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Distractibility When Suffering from Mental Fatigue after a Mild Traumatic Brain Injury

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Abstract

Most Traumatic Brain Injuries are mild (mTBI) yet many people suffer from long-term mental fatigue and cognitive impairment. Despite comments from patients, cognitive difficulties can go undetected. Distractibility is commonly reported but is seldom included in standard neuropsychological assessment. This study was designed to investigate the effect distraction may induce in top-down and bottom-up attention among people who suffer from mental fatigue after mTBI. Thirty mTBI patients suffering from mental fatigue and 30 healthy controls performed a computerized test, including Simple Reaction Time, Choice Reaction Time and Attentional Capture tasks with a salient distractor. A slower processing speed was found in all subtests for the mTBI group and was particularly noticeable for the decision-making task. The distraction stimulus reduced processing speed for both groups, while the mTBI group made more omissions when a distractor emerged, indicating increased distractibility. However, no effect in top-down and bottom-up attention was found. Response time in the presence of a distractor was a predictor for mental fatigue, while depression and anxiety were not, showing the importance to carefully distinguish between emotional distress and mental fatigue. In conclusion, it is suggested that people suffering from mental fatigue after mTBI are slower at processing information, and this is more pronounced when a cognitive demand is added to the task. Distractibility was indicated with more omissions during distraction, but a distinction between top-down and bottom-up systems was not found. Further research is needed to better understand the link between distractibility and mental fatigue after a brain injury.

Keywords: Mild TBI; Mental fatigue; Distractibility; Attention; Processing speed

Introduction

People of all ages can suffer a Traumatic Brain Injury (TBI) and approximately 70-90% of these are mild TBI (mTBI) [1]. Many recover within one to three months but not all and among traffic-related mTBI 23% did not recover within a year [2]. From a study performed in the Netherlands an unfavorable outcome was reported for 30% of all mTBI patients [3]; from a review approximately half of the individuals with a single mTBI demonstrated long-term cognitive impairment [4]. The estimation varies depending on definition of mTBI and outcome measures. At all events, it is clear that long-term difficulties can persist after an mTBI. More importantly for the individual are the consequences for everyday life and it has been shown that long-term cognitive impairment after an mTBI is related to reduce community participation [5].

For those patients with insufficient recovery after mTBI, pathological mental fatigue is common having impact on well-being and quality of life [6]. From a longitudinal study only 27% recovered an mTBI within the first year; the most common symptoms reported were headache, difficulty concentrating and fatigue [7]. It has been proposed that fatigue after TBI correlates with poor performance in terms of attention span and reduced processing speed [8-15], as well as reduced social and recreational activities [10] and employment status [16].

Common cognitive and behavioral impairments related to executive function after an mTBI include the following: difficulties with attention, memory, planning, decision-making, emotional control, motivation and impulsivity [17]. Attention is an important factor for executive function and distractibility is suggested to be one of the most troublesome effects after an mTBI [18]. In the clinic, mTBI patients commonly comment that important as well as unimportant information is recognized and that they are easily distracted even when, according to normative data cognitive tests are within normal range. Only a few studies in clinical populations have been reported measuring cognitive function while a distraction is present. The ability to apply and sustain one's attention in the presence of a distractor in the form of background noise was studied with participants who had suffered an mTBI [18]. The test consisted on an extended version of the 2 and 7 Selective Attention test [19] adding two distractors, a non-relevant distraction involving a background noise from a radio talk show and a relevant distractor involving instructions from a tape recorder on how to calculate a math problem. The processing speed was found to be reduced for mTBI group on the relevant distractor task. Accuracy was maintained for controls and the mTBI subjects. The symptoms of slowed thinking and fatigue were related to processing speed in the non-relevant distractor task and the relevant noise distractor task was related to processing speed and slowness of thinking. A study with a visual reaction time go-no-go

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task adding a visual distractor with a varied onset time was done. This was used to compare a group who had suffered a TBI with a control group [20]. When the distractor occurred at or shortly after the target a slowing in reaction time was detected; this was significantly greater for the TBI group. Accuracy was not affected. The authors suggest that the distractor caused most interference with response planning and execution as opposed to target detection. From another study, comparison was done between mTBI, a group with major depression and a control group using standard neuropsychological tests in a standard setting and in a setting with visual and auditory distractors [21]. While reading the story during the logical memory test from the Wechsler Memory Scale (WMS), a distraction with a woman reading the news was shown on a laptop screen and, when conducting the subtest Digit Span and Letter-Number-Sequencing from the Wechsler Adult Intelligence Scale (WASI-IV) a distraction with random number of digits was shown on the computer screen. Baseline testing without distraction showed similar results between the groups while a significant deterioration in working memory during distraction setting was found for the mTBI group. The control group remained unchanged. The depressed group improved during the test session on working memory during the distraction setting and reported more emotional distress compared to the mTBI and control groups. The mTBI group reported dizziness, headaches and feeling puzzled and these patients did not report emotional distress as a result of the distraction. The author also concluded that significant change in the distraction condition indicate that the patient is not ready to successfully return to an occupation involving complex attentional demands [21]. In a memory and virtual street task with distractors the group with severe TBI performed less well compared with the controls and was also more affected by distractions while no difference in logical memory (WMS-III) was found between the groups [22].

Only a few studies are reported in clinical populations exploring distraction in relation to mental fatigue. Fatigue and cognitive dysfunction are common among people suffering from Multiple Sclerosis (MS), and when cognitive tests with and without distraction, mimicking background office noise was compared, reduced processing speed was found for MS participants in presence of an auditory distraction [23]. From a study of patients suffering from stress-related exhaustion, increased mental fatigue was reported after a neuropsychological testing with auditory distraction. The control group did not rate any changes in mental fatigue. Compared to the control group, cognitive performance was not affected according to common neuropsychological tests measuring executive function, working memory and complex attention [24].

Attention is commonly categorized into two distinct functions; the goal-driven and voluntary allocation of attention referred to as top-down or endogenous attention, and the stimulus-driven attention referred to as bottom-up or exogenous attention, being driven by external events in the environment [25]. Normally, by filtering out less relevant information people allows to respond quickly and to achieve behavioral goals more efficiently. Processes mediating bottom-up and top-down attention has been argued, and a frontoparietal network is suggested being essential in both types of attentional processes, based on studies in nonhuman primates [26]. Tommasi et al. [27] used a computerized test measuring attentional capture and goal-driven attention with a salient distractor, with the intention to compare top-down and bottom-up attention. They reported increased distractibility for the Parkinson's group compared to the controls, with the Parkinson group having a slower reaction time and more omissions when the distractor was present and having an increase in time of attentional capture and a delay in target selection in the absence of any salient distractor. They suggested that their result reflect impaired top-down attention compared with controls. They did not include fatigue in their study, but fatigue is common among patients suffering from Parkinson´s disease [28]. Liu et al. evaluated mental fatigue associated with mTBI using a psychomotor vigilance test combined with arterial spin labeling fMRI (functional Magnetic Resonance Imaging) [29] and suggested that mental fatigue was associated with both weakened top-down and bottom-up attention.

The present study was based on the work performed by Tommasi et al. [27] and the objective was to investigate distraction and the influence of top-down and bottom-up attention among people who suffer from mental fatigue after mTBI.

Materials and Methods

Subjects

The clinical group consisted of 30 people who had sustained mTBI and were suffering from mental fatigue at least 6 months after the mTBI. Their injury was evaluated on the basis of a personal interview and they were diagnosed with mTBI according to the definition proposed by The WHO Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury [30], having a sum score above the cut-off score on the Mental Fatigue Scale (MFS, cut-off 10.5) [31]. The patients were aged 20-65 years and were not suffering from any other psychiatric or neurological disorders. Eight had been receiving stimulant medication for approximately 5-6 years but had not taken methylphenidate for four weeks prior to inclusion in this study. Their cognitive test results and rating on MFS had returned to baseline after four weeks without methylphenidate [32]. All mTBI participants had recovered well and were independent in their daily lives, with the exception of their prolonged mental fatigue. The clinical group was selected from a rehabilitation unit and a pain clinic and from an announcement in a Facebook group for mental fatigue as it was not possible to recruit enough patients from the clinics. No specific concussion nor mTBI clinic was present. Thirty healthy controls, also aged 20-65, who neither suffered from mental fatigue (below 10.5 points on MFS), nor from any psychiatric or neurological disorders were recruited at the request of the general community. The study was approved by the regional Ethical Review Board in Gothenburg. The participants gave their informed consent. All received a cinema ticket to thank for their participation.

Self-assessment scales

The Mental Fatigue Scale (MFS) is a multidimensional questionnaire comprising 15 questions. Each question included examples of common activities and was then related to four exemplified alternatives. Higher scores reflected a more severe symptom. The questions included in the scale were found to have an adequate internal consistency with a Cronbach´s alpha of 0.944S [33]. MFS has a cutoff score at 10.5 [34]. MFS has been evaluated for TBI and stroke subjects and was found to be invariant in patients aged 18-65 years; it did not vary with time since injury, gender and education

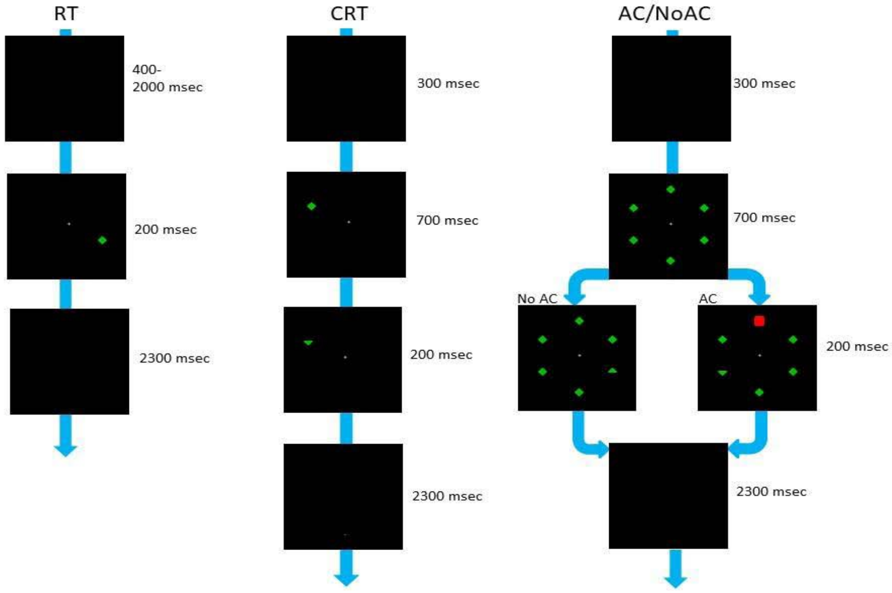

Figure 1: The computerized test with the three subtest measuring Reaction Time (RT), Choice Reaction Time (CRT) and the longer subtest with and without an Attentional Capture (AC). All subtests were repeated tree times in the following order: 3x (RT-CRT-AC).

[10,34]. An evaluation of MFS demonstrated that processing speed was a significant cognitive predictor for rating on MFS [10,34].

The Comprehensive Psychopathological Rating Scale (CPRS) was used to assess depression and anxiety [35,36]. The CPRS depression scale is identical to the Montgomery Åsberg Depression Rating Scale (MADRS) except that the rating is doubled up in the MADRS [37]. Mild depression (according to CPRS rating) has been associated with a rating ranging between 6.6 and 9.5 for mild; moderate between 10-17; and severe ≥17.5 [38].

The MFS and CPRS have a similar construction with four exemplified alternatives for each question, making it easy to compare the ratings from the two scales. Four items from the MFS and CPRS are overlapping and are the same. Concentration difficulties, lack of initiative and decreased sleep are all included in MFS and CPRS depression; irritability is included in MFS and CPRS anxiety (the separate items are shown in Figure 2).

Test procedure

A computerized test was used based on the test described by Tommasi et al. [27]. Their test procedure was adapted for participants with Parkinson's disease; their objective was to study attention and distraction/stimulus. This is a test with an attentional capture task/distractor (AC). AC is defined as an involuntary directed attention towards a target stimulus/distractor [39]. The computerized test was adapted to run on PC [27] by a professional computer programmer (Figure 1).

The test included three subtests and these were all repeated three times. Repetition was of interest as, in previous studies, altered performance after repetition has been reported for subjects suffering from mental fatigue after TBI compared to controls [8,40-43]. The three subtests included a simple Reaction Test (RT), a Choice Reaction Test (CRT) and an AC test presenting randomly a salient distractor in 1/3 of the trials and without a distractor in 2/3 of the trails. The reason for including all three tests was to be able to delineate the difference between motor reaction time, perceptual discrimination or decision-making (CRT-RT), top-down effect (CRT-AC with no silent distractor) and bottom-up effect comparing AC with and without a distractor/salient stimulus.

The test was run on a laptop with an Intel core I5-6300U 2.3GHZ and a 14.0 inc screen.

The adjacent keys 'up' and 'down' were used. The 'up' key was used for diamonds with the upper corner removed and the down key with the lower corner removed (Figure 1). The participant practiced each subtest just before the first time the subtest was run. If the participant required, another practice run was offered. In all subtests, a white fixation cross was presented in the center of the screen on the black background before the response stimulus was presented. The white cross remained on the screen during the stimulus presentation and the participants were requested to maintain gaze on the cross.

In total, the test session lasted for 35 minutes and the subtests were repeated three times in the following order: RT-CRT- AC.

Simple Reaction Time (RT)

Each RT run included 20 trials. A green diamond target appeared on the screen for 200msec after variable exposure of the white cross between 400 and 2000 msec. A green diamond appeared on the screen randomly in one of the six positions surrounding the white cross (Figure 1). Participants were instructed to respond as quickly as possible. They practiced the RT task 5 trial before the first run of the RT.

Choice Reaction Time (CRT)

Each CRT run included 20 trials. A single green diamond appeared for 700msec at random in one of the six positions around the white cross in the center of the screen. The diamond was directly followed by a diamond with a removed tip on the top or the bottom,

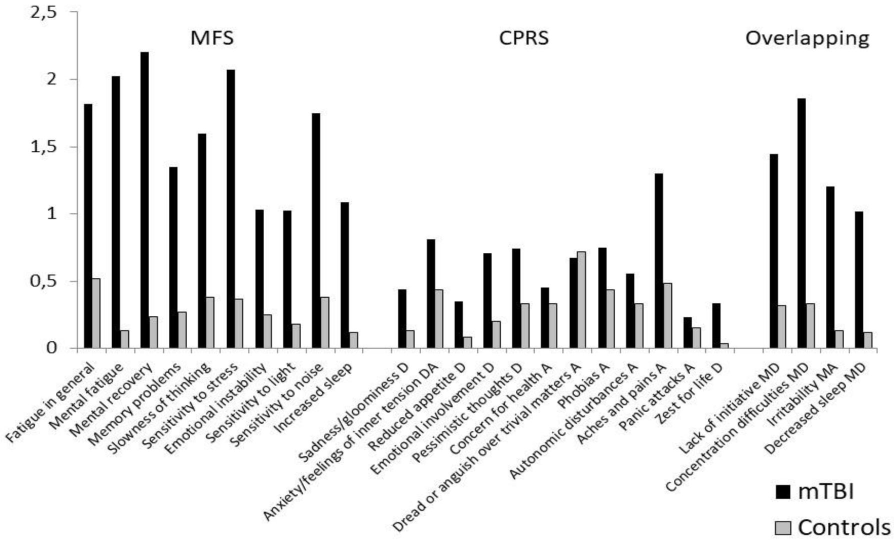

Figure 2: The figure shows the mean value from the separate questions included in Mental Fatigue Scale (MFS), the subscales, depression and anxiety from Comprehensive Psychopathological Rating Scale (CPRS) and the overlapping questions for MFS and CPRS. M: MFF; D: Depression; A: Anxiety.

appearing for 200msec. The diamond could appear in the same or another of the six positions. Participants were instructed to respond as quickly as possible and to press the key pointing up if the top of the diamond was removed and the key pointing down if the bottom of the diamond was removed. The participants practiced the CRT task 5 trials before the start of the first run.

Distractor task/Attention Capture Task (AC)

Each AC run included 120 trials, 80 without a distractor a 40 with a distractor, all presented in a random order. The AC task started with a white cross, as for the CRT, but now all six positions were occupied by green diamonds; this first one appeared for 700msec and then one of the diamonds appeared suddenly for 200msec with a missing top or bottom. When a distractor appeared simultaneously one of the diamonds was changed to a red square in a random place from one of the six positions. The participants were instructed to respond to the diamonds with a missing top/bottom in the same way as in the CRT run using the same keys. The participants practiced the AC task 12 trials before start of the first run.

Statistical analysis

A two-way repeated Analysis of Covariance (ANCOVA) with within-subject factor time (3 repetitions) and the between-subject factor group was used. Mauchly´s test of sphericity indicated that the sphericity assumption did not hold and adjusted degrees of freedom were therefore used for all tests (Greenhouse-Geisser correction). Age was added as a covariate. Chi-square analysis was used for nominal data. A linear regression using the 'enter' model was conducted to examine predictors for mental fatigue. Pearson's correlation coefficient was used for correlation analysis. The first response for each trial was not included in the analysis as it was assumed that this could be less accurate if the participant was not fully alert and ready for the run. Statistical analyses on reaction time were performed only on correct responses. Numbers of errors and omissions were recorded in CRT and AC. Statistical analyses were performed on proportion of omissions and errors according to numbers of trials/runs with and without a distractor. The time for decision-making was calculated as the difference between CRT and RT. The distractor effect was measured as the difference between the task with a distractor and the task with no distractor in the AC test [27]. SPSS 25.0 for Windows was used for data analysis.

Results

Participants' characteristics

Demographical and clinical characteristics of the study groups are presented in Table 1. The mTBI group was significantly older than the control group (Table 1). There was also a significant difference in education. There was no difference in numbers of men and women between the groups.

The mTBI groups reported a significantly higher rating on MFS, depression and anxiety compared to the control group (Table 2, Figure 2). No correlation to MFS and age was found for either of the groups (mTBI r=0.004, p=0.985, and controls r=0.061, p=0.751). There was no difference between the men and women and their rating of MFS (mTBI women 21.8±4.2, men 19.7±2.8, controls women 3.7±2.9, men 3.8±2.5). Nor was any difference in MFS rating found if they had suffered one (n=17) or several (n=13) mTBI (MFS rating; one injury, 21.9; two or more injuries 20.5; p=0.359) and no correlation between MFS and time since injury (r=0.170, p=0.359).

Table 1: Demographics. Mean and standard deviation (±), frequencies and p-values from t-test (equal variance not assumed was used for comparison) and Chi-square analysis.

	mTBI, N=30	Controls, N=30	p-value
Age (Years) Mean ± SD	46.5 ± 9.5	38.3 ± 14.5	0.013
Sex; Women/Men	23/7	17/13	0.1
Education	18 University	27 University	0.023
	10 Secondary School	3 Secondary School	
	2 Elementary School		
Time Since Injury (Years ± SD)	8.1 ± 9.2 (median 3.5 years)		

Table 2: Comparison between mTBI and control groups for self-assessment of mental fatigue using the Mental Fatigue Scale (MFS) and depression and anxiety from the Comprehensive Psychopathological Rating Scale (CPRS) including overlapping items. Mean, standard deviation (±) and p-values from t-test are shown. Equal variance not assumed was used.

Variable	mTBI	Controls	p-value
MFS	21.3 ± 4.0	3.7 ± 2.7	<0.001
Anxiety	7.1 ± 3.8	2.9 ± 1.7	<0.001
Depression	7.4 ± 3.5	1.4 ± 1.3	<0.001

No significant difference between those who had been receiving methylphenidate previously and those with no medication was found for MFS (p=0.795), depression (p=0.276), anxiety (p=0.813), reaction time with distractor present (0.100) nor omissions with distractor (p=0.665).

Distractor test

As age differed between the groups and it is well-known that processing speed and attention correlates with age [44], all the statistical calculations for the distraction tests were controlled for age (ANCOVA). The mTBI group was significantly slower in their reaction time in all three subtests. For both groups, the reaction time increased with higher demand of the subtest with the slowest performance being in AC (Table 3, Figure 2a). No effect of time (repetition of tasks) was found nor was there any interaction for each of the subtests (Table 3). An interaction effect was found when mean sums of respective subtests were compared (Repeated ANCOVA, F=6.279, p=0.003); the interaction was due to the steeper reaction time increase in CRT for the mTBI group. The difference between CRT minus RT varied significantly with the mTBI group being slower in their decision-making (Table 3). No bottom-up (AC-AC with no distractor) and top-down effect were detected (CRT- AC with no distractor, Table 3).

Omissions and errors were analyzed in CRT and AC with and without a distractor. No difference in errors made was found between the groups. However, a difference in omissions was detected between the groups in the AC distractor task, with the mTBI group making significantly more omissions. When comparing the difference between distractor (AC% omission) and no distractor (no AC% omission), no significant difference was found between the groups (Table 4, Figure 2b). Processing speed in AC distractor task correlated positively with omissions for both groups (mTBI p=0.038, r=0.381, controls p=0.021, r=0.421).

Linear regression

A linear regression was conducted to examine whether the mental fatigue score (with no overlapping items between MFS and CPRS) was determined by any of the predictors included in the model. In this linear regression analysis, the overlapping items were removed as MFS and CPRS depression and anxiety have overlapping questions (Figure 1). The rationale for this was to enable scaling with a clear distinction from central symptoms. Overlapping items could blur the distinction between depression and fatigue [45]. The predictor variables added to the model included age, depression, anxiety, omissions for AC with distractor and reaction time for AC with distractor (mean of the three repetitions). Using the 'enter' method, a significant model emerged F [5,54] = 10.457, p <0.001. The model explains 44.5% of the variance (Adjusted $R^2 = 0.445$). Table 5 provides information for the predictor variables entered in the model. The only

Table 3: The table shows the results for reaction time (msec) from a two-way repeated ANCOVA (controlling for age) with within-subject factor, time (3 repetitions) and the between-subject factor, group. Mauchly´s test of sphericity indicated that the sphericity assumption did not hold and adjusted degrees of freedom were therefore used for all tests (Greenhouse-Geisser correction). Mean, standard deviation (±) and p-values are shown. RT: Simple Reaction Time; CRT: Choice Reaction Time; No AC: No Distractor in the Attention Capture Task; AC: Capture Task with Distractor.

Variable	mTBI	Controls	Time p-value	Interaction p-value	Group p-value
RT	510.9 ± 135.9	369.0 ± 48.5	0.187	0.474	<0.001
CRT	950.6 ± 266.8	647.2 ± 112.1	0.127	0.241	<0.001
No AC	935.3 ± 246.5	674.6 ± 113.6	0.321	0.084	<0.001
AC	1046.4 ± 269.4	751.8 ± 115.4	0.081	0.667	<0.001
CRT-RT	439.7 ± 201.0	278.2 ± 92.6	0.25	0.142	0.002
CRT-No AC (top-down)	-15.3 ± 95.8	27.4 ± 68.0	0.48	0.051	0.077
Distractor effect (AC-No AC) (bottom-up)	111.0 ± 91.4	77.2 ± 47.9	0.425	0.202	0.159

Table 4: The table shows the results for omissions and errors made from a two-way repeated ANCOVA (controlling for age) with within-subject factor, time (3 repetitions) and the between-subject factor group. The analyses are based on % of omissions and errors in relation to numbers of repetitions for each task. Mauchly´s test of sphericity showed that the sphericity assumption did not hold and adjusted degree of freedom was therefore used for all tests (Greenhouse-Geisser correction). Mean, standard deviation (±) and p-values are shown. RT: Simple Reaction Time; CRT: Choice Reaction Time; No AC: No Distractor in the Attention Capture Task; AC: Capture Task with Distractor.

Variable	mTBI	Controls	Time p-value	Interaction p-value	Group p-value
CRT omissions	7.0 ± 9.4	5.2 ± 7.9	0.826	0.931	0.397
CRT errors	5.6 ± 5.9	2.9 ± 4.2	0.864	0.709	0.248
No AC omissions	19.4 ± 18.8	10.0 ± 11.1	0.791	0.106	0.11
No AC errors	4.4 ± 5.4	3.1 ± 2.2	0.242	0.105	0.331
AC omissions	31.6 ± 22.3	16.0 ± 16.1	0.598	0.833	0.036
AC errors	5.5 ± 6.0	4.0 ± 3.6	0.091	0.977	0.274

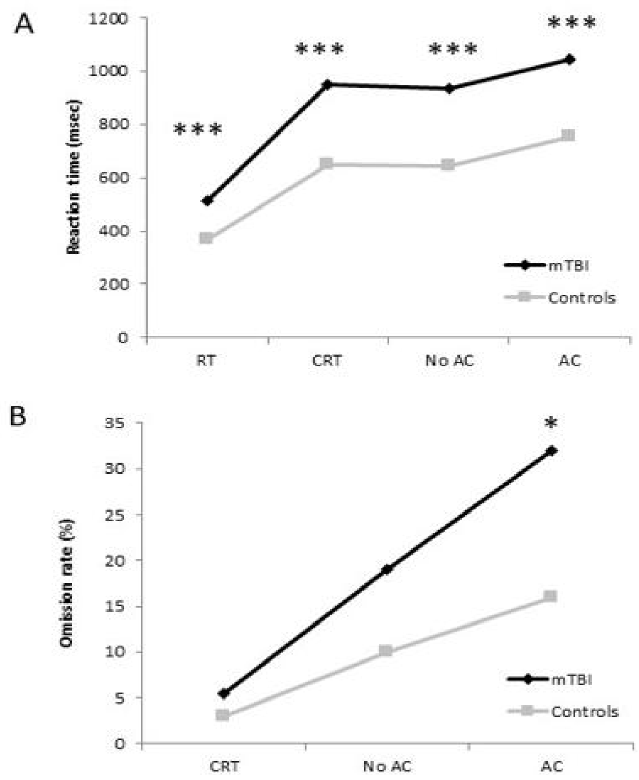

Figure 3: Figure A shows reaction time (msec) for simple reaction (RT), Choice Reaction Time (CRT), attentional capture without distractor (No AC) and attentional capture with distractor (AC). Figure B shows omissions for CTR, no AC and AC. ***p<0.001; *p<0.05.

Table 5: Linear regression with the enter method determine predictor variables for mental fatigue, MFS with no overlapping items.

Variable	B	SE B	β	p-value
Age	0.055	0.065	0.099	0.4
Depression, no overlap	0.782	0.429	0.27	0.074
Anxiety, no overlap	0.462	0.372	0.181	0.219
Omission AC with distractor	0.027	0.41	0.079	0.505
RT/AC with distractor	0.011	0.003	0.4	0.002

significant predictor for mental fatigue was reaction time for AC test with distractor. The other four variables were not.

Discussion

Slower processing speed in all subtest were found for the mTBI group suffering from mental fatigue compared to controls. When comparing response time for the subtests, an interaction was detected for the CRT. The mTBI group showed a distinct slower response time after removal of motor reaction time, indicating a slower perceptual discrimination compared to controls. When the numbers of diamonds increased from one to six, the reaction time remained on a slightly similar level for both groups while there was an increased reaction time for both groups when a distractor was present. This demonstrated that a salient distractor was associated with attentional capture and that the subtests used in this study had a reliable effect with demand differences. AC reaction time was the only significant predictor for mental fatigue. The mTBI group also made more omissions during the AC task. A similar result was reported by Tommasi et al. with the Parkinson's patients having a slower reaction time and making more omissions when a distractor was present [27]. In this study as well as the study by Tommasi et al. [27], no significant difference in error rate was found. Processing speed in AC task correlated positively with omissions for both groups showing more omission when response time was longer. The result here is in line with previous studies for people who had suffered mTBI with a slowing down in processing speed with maintained accuracy in the presence of a distractor [18,20]. However, no distinction between bottom-up (stimulus- driven) and top-down (goal-driven) attention in response time was found.

The distractibility people who suffer from mental fatigue after mTBI commonly report may not be due to an imbalance between bottom-up or top-down attentional systems. Both a weakened top-down and bottom-up attention was suggested for mental fatigue associated with mTBI using a psychomotor vigilance test combined with arterial spin labeling fMRI [29]. The brain needs fine-tuned signaling and coherence between nerve cell networks. A disturbance in any signal system in the brain due to injury reduces the ability of the brain to work efficiently. This may result in slower processing speed and having consequences in a hectic world when there is a need to respond accurate and quickly to situations e.g. when faced with a traffic incident, following a conversation or capturing the whole essence of a discussion.

Mental fatigue, depression and anxiety were all rated higher for the mTBI mental fatigue group. However, the linear regression analysis showed the reaction time with a salient distractor to be a significant predictor for mental fatigue while anxiety and depression were not. This shows the importance of carefully delineating fatigue, depression and anxiety as separate entities. Scales have overlapping questions and can give misleading results if the analysis is not done carefully [45].

Limitations

In this study, pathological mental fatigue was present for all patients in the mTBI group. It is not possible to determine whether mental fatigue or the injury itself contributed more to the results as there was not an mTBI group without mental fatigue included. However, from a recent study including a recovered mTBI group, no difference was found in Mental Fatigue (MFS); reaction time between those who recovered and controls was reported while a significantly higher MFS and also a slower reaction time for the persistent mTBI group was reported [46]. Another limitation is that the groups differed in age and education. Age and education have not been related to MFS in previous studies [34] nor in this study. In contrast, it is well known that processing speed is age-related and accordingly age was controlled for in all the statistical analyses related to the computerized test. Depression and anxiety were also measured and these could have been cofounding factors for the mental fatigue rating. However, the regression analysis including depression and anxiety with overlapping questions deleted indicated that the only significant predictor for mental fatigue was AC reaction time.

Conclusion

In conclusion, it is suggested that people suffering from fatigue after mTBI is slower in processing of information, and this is more pronounced when a cognitive demand is added to the task, as was particularly noticeable for the decision-making task. It was also found that the distraction stimulus reduced processing speed for both the mTBI and control groups while the mTBI group made more omissions when a distractor emerged, indicating increased distractibility. Response time in presence of a distractor was also a predictor for mental fatigue. However, no distinction between top-down and bottom-up attention was found. As distraction is common in daily living, especially when considering the ability to successfully return to work suffering from mental fatigue after a brain injury, it is important to develop cognitive tests that are adapted to the real world. The results also show the importance to understand fatigue, depression and anxiety as separate entities. Currently the underlying origin of mental fatigue and distractibility after an mTBI are not well known and future studies are needed.

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