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Further Exploration into the Coma Recovery Scale - Revised and the Music Therapy Assessment Tool for Awareness in Disorders of Consciousness

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FURTHER EXPLORATION INTO THE COMA RECOVERY SCALE - REVISED AND THE MUSIC THERAPY ASSESSMENT TOOL FOR AWARENESS IN DISORDERS OF CONSCIOUSNESS

by

Alika D. Seu

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Thesis Committee:

David S. Smith, Ph.D., MT-BC, Chair
Edward A. Roth, M.M., MT-BC
Wendy Magee, Ph.D, MT-BC

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Alika D. Seu, M.M.

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Due to the high rate of misdiagnosis of individuals with disorders of consciousness (DOC) it has been a priority to develop clinical tools to accurately diagnose and assess these individuals (Seel et al., 2010). The Coma Recovery Scale – Revised has been regarded as the gold standard assessment for this population, however, a recent pilot study has shown that the Music Therapy Assessment Tool for Awareness in Disorders of Consciousness (MATADOC) may have increased sensitivity in several assessment domains (auditory, visual, arousal, and verbal commands) in relation to the overall diagnostic outcome. The data sets from this pilot study were re-analyzed to further investigate how items between each assessment compare, to determine the relationship between arousal and the other assessment items within each assessment, and to investigate what other relationships are present between the items within each assessment. Results showed significant relationships between arousal, visual, and verbal command items in the MATADOC and arousal, visual, and communication items within the CRS-R. Findings continue to show strong similarities between the two assessments and support further investigation into the use of the MATADOC as a behavioral assessment for individuals with disorders of consciousness. Further research is recommended to continue to investigate the influence of music on arousal and influence this may have on the other assessment items.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Disorders of consciousness (DOC) can occur following severe brain injury and involve a change in awareness of oneself and one's environment. Loss of consciousness following a moderate to severe brain injury is extremely common and in severe brain injuries loss of consciousness can continue for prolonged periods of time, providing increased complexity to an already complicated injury. According to the National Hospital Discharge Survey, in 2010 there were 91.7 hospitalizations related to traumatic brain injury for every 100,000 people in the United States (CDC, 2010). Considering that lifetime cost of care for an individual with a severe traumatic brain injury can range from $600,000 to $1,875,000, being able to accurately assess and treat these individuals to help them reach their highest level of independence is not only compassionate, but may be cost effective as well (Giacino et al., 2002). These costs cover everything from hospitalizations, scans (CT, PET, MRI…), nursing, home health aides, therapies, wheelchairs, orthotics, and other adaptive equipment. More recent studies conducted outside of the United States suggest similar high costs of brain injury care. In 2010 the cost of care for individuals in the European Union with brain disorders was €33 billion (Olesen, Gustavsson, Svensson, Wittchen, & Jonsson, 2012). In Australia in 2004-2005 the estimated cost of care for individuals with traumatic brain injury was $184 million in Australian dollars (Ponsford, Spitz, Cromarty, Gifford, & Attwood, 2013). According to Ponsford et al. (2013), long-term care costs were most expensive, with hospital and paramedic costs following behind. In addition, they found that the longer the duration of post traumatic amnesia following brain injury, the higher costs at all levels (hospitalization, long-term care, paramedics…) tended to be. Abnormal CT scans as well as epilepsy following injury were also related to higher long-term costs.

On top of the costs associated with brain injury and DOC, misdiagnosis of these individuals has also been a major concern in the medical community. Schnakers et al. (2009) compared the diagnostic information provided by the physicians of 103 individuals based on observations of behavior made by medical staff, to the Coma Recovery Scale – Revised (CRS-R) assessments, which is the gold standard of DOC assessments, performed by she and her fellow researchers. They found that 41% of individuals (18 of 44) described to be in vegetative states (VS) by the medical staff were actually in minimally conscious states (MCS) as determined by the CRS-R. Additionally, of those that the medical staff could not decide on a diagnostic category for, 89% were found to be in MCS.

While brain injuries resulting in DOC are very complex, over the past two decades there has been an increased amount of research on brain injury and the individuals who are affected by them (Gosseries, Di, Laureys, & Boly, 2014; Sannita, 2015; Trojano et al., 2012; Real et al., 2016). Due to this complexity and the high incidence of misdiagnosis, one of the primary areas of focus of recent research has been assessment (Seel et al., 2010; Schnakers et al., 2009).

Rationale for the Research

The Music Therapy Assessment Tool for Awareness in Disorders of Consciousness (MATADOC) is a music therapy assessment that is used to determine an individual's overall level of awareness based on their responses to music and different musical elements (Magee, Lenton-Smith, & Daveson, 2015a). The MATADOC looks at the specific items of arousal, command following, awareness of visual, auditory, and musical stimuli, as well as a number of other behavioral responses to music such as changes in respiration, increased motor movement, vocalization, and facial gestures. The assessment procedure is administered four times within the span of 10 days. Once completed, the raw scores are then calculated into converted scores which then determine a final diagnostic outcome, with a summary of behavioral responses and the stimuli that were present when they were observed. The five previously mentioned assessment items compose the Essential Categories Primary Subscale of the MATADOC, which are the items that determine diagnostic outcome (Table 1). The totals of converted scores for each of the five items in the principle subscale are added together to obtain a final score which is out of 10 points, with a maximum of two points possible for each item. Diagnosis is determined based on these final scores, with those scoring between 0-3 falling into the VS range, 4-7 into MCS range, and 8-10 in the emerging range. In order to determine the final diagnostic outcome from the four MATADOC sessions, the most prevalent diagnosis is taken. For example, if an individual scores within the VS range in three sessions and MCS in the fourth then the individual would be scored as VS. However, if an individual were to score two sessions in the VS range and two sessions in the MCS range then the clinician is required to look at other aspects of the individual's behavior and determine whether they more appropriately conform to traditional VS behaviors or whether their responses were more indicative of MCS. It is recommended by the MATADOC assessment manual that in cases like this, arousal scores be taken into consideration, as well as whether any of the scores were ‘borderline’. For example, if the individual described in the previous example had two MCS scores of five and six and two VS scores of three then the clinician may decide that since the individual's two VS scores were on the higher end of the range (0-3) and closer to the MCS range that his or her responses would better fit a diagnosis of MCS rather than VS.

Table 1

MATADOC Assessment Subscales

Subscale Name: Item Title and Number	**Domain**	**Purpose of Item**
Essential Categories Primary Subscale		
1. Responses to Visual Stimuli	Visual	Assessment
2. Responses to Auditory Stimuli	Auditory	Assessment
3. Awareness of Musical Stimuli	Auditory	Assessment
4. Response to Verbal Commands	Auditory	Assessment
5. Arousal	Arousal	Assessment
Musical Parameter and Behavioral Response Type		
6. Behavioural Response to Music	Auditory	Assessment
7. Musical Response	Auditory	Assessment
Clinical Information to Inform Goal Setting and Clinical Care		
8. Vocalization	Communication	Treatment
9. Nonverbal Communication	Communication	Treatment
10. Choice Making	Communication	Treatment
11. Motor Skills	Motor	Treatment
12. Attention to Task	Arousal/Motor/Auditory	Treatment
13. Intentional Behaviour	Motor	Treatment
14. Emotional Response	Communication	Treatment

The Coma Recovery Scale - Revised (CRS-R) is the gold standard assessment used to assess individuals with DOC, and as such has been recommended by the American Congress of Rehabilitation Medicine for use with minor reservations (Seel et al., 2010). It differs from the MATADOC in that it generally does not utilize music, however it looks at similar behaviors. The CRS-R also only requires a single administration rather than the four required by the MATADOC, though it is often used as a serial assessment (repeated at designated time points to track progress) in clinical practice. The CRS-R assessment items include auditory, visual, motor, oromotor/verbal, communication, and arousal which are very precisely defined in the assessment protocol. While at first glance the MATADOC assessment items do not all seem to directly compare to those of the CRS-R, they have been defined and validated (see Table 1, modified from Magee, Siegert, Daveson, Lenton-Smith, & Taylor, 2014) to assess the same areas of functioning relevant in determining an individual's level of awareness (Magee et al., 2014). However, both the CRS-R and the MATADOC have assessment items that are unique, which can make comparing the two assessments challenging.

A pilot study conducted by Bodine (2015) showed that the MATADOC and the CRS-R correlate strongly. Diagnostic outcomes between the two assessments were consistent in five of the eight participants showing a strong positive relationship ($r_s = .85$, $p < .01$) in numeric scores. Positive correlations in arousal, auditory, and visual items also all showed positive relationships ranging between $r = .68 - .81$, $p < .05$. Several differences exist between the MATADOC and the CRS-R, one of the most prominent being that the MATADOC requires four separate sessions conducted over the span of a 10-day period in order to complete the full assessment, whereas the CRS-R can be completed in one session of less than 30 minutes. To allow for comparisons between the two, Bodine (2015) selected the single session MATADOC score that was completed closest to the date of the CRS-R, and utilized that score for two of the three primary analyses. While this did facilitate direct comparison between the two instruments, it may have diminished "some of the strength of the MATADOC to capture a more accurate picture of the patient's status and performance across time (Bodine, 2015, p. 50)." One of the primary strengths of the MATADOC is that it looks at behavioral responses across different days, giving the assessor a better idea of what responses an individual is capable of, while also taking into account fluctuating states of arousal. The CRS-R is administered only once in order to obtain its scores and diagnostic outcome, however, repeated measures are recommended for best practice, again, in order to take into account fluctuating states of arousal (Seel et al., 2010).

Bodine (2015) investigated the way each item within each assessment correlated with the outcome diagnosis, leaving examining the relationship of each item with the other items within the assessment for subsequent study. Music can be a useful stimulus when assessing awareness due to music's ability to elicit responses from both external brain networks. It also gathers information from networks involved in awareness of environment, such as language processing, working memory, attention, and internal brain networks, or those involved with awareness of self, such as autobiographical and self-referential re-experiencing (Perrin, Castro, Tillmann, & Luauté, 2015; Heine, Castro, Martial, Tillmann, Laureys, & Perrin, 2015). One hypothesis suggests that music may promote increased arousal, which in turn improves an individual's responsiveness, which was supported by the significant finding of a strong relationship between MATADOC arousal scores and diagnostic outcome (Bodine, 2015; O'Kelly & Magee, 2013). However, looking at the relationship between arousal scores on the CRS-R and diagnostic outcomes may prove helpful in better understanding the similarities and differences between the MATADOC and CRS-R. In addition, looking at the relationships between each of the assessment items within each assessment may lead to insights into the role of a music-based assessment, as it compares to the gold standard.

CHAPTER II

LITERATURE REVIEW

Diagnosis in Disorders of Consciousness

Consciousness is something that cannot be observed, which makes it incredibly difficult to assess (Seel et al., 2010). In 2002 the American Academy of Neurology (AAC) defined the minimally conscious state (MCS), determined its diagnostic criteria, as well as emergence from it, and clarified the previously established criteria for the vegetative state (VS) (Giacino et al., 2002). Behavioral characteristics of VS include presence of sleep/wake cycle, posturing or withdrawal to noxious stimuli, occasional non-purposeful movements, visual and/or auditory startle, brief orientation to visual and/or auditory stimuli, and reflexive smiling or crying. The difference between VS and MCS is that in MCS there is preservation of some level of conscious awareness whereas in VS consciousness is not present.

Giacino et al. (2002) defined MCS as "a condition of severely altered consciousness in which minimal but definite behavioral evidence of self or environmental awareness is demonstrated (p. 350-351)." In order for a diagnosis of MCS to be made, one or more of the following behaviors must be present on either a sustained or reproducible basis: simple command following; verbal or nonverbal yes/no, whether accurate or not; intelligible verbalizations; or some sort of purposeful behavior (movement, voicing, emotional responses...) that are contingent to environmental stimuli. In addition to defining and setting diagnostic criteria for MCS, Giacino et al. (2002) also suggested criteria that indicate emergence from MCS to higher levels of consciousness, which includes functional interactive communication and functional use of two different objects. The CRS-R follows these guidelines fairly strictly in its diagnostic determination, which will be discussed in more detail in the next section. More recently, the literature has suggested potentially further subdividing MCS to an MCS+ and MCS- (Bruno et al., 2009; Bruno, Vanhaudenhuyse, Thibaut, Moonen, & Laureys, 2011; Bodart, Laureys, & Gosseries, 2013).

Coma Recovery Scale – Revised

As previously described, the CRS-R is an assessment used with individuals with DOC to determine their level of awareness by looking at behavioral responses across six items: auditory, visual, motor, oromotor/verbal functioning, communication, and arousal. The assessment includes specific procedures for assessing each item and is conducted in a top-down fashion (i.e. providing opportunities for more advanced responses before moving lower on the scale). Diagnostic outcome is determined by the presence of specific behavioral responses as defined in the literature (Bruno et al., 2011; Giacino et al., 2002; Seel et al., 2010). The presence of functional accurate communication or functional object use is indicative of a diagnostic outcome of “emerging” (from MCS, or minimally conscious state). Presence of consistent movement to command, reproducible movement to command, object recognition, object localization – reaching, visual pursuit, visual fixation, automatic motor response, object manipulation, localization of noxious stimuli, intelligible verbalization, or non-functional intentional communication is indicative of a diagnostic outcome of “MCS”. Absence of any previously mentioned behaviors is indicative of a diagnostic outcome of “VS” (vegetative state). While there is no direct reference to why arousal is not considered in the diagnostic determination in the CRS-R, what *is* included is consistent with the criteria laid out by Giacino et al. (2002) for VS, MCS, and emerging consciousness.

As previously mentioned, the CRS-R has been identified as the gold standard diagnostic assessment for disorders of consciousness and it has held up over the years as new research has unwrapped new information about the DOC population (Seel et al., 2010). Naro et al. (2016a) found that electrophysiological measurements of the visual system in those with DOC had a strong positive correlation with scoring in the visual item of the CRS-R ($r = .792$, $p < .001$). Thonnard et al. (2014) looked at whether visual response on the CRS-R in individuals in MCS was influenced by choice of visual stimulus and by which plane the stimulus was moved within. They found that use of the mirror was preferentially tracked as opposed to a moving person or object. In addition, those showing visual pursuit preferred to track within the horizontal plane rather than the vertical.

Music Therapy Assessment Tool for Awareness in Disorders of Consciousness

Within the field of music therapy an assessment has been developed for awareness in this population called the Music Therapy Assessment Tool for Awareness in Disorders of Consciousness (MATADOC) (Magee, 2007). The MATADOC has three sections: the Essential Categories Primary Subscale, the Musical Parameter and Behavioral Response Type, and the final one that includes Clinical Information to Inform Goal Setting and Clinical Care. The primary subscale, which covers items 1-5, looks at behavioral responses within the items of arousal, command following, responses to visual and auditory stimuli, and awareness of musical stimuli, and is used to determine the diagnostic outcome. The Musical Parameter and Behavioral Response Type subscale, which covers items 6-7, notes specific behaviors that occurred within a session and what musical element the response was linked to (dynamics, tempo, mood…). The third subscale, which covers items 8-14, includes clinical information to inform goal setting and clinical care. This final section of the MATADOC looks at behaviors to specifically assist in informing goal setting and clinical care, specifically vocalization, any non-verbal communication that may be present, choice making, motor skills, attention to task, intentional behavior, and emotional response.

As previously mentioned, the MATADOC is completed four times within a 10-day period (Magee et al., 2015a). Raw scores within each item of the primary subscale from every individual session are converted into ranked scores, which are then added together with the maximum possible sum of ranked scores being 10. Primary subscale scores ranging from 0-3 are considered VS, 4-7 are considered MCS, and 8-10 are considered emerging. Since the MATADOC is conducted four times the final diagnostic outcome isn't determined until all four administrations have been completed. When three or four of the diagnoses are consistent across the four sessions this determines the diagnostic outcome (i.e. three or four scores in the MCS range and one in VS makes the final diagnostic MCS). When scores are even (i.e. two scores of MCS and two scores of emerging) it is the responsibility of the assessor to 'break the tie' and determine the final diagnostic outcome between the two. It is important to note here that in these cases, item 5, or arousal scores, plays a huge role, as do levels of response in items 8-14 in determining the final diagnostic outcome.

In individuals with DOC, cognitive, visual, speech/communication, and sensorimotor functioning tend to be the most impaired, while research has suggested that the auditory system remains most intact (Boly et al., 2004). It is in part due to the strength of the auditory system in these individuals that the MATADOC was developed as a complementary assessment to the CRS-R (Magee, 2005; Magee, 2007; O'Kelly & Magee 2013; Magee et al., 2014). The MATADOC, which was originally called the MATLAS or Music Therapy Assessment Tool for

Low Awareness States, was developed as a companion assessment to the CRS-R based on research suggesting that the auditory system seems to remain most intact (Magee, 2005).

Assessment Items

The MATADOC and CRS-R both overlap with the majority of items that they look at, however, there are a few items that are unique to each assessment. The primary subscale of the MATADOC includes responses to visual and auditory stimuli, as well as general arousal, which all overlap with the CRS-R (Table 2).

Table 2

MATADOC and CRS-R Assessment Items

MATADOC	CRS-R
Response to Visual Stimuli	Visual Function Scale
Response to Auditory Stimuli	Auditory Function Scale
Awareness of Musical Stimuli	---
Response to Verbal Commands	---
Arousal	Arousal Scale
---	Motor Function Scale
---	Oromotor/Verbal Function Scale
---	Communication Scale

In addition, the MATADOC also includes a section on awareness of musical stimuli as well as responses to verbal commands. The CRS-R on the other hand includes assessment of motor function, oromotor/verbal function, and communication. While some of these items have different names from one assessment to the other, there is some overlap in the behaviors that they assess. For example, the auditory function scale in the CRS-R looks at localization to sound, which the auditory item in the MATADOC also does. However, the auditory item in the CRS-R also looks at reproducible movement to command which requires a motor component and has some overlap with the response to verbal command item in the MATADOC.

In diving a bit deeper into the assessment items, research has shown that while visual impairment is quite common in individuals with DOC, visual cognition may be preserved (Monti, Pickard, & Owen, 2013). This suggests that some people with DOC maintain the ability to form visual representations in their minds. Other studies show that this may also be the case with other sensory systems such as the auditory system (Beukema et al., 2016). While visual fixation in individuals with a VS diagnostic outcome is possible, it is not very common (Naro et al., 2016a). There is some evidence which shows that individuals with a diagnosis of VS who show visual fixation may be aware, though do not have the ability to clearly display this due to severe motor output dysfunction, or other impairments (Naro et al., 2016a). The reason the visual system is so difficult to assess is because the brain can show responsiveness to changing visual stimuli even when an individual does not have subjective perception (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). Andrews, Murphy, Munday, & Littlewood (1996) found that in their sample of individuals with DOC, 65% of those that were misdiagnosed were either blind or severely visually impaired. Due to the fact that most DOC assessments take visual response (visual tracking, fixation, startle…) into account when determining awareness, individuals with severe visual dysfunction remain at a disadvantage, which helps to explain the high incidence of misdiagnosis.

In regard to motor functioning in individuals with DOC, Naro et al. (2016b) found dysfunction in the connectivity within the primary motor area, as well as in the circuitry between the premotor and primary motor area. Interestingly, they found that this dysfunction in circuitry correlated very closely to CRS-R scoring. Their results suggest that lack of motor response seen in some individuals with DOC could simply be because of a failure in output, as opposed to connectivity issues between premotor and motor areas of the brain.

Personally relevant stimuli, and particularly music, have been shown to elicit higher behavioral responses as compared to other stimuli (Perrin et al., 2015). Listening to familiar or preferred music elicits responses from both internal and external brain networks bringing together awareness of self, and of the environment, which is a benefit of using music with individuals with DOC. Perrin et al. (2015) suggested further studies investigate the specific cognitive processes that are enhanced by familiar music. Beukema et al. (2016) looked at the level of auditory processing in both healthy individuals and individuals with DOC and found event related potentials (ERP) indicated that some individuals with DOC indicated higher levels of auditory processing than were evident from behavioral assessment. However, this study also found no significant differences in auditory processing between participants in VS and MCS. It's important to note that this study used a small sample size of 16 participants which provides some context to its limitations. While clinical presentation of individuals in VS and MCS appear more consistent, functional neural imaging shows that when exposed to auditory, emotional and noxious stimuli, those in MCS are more consistent with healthy controls than individuals in VS (Boly et al., 2005). Boly et al. (2005) compared PET scan data from individuals with DOC and compared them to healthy controls and found that individuals in MCS showed similar neural activation to healthy controls when exposed to auditory, emotional and noxious stimuli, compared to individuals in VS who showed very little neural activity.

Some research has even shown that pairing of auditory and visual stimuli can help those with visual neglect and other visual deficits (Frassinetti, Pavani, & Ladavas, 2002; Frassinetti, Bolognini, Bottari, Borona, & Ladavas, 2005). In one study conducted by Frassinetti et al. (2005), individuals with visuospatial impairments were tested to see whether they would be able to detect a flash of light in six possible special positions. The participants were put into two different groups, one group that only received the light flash and the other in which the light was paired with a sound. The researchers found that those in the group where the light was paired with sound had significantly higher rates of visual detection. Frassinetti et al. (2005) explained that pairing sound presented from the same originating location as the flash of light seemed to help participants detect its location even when in previous conditions, where the light was presented on its own, the participants seemed to struggle to detect it. The authors explained the reasoning for this to be, similar to what is found in animal models, humans have multisensory or bimodal neurons which show enhanced responses when receiving stimuli from more than one sensory system. In this case, auditory and visual are located within its excitatory field. This seems to provide strong evidence that auditory and visual processing may be closely related.

While some individuals with DOC show signs of arousal, evidenced by eye opening and regular sleep wake cycles, and seem to attend to some stimuli, this does not always mean that they are aware or have any level of consciousness (Chennu & Bekinschtein, 2012). Schiff (2008) suggested that interventions which target the central thalamus may help to address issues related to impaired arousal in those with severe brain injury. The arousal system in the brain is regulated by the brainstem and basal forebrain along with frontal cortical systems that have converging projections in the central thalamus (Schiff, 2008). The central thalamus helps to sustain organized behavior while we are awake, as well as to network activity to other parts of the brain. The central thalamus is particularly important when increasing demand is required from stress, fatigue, or other issues that cause decreases in behavioral performance.

Pilot Study

The pilot study conducted by Bodine (2015), compared the MATADOC and CRS-R on several levels. Specifically, the level of agreement of diagnosis between the MATADOC and CRS-R, whether significant differences in scores were present between each comparative domain (visual, auditory, and arousal), how each domain corresponded to the diagnostic outcome within each assessment.

In terms of diagnostic outcomes of the two assessments, Bodine (2015) found the correlation between MATADOC and CRS-R diagnostic outcomes was strong and positive (r = .85, p < .01). While the sample size was fairly small at eight subjects, it may suggest that based on this strong relationship, the MATADOC could potentially be a valid assessment with further investigation. It is important to note that in three of the eight cases the diagnostic outcomes for the MATADOC and CRS-R did not agree, with the MATADOC providing higher outcomes (i.e. MCS over VS, emerging over MCS) than the CRS-R. Possible reasons for the difference, put forward by the researcher includes rater bias, or that the MATADOC could be more or less sensitive than the CRS-R.

The degree to which each of the assessment items correlated between the two assessments was also investigated. While the MATADOC and CRS-R vary in which functional items they examine, three of them do overlap; auditory, visual, and arousal. Bodine (2015) found moderate to strong positive relationships with all of them (auditory: r = .76; visual: r = .81; arousal: r = .68), however, only the auditory and visual items demonstrated a level of significance (p < .05).

The final area of interest was whether any relationships existed between each item and the diagnostic outcome within each of the respective assessments. Strong positive relationships were found between the auditory ($r = .94$, $p < .05$), visual ($r = .93$, $p < .05$), arousal ($r = .82$, $p < .05$), and verbal command ($r = .82$, $p < .05$) items of the MATADOC and the diagnostic outcome, however, within the CRS-R the only strong positive relationships to the diagnostic outcome were between the auditory ($r = .80$, $p < .05$) and communication ($r = .72$, $p < .05$) items. It's worth noting that within the CRS-R, the oromotor/verbal item was unable to be analyzed because once all scores were ranked all participants had the same score. The arousal item was not analyzed because in the CRS-R arousal scores do not have an influence on diagnostic outcome. As previously mentioned, while there does not seem to be a direct reference in the literature as to why arousal does not have an influence on diagnostic outcome in the CRS-R, the aspects of the assessment that *are* considered in the diagnostic are consistent with the behavioral criteria laid out by Giacino et al. (2002).

Since the completion of this pilot study by Bodine (2015), new research studies have been completed. One examined the reliability and validity of the MATADOC's second and third scales which look at specific musical parameters and behaviors as well as additional clinical information (Magee, Ghetti, & Moyer, 2015b), and another which looked at the feasibility of the MATADOC for use with pediatric populations (Magee, Siegert, Taylor, Daveson, & Lenton-Smith, (2016). Magee et al. (2015b) found that overall there was good agreement in the second and third subscales of the MATADOC both within and across assessors, though there was some variability with the musical response item and the choice making item. It is important to note here that scores in the second and third subscales do not have any direct influence on diagnostic outcome, however, as previously mentioned, in cases when an individual has split scores in the four assessment sessions, responses in scales two and three may be considered when determining which diagnosis is most appropriate (Magee et al., 2015a). In investigating the feasibility of use of the MATADOC with pediatric populations, it was found that the tool provided useful clinical information, and was an appropriate protocol and measure of behavior, though required further investigation (Magee et al., 2015b).

Research Questions

Based on the results of the pilot study (Bodine, 2015), the following research questions were developed in order to further understand how the MATADOC and CRS-R compare, as well as to provide insights into the role of arousal on the other assessment items. Data sets were extracted directly from the pilot study manuscript (Bodine, 2015), with verbal permission from the author, for use in these analyses.

1. Using data from the pilot study (Bodine, 2015), what is the difference between total average MATADOC item scores for each domain compared to single item CRS-R scores?
2. What is the correlation between scores for the arousal item and scores for all other items within each of the MATADOC and CRS-R measures?
3. What interactions exist between the individual items within the MATADOC and between which items do they exist?
4. What interactions exist between the individual items within the CRS-R and between which items do they exist?

CHAPTER III

METHOD

Data Extraction

Score data for both the MATADOC and CRS-R assessments were taken, for all eight participants, directly from Table 3 and Table 4 of the pilot study conducted by Bodine (2015), and entered into SPSS for analysis.

Participants

Participants included eight individuals whose data were obtained by convenience sample from a rehabilitation hospital in Grand Rapids, Michigan (Bodine, 2015). Ages ranged from 19 to 47 years and homogenous injury etiology of TBI with the exception of one participant whose injury was the result of an aneurysm. Patients who were included in the pilot study were all required to meet the following criteria: be between the ages of 16 and 70 years, be medically stable, and have a DOC diagnosis with unconfirmed level of awareness. See Table 3 for participant demographics.

Table 3
Participant Demographics

Subject	Gender	Age	Etiology	Months Since Injury
1	Make	19	TBI	3
2	Female	22	Aneurysm	3
3	Male	26	TBI	78
4	Female	47	TBI	66
5	Female	22	TBI	16
6	Female	45	TBI	1
7	Male	22	TBI	1
8	Male	33	TBI	84

Note. TBI = traumatic brain injury

Analysis

Research Question #1

The relationships between the comparative items (visual, auditory, and arousal) on the two assessments were analyzed with the Spearman test for correlation to determine the strength and direction of the relationship between them (Bodine, 2015). In addition, the relationship between the response to verbal command item of the MATADOC and the communication scale item in the CRS-R were analyzed as both assess the communication domain (Magee et al., 2014). Analyses were also conducted to determine the relationship between the awareness of musical stimuli item of the MATADOC and the auditory item of the CRS-R as this item of the MATADOC has been shown to also assess auditory functioning (Magee et al., 2014). Differing from Bodine, (2015), to reflect the clinical administration of the MATADOC, which requires completing the assessment four times, the converted scores for the four MATADOC sessions for each participant were averaged in order to obtain a single data set for comparison. Once averages were calculated for all assessment items described above, Z-scores were calculated, in order to convert them to the same scale, as they are both on different scales, with the exception of the arousal scores. The arousal items of the MATADOC and CRS-R are both on three-item scales, so Z-scores did not need to be calculated for this item. Once the item scores were converted to z-scores in both assessments for all participants, Spearman correlations were conducted between each comparative item pair.

Research Question #2

Item scores in the CRS-R were converted to z-scores in order to put them on the same scale as the majority of pairs were on different scales, with the exception of the arousal item and oromotor/verbal item pair; This pair was analyzed using the original raw scores as they were on the same scale. Spearman correlations were conducted on the CRS-R data between the arousal item scores and the other five items to determine whether there were any relationships between arousal and the other items.

Similarly, the converted MATADOC scores within each item were averaged for each participant to obtain a single score for each item. Again, scores were converted to z-scores so as to put them on the same scale for comparison. However, in the MATADOC all items are on the same scale except for the response to musical stimulation item. Thus, conversion to z-scores was only required for the comparison of arousal and response to musical stimulation. Spearman correlations were then conducted between the arousal item and each of the other four items to determine the strength of relationships that exist.

Research Question #3

In order to analyze interactions between items in the MATADOC, z-scores needed to be calculated to ensure that each item was on the same scale. As previously stated, z-scores were only required when the pair being analyzed included the awareness of musical stimulation item as this is the only item within the MATADOC that is not on a 0-3 point scale. Thus, when analyzing all other pairs, raw scores were used. Spearman correlations were conducted between all possible item pairs within the MATADOC to determine whether any interactions were present and if so, between which item pairs.

Research Question #4

To analyze interactions between individual items within the CRS-R, similar to the analysis of items within the MATADOC, z-scores needed to be calculated to ensure each item was on the same scale. Unlike the MATADOC, all item pairs within the CRS-R required z-scores for analysis with the exception of the arousal item and oromotor/verbal item pair which were both already on 0-3 point scales. Spearman correlations were conducted between all possible item pairs within the CRS-R to determine whether any interactions were present, and between which item pairs.

CHAPTER IV

RESULTS

Research Question #1

Using data from the pilot study (Bodine, 2015), what is the difference between total average MATADOC item scores for each domain compared to single item CRS-R scores?

There was a significant relationship between the arousal item on the MATADOC and the arousal item on the CRS-R, $r = .80$, p *(one-tailed)* $< .01$. There was a significant relationship between the auditory item on the MATADOC and the auditory item on the CRS-R, $r = .85$, p *(one-tailed)* $< .01$. There was a significant relationship between visual item on the MATADOC and visual item on the CRS-R, $r_s = .76$, p *(one-tailed)* $< .05$. There was not a significant relationship between the awareness of musical stimuli item on the MATADOC and the auditory item on the CRS-R, $r_s = .59$, p *(one-tailed)* $> .05$. There was a significant relationship between the verbal command item on the MATADOC and the communication item on the CRS-R, $r_s = .78$, p *(two-tailed)* $< .05$. Data for question #1 and comparative data from the pilot study are displayed in Table 4.

Table 4
Question #1 Bodine (2015) Result Comparisons

Item Comparison	Bodine (2015) r Value	Significance: Bodine (2015)	Present Analysis r Value	Significance Present Analysis
Visual	.81	$p < .05$	.76	$p < .05$
Auditory	.76	$p < .05$	.85	$p < .01$
Awareness of Musical Stimuli (MATADOC) vs Auditory (CRS-R)	N/A	N/A	.59	$p > .05$

Table 4 – Continued

Item Comparison	Bodine (2015) *r* Value	Significance: Bodine (2015)	Present Analysis *r* Value	Significance Present Analysis
Verbal Command (MATADOC) vs Communication (CRS-R)	N/A	N/A	.78	$p < .05$
Arousal	.68	$p > .05$	.80	$p < .01$

Research Question #2

What is the correlation between scores for the arousal item and scores for all other items within each of the MATADOC and CRS-R measures?

There was not a significant relationship between the arousal item and the motor item on the CRS-R, $r = .34$, p *(two-tailed)* $> .05$. There was not a significant relationship between the arousal item and the oromotor/verbal item on the CRS-R, $r = .45$, p *(two-tailed)* $> .05$. There was a significant relationship between the arousal item and visual item on the CRS-R, $r = .88$, p *(two-tailed)* $< .01$. There was a significant relationship between the arousal item and the auditory item on the CRS-R, $r = .89$, p *(two-tailed)* $< .01$. There was a significant relationship between the arousal item and the communication item on the CRS-R, $r = .74$, p *(two-tailed)* $< .05$. Data for the CRS-R components of question #2 are shown in Table 5.

Table 5
Question #2 CRS-R Comparisons

Comparison Pairs	r_s Value	p Value
Arousal and Motor	.34	>.05
Arousal and Oromotor/Verbal	.45	>.05
Arousal and Visual	.88	<.01
Arousal and Auditory	.89	<.01
Arousal and Communication	.74	<.05

There was a significant relationship between the arousal item and the auditory item on the MATADOC, $r = .91$, p *(two-tailed)* $< .01$. There was not a significant relationship between the arousal item and verbal command item on the MATADOC, $r = .66$, p *(two-tailed)* $> .05$. There was not a significant relationship between the awareness of musical stimulation item and arousal item on the MATADOC, $r = .50$, p *(two-tailed)* $> .05$. There was a significant relationship between the visual item and arousal item on the MATADOC, $r = .90$, p *(two-tailed)* $< .01$. Data for the MATADOC components of question #2 are shown in Table 6.

Table 6
Question #2 MATADOC Comparisons

Comparison Pairs	r_s Value	p Value
Arousal and Visual	.90	<.01
Arousal and Auditory	.91	<.01
Arousal and Response to Musical Stimuli	.50	>.05
Arousal and Verbal Commands	.66	>.05

Research Question #3

What interactions exist between the individual items within the MATADOC and between which items do they exist?

There was a significant relationship between the visual item and the auditory item on the MATADOC, $r = .98$, p *(two-tailed)* $< .01$. There was a significant relationship between the visual item and arousal item on the MATADOC, $r = .90$, p *(two-tailed)* $< .01$. There was a significant relationship between the visual item and the verbal command item on the MATADOC, $r = .90$, p *(two-tailed)* $< .01$. There was not a significant relationship between the visual item and the awareness of musical stimulation item on the MATADOC, $r = .58$, p *(two-tailed)* $> .05$. There was a significant relationship between the auditory item and the arousal item on the MATADOC, $r = .91$, p *(two-tailed)* $< .01$. There was a significant relationship between the auditory item and verbal command item on the MATADOC, $r = .88$, *p (two-tailed)* $< .01$. There was not a significant relationship between the awareness of musical stimulation item and the auditory item on the MATADOC, $r = .50$, *p (two-tailed)* $> .05$. There was not a significant relationship between the arousal item and verbal command item on the MATADOC, $r = .66$, *p (two-tailed)* $> .05$. There was not a significant relationship between the awareness of musical stimulation item and arousal item on the MATADOC, $r = .50$, *p (two-tailed)* $> .05$. There was not a significant relationship between the verbal command item and the awareness of musical stimulation item on the MATADOC, $r = .58$, *p (two-tailed)* $> .05$. Data for question #3 are displayed in Table 7.

Table 7
Question #3 Results

Items Compared	r_s Value	*p* value
Visual and auditory	.98*	<.01
Visual and arousal	.90*	<.01
Visual and verbal command	.90*	<.01
Visual and awareness of musical stimuli	.58	>.05
Auditory and arousal	.91*	<.01
Auditory and verbal command	.88*	<.01
Auditory and awareness of musical stimuli	.50	>.05
Arousal and verbal command	.66	>.05
Arousal and awareness of musical stimulation	.50	>.05
Awareness of musical stimuli and verbal command	.58	>.05

*Statistically significant

Research Question #4

What interactions exist between the individual items within the CRS-R and between which items do they exist?

There was not a significant relationship between the arousal item and the motor item on the CRS-R, $r = .34$, p *(two-tailed)* $> .05$. There was not a significant relationship between the arousal item and the oromotor/verbal item on the CRS-R, $r = .45$, p *(two-tailed)* $> .05$. There was a significant relationship between the arousal item and visual item on the CRS-R, $r = .88$, p *(two-tailed)* $< .01$. There was a significant relationship between the arousal item and the auditory item on the CRS-R, $r = .89$, p *(two-tailed)* $< .01$. There was a significant relationship between the arousal item and the communication item on the CRS-R, $r = .74$, p *(two-tailed)* $< .05$. There was not a significant relationship between the motor item and the oromotor/verbal item on the CRS-R, $r = .00$, p *(two-tailed)* $> .05$. There was not a significant relationship between the motor item and the visual item on the CRS-R, $r = .09$, p *(two-tailed)* $> .05$. There was not a significant relationship between the motor item and the auditory item on the CRS-R, $r = .08$, p *(two-tailed)* $> .05$. There was not a significant relationship between the motor item and the communication item on the CRS-R, $r = -.22$, p *(two-tailed)* $> .05$. There was not a significant relationship between the oromotor/verbal item and the visual item on the CRS-R, $r = .69$, p *(two-tailed)* $> .05$. There was not a significant relationship between the oromotor/verbal item and the auditory item on the CRS-R, $r = .50$, p *(two-tailed)* $> .05$. There was not a significant relationship between the oromotor/verbal item and the communication item on the CRS-R, $r = .64$, p *(two-tailed)* $> .05$. There was a significant relationship between the visual item and the auditory item on the CRS-R, $r = .91$, p *(two-tailed)* $< .01$. There was a significant relationship between the visual item and the communication item on the CRS-R, $r = .80$, p *(two-tailed)* $< .05$. There was a significant relationship between the auditory item and the communication item on the CRS-R, $r = .72$, p *(two-tailed)* $< .05$. Data for question #4 are shown in Table 8.

Table 8
Question #4 Results

Items Compared	r_s Value	p value
Arousal and motor	.34	>.05
Arousal and oromotor/verbal	.45	>.05
Arousal and visual	.88*	<.01
Arousal and auditory	.89*	<.01
Arousal and communication	.74*	<.05
Motor and oromotor/verbal	.00	>.05
Motor and visual	.09	>.05
Motor and auditory	.08	>.05
Motor and communication	-.22	>.05
Oromotor/verbal and visual	.69	>.05
Oromotor/verbal and auditory	.50	>.05
Oromotor/verbal and communication	.64	>.05
Visual and auditory	.91*	<.01
Visual and communication	.80*	<.05
Auditory and communication	.72*	<.05

*Statistically significant

CHAPTER V

DISCUSSION

The purpose of this study was to reassess the data from Bodine (2015) to investigate additional comparisons between the MATADOC and the CRS-R. In order to do this the following research questions were posed:

1. Using data from the pilot study (Bodine, 2015), what is the difference between total average MATADOC item scores for each domain compared to single item CRS-R scores?
2. What is the correlation between scores for the arousal item and scores for all other items within each of the MATADOC and CRS-R measures?
3. What interactions exist between the individual items within the MATADOC and between which items do they exist?
4. What interactions exist between the individual items within the CRS-R and between which items do they exist?

Research Question #1: Using data from the pilot study (Bodine, 2015), what is the difference between total average MATADOC item scores for each domain compared to single item CRS-R scores?

There were significant relationships found between the arousal, visual, and auditory items between the two assessments. In addition, there was also a significant relationship between the response to verbal command item on the MATADOC and the communication item on the CRS-R. However, there was not a significant relationship between the awareness of musical stimulation item in the MATADOC and the auditory item in the CRS-R. In comparing these results to those of Bodine (2015), one major difference was noted in that comparisons of arousal scores between the assessments were found to be significant when using averaged converted MATADOC scores in this investigation, but not significant when using a single session score in the earlier Bodine (2015) study. This could be because the level of arousal in individuals with disorders of consciousness often wax and wane. In taking into account all four MATADOC sessions, which is more in line with the clinical application of the MATADOC, one gets a more comprehensive snapshot of an individual's highest behavioral potential.

It is interesting to note that the comparison of the verbal command item of the MATADOC and the communication item in the CRS-R was found to be significantly correlated while the comparison of the awareness of musical stimulation item of the MATADOC and the auditory item of the CRS-R was not found to have any significant relationship. In terms of complexity of behavior this does make sense as following of verbal commands requires understanding of the verbal command and then the translation of that understanding into the follow through of initiating and completing the command itself. It may also be helpful to understand what behaviors each assessment is looking for within each of these two items. In the CRS-R the communication item simply has three possible scores from no response, to non-functional though intentional communication, and finally, functionally accurate communication (Giacino & Kalmar, 2006). In order to score functionally accurate communication, the individual being assessed must answer six orientation-based questions (ex. *Am I touching my ear?* Or *Am I clapping my hands?*) correctly using either verbal or non-verbal yes/no responses. Answering at least two but less than five of six questions currently necessitates a score of non-functional though intentional communication (Magee et al., 2015a). Similarly, within the MATADOC's response to verbal command item, individuals being assessed are scored from no activity to verbal commands, to consistently following verbal commands. While responding to verbal command is clearly different from answering yes/no questions correctly, they both require intact receptive language, cognitive understanding of what is being asked, and some ability to respond either verbally or motorically.

The fact that there was not a significant relationship between the awareness of musical stimulation item in the MATADOC and the auditory item of the CRS-R also seems logical as they focus on different behaviors. The auditory function item within the CRS-R looks at responses to auditory stimuli from the very basic reflexive auditory startle response, to reproducible movement to command, and consistent movement to command. Within the MATADOC, the response to musical stimulation item also requires that the individual being assessed have an intact auditory system, though it removes the element of the necessity of intact receptive and expressive language, since it looks at responses within a musical exchange. The behaviors within this item that are looked at range from no response or little change in response from baseline, to inconsistent and consistent interactive responses within a musical exchange. This definition seems quite vague, though it includes any interactive behaviors such as turn taking through instrument play or responding appropriately to dynamic or temporal changes in the music, with changes in instrument playing to reflect these. Thus, it may have been an appropriate analysis to compare the awareness of musical stimulation item to the communication item of the CRS-R, rather than the auditory.

Research Question #2: What is the correlation between scores for the arousal item and scores for all other items within each of the MATADOC and CRS-R measures?

Within the CRS-R, significant relationships were found between the arousal item and the visual, auditory, and communication items, respectively, but no significant relationships were found between the arousal item and the oromotor/verbal and motor items respectively. Within the MATADOC, significant relationships were present between the arousal item and the visual and auditory items, respectively, but no relationships were found between the arousal item and the verbal command and response to musical stimuli items, respectively. Since arousal is inherently necessary in order to assess any visual responsiveness, it makes sense that a significant positive relationship would be present between those items in both the CRS-R and the MATADOC. It would be nearly impossible to assess individuals' visual functioning when they do not have their eyes open. For example, if they had some sort of motor dysfunction that limited or takes away their visual functioning, it might be difficult to discern whether they are limited in their arousal, or whether they are physically incapable of opening their eyes. Neither the MATADOC nor the CRS-R make note regarding the appropriateness of physically lifting an individual's eyelids in order to assess visual functioning when an individual does not present with arousal at baseline and does not respond to sensory stimulation to help facilitate arousal. Either way, it seems logical that the better an individual's level of arousal, the easier it would be to assess visual functioning. Similarly, it would also seem logical that the lower an individual's level of arousal the lower the visual item scores would be on both assessments due to lack of independent eye opening.

Within the MATADOC there was not a significant relationship found between the arousal item and the awareness of musical stimuli item. Since it is thought that music may act as an attention grabbing and, for lack of a better word, arousing stimuli due to its strong ties to emotion and memory, it is curious that a significant relationship was not found. Perhaps another comparison that could be done would be to determine the relationship between musical stimuli and arousal by looking at an individual's ratings in section two of the MATADOC, which looks at specific musical parameters and behavioral response types. Within this section there is a specific rating of whether there were any changes in arousal observed as a response to music, which may provide some additional insights.

Research Question #3: What interactions exist between the individual items within the MATADOC and between which items do they exist?

Significant positive relationships were seen between the visual and auditory items, visual and arousal items, visual and verbal command items, auditory and arousal items, and auditory and verbal command items. Since relationships between arousal and the other assessment items were analyzed in question #2, they will not be discussed in any detail in this section. The positive relationships shown between the verbal command item and the visual and auditory items, respectively, seems to make logical sense when looking at the content and behavioral requirements within each of those items. Within the verbal command item, responses are scored based on whether an individual is able to follow verbal commands consistently (defined by the MATADOC assessment manual as 75% of the time), follow verbal commands inconsistently, whether there was a response though not related to the command given, or no activity at all (Magee et al, 2015a). Specific commands given to each individual during the assessment can also vary depending on the individual's abilities and strengths (ex. Digit movement vs gross upper extremity movement vs lower extremity movement). Responsiveness within the auditory system is required, at least to some extent, for responses to verbal command to be possible. If an individual does not have the ability to process auditory stimuli or has limitations in receptive language then hearing, understanding, and following through with verbal commands would suffer as well due to the reliance on the auditory system.

The positive relationship between the visual item and the verbal command item is a bit less expected since at face value these two items don't appear as though they would have any clear relationship. One possibility here is that these two are both influenced heavily by an individual's motor functioning. For example, as previously mentioned, an individual must be able to show some sort of clear active response, more often than not related to motor functioning (ex. striking a drum, moving a finger to play an electronic instrument, kicking a tambourine…). While an individual may have some sort of awareness, he or she may be unable to show this through visual tracking due to limitations in oculomotor control or motor strength and/or coordination. Thus, the higher an individual's motor functioning the easier it may be to determine conscious awareness because they are more capable of showing clear responses. While this is a possibility, it does not necessarily mean that if an individual has higher motor functioning that he or she is more likely to show conscious awareness. That would be a whole other statement entirely and is not the intent of this author.

With regard to the positive relationship between the visual and auditory items, past research has shown these sensory systems to be closely linked, which could explain why such a strong positive relationship was seen between them (Frassinetti et al., 2002; Frassinetti et al., 2005). While in the MATADOC these items are assessed separately, i.e. visual tracking without any auditory stimuli and auditory localization with the source of the sound presented outside of the visual field, their relationship within the brain may indicate why they were so closely related here.

Interestingly, there was not a positive relationship between the awareness of musical stimuli item and the auditory item. Due to the high reliance of both of these items on the auditory system, one might assume that higher scores in one might positively correlate to the other; however, that was not the case within this data set. While one might also think the same thing regarding the awareness of musical stimuli item and the verbal command item, that was not the case either. Since those two items also rely on the auditory system, it seems logical that they would correlate to each other. Though it is important to point out here that while the awareness of musical stimuli item does require an intact auditory system to some degree, it does not require as heavily on motor responses as the verbal command item. Within the response to musical stimuli item, in order to score the highest rating of "consistent interactive responses within musical exchange," an individual could simply be voicing at appropriate times within a song (ex. When singing "hello" or to fill in an expectancy violation within the music).

Research Question #4: What interactions exist between the individual items within the CRS-R and between which items do they exist?

Significant positive relationships were seen between the arousal and visual items, arousal and auditory items, arousal and communication items, visual and auditory items, visual and communication items, and the auditory and communication items. Since relationships between arousal and the other assessment items were analyzed in question #2, they will not be discussed in any detail in this section. It is interesting to note here that, similarly to the comparisons with the MATADOC in question #3, the auditory and visual items in the CRS-R were also significantly positively correlated. Again, it's possible that the reason for this is because these two sensory systems are closely linked within the brain. Again, causation cannot be determined but the evidence seems to show this to be likely.

The correlation seen between the communication item and the auditory item also seems to be logically linked, though the relationship was more moderate. The communication item in the CRS-R looks at functional communication, which can be verbal or non-verbal, and rates an individual on whether communication is not present, is intentional (verses reflexive or spasticity related), or accurate. In order to score this item, the assessor must ask the individual several orientation-related questions, which require an intact auditory system, auditory processing, and receptive language.

A significant relationship was also seen between the visual and communication items of the CRS-R, which is quite interesting as these two items don't seem to have much in common in terms of what they assess and how the assessment is implemented. When assessing the communication scale of the CRS-R the protocol gives options for both visual and aurally based orientation questions to assess functionally accurate communication, which is the highest score possible for this item. For example, a visual question might be, "Am I touching my nose right now?" Whereas an aural question might be, "Am I clapping my hands right now?" Since the CRS-R gives the option for both visual and aural in order to best accommodate an individual's abilities and strengths, this item does not require an individual to have any significant visual functioning in order to score high. Similarly, in assessing the visual item, no expressive communication skills are required at any scoring level of this item. The most complex behavior required in the visual function item is object recognition, which simply requires an individual to either reach for or visually fixate to one of two objects presented simultaneously to command or to show movement to command in three out of four trials. While this does not require any direct functional communication, it does require an individual to have intact receptive language in order to understand what is being asked of them and to respond appropriately.

One might expect to see a relationship between the oromotor/verbal item and the communication item since they seem inherently related as most individuals communicate through verbal speech. However, these two items are not quite as closely related as they may seem. The oromotor/verbal item only looks at voicing and oral motor movements and does not necessarily require those words to make any communicative sense. In order to obtain the highest score of “intelligible verbalizations” in this item an individual must show a combination of behaviors. First, he or she must respond to a prompt (“I would like to hear your voice”) with each response consisting of a consonant-vowel-consonant sound, then verbalize two different words through this portion of the assessment. The CRS-R also allows for the option of either verbal or non-verbal responses in that it considers words expressed by letter board or writing to be acceptable. The protocol does not require individuals to necessarily provide coherent answers, just consistent voicing with consonant-vowel-consonant sounds and two coherent words. Thus, for example, an individual with a brain injury who presents with confused speech/voicing could potentially score “intelligible verbalization” if he or she is able to respond to each prompt appropriately as previously described, and verbalize two coherent words. The protocol even notes that the verbalizations do not need to be appropriate or accurate to the context in which they were given. On the other hand, the communication item requires a bit more cognitive complexity in that an individual must be able to accurately communicate and respond to yes/no questions with either a non-verbal or verbal yes/no. Therefore, because the communication item requires a bit more cognitive fortitude than the oromotor/verbal item, this may be why there was no significant relationship reflected in the analysis.

Curiously, the visual, auditory, command following, and arousal items in the MATADOC were all very closely related as they all showed positive relationships in all possible combination pairs with the exception of arousal and verbal command, which was approaching significance at $r = .66$, $p = .08$. Similarly, within the CRS-R, the arousal, visual, auditory, and communication items were all very closely related as they all also showed positive relationships in all possible combinations. Question #2 showed a strong relationship between the communication item in the CRS-R and the verbal command item in the MATADOC, which shows that these two items may be comparable to some degree. It is quite interesting that in both the CRS-R and the MATADOC, these all showed significant relationships with each other. Furthermore, the relationships between these items were the only ones of any significance found within both assessments.

CHAPTER V

CONCLUSION

Assessment of awareness will always be tricky, and researchers continue to investigate the most accurate and non-invasive ways to determine level of consciousness. A major difficulty in assessing awareness in individuals with disorders of consciousness, particularly for those in MCS, is that by definition those in MCS may show instances of behavior that suggest conscious awareness though if assessed another day, or even another hour, may show different behavioral responses. While the CRS-R and MATADOC take slightly different approaches to assessing awareness in disorders of consciousness, they seem to have some similarities in the relationships between assessment items. Within each assessment, positive correlations were found primarily between the visual, auditory, arousal, and command following items with the exception of the arousal and verbal command/communication pairs, respectively. Similar to Bodine (2015), positive relationships were seen in both assessments between the auditory and visual items, however, breaking from the results of Bodine, a positive relationship was also found between the arousal items. Additionally, the verbal command item in the MATADOC was positively correlated with the communication item in the CRS-R though no relationship was found between the awareness of musical stimuli item in the MATADOC and the auditory item in the CRS-R.

It also seems important to note that the MATADOC takes into account the whole assessment session when scoring several of the items, whereas the CRS-R follows a very strict protocol and requires responses within 10 seconds. Motor issues, which are common in this population, can confound accuracy of this, as some people may respond, but need more than 10 seconds to do so. Issues with response time become apparent quickly though, because if you wait long enough for a response you will likely see it at some point.

Limitations

Since the data for this study were generated by Bodine (2015), limitations expressed by that researcher are still applicable, namely the small sample size, and manipulations to the MATADOC data during analysis (i.e. shifting four MATACOC session scores into one). While one must be careful in interpreting these results due to the small sample size, it is important to take into account all four MATADOC session scores rather than relying on a single session for analysis. It would be beneficial for further studies to look at obtaining four CRS-R scores to compare to the four MATADOC scores in order to better control for day to day variances in performance on each assessment. As previously mentioned by Bodine (2015), it would also be important in future studies to ensure that assessors implementing each assessment are blind to the results of the other. While it was mentioned that the assessors were blinded to this it was not a variable that was controlled for so it's possible that results of the assessments were known. With the small sample size of this study, it is uncertain whether these results would hold true under more robust research conditions.

Suggestions for Future Research

It is recommended that additional research be conducted to further understand the influence of musical stimuli in detecting awareness in individuals with disorders of consciousness as well as to further investigate how the MATADOC matches up against the gold standard CRS-R. Again, as mentioned by Bodine (2015) a larger study would be required to gain a sample size large enough to obtain statistical power. The addition of extra CRS-R administrations along a similar timeline to the four MATADOC administrations would also be helpful in future studies. Continued investigation of the role of music in arousal and the consequent effect on performance in other assessment items is also encouraged.

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APPENDIX A

WMU HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Date: December 12, 2017

To: David Smith, Principal Investigator
Alika Seu, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: HSIRB Project Number 17-12-04

This letter will serve as confirmation that your research project titled "An In-Depth Analysis of "A Comparison Study of Diagnostic Outcomes between Music Therapy Assessment Tool for Awareness in Disorders of Consciousness (MATADOC) and the JFK Coma Recovery Scale-Revised (CRS-R)"" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: **December 11, 2018**

Office of the Vice President for Research
Research Compliance Office
1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
WEBSITE: wmich.edu/research/compliance/hsirb

CAMPUS SITE: 251 W. Walwood Hall