Euphoria in Multiple Sclerosis and Traumatic Brain Injured as a result of motor vehicle accidents patients

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Abstract

Euphoria is a common symptom in patients with multiple sclerosis (MS). The cause of the symptom, however, remains unclear despite its correlation with severe cognitive impairment (i.e. executive dysfunction) and white matter damage in MS. This research study investigated this correlation by comparing MS patients to a traumatic brain injury as a result of motor vehicle accidents (MVA TBI) patients, who do not appear to present with euphoria despite presenting with white matter damage and executive dysfunction, to determine whether euphoria is associated with white matter damage and/or executive dysfunction in general, or whether it is as a result of something, specific to MS. A quasi-experimental, between-subjects design, with cross-sectional and quantitative data was used to recruit 30 participants (10 MS, 10 MVA TBI, 10 healthy controls) who matched on key socio-demographic variables. Classical and modern measures assessed euphoria based on its 3 sub-types: euphoria sclerotica (emotional well-being), eutonia sclerotica (physical well-being) and spes sclerotica (undue optimism). Measures of cognition assessed the relevant executive domains. Neither the results for the classical measures nor modern measures of euphoria indicated statistically significant between-group difference between MS and MVA TBI groups for the 3 sub-types of euphoria. MS and MVA TBI groups also performed similarly on cognition. The results for the association between euphoria and executive dysfunction indicated statistically significant positive correlations between attention and visuospatial measures and the modern measure of eutonia sclerotica in MS participants, and statistically significant negative correlations between speed of information processing and the modern measure of eutonia sclerotica in MVA TBI participants. It can therefore be concluded that MS and MVA TBI patients appear to present with similar frequencies of euphoria across the 3 sub types; with similar cognitive impairment, and that correlations exist between some of these variables. Thus, euphoria in MS may be the result of white matter damage and executive dysfunction.

Keywords: Multiple Sclerosis, Traumatic Brain Injury, euphoria, sub-types; executive dysfunction, white matter damage.

Introduction

Although correlations have been demonstrated between euphoria, severe cognitive impairment (mainly that of executive dysfunction) and white matter damage of the brain in multiple sclerosis (MS), the cause of this affective symptom remains unclear. In order to further investigate this phenomenon, a comparison will be made between patients with MS and patients with another condition which results in executive dysfunction and affects the white matter of the brain diffusely: traumatic brain injured patients as a result of motor vehicle accidents (MVA's). This comparison will test the hypothesis that, although they both present with cognitive impairment and similar white matter brain damage, euphoria is specific to MS patients and may be due to something other than difficulties in executive control alone or the neuroanatomical location of disease involvement.

Multiple sclerosis (MS) is a progressive, inflammatory disease of the central nervous system (CNS) characterised by demyelination, hard plaque formation, and brain and spinal cord atrophy (Benedict, Carone & Bakshi, 2004). It can affect a number of structures in the CNS which may include, but are not restricted to, the optic tract, spinal cord, brain-stem, cerebellum and cerebrum (Benedict et al., 2004). Although grey matter involvement is increasingly becoming recognised in the disease, MS is traditionally known as a white matter disease as the demyelinating process predominantly affects the axons (Sastre-Garriga et al., 2004). The clinical features of MS centrally include motor and sensory dysfunction, but can also cause cognitive and affective impairment (Benedict et al., 2004; Finger, 1998). Cognitive impairment in MS usually revolves around executive dysfunction, which includes impairment in working memory, problem solving, initiation and inhibition of responses, conceptual ability, strategic planning, and difficulties with verbal fluency, inhibition and set shifting (Foong et al., 1997), and is the result of white matter subcortical frontal lobe damage (Jennekens-Schinkel & Sanders, 2013). With regards to the affective symptoms, since MS patients present with problems of movement, vision and fatigue one would assume that they could become depressed. However, although MS patients do sometimes present with major depressive disorder, they can also present with a variety of other mood or affective disorders, including euphoria, and many MS patients appear cheerful and claim that they feel good (Finger, 1998).

Descriptions of these euphoric patients have varied over the years, from Finger's (1998) definition of a "stupid indifference" to emotional disinhibition in the context of executive dyscontrol (Fishman, Benedict, Bakshi, Priore & Weinstock-Guttman, 2004). By far the most comprehensive, however, is that of Cottrell and Wilson (1926). According to Cottrell and Wilson (1926) there are three subtypes of euphoria, namely euphoria sclerotica, eutonia

sclerotica and spes sclerotica. Euphoria sclerotica refers to the feeling of affective or emotional well-being (e.g. cheerfulness). Eutonia sclerotica refers to the feeling of physical well-being, while spes sclerotica refers to a symptom of undue optimism (Cottrell & Wilson, 1926).

Despite a long history of interest concerning this symptom, the cause of euphoria in MS remains unclear. It is, however, believed to be a result of brain involvement and not a psychological reaction to a disabling disease (Fishman et al., 2004; Rabins et al., 1986; Sanfilipo, Benedict, Weinstock-Guttman & Bakshi, 2006).

As stated, grey matter involvement is increasingly being found to contribute to disability in MS, particularly that of physical and cognitive impairment (Chen et al., 2004). A link between grey matter or neocortical atrophy and euphoria has also recently been proposed by Sanfilipo *et al*. (2006) and Benedict *et al*. (2008). However, the primary view, based on considerable evidence, accepts that euphoria is likely the result of white matter damage and executive dysfunction. For example, Rabins *et al*. (1986) used computerized tomography (CT) imaging to show that patients that present with MS appear to have a relationship between central brain atrophy in terms of enlarged ventricles, and pathologic euphoria. The later findings of Benedict *et al.* (2004) appear to be consistent with that of Rabins *et al*. (1986), as they found that one of the risk factors for euphoria is ventricle enlargement as well as brain atrophy and lesion burden and proposed, along with Ron and Logsdail (1989) that euphoria is most probably a clinical manifestation of executive dysfunction. Fishman *et al*. (2004) have also demonstrated a link between impaired cognition and euphoria in MS patients, and suggested that euphoria can possibly be explained as a result of white matter damage which causes a disconnection of the prefrontal cortex and limbic structures.

However, not all patient groups with white matter damage and executive dysfunction experience the type and frequency of euphoria seen in MS patients. One such group is that of patients with traumatic brain injury (TBI) due to MVA's.

TBI's are classified according to (1) type of injury- open versus closed, (2) severity of injury- mild, moderate, severe, and (4) area involved – focal or diffuse. In MVA TBI, the type of injury is 'closed', often resulting from accelerating and decelerating forces being applied to the brain (Zillmer, Spiers & Culbertson, 2008). Severity can range from mild to severe and is measured by the Glasgow Coma Scale (GCS) score at admission (Zillmer et al., 2008). The lower the GCS at admission the more severe the TBI (Zillmer et al., 2008). Furthermore, these types of TBI's are most often diffuse, due to the aforementioned inertial forces of deceleration and acceleration, which eventually lead to diffuse axonal injury (DAI) (Smith, Meaney & Shull, 2003), or widespread damage to the axons within the white matter of the brain that are not strong

enough to withstand such forces and tend to shear and tear, producing tissue deformation, and, later, white matter atrophy (Bigler & Maxwell, 2011; Smith et al., 2003). The areas' most often affected include the central white matter of the cerebral hemispheres, cerebellum, brain-stem, and, in some cases, thinning of the corpus callosum (Bigler & Maxwell, 2011; Maxwell, 2012). DAI is an important pathological characteristic of MVA TBI and may largely account for its clinical manifestations (Smith et al., 2003; Maxwell, 2012).

Like MS, TBI's are often associated with impairment of mood and cognition (Maxwell, 2012). The cognitive deficits associated with TBI are similar to that of MS and include executive impairments of attention, concentration, memory, poor organization, planning, sequencing, set shifting, impaired judgement and impulse control, all of which have been related to white matter involvement (Rao & Lyktestos, 2000). Disorders of mood also occur with TBI, however, unlike MS, although it can occur, euphoria is not a prominent or well recognised symptom, and symptoms of mood and behaviour in TBI are rather characterised by depression, mania, apathy, irritability, insomnia, agitation, aggression, impulsivity, anxiety disorders, behavioural control disorders and even violent behaviour (Stuart & Hemsath, 1988).

Rationale and Significance of Current Study

The cause of euphoria among patients with MS remains unclear; however, euphoria is believed to correlate with severe cognitive impairment (in terms of executive dysfunction) and white matter or subcortical damage. If this were the case, all patients experiencing white matter changes and executive dysfunction should demonstrate euphoria; however patients with MVA TBI do not appear to present in this way. This research will therefore be significant as it will utilise neuropsychological measures of mood and cognition, in both patients with MS and MVA TBI in order to attend to the gap in the research on neuropsychological testing pertaining to executive dysfunction and symptoms of euphoria, and to increase our understanding of this affective symptom by addressing the question as to whether euphoria is related to white matter damage and/or executive dysfunction in general, or if it caused by a factor specific to MS.

Research Aims and Hypotheses

This research aimed to investigate whether euphoria is associated with white matter damage and/or executive dysfunction in general, or whether it is as a result of something, specific to MS. The aims of the study are listed below.

Aim 1: To determine the frequency of the 3 sub-types of euphoria among a sample of MS patients in comparison to a sample of patients with MVA TBI, as compared with a reference healthy control (HC) group.

Aim 2: To characterise the cognitive impairment in MS versus MVA TBI patients, as compared with a reference healthy control (HC) group.

Aim 3: To determine whether cognitive impairment is correlated with euphoria in either MS or MVA TBI patients.

Based on these aims, the following hypotheses were tested:

H_1: Only MS participants will demonstrate all 3 sub-types, and frequencies of euphoria will be higher amongst MS participants than MVA TBI participants.

H_2: MS and MVA TBI participants will present with similar cognitive impairment.

H_3: The cognitive impairment, in terms of executive dysfunction, will not correlate with the 3 sub-types of euphoria in either MS or MVA TBI participants.

Methodology

Research design

This research study formed part of a larger study and made use of a quasi-experimental, between-subjects design, with cross-sectional and quantitative data to investigate whether euphoria is due to white matter damage or is a specific feature of MS.

Participants

A sample of 30 participants, 10 MS patients, 10 MVA TBI patients, and 10 healthy controls (HCs) were recruited for this study. Participants varied according to gender (male and female), age (21 years -58 years), race (Coloured/Indian and White/Caucasian), socioeconomic status (SES; of an average combined household income per month which ranged between R1200.5-R19200.5) and highest level of education completed (which ranged between graded 8 and a certificate). The control groups consisted of the MVA TBI participants and the HCs, both of which were matched to the MS participants on the aforementioned key socio-demographic variables. The HCs matched the MS participants, participant to participant, while the MVA TBI participants matched the MS participants as closely as possible.

MVA TBI and MS participants were recruited via purposive sampling techniques where neurologists, neurosurgeons and neuropsychologists acted as key informants (Terre Blanche, Durrheim, Painter, 2006). Ten MVA TBI participants, all of whom experienced a loss of consciousness at the time of their TBI, varied in injury severity ranging from mild to severe as measured by the Glasgow Coma Scale rating at the time of admission (Zillmer, 2008) were recruited from Groote Schuur Hospital (GSH) and a non-profit organization (NPO) is South Africa, namely the Brain Injury Group in Cape Town. However, due to the small sample size, they were not divided into groups according to severity, but rather treated as one group. There were a greater number of male participants compared to females; they varied across race; age-

ranging from 23-52 years; highest level of education – ranging from grade 8 (std. 6) to grade 12 (std. 10); and average combined household income per month- ranging from R2400.50-R19200.50.

Ten MS participants were recruited from private neurologists in Cape Town and from a NPO, Multiple Sclerosis South Africa. There were a greater number of female participants as compared to males, they varied across race, age- ranging from 21–58 years; highest level of education- ranging from grade 8 (std. 6) to degree; and average combined household income per month- ranging from R1200.50 -R19200.50.

Ten HC participants were recruited through convenience and snowball sampling (Terre Blanche, et al., 2006), where potential HCs were contacted via participants already recruited in the study. There were a greater number of female participants compared to males, they varied across race, age- ranging from 23–56 years; highest level of education- ranging from grade 11 (std. 9) to degree; and average combined household income per month- ranging from R1200.50 - R19200.50.

Eligibility criteria

Inclusion criteria. MS participants who had received a confirmed diagnosis of clinically definite MS; MVA TBI participants who had sustained a MVA TBI at least a year ago, since the brain undergoes significant trauma immediately following MVA TBI (Biasca & Maxwell, 2007); and the researcher ultimately wanted to know what occurs once all the swelling has subsided and the pathology is restricted to that of white matter damage alone, and who matched the MS participants on the key socio-demographic variables; and HC participants who matched the MS and MVA TBI participants on the key socio-demographic variables were eligible for inclusion in this study.

Exclusion criteria. HCs who presented with the following criteria were ineligible to participate in this study: a current or past infectious, immunological, or neurological disease (e.g. HIV/AIDS, meningitis, systemic lupus erythematosus, Addisons disease, Huntington's disease, and Parkinson's disease). A history of other brain injury (e.g. stroke, epilepsy, near drowning/heart attack). A history, or current diagnosis of psychiatric disorder, predating the MS or TBI. A history of developmental disorder or delay (e.g. ADHD, learning disability), as measured by the lack of completion of Standard 8/Grade 10, in a mainstream school, by the age of 18. A history, or current abuse of alcohol or other substances. However, the criteria was not used for exclusion for MVA TBI and MS participants due to limited availability, but were rather noted.

Procedure

The larger study, of which this research study formed a part of, obtained ethical approval from the University of Cape Town's (UCT) Faculty of Health Sciences Human Research Ethics Committee (see Appendices A and B), and was also responsible for the data collection of the MS and HC groups.

MVA TBI participants who fit the inclusion criteria were contacted telephonically by the researcher, told about the study and its purpose, and asked whether s/he would be interested in taking part in the research study which consisted of a once off interview lasting approximately 1.5 – 2 hours. Once verbal consent was attained, relevant demographic and medical information was collected (see Appendix B) in order to identify eligibility. Thereafter a suitable interview time was scheduled to take place at either the home of the participant or at GSH, based on the preference of the participant.

At the interview, prior to the administration of the tests, a consent form was given to the MS participants (see Appendix C) the mild and moderate MVA TBI participants (see Appendix D), the guardians of the severe MVA TBI participants (see Appendix E), and the HCs (see Appendix F). An assent form was given to the severe MVA TBI participants (see Appendix G). This provided the participant with the necessary information about the study as well as his/her role in the study such that participation is voluntary, withdrawal from the study can be done at any time or a break can be taken an time during the testing period should they feel fatigued, the data will be treated with confidentiality. Confidentiality was maintained by employing a coding system which assigned each participant with a unique number, in place of using their names, and the data was kept in a locked cupboard and on a password protected computer, accessible only to the researchers involved. The researcher explained that there were no risks other than time invested in the study; and that the benefits included the issuing of an information pamphlet and neuropsychological report following participation, as well as knowing that they were contributing to research on MS and brain injury.

On completion of the consent form, participants were informed that they would be completing various tasks, some of which would require their responses to be timed. The researcher began the assessment by administering neuropsychological tests, which were explained to the participant prior to administration, in the same order for every participant, specifically placed to avoid anxiety and/or loss of concentration. The loved one who the participants were asked to identify also asked were required to answer some questions about them (see Appendix H).

Once all the tests were administered, MS and MVA TBI participants (but not HCs) were issued with a pamphlet (see Appendix I and Appendix J) which consisted of the potential symptoms of mood and cognition they may be experiencing as a result of their MS or MVA TBI, together with coping strategies for these symptoms. The participant was then thanked and debriefed providing him/her with information about the implications of the study and the extent to which the results will be used. S/he was given an opportunity to ask questions and the researcher's contact details were provided in case the participant had any further questions pertaining to the study.

Data Collection

Socio-demographic and medical information were collected from the participants (see Appendix K) for the purpose of assessing eligibility matching the MVA TBI patients and the healthy participants to the MS patients. A battery of neuropsychological measures were used in order to assess cognition and mood in MS, MVA TBI and healthy control participants (Or the three groups). The measures of mood and affect assessed the domains of euphoria sclerotica (feeling of affective or emotional well-being), eutonia sclerotica (feeling of physical well-being) and spes sclerotica (a symptom of undue optimism). The measures of cognition assessed the executive domains of attention, information processing, speed, working memory, generativity, learning and memory, planning, abstraction, inhibition and set-shifting. For several of these measures (i.e. Neuropsychiatric Inventory (Cummings et al., 1994), Positive and Negative Affect Schedule (Crawford & Henry, 2004), Life Orientation Test Revised (Scheier & Carver, 1985), Brief Visuospatial Memory Test Revised (Benedict Schretlen, Groninger, Dobraski, & Shpritz, 1996)), Cronbach's alpha was above 0.70, indicating that they were all reliable and valid measures therefore supporting their inclusion (Benedict et al., 1996; Benedict et al., 2004; Crawford & Henry, 2004; Prigatano et al., 1990; Scheier & Carver, 1985). Although information regarding the reliability for the remaining measures could not be sourced they were nevertheless deemed important to include as justified below.

Measures of Mood and Affect

Mood and affect was measured using the Neuropsychiatric Inventory (*NPI*) (Cummings et al., 1994), Positive and Negative Affect Schedule (*PANAS*) (Crawford & Henry, 2004), Internal State Scale (*ISS*) (Bauer, et al., 1991) and the questions of Cottrell and Wilson (1926) to measure euphoria sclerotica; the questions of Cottrell and Wilson (1926), the physical ability scale, Awareness Interview (*AI*) (Anderson & Tranel, 1989) and the Neuropsychiatric inventory (*NPI*) (Cummings et al., 1994) to measure eutonia sclerotica; and the questions of Cottrell and Wilson (1926), Optimism and Pessimism Scale (*OPS*) (Dember, Martin, Hummer, Howe &

Melton, 1989), the Life Orientation Test Revised (*LOT-R*) (Scheier & Carver, 1985), and the Comparative Risk Judgement Rating Forms *(CRJRF)* to measure spes sclerotica. These measures are further described and justified for inclusion (see Appendix L).

Measures of Cognition

Cognition was measured using the 0 and 2 *n*-Back Task (Owen, McMillan, Laird, & Bullmore, 2005; Parmenter, Shucard, Benedict & Shucard, 2006) to measure attention, information processing speed, working memory, the Controlled Oral Word Association Test (*COWAT*) (Benton & Hamsher, 1989) to measure generativity, the Rey Auditory Verbal Learning Test (*RAVLT*) (Lezak, 1983) and Brief Visuospatial Memory Test Revised (*BVMT-R*) (Benedict et al., 1996) to measure learning and memory, the Rey-Osterrieth Complex Figure (*ROCF*) (Lezak, Howieson & Loring, 2004) to measure planning, the D-KEFS Sorting Test (*DST)* (Delis, Kaplan & Kramer, 2001) to measure abstraction, and the D-KEFS Colour-Word-Interference Test (*CWIT*) (Delis et al., 2001) to measure inhibition and set-shifting. These measures are further described and justified for inclusion (see Appendix V).

Data Analysis

The data was analysed by making use of Version 21 of the Statistical Package for the Social Sciences (SPSS Inc., 2012). Descriptive statistics of the sample was first investigated for the purpose of making group comparisons. The data was then analysed with respect to the aims of the study by scoring the measures and comparing MS to MVA TBI participants, as well as MS and MVA TBI to HC participants so that between-group difference could be detected. For all statistical analyses, the significance level was set to p=.05

Three raters scored the classical measures of euphoria, and the visuospatial, visual memory and planning measures of cognition, of which the average score was used for statistical analyses. This was done in order to have inter-rater reliability for these measures. While the scores on the remaining measures were not required to be inter-rated.

Chi-square independent samples analyses were performed on the categorical data, the relevant parametric and non-parametric tests were performed on the continuous data, and correlations were performed on all the necessary data. These are further described in conjunction with the results.

Chi- square independent samples analyses were performed on the classical measures of euphoria to determine the frequency of the 3 sub-types of euphoria among the three groups. One-way analyses of variance (ANOVA) were performed despite having non-normally distributed data, since ANOVA is robust against problems of distribution (Field, 2009). To control for distribution problems and to confirm the results obtained from one-way ANOVA, a non-

parametric, ANOVA equivalent test, Kruskal-Wallis tests were performed. One- way ANOVAs were performed on the modern measures of euphoria to investigate whether the MVA TBI or MS group were significantly more happy, unaware or optimistic compared to the reference HC control group. On emergence of between-group significance Turkey's HSD post hoc analyses were performed.

Outcome measures were grouped into domains based on theoretical assumptions (Lezak, et al., 2004). Then, in order to combine variables into composite variables, factor analysis (FACAN) was performed. FACAN was performed in order to reduce the number of variables initially examined. All the cognitive variables analysed to deduce which variables could be grouped together. FACAN derived one composite: Cognitive flexibility (abstraction (*DST*), inhibition and set-shifting (*CWIT*)). The remaining variables did not load well when a FACAN was performed, was run, thus correlation of the variables were attempted, but the variables did not correlate well so could not be combined.

Correlations were conducted among the scores for the cognitive variables and the 3 sub-type of euphoria for both the classical and modern measures of euphoria. Three measures (one per subtype of euphoria) were used for the classical measure of euphoria. FACAN were performed to deduce whether composite variables could be formed for each sub-type of the modern measures of euphoria. Modern measures (three per sub-type) did not combine well on the factor loadings of the FACAN nor on the correlations. Thus, the modern measure of euphoria followed a similar structure to the classical measure, i.e. having one measure per sub-type of euphoria. The *NPI* measure was used as the measure for euphoria sclerotica as it is the most common modern measure used to elicit euphoria (Benedict et al., 2004). The discrepancy score for physical ability was used as opposed to unawareness of cognitive or mood/behavioural deficit as the measure for eutonia sclerotica, as Cotrell and Wilson (1926) believed that euphoria was due to unawareness of physical deficit, and the *LOT-R* was used as the measure for spes sclerotica since a measure of trait optimism is better than a measure of state optimism, thus *LOT-R* was considered to be a better measure than the *OPS* or *CRJRF* (Burke, Joyner, Czech, & Wilson, 2000).

Results

Socio-demographic, medical details and distribution of sample

The socio-demographic characteristics of the MVA TBI group (n = 10), the MS group (n = 10), and the HC group (n= 10) are presented in *Table 1*. The medical details of the sample are described below.

For the MVA TBI group, 2 participants reported having post TBI epilepsy, no participants was deemed to abuse alcohol, however 1 participant admitted to smoking marijuana but did not consume it 48 hours prior to the interview.

For the MS group, 1 participant reported having a TBI but did not experience a loss of consciousness, 1 participant reported having had epilepsy, 3 participants reported having had depression after being diagnosed with MS, 2 participants reported having been premature, 1 participant reported having had dyslexia, and 1 participant admitted to smoking marijuana, but did not consume it 48 hours prior to the interview.

Table 1

Descriptive Statistics for Key Socio-demographic Variables

Socio-demographic variables	Group type		
	Healthy control (HC) (*n*=10)	Traumatic Brain Injury (MVA TBI) (*n*=10)	Multiple Sclerosis (MS) (*n*=10)
Gender *female: male*	8:2	1:9	8:2
Race *White/Caucasian: Coloured/Indian*	4:6	2:8	2:8
Age	39.40 (10.42)	34.00 (7.99)	39.80 (11.45)
Income	R12120.5 (6656.13)	R7680.5 (5034.28)	R11160.5 (6198.06)
Education	12.7 (1.42)	10.6 (1.43)	12 (1.83)

Note. The data presented for age, income, and education are means with standard deviations in parentheses. Income=average combined household income per month; Education=highest level of education completed (9,10,11,12= Grade 10, 11,12; 13=certificate; 14=diploma; 15=degree).

A chi-square test of independence was used to determine whether there were between-group differences for categorical variables of gender and race. The analysis revealed a statistically significant between-group difference for gender, $\chi^2(2) = 13.30$, $p = .001$, where the MS group consisted of more females (80%) as opposed to the MVA TBI group which consisted of more males (90%), but not for race, $\chi^2(2) = 2.61$, $p = .271$.

A one-way analysis of variance (ANOVA) was used to determine whether between-group differences for continuous variables of age, education, and income (see *Table 2*). The analysis revealed no statistically significant between-group difference for age, F (2, 27) =1.038, p=.368, and income, F (2, 27) =.790, p=.464, η^2=.07. However, it revealed a statistically significant between-groups difference for education, F (2, 27) = 4.642 p=.019, η^2.05. Turkey's

HSD post hoc analysis revealed that, on average, participants in the HC group were significantly more educated (highest level of education completed-grade 12 (Std10)) than participants in the MVA TBI (highest level of education completed-grade10 (Std.8)) group, p=.016.

Results for hypotheses tested

H_1: Only MS participants will demonstrate all 3 sub-types, and frequencies of euphoria will be higher amongst MS participants than MVA TBI participants.

The descriptive statistics and results for both the classical and modern measures of euphoria are illustrated (see *Figure 1*) for the purpose of determining whether only MS participants demonstrates, and have the highest frequency of, all 3 sub-types of euphoria in comparison to MVA TBI participants.

Table 2

Summary of ANOVA for Age, Education and Income

		Sum of Squares	df	Mean Square	F	Sig
Age	Between Groups	209.87	2	104.93	1.038	.368
	Within Groups	2730.00	27	101.11		
	Total	2939.87	29			
Education	Between Groups	22.87	2	11.43	4.642	.019
	Within Groups	66.50	27	2.46		
	Total	89.367	29			
Income	Between Groups	2.07	2	1.03	0.790	.464
	Within Groups	35.30	27	1.31		
	Total	37.37	29			

The classical measure of euphoria

The classical measure of euphoria consisted of three categorical variables, namely euphoria sclerotica, eutonia sclerotica, and spes sclerotica. A chi-square test of independence was therefore used to determine whether there were between-group differences in the frequency of the 3 sub-types of euphoria for the classical measure of euphoria. The analysis revealed no statistically significant between-group difference for euphoria sclerotica, $\chi^2(4) = 4.00$, $p = .406$. Since the sample size was small, the likelihood ratio is preferred (Field, 2009), this too revealed no statistically significant between-group difference for euphoria sclerotica, p=.213. This showed a small effect, Cramer's V= .258, as illustrated by the graphical representation (see *Figure 1*) which demonstrates that the same amount of HC, MVA TBI, and MS participants presented with strong euphoria sclerotica ($n_{HC} = n_{MVA\ TBI} = n_{MS} = 2$ [20%]). However, more HC

participants presented with mild euphoria sclerotica in comparison to MS and MVA TBI patients (n_{HC} = 8 [80%], $n_{MVA\ TBI}$ = n_{MS} = 5 [50%]).

The analysis revealed no statistically significant between-group difference for eutonia sclerotica, $\chi^2(4) = 8.082$, p=.089. Since the sample size was small, the likelihood ratio is preferred (Field, 2009), this too revealed no statistically significant between-group difference for eutonia sclerotica, p=.064. This showed a moderate effect, Cramer's V = .367, as illustrated by the graphical representation (see *Figure 1*) which demonstrates that more HC participants presented with strong eutonia sclerotica in comparison to MVA TBI and MS participants (n_{HC} = 3 [30%], $n_{MVA\ TBI}$ = n_{MS} =0 [0%]). However, the same amount of MVA TBI and MS patients presented with mild eutonia sclerotica, which was more than that presented in the HC participants (n_{HC} = 3 [30%], $n_{MVA\ TBI}$ = n_{MS} = 7 [70%]).

The analysis revealed no statistically significant between-group difference for spes sclerotica, $\chi^2(4) = 5.3$, p=.258. Since the sample size was small, the likelihood ratio is preferred (Field, 2009), this too revealed no statistically significant between-group difference for spes sclerotica, p=.197. This showed a small to moderate effect, Cramer's V = .297, as illustrated by the graphical representation (see *Figure 1*) which demonstrates that more HC participants presented with strong spes sclerotica in comparison to MVA TBI and MS participants (n_{HC} = 9 [90%], $n_{MVA\ TBI}$ = 6 [60%], n_{MS} = 5 [50%]. However, more MVA TBI participants presented with mild spes sclerotica in comparison to HC and MS participants (n_{HC} = 0 [0%], $n_{MVA\ TBI}$ = 2 [20%], n_{MS} = 1 [10%]).

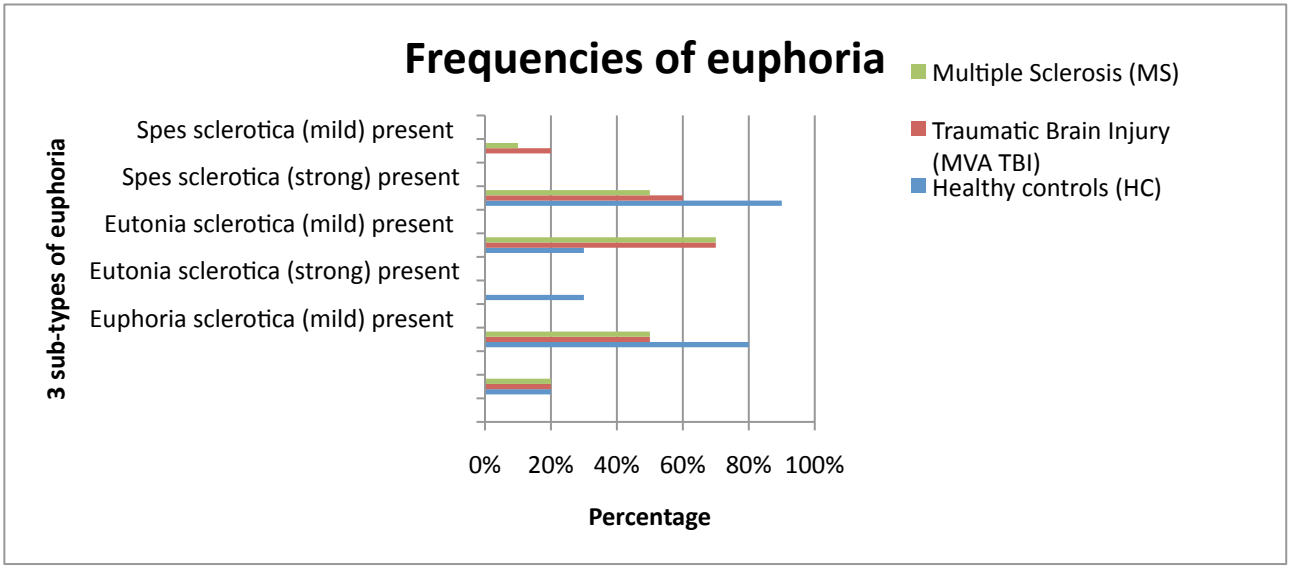

Figure 1. The frequencies of euphoria for the classical measure of euphoria

Modern measures of euphoria

The modern measure of euphoria consisted of eight continuous variables, two which measured euphoria sclerotica (positive subscale of the *PANAS*, well-being subscale of the *ISS*), three which measured eutonia sclerotica (participant/informant discrepancies of awareness of physical ability-physical ability scale, participant/informant discrepancies of awareness of cognitive ability - *AI*, participant/informant discrepancies of awareness of mood/behavioural difficulties-*NPI*) and three which measured spes sclerotica (optimism subscale of the *OPS*, optimism subscale of *LOT-R*, total unrealistic score of the *CRJRF*); and one categorical variable which measured euphoria sclerotica, namely self-reported euphoria on the *NPI*.

A one-way ANOVA was therefore used for the continuous variables, and a chi-square test of independence was therefore used for the categorical variable, to determine whether there were between-group differences in the demonstration of the 3 sub-types of euphoria for the modern measure of euphoria. A Kruskal-Wallis analysis was used to confirm these results. [1]

Euphoria sclerotica. The one-way ANOVA revealed no statistically significant between-group difference for two measures of euphoria sclerotica, the positive subscale of the *PANAS* $F(2, 27)= 1.35$, $p= .277$, $\eta^2= .090$, and the well-being scale of the *ISS* $F(2, 27)= 2.46$,$p=.104$, $\eta^2=.15$. MVA TBI and MS participants therefore presented with similar scores on the measures of euphoria sclerotica (*PANAS,* $p=.998$; *ISS,* $p=.942$). Thus MVA TBI and MS participants are equally positive/euphoric.

The chi-squared independent samples analysis, revealed no statistically significant between-group difference for the self-report measure of euphoria of the *NPI,* $\chi^2(2) =5.00$, $p=.082$, Cramer's $V=.408$. However, since the sample size was small, the likelihood ratio is preferred (Field, 2009), which revealed statistically significant between-group difference for the

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A Kruskal-Wallis test was conducted to evaluate between-group difference for the 3 sub-types of euphoria. The test which was corrected for tied ranks, was significant for measures two measures of eutonia sclerotica physical ability measure, χ^2 (2, N=30) = 6.74, p= =.034 and the *NPI* measure, χ^2 (2, N=30) = 12.22, p=.002; and one measure of spes sclerotica CRJRF =χ^2 (2, N=30) = 9.37, p= .009 Follow-up tests were conducted to evaluate pairwise differences among the three groups, The HC group was found to differ significantly from the MVA TBI group on the *NPI* measure of euphoria sclerotica and the *CRJRF* measure of spes sclerotica. The MS group was found to differ significantly from the MVA TBI participants on the physical ability and *NPI* measures of eutonia sclerotica. The HC group was found to differ significantly from the MS group on the *ISS* measure of euphoria and the physical ability measure eutonia sclerotica.

self-report measure of the *NPI*, p=.038. This showed a moderate effect Cramer's V=.408 as illustrated by the graphical representation (see *Figure 4*) which demonstrates that more MVA TBI participants reported having euphoria compared to HC an MS participants.

Eutonia sclerotica. The one-way ANOVA revealed statistically significant between-group difference for the unawareness of physical deficit measure eutonia sclerotica, $F(2,27) = 3.617$, p= .041, η^2= .21. Turkey's HSD post hoc analysis indicated the MS participants were more unaware of potential physical deficits than the HC participants, but this difference did not reach significance, p= .069, and also that MVA TBI participants were more unaware of potential physical deficits than MS participants, this too did not reach significance, p= .069.

However, the one-way ANOVA revealed no statistically significant between-group difference for the unawareness of cognitive deficit (p=.275) and unawareness of mood/behavioural difficulties (p=.067) measures of eutonia sclerotica.

Although no statistical difference was been reached, MVA TBI participants performed worse than MS participants on all the eutonia sclerotica measures (unawareness of physical deficit, p=.069; unawareness of cognitive deficit, p=.262; and unawareness of mood/behavioural difficulties, p= .140). Thus MVA TBI participants were more unaware of potential physical, cognitive and mood/behavioural deficits/disturbances than MS participants.

Spes sclerotica. The one way ANOVA revealed statistically significant between-group difference for the *CRJRF* measure of spes sclerotica, $F(2,27)=6.075$, p=.007, η^2=31. Turkey's HSD post hoc analysis indicated that HC participants were significantly more unrealistically optimistic than MS participants, p=.005. Although, no statistical difference was reached, the MS participants were more unrealistically optimistic than the MVA TBI participants, p=. 304.

However, the one way ANOVA revealed no statistically significant between-group difference for the *OPS* ($F(2,27)$= .55 p= .579, η^2=.04) and *LOT-R* ($F(2,27)$= .62, p= .548, η^2=.04) measures of spes sclerotica. MS and MVA TBI particpants therefore presented with similar scores for these two measures of spes sclerotica (*OPS, p*=.999*; LOT-R, p*=1.000). Thus MVA TBI and MS participants are equally optimistic.

Table 4

Descriptive Statistics for Modern Measure of Euphoria

Sub-types of euphoria	Group type		
	Healthy controls (HC) (*n*=10)	Traumatic Brain Injury (MVA TBI) (*n*=10)	Multiple Sclerosis (MS) (*n*=10)
Euphoria sclerotica			
PANAS (positive subscale)	37.60 (4.65)	32.50 (9.85)	32.70 (8.19)
ISS (well-being subscale)	11.60 (2.07)	9.50 (3.34)	9.10 (2.56)
Eutonia sclerotica			
Physical ability unawareness(participant/ informant discrepancies)	-5.00 (2.46)	-5.00 (3.37)	-3.30 (2.06)
Cognitive awareness (participant /informant discrepancies)	0.00 (.94)	-1.20 (2.78)	0.500 (2.88)
NPI score (participant/informant discrepancies)	8.60 (15.22)	-5.00 (10.81)	6.90 (14.15)
Spes sclerotica			
OPS (optimism subscale)	55.70 (5.54)	53.50 (4.83)	53.40 (6.08)
LOT-R (optimism subscale)	9.10 (1.29)	8.40 (1.17)	8.40 (2.22)
CRJRF (total unrealistic optimism score)	4.30 (2.31)	1.30 (1.70)	2.60 (1.71)

Note. The data presented are means with standard deviations reported in parentheses.
Abbreviations: PANAS=Positive and Negative Affect Scale; ISS= Internal State Scale; NPI= Neuropychiatric Inventory; OPS= Optimism and Pessimism Scale; LOT-R= Life Orientation Test-Revised; CRJRF= Comparative Risk Judgement Rating Forms; For the sub-type: Eutonia sclerotica= the lower the score, the greater the unawareness.

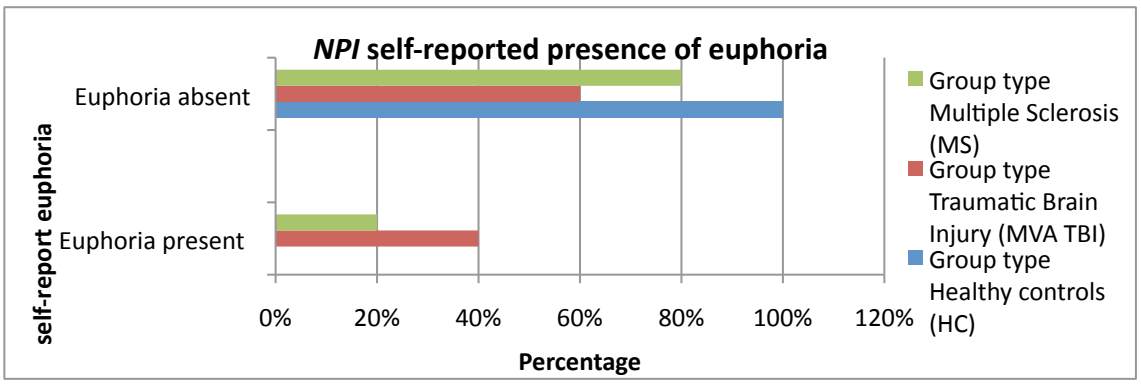

Figure 2. Participant self-reported euphoria for the *NPI* measure of euphoria sclerotica.

Table 5

Summary of ANOVA for Modern Measures of the 3 Sub-types of Euphoria: Euphoria Sclerotica, Eutonia Sclerotica and Spes Sclerotica

		Sum of Squares	Df	Mean Square	F	Sig
Euphoria sclerotica						
PANAS (positive subscale)	Between Groups	166.87	2	83.43	1.35	.277
	Within Groups	1671.00	27	61.89		
	Total	1837.87	29			
ISS (well-being subscale)	Between Groups	36.07	2	18.03	2.46	.104
	Within Groups	197.80	27	7.33		
	Total	233.87	29			
Eutonia sclerotica						
Physical ability (participant vs informant)	Between Groups	52.27	2	26.13	3.62	.041
	Within Groups	195.10	27	7.23		
	Total	247.37	29			
Cognitive awareness (participant vs informant)	Between Groups	15.27	2	7.63	1.36	.275
	Within Groups	152.10	27	5.63		
	Total	167.37	29			
NPI score (participant vs informant)	Between Groups	1098.20	2	549.10	3.00	.067
	Within Groups	4939.30	27	182.94		
	Total	6037.50	29			
Spes sclerotica						
OPS (optimism subscale)	Between Groups	33.80	2	16.90	.55	.579
	Within Groups	819.00	27	30.33		
	Total	852.80	29			
LOT-R (optimism	Between Groups	3.27	2	1.63	.62	.548

subscale)						
	Within Groups	71.70	27	2.66		
	Total	74.97	29			
CRJRF (total unrealistic optimism score)	Between Groups	45.27	2	22.63	6.08	.007
	Within Groups	100.60	27	3.73		
	Total	145.87	29			

Note. Abbreviations: PANAS=Positive and Negative Affect Scale; ISS= Internal State Scale; NPI= Neuropychiatric Inventory; OPS= Optimism and Pessimism Scale; LOT-R= Life Orientation Test-Revised; CRJRF= Comparative Risk Judgement Rating Forms; For the sub-type: Eutonia sclerotica= the lower the score, the greater the unawareness.

Table 6

Descriptive Statistics for Measures of Cognition

	Group type		
Cognitive variables	Healthy controls (HC)[a] (*n*=10)	Traumatic Brain Injury (MVA TBI)[b] (*n*=10)	Multiple Sclerosis (MS)[c] (*n*=10)
Attention	20.22 (0.67)	19.38 (1.99)	19.83 (0.75)
Working memory	23.89 (2.52)	17.50 (7.15)	19.33 (7.44)
Speed of information processing	527.86 (56.73)	561.58 (139.81)	549.33 (88.72)
Generativity	39.78 (11.68)	25.75 (6.56)	33.00 (16.80)
Planning	4.63 (0.73)	4.96 (7.44)	5.06 (0.904)
Visuospatial	33.20 (1.75)	30.81 (2.45)	30.97 (1.67)
Verbal memory	186.00 (10.15)	127.50 (31.88)	173.67 (20.52)
Visual memory	188.50 (24.58)	145.74 (47.50)	190.16 (20.81)
Cognitive flexibility	27.56 (5.43)	24.13 (5.89)	30.17 (3.81)

Note. The data presented are means with standard deviations reported in parentheses. A higher score for speed of information processing = a poorer performance. Cognitive flexibility=composite of 3 cognitive variables, namely abstraction, disinhibition, and set-shifting.[a]n= 9 for working memory measure. [b]n= 9 for attention measure and speed of information processing measure; [b]n= 8 for working memory measure. [c]n= 6 for working memory measure.

$H_{2:}$ MS and MVA TBI participants will present with similar cognitive impairment. The descriptive statistics and results for the cognitive measures are illustrated (see *Table 6* and *Table 7*) for the purpose of determining whether MS and MVA TBI participants present with similar cognitive impairment.

The cognitive measures consisted of fifteen continuous variables, which measured variables of attention, working memory, speed of information processing, verbal learning, verbal memory, verbal recognition, visual learning, visual memory, visual recognition, genaritivity, abstraction, planning, disinhibion, and set shifting. Verbal learning, memory and recognition were combined (*RAVLT*) to form one score, and visual learning, memory, and recognition were combined to form one score (*BVMT-R*). A composite of abstraction, disinhibion and set shifting was combined to form one score and named cognitive flexibility.

A one-way ANOVA was therefore used to determine whether there were between-group differences in cognitive impairment. The analysis revealed significant between-group difference in the visuospatial measure (*ROCF), F*(2,20) = 3.61, p= .046, η^2= .27, verbal memory measure (*RAVLT), F*(2,20) = 15.45, p < .001, η^2 = .61, and visual memory measure (*BVMT-R), F*(2,20) = 4.32, p= .028,. η^2 =.30. Turkey's HSD post hoc analysis indicated that the visuospatial measure (*ROCF*) tended toward significance between the HC and MVATBI participants, p= .061. The verbal memory measure (*RAVLT*) revealed significant difference between the HC and MVA TBI participants, p < .001, and between the MS and MVA TBI participants, p= .003. The visual memory (*BVMT-R*) measure revealed significant difference between the HC and MVA TBI participants, p=.043, and a difference between the MVA TBI and MS participants tended toward significance, p= .060. A Kruskal-Wallis analysis was used to confirm these results. [2]

MS participants performed significantly better than MVA TBI participants on the verbal memory measure (*RAVLT*), p <.001. MS participants also performed better than MVA TBI

[2] A Kruskal-Wallis test was conducted to evaluate between-group difference for measures of cognition. The test which was corrected for tied ranks, was significant for measures of verbal memory χ^2 (2, N=30) = 12.72, p=.002 and visual memory χ^2 (2, N=30) = 4.861, p=.010. Follow-up tests were conducted to evaluate pairwise differences among the three groups, The HC group were found to differ significantly from the MVA TBI group verbal memory. The MS group was found to differ significantly from the MVA TBI group on two measures of cognition, namely verbal memory and visual memory. The HC group was found to differ significantly from the MS group on only one measure of cognition, the visuospatial measure.

participants on the measures of working memory (*2-back task*), p= .832, speed of information processing (*0-back task*), p= .972, generativity (*COWAT*), p= .505, verbal memory (*RAVLT*), p= .003, visual memory (*BVMT-R*), p= .060, and cognitive flexibility, p=. 109. These measures, however, did not reach statistical significance. MS and MVA TBI participants performed equally well on the remaining measures of cognition: attention (*0-back*), planning (*ROCF*) and visuospatial (*ROCF*).

Table 7

Summary of ANOVA for Measures of Cognition

		Sum of Squares	Df[a]	Mean Square	F	Sig
Attention	Between Groups	3.04	2	1.520	.89	.427
	Within Groups	34.26	20	1.713		
	Total	37.30	22			
Working memory	Between Groups	183.52	2	91.76	2.67	.093
	Within Groups	686.22	20	34.31		
	Total	869.74	22			
Speed of information processing	Between Groups	4953.73	2	2476.86	.25	.785
	Within Groups	201939.14	20	10096.96		
	Total	206892.86	22			
Generativity	Between Groups	833.55	2	416.78	2.97	.074
	Within Groups	2805.06	20	140.25		
	Total	3638.61	22			
Planning	Between Groups	.78	2	.39	.64	.539
	Within Groups	12.29	20	.61		
	Total	13.07	22			
Visuospatial	Between Groups	29.64	2	14.82	3.61	.046
	Within Groups	82.09	20	4.11		
	Total	111.73	22			
Verbal memory	Between Groups	15518.32	2	7759.16	15.45	.000
	Within Groups	10046.83	20	502.34		
	Total	25565.15	22			
Visual memory	Between Groups	9847.13	2	4923.57	4.32	.028
	Within Groups	22794.65	20	1139.73		
	Total	32641.79	22			
Cognitive flexibility	Between Groups	129.03	2	64.51	2.34	.122
	Within Groups	551.93	20	27.60		
	Total	680.96	22			

[a]n=23 due to participants not having completed all the measures of cognition.

H_3: The cognitive impairment, in terms of executive dysfunction, will not correlate with the 3 sub-types of euphoria in either MS or MVA TBI participants.

The results for the correlation between the cognitive and mood variables are illustrated (see *Table 8* and *Table 9*) for the purpose of determining whether there is an association between cognitive impairment and the 3 sub-types of euphoria (classical and modern) in MS and/or MVA TBI participants.

The results for the correlation between the cognitive and mood measures are illustrated for the purpose of determining whether there is an association between cognitive impairment and the 3 sub-types of euphoria for either MS or MVA TBI participants.

Pearson's correlations were conducted and inspected. The correlations revealed a statistically significant positive correlation between attention (*0-back task*) and the modern measure of eutonia sclerotica in MS participants, r=.64, p= .049 (see *Table 8*); and between visuospatial (*ROCF*) and the modern measure of eutonia sclerotica in MS participants, r=.71, p= .022 (see *Table 8*). However, the correlations revealed a statistically significant negative correlation between speed of information processing (*0-back task*) and the modern measure of eutonia sclerotica in MVA TBI participants, r=-.69, p= .039 (see *Table 9*).

The correlations revealed no statistically significant correlations for the remaining measures of cognition and euphoria (classical and modern measures) in either MS or MVA TBI participants.

e and Mood Variables for MS Group

1	2	3	4	5	6	7	8	9	10	11	12	13
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
.547	.312	-.223	-.477	.635*	.181	-	-	-	-	-	-	-
-.537	.191	-.381	.110	.010	-.294	-	-	-	-	-	-	-
-.352	-.584	-.264	.507	-.325	-.412	-	-	-	-	-	-	-
.257	.198	-.066	-.468	-.281	.233	-	-	-	-	-	-	-
.500	.133	.098	-.605	.287	.442	-	-	-	-	-	-	-
.119	.320	-.233	-.250	.179	.007	-	-	-	-	-	-	-
.166	.317	.101	-.141	.012	.214	-	-	-	-	-	-	-
.372	.343	-.359	-.380	.706*	.024	-	-	-	-	-	-	-
.356	.572	-.105	-.357	.472	.164	-	-	-	-	-	-	-

es of euphoria; [b]=modern measures of euphoria.

e and Mood Variables for MVA TBI Group

1	2	3	4	5	6	7	8	9	10	11	12	13
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-.007	-.275	-.384	.217	-.047	-.044	-	-	-	-	-	-	-
-.076	-.254	-.078	.135	-.480	-.141	-	-	-	-	-	-	-
.338	.289	-.110	-.225	-.691*	.075	-	-	-	-	-	-	-
.191	-.310	.088	.012	-.281	-.208	-	-	-	-	-	-	-
.248	-.084	.170	.192	-.373	-.172	-	-	-	-	-	-	-
-.477	-.240	.134	-.327	.508	.400	-	-	-	-	-	-	-
-.540	-.269	-.085	-.175	-.042	-.173	-	-	-	-	-	-	-
-.299	-.546	-.204	.252	-.310	-.205	-	-	-	-	-	-	-
.004	-.461	-.057	.343	-.251	-.010	-	-	-	-	-	-	-

es of euphoria; [b]=modern measures of euphoria.

Discussion

The objective of this study was to investigate whether euphoria is associated with white matter damage and/or executive dysfunction in general, or whether it is as a result of something, specific to MS. The study had three hypotheses, that is, $H_{1:}$ only MS participants will demonstrate all 3 sub-types of euphoria, and the frequencies thereof would be higher amongst MS than MVA TBI participants, $H_{2:}$ MS and MVA TBI participants will present with similar cognitive impairment, $H_{3:}$ the cognitive impairment, in terms of executive dysfunction, will not correlate with the 3 sub-types of euphoria in either MS or MVA TBI participants.

Euphoria in MS and MVA TBI participants

Classical measure of euphoria. The classical measure of euphoria revealed no statistically significant between-group difference for the 3 sub-types of euphoria (euphoria sclerotica, eutonia sclerotic, spes sclerotica). Inspection of the these demonstrated that the same frequency of HC, MVA TBI and MS participants presented with strong euphoria sclerotica ($n_{HC} = n_{MVA\ TBI} = n_{MS} = 2$ [20%]); and a higher frequency of HC participants presented with mild euphoria sclerotica, while the same frequency of MVA TBI and MS participants presented with mild euphoria sclerotica ($n_{HC} = 8$ [80%], $n_{MVA\ TBI} = n_{MS} = 5$ [50%]).

A higher frequency of HC participants presented with strong eutonia sclerotica, while both MVA TBI and MS participants did not present with strong eutonia sclerotica ($n_{HC} = 3$ [30%], $n_{MVA\ TBI} = n_{MS} = 0$ [0%]). Although MVA TBI and MS participants did not present with strong eutonia sclerotica, they both presented with the same frequency of mild eutonia sclerotica, which was more than the frequency presented by the HC participants for mild eutonia sclerotica. ($n_{HC} = 3$ [30%], $n_{MVA\ TBI} = n_{MS} = 7$ [70%])

Similar to eutonia sclerotica, a higher frequency of HC participants presented with strong spes sclerotica, while MVA TBI participants presented with a slightly higher frequency of strong spes sclerotica than MS participants ($n_{HC} = 9$ [90%], $n_{MVA\ TBI} = 6$ [60%] $n_{MS} = 5$ [50%]). In addition, a slightly higher frequency of MVA TBI participants presented with mild spes sclerotica compared to MS and HC participants ($n_{HC} = 0$ [0%], $n_{MVA\ TBI} = 2$ [20%] $n_{MS} = 1$ [10%]).

Thus, for the classical measure of euphoria, MS participants were not the only group that presented with the 3 sub-types of euphoria, and did not present with higher frequencies thereof in compassion to MVA TBI participants. These results may well be due to the small sample size used for this study, which in turn, could have affected the distribution of the sample and

ultimately resulted in the loss of statistical power (Fields, 2009). Hence, failure to detect whether a genuine effect occurred. The MVA TBI and MS participants could have presented with similar frequencies on the 3 sub-types of euphoria since euphoria can be explained as the result of white matter damage, and the area most affected in MVA TBI and MS is the white matter (Bigler & Maxwell, 2011; Fishman et al., 2004; Maxwell, 2012); and since euphoria can occur in TBI patients, although it is not a prominent symptom (Stuart & Hemsath, 1988).

Modern measures of euphoria. Contrary to the classical measure of euphoria, the modern measures of euphoria revealed statistically significant between-group difference for the 3 sub-types of euphoria. Each sub-type consisted of three measures, however, only one measure per sub-type was deemed significant, the *NPI* measure for euphoria sclerotica, the u physical ability measure for eutonia sclerotica, and the *CRJRF* measure for spes sclerotica.

The MVA TBI and MS participants were expected to differ significantly on these measures; however, both MVA TBI and MS participants differed significantly from the HC participants but not from each other. MVA TBI and MS participants performed similarly on two measures of euphoria sclerotica, the *PANAS* and *ISS*. Therefore both MVA and MS participants appear to be equally as positive/euphoric. However, although no statistical significance has been reached between MVA TBI and MS participants for the *NPI* measure of euphoria sclerotica; more MVA TBI than MS participants reported having euphoria. Thus MVA TBI may be more euphoric than MS participants.

MVA TBI and MS participants differed in performance on all three measures of eutonia sclerotica, such that MVA TBI participants performed worse than MS participants the measures of eutonia sclerotica (unawareness of physical deficit (physical ability scale), unawareness of cognitive deficit (*AI*), and unawareness of mood/behavioural difficulties (*NPI*). This difference, however, did not reach statistical significance. Therefore MVA TBI participants were more unaware of their physical, cognitive, and mood/behavioural deficits in comparison to MS participants. These results are to some extent, consistent with that of Sherman *et al*., (2008) findings that MS patients may be unaware of or fail to acknowledge the extent of their physical, cognitive, and mood/behavioural difficulties; and Anderson and Tranel (1989) finding that patients who underwent head trauma may be unaware of cognitive deficits.

MVA TBI and MS participants performed similarly on two measures of spes sclerotica, the *OPS* and *LOT-R.* Therefore MVA TBI and MS participants are equally optimistic. However, although no statistical significance has been reached between MVA TBI and MS participants for the *CRJRF* measure of spes sclerotica; MS participants performed higher than MVA TBI participants for this measure. Thus MS participants are more unrealistically optimistic than

MVA TBI participants. These results are consistent with Cottrell and Wilson's (1926) statement of MS patients being optimistic, and it further discovered the first evidence for the role which which unrealistic optimism plays in MS.

This study therefore did not support hypothesis (1) since MS participants were not the only group to present with all 3 sub-types of euphoria, nor was the frequency of these sub-types higher among MS compared to MVA TBI participants.These findings contradicts that of Stuart and Hemsath (1988) who argues that although euphoria can occur in TBI patients, it is not a prominent or well recognised symptom of mood or behaviour in TBI.

Executive dysfunction in MS and MVA TBI participants

The measures of cognition revealed statistically significant between-group difference for the visuospatial measure (*ROCF),* the verbal memory measure (*RAVLT)*, and the visual memory measure (*BVMT-R)*. For all these measure, the HC performed significantly better than the MVA TBI and MS participants; and for one of these measures, the verbal memory measure (*RAVLT*), the MS participants performed significantly better than the MVA TBI participants.

However, although no statistical significance has been reached between MVA TBI and MS participants for the remaining measures of cognition; MS participants also performed better than the MVA TBI participants on a number of other measures of cognition, namely, working memory (*2-back task*), speed of information processing (*0-back task*), generativity (*COWAT*), verbal memory (*RAVLT*), visual memory (*BVMT-R*), and cognitive flexibility (*DST&CWIT composite*), and set-shifting (*CWIT*). While, MVA TBI and MS participants performed equally well on measures of attention (*0-back*), planning (*ROCF*), and visuospatial (*ROCF*).

This suggests that MVA TBI and MS participants presented with similar cognitive impairment on all, but one measure of cognition: *RAVLT*. This difference could have been due to the fact that MVA TBI and MS participants were matched as closely as possible but not participant to participant on the socio-demographic variables which could have impacted on the results.

The findings of this study therefore largely support hypothesis (2) and are consistent with previous research which found that TBI and MS patients both demonstrate executive dysfunction in the domains of working memory, problem solving, conceptual ability, strategic planning, and difficulties with verbal fluency, inhibition and set shifting, attention, concentration, memory (Foong et al., 1997; Rao & Lyktestos, 2000).

The association between executive dysfunction and euphoria in MS and TBI participants

The Pearson correlations revealed a statistically significant positive correlation between two measures of executive dysfunction and one sub-type of euphoria in MS participants, namely,

between attention (*0-back task*) and the modern measure of eutonia sclerotica (unawareness of physical deficit-physical ability scale), and between the visuospatial (*ROCF*) measure and the modern measure of eutonia sclerotica (unawareness of physical deficit-physical ability scale). These results could have been due to the fact that literature demonstrates correlations between euphoria, severe cognitive impairment (mainly that of executive dysfunction) and white matter damage of the brain in MS (Fishman et al., 2004; Rabins et al., 1986; Sanfilipo, et al., 2006). Furthermore, inter-rater bias could have occurred when scoring the visuospatial construction.

The Pearson correlations revealed statistically a significant negative correlation between one measure of executive dysfunction and one sub-type of euphoria in MVA TBI participants, namely, speed of information processing (*0-back task*) and the modern measure of eutonia sclerotica (unawareness of physical deficit-physical ability). These results could have been due the fact that only 90% of MVA TBI participants as opposed to 100% of MS participants completed the measure for speed of information processing (*0-back task*). This finding is consistent with Stuart and Hemsath's (1988) argument that euphoria is not a symptom by which TBI is characterised.

Therefore, these findings largely support hypothesis (3) since, for the majority of the measures, cognitive impairment in terms of executive dysfunction is not associated with euphoria in either MS or MVA TBI participants.

Limitations

Methodological limitations. This study had methodological shortcomings which had to be taken into consideration when interpreting the results. One major limitation of this study was the sample that was utilized. This was due to the short time frame given for completion of this study, and the access to a limited amount of participants. The inaccessibility resulted from some invalid contact details which have been provided by GSH for possible MVA TBI participants, as the patients may have been admitted quite a few years ago; from various unforeseen circumstances experienced by possible participants which led to them not being able to participate; and from the inability to get hold of participants when contacted them to confirm their interview.

The small sample limited statistical power for investigating whether euphoria is a specific feature of MS. This suggests that some of the non-significant results which were yielded across the testing of the three hypotheses may have been due to type II error. Moreover, the statistical power could have been the reason that this study could not formally correct or control for possible type I error although the statistical analyses which were conducted attempted to control for the small sample. Thus, the primary results which were found could have been due to

chance alone despite having used likelihood ratios and one-way ANOVA to control for type I error, and Kruskal-Wallis tests to confirm primary results found; and by combining variables to reduce the number of correlational analyse ran. Therefore, these findings can merely draw tentative conclusions.

Socio-demographic and medical limitations. There were between-group differences for two of the key socio-demographic variables, namely, the distribution of gender and education (i.e. highest level of education completed). The statistically significant between-group gender difference was between the MS and MVA TBI participant groups. This difference was an unavoidable factor since the majority of the MS participants onto which the MVA TBI participants had to be matched, were female; thus it cannot be disregarded that it influenced the findings. The statistically significant between-group difference for education was between the HC and MS participants groups, and it could not further be controlled for. The MS and MVA TBI participant-groups never-the-less performed similarly on cognitive testing, so it does not seem likely that their cognitive dysfunction was due to a lower average education. The sample however, were homogenous on the remaining key socio-demographic variables, namely, mean age, race, and income, but this does not make it plausible to generalize the findings to the broader population.

In addition, a few of the MVA TBI and MS participants presented with medical conditions which ought to have been excluded but was retained due to but limited access to participants. These conditions, for the MVA TBI participant group, included post TBI epilepsy; and, for the MS participant group, included the report of having had a TBI, epilepsy, post MS diagnosis depression, prematurity, dyslexia as a child. Both MVA TBI and MS participant groups included participants who reported marijuana consumption, which was retained as it was controlled for by ensuring that they did not consume marijuana 48 hours prior to the interview.

Administration and/or testing limitations. The fact that the entire sample did not complete the *n-back task* could have influenced the findings which measured attention, working memory and speed of information processing. This could have occurred as a result of the task being too complex for them. Furthermore, the length, as well as the time of day of the interview could have impacted on the performance of the participants. Although the participants were allowed take a break at any time of the interview, the interview itself was long and could have resulted in participants becoming restless, frustrated or fatigued. Control for the attention and concentration levels were demonstrated through the attempt to undertake the interview in the morning; a few interviews, however, were held in the afternoon a result of participant availability. This could have impacted on participants' performance for the cognitive measures.

A final and important limitation for this study was that the neuropsychological measures deployed were not standardized to fit South African norms. This limitation was, nonetheless, addressed by the inclusion of the HC participants which served as a reference group to which the MVA TBI and MS participants were compared.

Conclusion and future recommendations.

The correlation between severe cognitive impairment in terms of executive dysfunction and white matter subcortical damage and euphoria in MS was investigated by comparing MS patients to MVA TBI patients. This was done to determine whether euphoria is associated with white matter damage and/or executive dysfunction in general, or whether it is as a result of something specific to MS. This study found that euphoria in MS may be the result of white matter damage and executive dysfunction since MS and MVA TBI patients appear to present with similar frequencies of euphoria across the 3 sub-types; with similar cognitive impairment; and with a few correlations between cognitive impairment, in terms of executive dysfunction, and the 3 sub-types of euphoria in MS patients. This study has therefore increased our understanding of the affective symptom of euphoria by addressing the gap in neuropsychological testing research pertaining to executive dysfunction and symptoms of euphoria.

However, due to the limitations which emerged, this study ought to be taken as preliminary in nature and is in need of future adaption. Future research ought to carry out more extensive research on the cause of euphoria. Furthermore, this type of research ought to be conducted on a larger sample as to ensure that reliable conclusions are drawn. Future research ought to aim at the establishment of standardized South African measures so that norms are created which could yield more conclusive results, to increase the number of socio-demographical variables by adding language and investigating whether it has any effect on measures of mood and cognition, and to reduce the amount of measures to avoid fatigue over lengthy period of testing.

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