training. Wood (as cited by Mateer, Sohlberg & Youngman, 1996) used a token reinforcement procedure, to improve attention behavior for both visual and auditory training tasks in case of severely head-injured patients. Enhancement in memory and attention was noted as a result of the training in other therapeutic environments. Similarly improvement in attention to visual details, visuo-motor speed, and reaction time were noted by Ben-Yishay and Dillard during their attention training tasks as cited by Mateer, Sohlberg & Youngman, 1996.

While the above studies demonstrated improvement following attention training, other studies failed to do so. A study conducted by Niemann (as cited by Mateer, Sohlberg & Youngman, 1996) evaluated the benefits of attention training versus memory training reported specific gains in attention and memory in the group receiving attention training. However, the subjects failed to demonstrate better results on an independent set of functional neuropsychological measures administered pre and post-treatment. The results of this study imply that the training procedures were not efficient enough to influence generalization to similar tasks in therapy and in standard neuropsychological and functional assessment measures. Malec et al. (1984) examined the effects of a two-
week visual training program on ten patients with severe head injury within six months of the trauma. No improvements as a result of the experimental task were noted. Some of the problems encountered were spontaneous recovery, short training period and the use of a single visual training task.

All the above studies indicate that attention retraining plays a considerable role in the cognitive rehabilitation of individuals with TBI. Treatment of attentional deficits is an appropriate and promising focus for rehabilitation efforts. However the carry over and generalization of the attention training to the real life situations remains a challenge in cognitive rehabilitation. Attention and memory go hand in hand and are important and significant aspects of cognitive functioning for the successful execution of activities of daily living.

Memory

Memory has been of interest to researchers since the beginning of the 19th century. Broadbent presented the earliest known model in 1958. This model took into account the processing of information and talked about the concepts of short term and long term memory. Broadbent presented subjects with “dichotic” tape recordings, and found that subjects could not recall most of the unattended information of the dichotic tape but were able to still recall the most recent several seconds of the unattended channel. The inference drawn from this study was that the brain temporarily retains all incoming stimuli, but this information fades away and does not permit retrieval at a later time unless a specific memory trace is created for that stimulus. Atkinson and Shiffrin (1968) modified the model presented by Broadbent to take in to account the fact that decisions about information processing in the limited capacity system or the short term memory determined the extent to which the information would be saved in the long term memory. Craik and Lockhart (1972) stated that the durability of the memory trace was dependant on the manner in which the stimulus was coded. A visual presentation of the word would lead to a very shallow encoding, leading to very rapid forgetting as opposed
to the sound of the word leading to a more durable encoding of the stimulus. Baddeley and Hitch (1974) presented the Working Memory concept which referred to that stage where the information was temporarily held and manipulated before it could be stored permanently in the long term memory. The most commonly referred memory models include the Classical Model and the Information Processing model.

Classical Model of Memory

The classical model of memory divides the system into short-term memory, working memory and long-term memory. The classical model treats memory more like a process that can be explained well in terms of its three stages.

Short-term memory.

Short-term memory (STM) is a limited capacity store with rapid output and retrieval (Baddeley, 1986). It stores information as near perfect replicas of experience (Parente and DiCesare, 1991). The function of short-term memory or sensory memory is to retain the sensory information perceived by the brain for selection and processing by the working memory. Any disruption in the functioning of the sensory memory store will cause the working memory to receive erroneous information and will hence result in inaccurate information to be stored in the long-term memory. The classic paper ‘The magic number seven’ by Miller (Baddeley1986) stirred interest in the concept of short-term memory in the United States. He stated that humans could handle about seven plus or minus two alternatives or chunks of information, which placed restrictions on the memory span and explains for the limitations in our capacity.

Working memory.

Baddeley and Hitch (1974) presented a working memory model that included a supervisory controlling system, the Central Executive that was aided by the visuo-spatial scratch pad and the articulatory loop. It refers to the ability to process information presented sequentially through the auditory verbal and the visual modalities.
Working memory implies a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks such as comprehension, learning, reasoning, and categorization. Working memory is that aspect of memory that is compromised the most as a result of a traumatic brain injury.

Short-term memory and working memory should not be confused with each other. Working memory is more concerned with the processing of information. Working memory encodes information for effective storage and retrieval (Parente & DiCesare, 1991) and incorporates strategies such as rehearsal, categorization, and association. On the other hand, STM only implies to the station where information is stored for a brief amount of time.

Long-term memory.

Long-term memory is that stage of memory where information is stored permanently after it is encoded (Parente & DiCesare, 1991). It is known to have infinite capacity to store information; however, the availability of the stored information depends on the establishment of the appropriate access routes. This explains the phenomenon when an individual is unable to retrieve information on his own, but can recognize or access the information easily when provided with appropriate cues.

Long-term memory has several divisions. One type of distinction is between the declarative and the non-declarative memory. Declarative memory can be classified further into semantic and episodic memory. Semantic memory refers to the facts and acquired knowledge about the world whereas episodic memory deals with the recordings of experiences that are unique to the individual and include information about the time, place and the context in which a particular event occurred. Episodic memory is likely to be affected to a greater degree than semantic memory in case of a traumatic brain injury (Sohlberg & Mateer, 2001).
Information Processing Model

The Information processing model divides the process of memory in the following stages: attention, encoding, consolidation, storage, and retrieval. Attention as described previously consists of 5 hierarchical stages that include focused, sustained, selective, alternating, and divided attention. The encoding stage involves strategies such as the chunking techniques, the rehearsal process and the organization of incoming sensory information. The consolidation phase of the information-processing model, involves transfer of information to a location for permanent storage. The storage phase of the model is concerned with permanent storage of the information. The retrieval is related to access stored information and to monitor the accuracy of retrieved information.

Memory retraining is an important aspect of cognitive rehabilitation. Traditional therapy focuses a lot on memory retraining. After a head injury, the person’s ability to process information could be disrupted causing encoding problems (Parente’ & DiCesare, 1991). Therapy thus involves directing conscious attention to the temporal aspects of what is seen and heard and may also require alternate strategies such as mnemonic devices or imagery. Some of the commonly used techniques and strategies for memory retraining are domain-specific training (Schacter & Glisky, 1986), wherein the subject is trained to match the task demands in therapy with those in the real world. Research indicates that this method is effective and results in maximum transfer to the real life situation. Sensory Memory retraining (Parente’, 1989) is primarily used to improve sensory iconic memory by eliminating sensory and attentional deficits in the early stages of cognition. Some of the other methods used are academic therapy which works towards reestablishing the old skills by providing structured practice and Stimulation Therapy that includes the use of paper-pencil and computer tasks to exercise the brain. (Parente’ 1989). Some of the common techniques advised for better memory performance are verbal labeling, number chunking and use of embedded sentences and imagery. These methods require integration of mental thoughts into visual imaging. While some of the
various memory techniques implemented in research paradigms were successful in improving function, it is not clear whether their impact is long lasting or whether the patient would be able to generalize their abilities into new situations. Of the various memory models, the domain-specific training seems to be the most ecologically pertinent. However, again it is not clear whether such training would generalize into new tasks.

*Categorization and Category Learning*

Categorization is an important aspect of cognitive science and plays a significant role in perception, thinking, and language. Human beings sort objects into concrete entities such as animals or household tools or into abstract entities such as emotions. The process by which humans concise or summarize the regularities in the environment is termed as the categorization process. This categorical information in synopsis is referred to as the ‘schema’ or the ‘prototype’. When two or more discernible objects are treated equivalently, they are said to be members of the same category. Objects or events can be considered as members of the same category on the basis of their attributes or functions. A car, a bus, a ship and an airplane are considered as members of the same category on the basis of their function that is “means of transport”, though these objects do not share the same attributes.

Categorization takes place on several hierarchical levels. Several studies have been done to determine the most fundamental level of categorization and have demonstrated that the basic level is the most general level of categorization. The basic level consists of category members that have similar overall shapes and sizes and a mental image that reflects the entire category. Rosch (as cited in Estes, 1994) performed attribute analysis for three level hierarchies of common concrete objects (e.g. furniture, chair, and easy chair) and found the level corresponding to the ‘chair’ to possess the characteristics of the basic level categories.
The earliest known approach to categorization can be referred to the theory of hypothesis testing given by Heidbreder in 1924 as cited by Estes (1994). The hypothesis testing approach treats concept formation as a form of problem solving. It implies that categorization is based on critical features or properties common to all members of the category and which are essential for category membership. This theory states that the learner has to formulate the hypothesis about the significant features and then test the hypotheses against observations of a sequence of exemplars until an adequate hypothesis is reached. This theory can be equated to our experience about trying a new recipe by a trial and error method until it is perfected.

Another approach to categorization is the category learning approach (Estes, 1994), which depends on the nature of the learning situation. One of the determining factors of this approach is the distinction between finite and infinite categories. Rote memorization plays a significant role in the learning of finite categories that are comparatively small such as the cards in an ordinary playing deck, but memorization in itself is not sufficient when the finite categories are extensive such as animals belonging to a particular species.

Another important aspect of category learning is the distinction between taxonomic and probabilistic classifications (Ashby & Casale, 1998). Taxonomic classifications denote common or critical attributes to the objects in a particular category such as speech sounds by phonemic categories or all animals belonging to the same species such as mammals. The probabilistic classification involves the association between features of the object and the probability that it would belong to that particular category. The possibility that the symptoms shown by a patient can be diagnosed by a physician as being a particular disease on the basis of some diagnostic tests is an example of probabilistic categorization.

Category learning begins at a very early age. It is difficult for any individual to attend to the infinite stimuli in the environment and experience the innumerable events all
at the same time. Human beings group together the stimuli that they perceive in the environment, depending on their similarities and differences into various categories, which leads to the thought that even infants should have the capacity to categorize.

Younger and Fearing (1999) demonstrated that infants 3-4 weeks old could form a single category whereas infants about 10 weeks old could differentiate between categories. In this study the infants were first familiarized with several of the category members and then presented with a novel member of the same category. The categories consisted of male and female faces and the novel members were represented by male and female faces that were not true representative of the categories. Since the infants had formed a category in their mind, based on the similarities and differences between the presented stimuli, they stared at the novel member of the same category for longer time than usual, signifying the placement of the novel stimuli into a separate category.

Category learning in adults is thought of as an explicit process as it is accessible to conscious awareness (Ashby and Casale, 1998). Category learning can be defined as explicit when the subject can verbally describe the categorization rule that he or she utilized (Ashby, et al., 1998). Category learning is said to be of the implicit variety if no trial-by-trial feedback of any kind is provided. Free sorting, is an example of true implicit processing of the categories, as feedback is not provided about the accuracy of the responses to the participants nor are they told about the number of contrasting categories (Ashby & Maddox, 1998).

Various studies have been done to determine the way in which humans assign objects to various categories or formulate categories. Human beings generate new categories by combining or subdividing the categories they have already learned. Category learning theories are generally based on explicit rules, family resemblance, or probability distributions. A category learning experiment basically requires the subjects to assign the stimulus items to various categories. The subject is generally shown an item, is asked to randomly assign the item to a particular category, and receives informative
feedback about the stimulus assignment to the category from the examiner. After a series
of stimuli presentation the subject is asked to formulate the rule that decides which object
is assigned to that particular category. The subject tries to compute the similarity of the
stimulus items that are assigned to a particular category on the basis of the examiner’s
feedback and comes up with a rule depending on the similarity associated with all the
members of the category. The most commonly identified types of category learning
structures include, the rule-based tasks, information-integration tasks and the prototype
distortion tasks.

Rule based category learning tasks facilitate category learning through explicit
reasoning process. An important property of rule-based category learning task is that the
optimal rule can be described verbally. This form of category learning is most favored by
the proponents of classical theory of categorization and assumes that the process of
discovering the set of necessary and sufficient conditions determines category
membership (Ashby & Ell, 2001). This type of category learning is used in most
neuropsychological testing including the famous Wisconsin Card Sorting Test (WCST)
(Heaton, 1981). The rule based category exemplars usually differ on one dimension;
thus, the explicit rule that perfectly distributes the stimuli into two different categories is
unidimensional (Ashby and Casale, 1998).

Information–integration category learning tasks combine the information from
two or more stimulus components at some pre-decisional stage. The decision bound
theorists consider category learning as a process of associating category labels with
regions of perceptual space and traditionally use information-integration tasks per
category exemplar (Ashby and Ell, 2001).

In the prototype category learning tasks, each category is created by first defining
a category prototype and then creating the category members by randomly distorting
these prototypes. The way in which humans learn concepts or categories is central to
investigations of human learning. It has been found that humans tend to seek simple rules
rather than prototypes. Prototype distortion tasks are commonly used by prototype theorists who believe that categorization is the task of comparing the presented stimuli with the prototype of each contrasting category (Minda & Smith, 2001).

Studies reveal that conjunctive (and) concepts are learnt more easily than the disjunctive (or) concepts. Thus, a conjunctive rule such as “any object that is red and circle is part of the category A” is easier than a disjunctive rule such as “any object that is red or a circle is a part of the category A”. A conjunction task is a rule-based task rather than an information-integration task as separate decisions are first made about each dimension and then the outcome of these decisions is combined, i.e. integration is not pre-decisional (Ashby & Casale, 1998).

Categorization behavior and category learning are two different processes as they involve different facets of the neural mechanisms and pathways. Individuals who are impaired in category learning (frontal lobe injury and Parkinson’s disease) do not lose old familiar categories such as animals or fruits (Ashby & Ell, 2001). The role of the visual cortex in the process of category learning is highly controversial. There is some research that suggests that category structure is represented in the visual cortex. Category specific agnosias have ignited interest in the representation of the familiar categories in the brain. Category specific agnosias refer to the ability to perceive or categorize most visual stimuli normally, but a reduced ability to recognize exemplars from a specific category e.g. prosopagnosia or inability to recognize human faces. Representation of the familiar categories in the visual cortex does not necessarily mean that category learning occurs in the visual cortex, as then category-learning deficits would always co-occur with category specific agnosias (Ashby & Ell, 2001).

The neural structures that mediate learning in various category-learning tasks are said to include the pre frontal cortex and the basal ganglion. Studies indicate that patients with frontal or basal ganglia dysfunction are impaired in rule-based tasks (Kolb & Whishaw, 1990); however patients with medial temporal lobe damage are normal in this
type of category learning tasks. The above results have been verified by the f-MRI studies carried out on rule-based tasks similar to the WCST. Studies conducted by Rao et al., (as cited in Ashby & Casale, 1998) indicate that the regions in the brain that were activated as a result of the rule-based tasks include the right dorsal- lateral prefrontal cortex, the anterior cingulate and the head of the right caudate nucleus, which primarily corresponds to the pre-frontal area in the brain.

Traumatic brain injury often results in extensive focal damage to the frontal and the temporal lobes (Constantinidou, 1995). The frontal and the temporal lobes are primarily responsible for attention and memory and thus play a significant role in categorization and category learning based on the above-mentioned discussion. Kreimer (2000) in a feature description study presented that, adults with traumatic brain injury differed from the normal population in their ability to learn and apply perceptual features in order to describe common objects. Thus TBI seems to interfere with basic categorization abilities such as description of common objects.

Scharp (2002) investigated feature description abilities between the normal subjects and subjects with TBI. She demonstrated that subjects with TBI benefit from repeated presentation of the stimulus information and show enhanced working memory performance. Individuals with TBI required more training trials than the normal subjects in order to learn the perceptual features and recalled fewer number of features per trial during the feature-training task. Subjects with TBI displayed significant improvement in the functional measure outcomes used as a result of the training procedure.

Neuropsychological studies of individuals with Traumatic Brain Injury have provided new insights to the rehabilitational approaches already in use with the TBI population (Gluck et al., 2002). Research based on category learning and categorization protocols holds great promise for the field of cognitive neuroscience and brain injury rehabilitation.
Summary

Traumatic Brain Injury as previously mentioned causes alterations in physical, emotional, cognitive, and psychosocial functioning of the individual. The basic and complex processes of cognition are affected significantly. Most of the rehabilitation programs available and currently practiced focus on at least one aspect of cognition such as attention or memory remediation.

Research has not investigated the effects of categorization training in TBI. The study under scrutiny is a part of a larger program that investigates the effectiveness of a systematic categorization-training program. The Categorization Program (CP) comprises of 2 parts. Part A includes the categories of common objects and consists of 5 levels such as perceptual feature training, similarities and differences, functional categorization, analogies and abstract concepts. Part B deals with category learning. Neuropsychological assessment is conducted before and upon completion of the CP training.

The current study incorporates the Part B of the CP. It examines the subjects’ ability to formulate rules on the basis of the feedback provided by the examiner. Part B deals with progressive rule learning tasks that are arranged into three levels with increased complexity. Level 1 stimuli includes geometric shapes that vary along two dimensions color (red, black or white) and shape (circle, square and triangle). Level 2 includes gauges that depict the condition of the power plant. Level 3 stimuli incorporate medical diagnoses that vary along the diagnostic test concerned with a particular organ in human body as well as the laboratory result depicted as high or low. Each level is further divided into 5 steps which present different situation for rule-based learning tasks. The steps include Affirmative, Conjunctive, Disjunctive, Exclusive, and Conditional conditions. Hence, this present study will try to compare the performance of TBI and normal subjects on the three levels. In addition it will test the hierarchical structure between levels 1-3 and within levels for steps (1-5).
Statement of the Problem

Traumatic brain injury causes disruption of several cognitive processes. Decline in cognitive abilities interferes with physical, psychosocial, behavioral, and vocational performance of the affected individuals. Categorization is a complex cognitive process that is interrelated with other basic cognitive processes like attention, memory, and learning for its accurate functioning. Cognitive rehabilitation programs focusing on categorization aspects and new category learning are of significance in order to determine suitable training programs for rehabilitation of traumatic brain injury. The present study focuses on using new category learning as an efficient tool for cognitive rehabilitation as a result of traumatic brain injury.

Research Hypotheses

- TBI subjects will receive more trials during the spontaneous categorization across the 3 levels (shapes, gauges, and words) as compared to the normal subjects.
- Subjects with TBI will make significantly more errors during the spontaneous categorization as compared to the normals.
- The TBI subjects will require cue levels 3 and 4 more frequently as compared to the normal subjects in order to delineate the rule which classifies items in categories A and B.
- The normal subjects will receive more trials during spontaneous categorization for Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2 when the presentation of the rules is counterbalanced for the normal population.
- The number of trials, received during spontaneous categorization, will significantly change as a function of the steps (1-5) within every rule, for the TBI and the normal group of subjects.
Chapter III
Methods and Procedures

Methods

The study under investigation was a part of a larger research project, conducted at the Neurocognitive Disorders lab at Miami University. This study incorporated the CP, an extensive training protocol to improve categorization abilities. Following is the general sequence of tasks pertaining to the project at large:

- Neuropsychological Battery
- Informal pretests
- Probe I
  - Part A –Level 1 (perceptual feature training)
  - Part A –Level 2 (similarities and differences)
- Probe II
  - Part A –level 3 (functional categorization)
  - Part A –Level 4 (analogies)
  - Part A level 5 (abstract concepts)
- Probe III
  - Part B –Progressive Rule Learning Level 1 (Shapes)
  - Part B –Progressive Rule Learning Level 2 (Gauges)
  - Part B –Progressive Rule Learning Level 3 (Words)
  - Posttests (comprising of the Neuropsychological battery and the informal posttest measures)

Subjects

The study at large incorporated 3 groups of subjects, two groups consisting of subjects with TBI and the third group of normal subjects. The subjects with TBI were
recruited from four residential rehabilitation centers across the United States while the normal subjects were obtained from Miami University and its surrounding communities.

Group 1, the experimental group consisted of subjects with TBI who received the entire CP protocol along with the pretest and the posttest informal measures and the extensive neuropsychological battery. Group 2, the treated control TBI group comprised of those subjects with TBI who received the traditional cognitive rehabilitational program practiced at their respective rehabilitation centers. These subjects however, did receive the entire Neuropsychological battery along with the pretest and the posttest informal measures and the probe tasks. The normal subjects in group 3 underwent training with the entire categorization protocol and also participated in the neuropsychological battery, the pretest, and the posttest informal measures.

Inclusion- Exclusion Criteria

Inclusion criteria for the TBI subjects.

- Adults male and females between ages 18-55.
- Primary diagnosis of moderate to severe closed head injury (CHI) indicated by the presence of three or more of the following severity indices: initial Glasgow Coma Scale score less than 12, abnormal initial computed tomography (CT) results, length of impaired consciousness greater than 20 minutes, length of acute hospital stay greater than 3 days. Positive neurological examination on hospital admission and discharge, medical complications secondary to the injury and head injury severity classification according to the hospital records (Gentillini, Nichelli & Schoenhuber, 1989).
- Level VI or a higher rating on the Rancho Los Amigos Scale (Hagen, Malkmus, & Durham, 1972).
- Absence of aphasia with the exception of mild to moderate word finding difficulties
- A Galveston Orientation and Amnesia test score of 76 or higher suggesting resolution of Post Traumatic Amnesia (PTA) (Levin et al., 1979).
- Enrollment in a residential comprehensive post-acute rehabilitation program at the onset of the study.
- Subjects were included within 4 years of their initial injury.

Exclusion criteria for TBI subjects.

- Penetrating head injuries
- History or possible occurrence of a stroke at the time of injury.
- Premorbid neurological history or learning disability.
- Documentation of premorbid psychological or personality disorders as defined by the Diagnostic and statistical manual of Mental Disorders, Fourth Edition (American Psychiatric Association, 1994) commonly known as DSM-IV:
  - Hospitalization for major depression
  - Evidence of incapacity to return to work due to psychiatric disorder.
- Current Beck Depression score II (Beck, Steer, & Brown 1996) of 25 or higher indicating the presence of depression that could interfere with performance on the protocol.
- Active or current substance abuse that interferes with participation.
- Need for surgical procedures while participating in the project.
- Deficits in auditory comprehension and moderate to severe word finding problems, two standard deviations below the mean on the Boston naming test (Goodglass, Kaplan & Weintraub, 2001) that could interfere with the subject’s ability to follow test or task instructions.
- English as a second language.
- Color blindness as measured by the Ishihara test for color blindness (www.toledo-bend.com).
Inclusion criteria for the normal subjects.

- Adult males and females between 18-50 years of age
- Adults for whom English is their primary language.

Exclusion criteria for the normal subjects.

- A medical history of neurological insult, disorder or organic brain disease.
- Documentation of psychological or personality disorders as defined by the DSM-IV:
  - Hospitalization for major depression
  - Evidence of incapacity to return to work due to psychological disorder.
- Current Beck Depression score II (Beck, Steer, & Brown 1996) of 15 or higher indicating the presence of depression that could interfere with performance on the protocol.
- Mini Mental State examination score of 23 or lower (Folstein, Folstein, & McHugh 1975)
- Active or current substance abuse that interferes with participation.
- Uncorrected vision
- Uncorrected hearing impairment
- Language or speech disorder
- English as a second language
- Color blindness as measured by the Ishihara test for color blindness

The normal subjects were screened to determine visual and hearing impairments. Normal subjects were asked to read five words aloud to the examiners, which were printed in black with 10-point font for the vision screening. The hearing screening was conducted in a therapy room and the subjects were screened at 1000, 2000, and 4000 Hz at 20 dB binaurally (ASHA, 1989). The vision and the hearing screening for the subjects
with TBI were carried out as per the traditional methods employed by their respective residential facilities.

**Measures**

*Neuropsychological Assessment*

A detailed neuropsychological assessment was carried out at the beginning of the Categorization Program. It also included 2 informal tests developed together with the Categorization Program. The informal test 1 was based on the skills that were trained in Part A whereas the informal test 2 corresponded to the category learning tasks emphasized in Part B of the CP. The neuropsychological tests along with the informal tests were repeated at the end of the program as a posttest measure.

The neuropsychological battery for the subjects with TBI is listed in appendix B and Appendix A consists of the tests used with the normal population. The subjects began Part A of the CP after the presentation of the neuropsychological battery along with the informal pretests 1 and 2.

*Experimental Tasks*

In the present study, first group of normal subjects (N=9) received the entire protocol. The performance of this group was compared to the progress of the TBI subjects. The other group of normal subjects (N=45) was subjected to the Part B of the training program only and did not receive training on the entire CP. The examiner counterbalanced the administration of the levels within this group of normal subjects. This was to determine the level of difficulty between levels 1-3 and test the assumption that the 3 levels are hierarchical in nature because the stimuli become more abstract. Table 1 is the order of rule presentation.

Table 1
**Order of Rule Presentation**

<table>
<thead>
<tr>
<th></th>
<th>Order Of Administration Of The Progressive Rule Learning Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PL1</td>
</tr>
<tr>
<td>GP1 (N=15)</td>
<td>1</td>
</tr>
<tr>
<td>GP2 (N=15)</td>
<td>3</td>
</tr>
<tr>
<td>GP3 (N=15)</td>
<td>2</td>
</tr>
</tbody>
</table>

GP1: Normal subjects group 1  
PL1: Progressive Rule Learning Level 1  
GP2: Normal subjects group 2  
PL2: Progressive Rule Learning Level 2  
GP3: Normal subjects Group 3  
PL3: Progressive Rule Learning Level 3

Part B consists of explicit categorization tasks allowing the patients to learn rule based classification strategies. The stimulus types used include pictures of different shapes in different colors, pictures of gauges depicting different conditions and written material presenting medical diagnosis. Thus the stimulus items follow the hierarchy from concrete to abstract. Each level consists of 5 steps that are arranged in the order of increasing difficulty such as Affirmative, Conjunctive, Disjunctive, Exclusive and Conditional (appendix D). The data collected on the larger group of normal subjects (N=45) was used to determine if the Progressive Rule Learning Levels 1, 2, and 3 were arranged in the order of increasing difficulty. This information would be of use to ascertain whether the stimuli used in level 1 i.e. shapes are easier than the gauges used as the test stimuli in Level 2 and the words which represent the test stimuli used for the Level 3.

**Experimental Procedure**

Subjects with TBI were recruited to group 1 following the exclusion and the inclusion criteria for the TBI population from Bancroft Rehabilitation Center in
Haddonfield, NJ, Casa Colina Centers for Rehabilitation in Pomona, CA, Center for Comprehensive Services in Carbondale, Illinois, Center for Neuro Skills in Bakersfield, CA. The normal subjects were chosen from Miami University and its surrounding communities. The subjects in both the groups- the TBI group and the normals were matched for age, sex and level of education. The experimental design for the study is explained in detail in appendix C.

Subjects in the TBI group and the first group of normal subjects were subjected to the neuropsychological assessment battery along with the informal pretests. The subjects then underwent a systematic training procedure comprising of levels one through five along with the probe tasks administered at regular intervals. A probe task was administered before starting with level 1 of the CP, at the end of Level 2 and after level 5 was completed in order to test generalization. Administration of Part B was resumed after probe task 3 was administered on the subject by the examiner.

The examiner began the explicit category learning process with step 1, which is the Affirmative rule in case of each Progressive Rule Learning Level. The subject was exposed to the task stimuli pertinent for that level and was asked to assign them randomly to either category A or Category B. The examiner then provided feedback to the subject after each stimulus presentation whether he was correct or incorrect. After a series of stimuli presentation the subject was asked to formulate the rule that divides all the stimuli into categories A and B. The subject’s task was to devise a rule that governed the sorting of the different stimuli into either category A or B.

In Progressive Rule learning level 1, the subject was shown some pictures of different shapes and colors such as white triangle, black square, or a red triangle and familiarized with all the possible pictures that he would be exposed to through out the trial. The examiner then began the spontaneous categorization process. The subject was asked to guess and assign each presented picture (e.g. black triangle, red square, or white circle etc.) to either category A or B. The examiner provided feedback by telling the
subject whether the guess was correct or incorrect. After the 9th trial, the examiner reminded the subjects that could narrate the rule to the examiner at any point of time they think they knew it. After the 18th trial the subject was asked to verbalize the rule they had been using to sort the test items presented, into categories A and B. The examiner recorded the verbatim response on the score sheet. If the rule expressed by the subject could sort all the stimulus cards with 100% accuracy, then the subject was asked to sort out the final deck of cards. If the subject was not able to come up with the right rule and has at least 7 correct responses on the first 18 trials, he was asked to continue with the process and complete all the 36 trials in the spontaneous categorization section. The subject was reminded to voice the rule to the examiner at any point during the testing. However, if the subject scored less than 7 points during the first 18 trials and could not verbalize the accurate rule, the examiner implemented the cueing hierarchy (appendix E) and used the cues as required. The cueing hierarchy used, comprised of errorless pointing, full map, partial map, and providing the rule. After each cueing level was employed the subject was asked to narrate the rule followed by sorting of the cards in the final deck. If the subject was unable to come up with the right rule, the next level in the cueing hierarchy was implemented. The same process was repeated through out the five different steps-Affirmative, Conjunctive, Disjunctive, Exclusive, and Conditional for level 1.

Progressive rule learning 2 or the level 2 consisted of the same category structures and progressive difficulty as the previous level. However, the stimuli simulated a real life situation and the test items included gauges that represented operating conditions in a power plant. The process of presentation of the trial items and the rules remained the same.

The underlying procedure of training and the principle remain the same for level 3 of Part B. However, the stimulus items included words and varied along two dimensions e.g. the diagnostic test concerned with a particular organ in the human body as well as if
the laboratory result is high or low (e.g. heart fluid is high, bone marrow count is low, lung capacity is high etc.). The cueing hierarchy followed was the same as that for the previous two levels and consisted of five steps as mentioned above in case of levels one and two.

Research Questions

1. Will subjects with TBI receive more trials during the spontaneous categorization across the 3 levels (shapes, gauges, and words) as compared to the normal group of subjects?
2. Will subjects with TBI make significantly more errors during the spontaneous categorization of objects as compared to the normal group?
3. Will the TBI subjects require cue levels 3 and 4 more frequently as compared to the normal subjects in order to delineate the rule which classifies items in categories A and B?
4. Will the normal subjects receive more trials during spontaneous categorization for Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2 when the presentation of the rules is counterbalanced for the normal population?
5. Will the number of trials received during spontaneous categorization significantly change as a function of the steps (1-5) within every rule, for the TBI and the normal group of subjects?

Null Hypotheses

➢ TBI subjects will not receive more trials during the spontaneous categorization across the 3 levels (shapes, gauges, and words) as compared to the normal subjects.
Subjects with TBI will not make significantly more errors during the spontaneous categorization as compared to the normals.

The TBI subjects will not require cue levels 3 and 4 more frequently as compared to the normal subjects in order to delineate the rule which classifies items in categories A and B.

The normal subjects will not receive more trials during spontaneous categorization for Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2 when the presentation of the rules is counterbalanced for the normal population.

The number of trials, received during spontaneous categorization, will not significantly change as a function of the steps (1-5) within every rule, for the TBI and the normal group of subjects.

**Statistical Analysis**

**Research Question 1**

Will subjects with TBI receive more trials during the spontaneous categorization across the 3 levels (shapes, gauges, and words) as compared to the normal group of subjects?

The data was analyzed using the Mixed Model ANOVA.

**Design**

<table>
<thead>
<tr>
<th>STEPS</th>
<th>PL1</th>
<th>PL2</th>
<th>PL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>S2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>S3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| TBI   |     |     |     |

| NORMALS |     |     |     |

TBI=Traumatic Brain Injury group

PL1=Progressive Rule Learning 1
PL2=Progressive Rule Learning 2
PL3= Progressive Rule Learning 3

Research Question 2

Will subjects with TBI make significantly more errors during the spontaneous
categorization of objects as compared to the normal group?

The data was analyzed using the Mixed Model ANOVA.

<table>
<thead>
<tr>
<th>Design</th>
<th>PL1</th>
<th>PL2</th>
<th>PL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEPS</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
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<tr>
<td></td>
<td>S4</td>
<td>S5</td>
<td>S1</td>
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<tr>
<td></td>
<td>S2</td>
<td>S3</td>
<td>S4</td>
</tr>
<tr>
<td></td>
<td>S5</td>
<td>S1</td>
<td>S2</td>
</tr>
<tr>
<td>TBI</td>
<td>S3</td>
<td>S4</td>
<td>S5</td>
</tr>
<tr>
<td>NORMALS</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

TBI=Traumatic Brain Injury group
EPL1=Errors in Progressive Rule Learning 1
EPL2=Errors in Progressive Rule Learning 2
EPL3=Errors in Progressive Rule Learning 3

Research Question 3

Will the TBI subjects require cue level 3 and 4 more frequently as compared to
the normal subjects in order to delineate the rule which classifies items in categories A
and B?

The data was analyzed by performing independent samples t-test separately for
cue levels 3 and 4 respectively.

Research Question 4

Will the normal subjects receive more trials during spontaneous categorization for
Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2 when the
presentation of the rules is counterbalanced for the normal population?
The data was analyzed using a basic ANOVA separately for each progressive learning level.

**Design**

<table>
<thead>
<tr>
<th>Level</th>
<th>STEPS</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORMALS</td>
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<td></td>
</tr>
</tbody>
</table>

**Research Question 5**

Will the number of trials received during spontaneous categorization significantly change as a function of the steps (1-5) within every rule, for the TBI and the normal group of subjects?

The data was analyzed using a within subjects ANOVA. Analysis will be performed for within levels and steps for each level separately.

**Design**

<table>
<thead>
<tr>
<th>Level</th>
<th>STEPS</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORMALS</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

TBI= Traumatic brain injury group
CHAPTER IV

Results

Descriptive Statistics

Subjects: Eleven subjects with traumatic brain injury matched the inclusion exclusion criteria for the Categorization Program and participated in the study at large. The study at large consisted of an extensive neuropsychological battery, Part A, the three probes and Part B of the CP. The present study focused on the Part B of the CP. Five subjects successfully completed Part B of the Categorization Program and were included in the TBI experimental group for the Part B analysis. Normals were closely matched with the TBI subjects for age and number of years of education. The normal subjects were recruited from Oxford OH, and the surrounding areas. Nine out of the 12 normal subjects who were recruited for the Categorization Program successfully completed the training protocol and were included in the study. Another group of normal subjects (N=45) were administered only the Part B of the Categorization protocol along with the Wisconsin Card Sorting test (WCST) and informal pretest 1 and 2 as part of some Neuropsychological testing. The administration of Part B was counterbalanced among the group of normal subjects and was used for the purpose of standardization of the Part B.

The average age of subjects with traumatic brain injury was 31.3 years (SD = 10.9, range =19-49 years) where as the normal group ranged from 19-50 years with a mean age of 29.7 years (SD=10.8). The average number of years of education for the normal subjects was 14.4 years (SD= 1.9, range = 12-18 years) and that for the TBI subjects was 13.1 years (SD= 2.2, range =10-17 years). The normal subjects who only received Part B had 16.28 years of education (SD= 1.21, range =12-18 years), whereas their average age was 23.55 years (SD= 5.22, range = 19- 49 years).
Inferential Statistics

Research Question 1: Will subjects with TBI receive more trials during spontaneous categorization of objects across the 3 levels (shapes, gauges, and words) as compared to the normal subjects?

The Part B of the Categorization Program comprised of 3 different levels and had 5 steps in each level. The levels were established on the basis of the stimuli used and were arranged in an increasing order of difficulty. Level 1 corresponded to shapes of different colors, level 2 consisted of gauges and level 3 included medical diagnosis. All the 5 steps in each level consisted of spontaneous categorization of the stimuli into categories A and B, followed by implementation of the cuing hierarchy such as the errorless pointing, full maps, partial maps and providing the rule. The examiner provided the subject with feedback during the spontaneous categorization of the stimuli. The following procedure was employed in order to help the subject formulate the rule that would thus divide the stimuli into category A and category B. The subject could receive maximum of 36 trials during spontaneous categorization for shapes and gauges in levels 1 and 2, however, the subject received a maximum of 32 trials for level 3. The subjects received 1 point for every correct categorization. The examiner computed the total number of trials administered to the subject for each step.

The total number of trials received for spontaneous categorization attained from each of the 5 steps in the 3 levels was subjected to mixed model ANOVA (α=. 05) in order to decide if TBI subjects received significantly more trials across 3 levels (shapes, gauges, and words) as compared to the normal subjects.

The between groups effect was significant at F(1,12) = 18.174, p = .001. Thus the TBI group received more trials during the spontaneous categorization as compared to the normal subjects. Table 1 is the display of the means and the standard deviations for each group across the three levels. Figure 1 is the graphical representation of the means of the
total number of trials received for spontaneous categorization irrespective of the individual steps for the TBI and normal subjects across the three levels.

Table 1

Trials Received During Spontaneous Categorization for TBI and Normal Subjects

<table>
<thead>
<tr>
<th></th>
<th>Level 1 Mean</th>
<th>Level 1 SD</th>
<th>Level 2 Mean</th>
<th>Level 2 SD</th>
<th>Level 3 Mean</th>
<th>Level 3 SD</th>
<th>Overall Mean</th>
<th>Overall SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td>31.56</td>
<td>1.78</td>
<td>33.20</td>
<td>1.77</td>
<td>30.28</td>
<td>0.97</td>
<td>31.68</td>
<td>1.15</td>
</tr>
<tr>
<td>Normal</td>
<td>21.46</td>
<td>1.32</td>
<td>21.53</td>
<td>1.32</td>
<td>23.08</td>
<td>0.72</td>
<td>22.03</td>
<td>0.86</td>
</tr>
</tbody>
</table>

SD=Standard Deviation.

The main effect for levels was not significant, F(2) = .210 at p = .812 Thus there was no difference between the three levels across groups. Similarly the levels by groups interaction was not significant, F(2) = 1.328 at p = .284. Therefore both groups of subjects followed similar patterns across the 3 levels. The number of trials received during spontaneous categorization was similar across the 3 levels.

Research Question 2:

Will subjects with TBI make significantly more errors during the spontaneous categorization of objects as compared to the normal group?

Each step in Part B of the Categorization Program began with spontaneous categorization of the stimuli into categories A and B, following which the examiner gave the subjects feedback as to whether the response was correct or incorrect. The total number of incorrect trials for both the TBI and normal subjects were computed at every step for each of the three levels. The total errors were analyzed using a mixed model ANOVA (α=.05) in order to determine if the TBI subjects made significantly more errors during the spontaneous categorization as compared to the normal group. The between-groups effect was found to be significant at F(1,12) = 5.503, p = .037. Thus
subjects with TBI made significantly more errors during spontaneous categorization of objects as compared to the normals. Table 2 is the display of the means and the standard deviations for each group. Figure 2 is the graphical representation of the means of the total errors for spontaneous categorization irrespective of the individual steps for the TBI and normal subjects across the three levels.

Table 2

*Spontaneous Categorization Errors for TBI and Normal Subjects*

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th></th>
<th>Level 2</th>
<th></th>
<th>Level 3</th>
<th></th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>TBI</td>
<td>9.56</td>
<td>1.24</td>
<td>12.04</td>
<td>1.54</td>
<td>11.6</td>
<td>1.37</td>
<td>11.06</td>
</tr>
<tr>
<td>Normal</td>
<td>7.13</td>
<td>0.92</td>
<td>6.57</td>
<td>1.14</td>
<td>8.57</td>
<td>1.02</td>
<td>7.43</td>
</tr>
</tbody>
</table>

SD=Standard Deviation

The main effect for levels was not significant at F(2) = 3.319 at p = .053. Also the group by level interaction was not significant at F(2) = 2.819 at p = .079. However there was a significant interaction between levels and steps, F(8) = 2.818, p = .008. Therefore the number of errors were significantly different across the 5 steps in each level.

Research Question 3:

*Will the TBI subjects require cue level 3 and 4 more frequently as compared to the normal subjects in order to delineate the rule which classifies items in categories A and B?*

Part B of the Categorization Program examined the subjects’ ability to formulate the rules on the basis of the feedback provided by the examiner. The subjects were first asked to spontaneously categorize the stimuli into categories A and B. If the subjects failed to delineate the rule, the examiner implemented the cueing hierarchy, which
comprised of errorless pointing (cue level 1), full maps (cue level 2), partial maps (cue level 3) and providing the rule (cue level 4). The total number of cueing levels 3 and 4 required by the subjects was computed for the purpose of statistical analysis.

An independent samples t-test at alpha level of .05 was performed for cueing level 3 and cueing level 4 between the TBI and the normal group to test whether TBI subjects as a group required more cueing as compared to the normal subjects. A significant difference for the two groups was noticed for cueing level 3, \( t(15) = 4.69, p = .000 \). Similarly a significant difference was observed for cueing level 4, \( t(15) = 3.986, p = .001 \). Tables 3 and 4 are the means and the standard deviations of the total number of cueing levels 3 and 4 for both the groups respectively.

Table 3

**Use of Cueing Level 3 by TBI and Normal Subjects**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td>6</td>
<td>3.5</td>
<td>2.07</td>
</tr>
<tr>
<td>Normal</td>
<td>11</td>
<td>0.36</td>
<td>0.67</td>
</tr>
</tbody>
</table>

N= Subject Size (N is variable due to incomplete portions of the data)

Table 4

**Use of Cueing level 4 by TBI and Normal Subjects**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td>6</td>
<td>2.33</td>
<td>1.75</td>
</tr>
<tr>
<td>Normal</td>
<td>11</td>
<td>0.18</td>
<td>0.41</td>
</tr>
</tbody>
</table>

N= Subject Size (N is variable due to incomplete portions of the data)
The analysis revealed a significant difference between the two groups with respect to the use of cueing level 3 and 4. The analysis suggested that most normal subjects were able to delineate the rule and did not require the examiner to provide them the rule in the end as with the TBI subjects.

Research Question 4:

Will the normal subjects receive more trials during spontaneous categorization for Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2 when the presentation of the rules is counterbalanced for the normal population?

Normal group of subjects (N=45) who were subjected to Part B of the CP were divided into three different groups. The examiner counterbalanced the order of presentation of the levels within the three groups. Group 1 received the three levels in the order of level 1, level 2 and level 3 respectively. Group 2 started with Level 2 and proceeded to level 3 and level 1 respectively. Group 3 began testing with level 3 and went on to receive level 1 and 2 in that order. The subjects were given a point for each correct categorization. The total number of trials administered for each step was computed.

A basic ANOVA test was used to analyze and determine if the normal subjects required more trials during spontaneous categorization for Progressive Rule Learning 3 as compared to Progressive Rule Learning 1 and 2.

Order analysis for level 1.

The analysis was significant for level 1 (shapes), F(2,42) = 8.835, p = .001. Table 4 displays the mean number of trials required when level 1 was administered first, second and third respectively.
Table 4

*Trials received during Spontaneous Categorization for Level 1*

<table>
<thead>
<tr>
<th>Groups</th>
<th>Order of level 1</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>15</td>
<td>121.2</td>
<td>16.88</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>15</td>
<td>96.33</td>
<td>21.08</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>15</td>
<td>96.86</td>
<td>17.03</td>
</tr>
</tbody>
</table>

Order= Order in which the three groups received level 1 during the testing process  
N= Subject size  
SD=Standard Deviation

Subjects who received level 1 at the beginning of the test took more trials to delineate the rule as compared to the subjects who received it second and third during the presentation of the three levels.

*Order analysis for Level 2.*

The analysis was not significant for level 2 (gauges), $F(2,42) = 0.80$, $p = .924$. Therefore the order did not affect performance on this level. Table 5 displays the mean number of trials for delineating rules in level 2 when the order of presentation was counterbalanced among the three groups such that group 2 received it first.

Table 5

*Trials received during Spontaneous Categorization for Level 2*

<table>
<thead>
<tr>
<th>Groups</th>
<th>Order of level 2</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>15</td>
<td>124.06</td>
<td>18.67</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>15</td>
<td>121.06</td>
<td>19.11</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>15</td>
<td>121.40</td>
<td>28.50</td>
</tr>
</tbody>
</table>
Order = Order in which the three groups received level 2 during the testing process
N = Subject size  SD = Standard Deviation

**Order analysis for Level 3.**  
Similarly the analysis was not significant for level 3 (words), F(2, 42) = 1.246, p = .298. As with level 2 the order had no effect in the number of trials administered.  
Table 6 displays the mean number of trials for delineating rules in level 3 when the order of presentation was counterbalanced among the three groups such that group 3 received it first.

Table 6  
**Trials received during Spontaneous Categorization for Level 3**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Order of level 3</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>15</td>
<td>89.53</td>
<td>18.80</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>15</td>
<td>86.60</td>
<td>14.57</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>15</td>
<td>98.26</td>
<td>27.64</td>
</tr>
</tbody>
</table>

Order = Order in which the three groups received level 2 during the testing process
N = Subject size  SD = Standard Deviation

Levels 2 and 3 did not show much difference in the number of trials required to formulate the rules when the presentation of the levels was counterbalanced among the three groups.
Research Question 5:

Will the number of trials received during spontaneous categorization significantly change as a function of the steps (1-5) within every rule, for the TBI and the normal group of subjects?

The 3 levels in Part B comprised of 5 steps each and was arranged in an increasing order of difficulty. Each level had steps based on affirmative, conjunctive, disjunctive, exclusive and conditional statements and in that order only. The steps for the various levels have been mentioned in detail in appendix D. The examiner computed the total trials administered for each step across the three levels.

A General Linear Model-Repeated Measures analysis (SPSS, version 11.0 for Windows) was performed at an alpha level of 0.5 for each level separately, in order to determine if the total trials administered increased as a function of the steps within every level.

Level 1.

The analysis was significant for steps, $F(4) = 5.248$, $p = .001$. Also the between subjects effects was significant at $F(1, 17) = 11.54$ at $p = .003$. Thus there was an increase in the trials received during spontaneous categorization between the two groups as a function of the steps. Table 7 is the display of the means and standard deviations of the trials received during spontaneous categorization for level 1 for both the groups. TBI subjects received more trials, which suggest difficulty in delineating the rule as the complexity increases. The normal subjects demonstrate difficulty during the last 2 steps. Step 4 was the most difficult across groups.

Table 7

Trials Received During Spontaneous Categorization for Various Steps in Level 1
Level 2.

Similarly the analysis was significant for steps, \(F(4) = 2.672, p = .042\). Also the between subjects effects was significant at \(F(1, 13) = 17.89\) at \(p = .001\). Thus there was an increase in the trials received during spontaneous categorization between the two groups. Thus the number of trials increased as a function of the steps for level 2. Table 8 is the display of the means and standard deviations of the trials received during spontaneous categorization for level 2 for both the groups. Both groups received more trials as the difficulty increased with subsequent steps. The difficulty between step 1 and step 5 for the TBI subjects is small; however there is almost a 15 trial difference between steps 1-5 for the normal subjects.

Table 8

\textit{Trials Received During Spontaneous Categorization for Various Steps in Level 2}

\begin{tabular}{|c|c|c|c|c|c|}
\hline
Steps & 1 & 2 & 3 & 4 & 5 \\
& Mean & SD & Mean & SD & Mean & SD \\
\hline
TBI & 24.5 & 9.6 & 28.25 & 8.9 & 31.00 & 7.7 \\
& & & & & 33.87 & 6.0 \\
& & & & & 29.75 & 8.7 \\
Normal & 13.27 & 5.7 & 9.09 & 11.7 & 9.09 & 10.4 \\
& & & & & 28.2 & 10.4 \\
& & & & & 23.1 & 10.3 \\
\hline
\end{tabular}

Level 3.

Similar to the previous levels, the analysis was significant for steps, \(F(4) = 6.016, p = .000\). Also the between subjects effects was significant at \(F(1, 16) = 9.308, p = .008\).
Thus there was an increase in the trials received during spontaneous categorization between the two groups as a function of the steps. Thus the number of trials increased as a function of the steps for level 2. Table 9 is the display of the means and standard deviations of the trials received during spontaneous categorization for level 3 for both the groups. There is a 6.5 trial difference seen between step 1 and step 5 for the TBI group and a 7 trial difference for the normal subjects.

Table 9

*Trials Received During Spontaneous Categorization for Various Steps in Level 3*

<table>
<thead>
<tr>
<th>Steps</th>
<th>1 Mean</th>
<th>SD</th>
<th>2 Mean</th>
<th>SD</th>
<th>3 Mean</th>
<th>SD</th>
<th>4 Mean</th>
<th>SD</th>
<th>5 Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td>24.28</td>
<td>9.8</td>
<td>32.0</td>
<td>0.0</td>
<td>32.0</td>
<td>0.0</td>
<td>31.28</td>
<td>1.8</td>
<td>30.74</td>
<td>3.4</td>
</tr>
<tr>
<td>Normal</td>
<td>16.18</td>
<td>9.1</td>
<td>27.36</td>
<td>6.6</td>
<td>25.0</td>
<td>10.2</td>
<td>28.45</td>
<td>5.1</td>
<td>23.36</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Figure 1

Trials Received During Spontaneous Categorization for TBI and Normal Subjects

Progressive Learning Levels

Trials

Trials-TBI

Trials-Normal
Figure 2

Errors During Spontaneous Categorization for TBI and Normal Subjects
CHAPTER V
Discussion

The study under examination investigated the subjects’ ability to spontaneously categorize objects and use the cueing hierarchy to delineate rules for the various steps across the three Progressive Learning Levels. The purpose of this study was to compare the performance of the TBI group with the normal subjects on a category learning protocol.

The study examined the differences between the TBI and the normal subjects with respect to the number of trials administered as well as the errors made by each group during spontaneous categorization. Furthermore, the frequency of use of the cueing hierarchy within the TBI and the normal subjects was investigated. Another objective of the study was to examine the hierarchical order of the protocol by counterbalancing the presentation of the levels (1-3) within normal subjects.

The TBI group received more trials during the spontaneous categorization of stimuli as compared to the normal subjects. The patterns of responses across the 3 levels were similar between the 2 groups. Traumatic brain injury generally influences the overall cognitive functioning of an individual. The frontal and the temporal lobes, which play an important role in the memory and attention processes, are affected to a great extent. The spontaneous categorization stage of category learning protocol required subjects to initially do a random assignment of the stimuli to either category. The subjects were expected to formulate a rule in their mind that would successfully segregate all the possible stimuli into two different categories based on the examiner’s feedback. The subjects were essentially required to keep track of the examiner’s feedback and apply it to the forthcoming stimuli. This process demands appropriate functioning of the basic as well as executive cognitive functions. Spontaneous categorization being a higher-level cognitive function is affected in case of a traumatic brain injury. The findings of this
study thus, support the literature as the normal subjects did show a better performance as compared to the TBI group on spontaneous categorization across the 3 levels.

The TBI group made significantly more errors during spontaneous categorization as compared to the normal subjects. This could be attributed to the difficulty faced by the TBI group to keep track of the examiner’s feedback and use the information for the following trials. Also there was no significant difference in the number of errors across the three levels (shapes, gauges, and words). Given the fact that the stimuli used for levels 2 and 3 (i.e. gauges and words in the form of medical diagnosis) are more abstract; one would expect an increase in the number of errors. However, the lack of significance could be attributed to the small sample size. Another possible explanation is that subjects learned from Rule 1 training and guided their performance to more abstract tasks. Finally, another speculation is that even though the gauges and the medical diagnosis were more abstract, they were meaningful to the subjects, and thus they provided contextual support.

The study used a reverse order of cueing hierarchy, which consisted of errorless pointing, full maps, partial maps and telling the rule. The study examined if the subjects with TBI used cueing levels 3 and 4 more frequently than the normal subjects. The analysis revealed a significant difference in the use of the cueing levels between both the groups. Results imply that the TBI group could not formulate the rules through spontaneous categorization of the stimuli and often required some assistance in the form of cueing levels. Cueing level 3 indicated that subjects required to look at the partial maps following which either they could delineate the rule or need the next cueing level which comprised of the examiner providing the rule itself. Normal subjects were able to recognize the rule using minimum help from the cueing levels.

The data collected from 45 normal subjects who were subjected only to the Part B of the Categorization Program was analyzed to determine if the subjects receive more trials during spontaneous categorization for progressive rule learning level 3 as compared to levels 1 and 2 when the presentation was counterbalanced across the three levels.
 Subjects required fewer trials when level 1 was preceded by levels 2 and 3. This suggests that subjects were able to benefit from their category learning experience, which guided their responses during level 1 task. The analysis for levels 2 and 3 was not significant. Therefore it may be beneficial to consider rearranging the order of rule administration in order to enhance performance on level 1.

Analysis for the various steps across the 3 levels (shapes, gauges and words) revealed a change in the number of trials required to delineate the rule as a function of the steps. The descriptive statistics indicate that there was an increase in the number of trials received during spontaneous categorization for step 5 as compared to the step 1. The analysis thus verified the assumption that the steps had been indeed arranged in an ascending order of difficulty.

Implications of the Study

The changes in the life of an individual after traumatic brain injury include an array of physical issues, emotional disturbances, and cognitive deficits. The TBI victims generally undergo a comprehensive rehabilitation program in order to experience success in implementing activities of daily living and function in an independent fashion for financial purposes. Most rehabilitation programs are based on attention and memory retraining and do not focus on the other executive cognitive deficits. Categorization as an executive cognitive process has not been much investigated as a treatment tool for the TBI population. Categorization indirectly requires good attention and memory capacity. Categorization is also significant as a cognitive tool for our daily problem solving and reasoning abilities.

There is a strong need to develop a standardized rehabilitation program for the TBI individuals that would focus on overall cognitive rehabilitation as compared to emphasis on a single process. This present study was a part of a larger rehabilitation program designed to improve categorization abilities with TBI population. The CP as a
whole utilized categorization ability in a structured manner to help individuals who demonstrated cognitive deficits due to traumatic brain injury.

Results suggest that TBI hampers category learning and thus this kind of training protocol maybe a worthwhile effort. The results indicated significant differences between the TBI and the normal subjects in the number of trials received for spontaneous categorization. Also the TBI subjects used cueing levels more frequently as compared to the normal subjects indicating the need for assistance in category learning tasks. The steps within each level have been arranged in an increasing order of difficulty as it might help individuals with TBI proceed from simpler to more complex rules eventually.

Limitations

The significant limitations to this study were posed by incomplete data obtained for the TBI group. This resulted in fewer subjects to be included in the TBI group to be compared with the normal group. Part B was administered at the end of the Categorization Program and hence more susceptible to subject attrition. The protocol was administered by several trained speech pathologists at various residential sites for the TBI group. Thus changes in the trained personnel at various sites were also some limiting factors for data collection.

Future Research

The study brought into light some significant differences between the TBI and the normal group of subjects. The TBI subjects were included from among 5 different sites across the country and hence it was more heterogeneous population as compared to the normal subjects who were obtained from areas around Miami University. Thus future research is required to investigate the differences between the two groups using a larger and more diverse sample size.
The present study focused on the spontaneous categorization feature. It did not, however, take into account the number of trials required to delineate the rule. Future research could investigate the TBI subjects’ performance without the implementation of the cueing hierarchy in order to obtain more information on the effects of TBI on category learning in general.
References


APPENDIX A

Neuropsychological Battery for Normal Subjects

1. Hearing Screening at 1000, 2000, and 4000 Hz at 20 dB (ASHA, 1989)
2. Vision Screening consisting of 5 words in 10-point, black font (Constantinidou, 1995)
3. Color Blindness Screening using the Ishihara test for color blindness (www.toledo-bend.com)
4. Beck Depression Inventory-II (Beck et al., 1996)
5. Mini Mental State exam (Folstein et al., 1975)
6. Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999)
7. Boston Naming Test (Goodglass, Kaplan, & Barresi, 2000)
8. Copy Administration of the Rey complex Figure (Meyers & Meyers, 1995)
10. Digit Span Forwards and Backwards (Wechsler, 1997)
11. Spatial Span Forward and Backwards (Wechsler, 1997)
13. Symbol digit Modalities Test (Smith, 1973)
14. Wisconsin Card Sorting test (Grant & Berg 1993)
15. The Category Booklet Test (DeFillipis & McCamphell, 1998)
17. The Picture Recognition Subtest from the Woodcock Johnson Psycho-Educational battery Revised (WJ-III) (Woodcock, Mcegrew, & Mather, 2001)
18. Analysis and Synthesis, Verbal Analogies, Concept Formation and Spatial Relations Subtests (WJ-III)
APPENDIX B

Neuropsychological Battery for Adults with TBI

1. Color Blindness Screening using the Ishihara test for color blindness
   (www.toledo-bend.com)
2. Beck Depression Inventory-II (Beck et al., 1996)
4. Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999)
5. Boston Naming Test (Goodglass, Kaplan, & Barresi, 2000)
6. Copy Administration of the Rey complex Figure (Meyers & Meyers, 1995)
7. Trail Making Tests A and B (Lezak, 1999)
8. Digit Span Forwards and Backwards (Wechsler, 1997)
9. Spatial Span Forward and Backwards (Wechsler, 1997)
11. Symbol digit Modalities Test (Smith, 1973)
12. Wisconsin Card Sorting test (Grant & Berg 1993)
13. The Category Booklet Test (DeFillipis & McCampbell, 1998)
15. The Picture Recognition Subtest from the Woodcock Johnson Psycho-Educational battery Revised (WJ-III) (Woodcock, Mcgrew, & Mather, 2001)
16. Analysis and Synthesis, Verbal Analogies, concept Formation and Spatial Relations Subtests (WJ-III)
18. Mayo Portland Adaptability Inventory-3 (Malec et al., 2000)
## APPENDIX C

### Experimental Design

<table>
<thead>
<tr>
<th>Part A</th>
<th>Part B</th>
</tr>
</thead>
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<tr>
<td>pretests</td>
<td>Levels posttests</td>
</tr>
<tr>
<td>P 1</td>
<td>P 3</td>
</tr>
<tr>
<td>L 1</td>
<td>L 1-3</td>
</tr>
<tr>
<td>L 2</td>
<td></td>
</tr>
<tr>
<td>L 3</td>
<td></td>
</tr>
<tr>
<td>L 4</td>
<td></td>
</tr>
<tr>
<td>L 5</td>
<td></td>
</tr>
</tbody>
</table>

| Group 1      | X                 |
| TBI          | X                 |
| Group IV     | X                 |
| Normal(1)    | X                 |
| Normal(2)    |                  |
| Normal(3)    |                  |

Pretests and the posttests include the neuropsychological measures, informal pretest and posttest of the Categorization Program

P1- probe 1       Normal (1) = Normal subjects Gp 1
P2- probe 2       Normal (2) = Normal subjects Gp 2
P3- probe 3       Normal (3) = Normal subjects Gp 3
L1- perceptual feature training
L2- similarities and differences
L3- functional categorization
L4- analogies
L5- abstract concepts
APPENDIX D

Progressive Rule Learning Level 1

Steps

1. Affirmative: All black objects are members of category A. Other objects are category B members.
2. Conjunctive: If the object is red and a circle, it is a member of category A; otherwise it is a category B member.
3. Disjunctive: The object must be white or a triangle to be in category A; otherwise, it is a member of category B.
4. Exclusive: The object belongs in category A if it is black or a circle, but not both. Otherwise, it belongs in category B.
5. Conditional: If an object is black and not a circle then it must be a member of category B; otherwise, it is a member of category A.

Progressive Rule Learning Level 2

Steps

1. Affirmative: The plant is condition A if Gauge 1 is at 10. Other situations are condition B.
2. Conjunctive: In order to be in condition A, Gauge 1 must be at 30 and Gauge 2 must be at 10. Other situations are condition B.
3. Disjunctive: The plant is in condition A if gauge 1 is at 20 or Gauge 2 is at 30. Other situations are condition B.
4. Exclusive: The plant is in condition A when gauge 1 is at 10 or gauge 2 is at 10, but not both. Other situations are condition B.
5. Conditional: If gauge 1 is at 10, gauge 2 must not be at 30 to make the plant condition B. Otherwise the plant is in condition A.
Progressive Rule Learning Level 3

Steps

1. Affirmative: The diagnosis is disease A if Heart fluid is low; otherwise the diagnosis is Disease B.

2. Conjunctive: The diagnosis is Disease A if Lung Capacity is low and Bone Marrow count is high, otherwise the Diagnosis is Disease B.

3. Disjunctive: The diagnosis is disease A if Heart Fluid is low or Bone Marrow count is high, otherwise the diagnosis is disease B.

4. Exclusive: The diagnosis is disease A if the Lung Capacity is high or Bone Marrow count is low but not both, else the diagnosis would be disease B.

5. Conditional: If heart fluid is high, lung capacity must not be high in order for the diagnosis to be disease B; otherwise, the correct diagnosis is disease A.
APPENDIX E

Cueing Hierarchy

Level 1: Pointing

When the level 1 implementation is reached, the examiner hands the errorless cueing deck to the patient, who holds forth the top card. The examiner simply points to the correct pile. The patient is specifically told to try and figure out the rule without making any actual guesses out loud. This continues until the deck is exhausted, with the examiner pointing to the correct pile. At the end of the errorless sort, the examiner asks the subject to verbalize the rule. If this is done correctly, the patient is asked to sort a final sort deck consisting of each of the 9 stimuli using the rule, and, the condition is complete. Otherwise, cueing level 2 is immediately implemented.

Level 2: Full Map

After level 1 cuing fails, the examiner places the Full Map for the step depicting all category A members near the category A sign and one depicting all category B members near the category B sign. The Full Map deck is used by the client, who sorts the cards. Again the client is reminded to tell the examiner the rule as soon as it becomes apparent. After the client sorts the deck, if the client cannot state the rule after this level of cuing, the examiner proceeds immediately to level 3.

Level 3: Partial Map

After level 2 cueing fails, the examiner places the Partial Map for the step depicting some of the category A members near the category A sign, and one depicting some of the category B members near the category B sign. The Partial Map deck is used by the client, who sorts the cards. Again, the client is reminded to tell the examiner the rule as soon as it becomes apparent. After the client sorts the deck, if the client cannot state the rule or indicate knowledge non-verbally after this level of cuing, or if he or she is still making errors the examiner proceeds immediately to level 4.
Level 4: Providing the Rule

After level 3 cuing fails, the examiner removes all stimulus materials and hands the client the Final Sort Deck. The examiner states the rule out loud and presents the client with the appropriate Rule sheet. The client is asked to sort the cards one last time.