Full-Length Article

Music-supported Systematic Treatment Strategies for People with Executive Dysfunction Following Traumatic Brain Injury: *Similarities and Divergencies in 7 Case Reports*

Berit Marie Dykesteen Vik[1]

[1]University of Bergen, Norway

Abstract

The present article explores in-depth, 7 case reports of patients with cognitive and social deficits following mild traumatic brain injury (mTBI). We sought similarities and divergencies which may have an impact of the final outcome of a music-supported intervention. The main question was to define the factors that might predict a positive or negative outcome for cognitive enhancement and improved social behavior after music-supported intervention for patients with cognitive and behavioral deficits following mTBI. This article is a cohort study, based on existing unpublished data from a recent study by Vik et al. [1] which describes how 8 weeks of structured piano-playing reorganized the functional neuronal networks of 7 patients with mTBI who evidenced significant enhanced cognitive performance. A case-study methodology is applied exploring behavioral data obtained from the study, that was not published. This methodology allows for an in-depth analysis of clinical data, inclusive of observational data during intervention and data from semi-structured interviews pre-post intervention, as well. 7 patients with executive dysfunction following mTBI participated in the music-based intervention. They were in a chronic phase and were either sicklisted or worked part-time. 6 out of 7 participants returned to work post-intervention. Results for analyses were taken from neurophysiological tests, fMRI and resting-state fMRI consolidated with enhanced cognitive performance and functional neuroplasticity in orbitofrontal cortex. These results were based on quantitative analysis with mean effect and did not give specific information about similarities and divergencies between the participants that may have had any impact on the final outcome. The aim of the present article is to broaden understanding of factors that may have an impact on a positive rehabilitation process for patients with cognitive and social deficits following mTBI. The results offer evidence that playing the piano, as described in the intervention protocol, may enhance executive functions. All patients achieved a significant increase of concentration and in their memorization capacity. However, in reference to social interaction, we identified two negative factors, namely pre-injury depression and pre-injury TBI. This is a replication of a well-known variables. These results may refine a systematic treatment strategy in support of music training to improve both cogntive and behavioral domains of functioning in patients following mTBI. I suggest that the successful intervention described (1) should implement a multidisciplinary program that would ideally accompany the music-supported intervention to catch patients that otherwise would be prone to negative outcomes.

Introduction

Traumatic brain injury (TBI) is one of the common causes of disability in physical, psychological, and social domains of functioning worldwide [2]. Cognitive problems play a central role in functional recovery in TBI [3]. The role of music in cognitive rehabilitation is expanding due to evidence-based research within neuromusicology and music cognition [3]. However, according to Hedge (3) the need for further systematic research studies is imperative to bridging the existing gap between increasing theoretical understanding of usage of music in cognitive rehabilitation and application of the same in a heterogeneous condition, such as TBI.

Traumatic brain injury is defined as damage to the brain as a result of an external force [4]. Depending of the severity of the injury, TBI is classified as mild, moderate, or severe [3]. Motor vehicle accidents and falls are the most prevalent risk factors for TBI together with sports and domestic injuries [1]. Also military personnel in war zones are at risk for head injuries [5]. The majority of brain injury cases are mild TBI which have positive prognoses. A meta-analysis study indicated that most cognitive functions of mTBI recover during the first weeks post injury and return to baseline 1 to 3

months [6]. However, a considerable number of mTBI patients reports disability post injury, and mTBI has been referred to as a "silent epidemic" because impairments in memory, cognition and social interaction are often undetectable [6]. TBI is relatively common in our society, and diagnostics, treatment and rehabilitation of head -injured patients contribute strongly to costs within our health care system [7].

Cognitive deficits most often affect executive functions such as attention, information processing, planning, decision-making, memory and social interaction. Dysfunctional cognitive control have a considerable impact on participation and return to work [6]. According to Vikane et al. [6], well designed studies of the efficacy of interventions in general and for enhanced ability to work in particular, is still lacking for this group of patients.

Brain plasticity as a result of playing an instrument, is a developing field of research within neurologic music therapy [3]. The term neurologic music therapy (NMT) stems from the scientific development of biomedical research in music therapy and neuroscientific research [8]. NMT is defined as the therapeutic application of music to cognitive, affective, sensory, language, and motor dysfunction due to disease or injury to the human nervous system. NMT is based on neuroscientific models of music perception and music production and their influence related to changes in non-musical brain and behavior function [8].

The brain that engages in producing music permits restoration and may regenerate new neural connections [9, 10].

Although NMT has been a research field for more than a decade, we are only begininng to fully understand the potential usage of music-based cognitive rehabilitation therapy within cognitive rehabilitation of patients with TBI [3].

Music is a powerful stimulus with respect to neuronal plasticity, that is, in its capacity to reconfiguration of functional and structural connections in the brain. Brain changes due to music learning and performance have been well documented [11-14].

During the past decade, brain imaging techniques as fMRI, TMS, PET have provided important insight into how the brain's neural networks engage in music-making [1, 10, 12, 15]. A paradigm shift in the field of music therapy has been influenced by the increase in the domain of neuromusicology, music cognition, and neurochemistry of musical processing [16].

In order to develop an evidence-informed systematic treatment strategy, the present study is concerned with an examinaton and analysis of factors which may have an impact of the intervention outcome. In this respect, I sought similarities and divergencies between data obtained from 7 patients who took part in the study described in Vik et al. [1]. These data have not been reported elsewhere and are mainly behavioral data. The results of the present article may further expand our understanding of cognitive and social processes as examined during intervention period and thus promote possible refinement of the method for future application of the intervention. A broader understanding of music-supported therapy in general within cognitive rehabilitation of patients with TBI may also be provided and lead to enhanced clinical outcome.

Intervention

The intervention has been described in detail in Vik et al. [1].Nevertheless, a short summary of the protocol is presented here. 8 weeks piano study for beginners was designed with two lessons per week, 30 minutes each lesson. Instructions to play a minimum of 15 minutes every day at home ensued. All participants were non-musicians, that is, none had received any formal music instruction pre-intervention. The programs were designed through application of a simple book for beginners [17]. The goal during the 8 intervention weeks was to read notation and play with both hands simultanously. The repertoire consisted of 20 pieces of musical material, mostly nursery rhymes. The lessons were designed with frequent repetitions as this is one of the strongest factors for developing new connections in the brain's neural networks [18]. Sessions started with a review of the previous learned material and then ended with a recap of the current session. This method was used in order to develop right and left hand dexterity simultanously, so as to activate both hemispheres during playing. Learning objectives included the implementation of playing within two octaves during intervention period.

3 groups were included in the study, one patient group with cognitive deficits two years post injury (*n=7*). All patients had received previously, a conventional cognitive training program, without any progress. They were either sicklisted, or worked part-time, mean age was 38 years. Two control groups of healthy participants were included, one group received the same music intervention as the patient group (*n=11*), and one control group as a baseline group without music (*n=11*), the mean age 38 years. The patient group were recruited through the hospital's medical records. The control groups were recruited through posters placed at the hospital and the university sites. We did not include a patient control group. There were several reasons for this decision. The patients were in a chronic and stable phase two years post injury. They had received conventional therapy without improvement.

It should be noted that evaluation of piano-performance was not a factor of interest. It is the actual training time that is of critical importance.

Participants signed a consent form and the protocol was approved by the Regional Ethics Committee of Norway /REK-Vest.

Case reports

7 mTBI patients participated in the study and were assessed pre-post-intervention with neuropsychological tests (CVLT 2) and fMRI including resting state. [1]. Additional information was obtained from semi-structured interviews and logs which the participants tabulated during intervention, and became part of the case-reports.

The case-reports include demographic and clinical data, in addition to detailed information obtained from semi-structured interviews. Individual cognitive problems and deficits in social interaction are presented in **Table 2.**

Results from neuropsychological tests, California Verbal Learning Test 2(CVLT), pre-post intervention, are presented with training time in T**able 3**, and CVL results pre-post in individual figures within each case-report.

The present study is restricted to evaluate the patient group and therefore results from the study presented formerly (1) in reference to the two control groups will not be presented and discussed here. However, it may be mentioned that the control group with music achieved enhanced cognitive performance post-intervention. Functional changes in the orbitofrontal cortex were seen only in the patient group. There were no changes in the neuropsycological tests in the control group (no music).

The discussion will raise questions related to the final outcome in reference to clinical data, neuropsychological test results and training time. An evaluation of what factors may predict a positive or negative outcome of the intervention will ensue. Social issues which may have an impact on the results, as well as problems of the individual participant that may have had any kind of influence on the final outcome, are reported. This information was obtained from semi-structured interviews and logs performed every day during the intervention period.

Results:

Table 1 displays demographical data, and clinical data obtained before the intervention.

Table 2 displays 3 groups of post-concussion symptoms following TBI, divided into cognitive problems (two first variables, somatic symptoms (8 next variables) and behavioral problems (last 3 variables). The data are obtained from semi-structured interviews pre- and post intervention.

Table 3 presents results from neuropsychological tests, California Verbal Learning Test 2(CVLT), pre-post intervention,with total individual training time.

Figure 1. ANOVA analyses of all three groups' CVL test.

Table 1.

Clinical data Pre-intervention

Patient	Injury date and date of examination	Prior treatment
42M P1	Commotio. 12.01.11. Examination date 10.03.11	Outpatient rehab.
41F P2	Commotio. 02.12.11 Examination date 05.03.13	Outpatient rehab.
31M P3	Contusions. 05.06.11 Examination date 22.08.11	1 month in TBI Unit
52F P4	Commotio. 11.03.12 Examination date 30.03.12	Outpatient TBI Rehab. 4 weeks
55F P5	Subdural haematoma (concervative management). 09.07.09. Examination date 07.09.09	Outpatient TBI Unit
30M P6	1991 and 2012. 08.07.91. Examination date 01.10.12 Contusions Frontal and temporal lobes, subdural haemotoma evacuated	TBI unit 1 month
19M P7	Epidural haematoma evacuated. 09.12.11 Examination date 08.01.12	TBI unit

Case 1

Male, 42 years.
Family/social status: Single. *Work*: within health-sector. 100 % sick-listed pre-intervention.
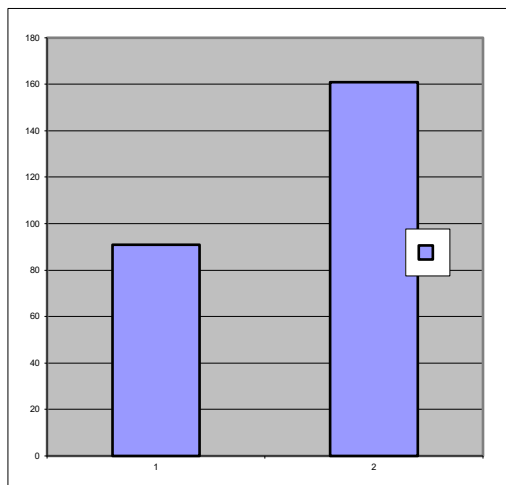Sports-injury: Injured during football training.
Reports:
Cognitive: Problems with concentration, memorization.
Somatic: fatigue, headache, vertigo, sensitive to sound.
Social interaction: Problems with social gatherings due to sensitivity to sound and concentration. Depressed.

CVLT scores pre-post intervention: 91-161.

Training-time piano total 8 weeks: 7 hours 45 minutes.

Subjective report: Chronic fatigue. Did not practice at home due to lack of motivation. Enjoyed piano-lessons. Increased fatigue after piano-lessons.
Motivational factors during intervention: "Enjoyable lessons despite being challenging due to fatigue."
Work post-intervention: 100 % sick-listed.

Case 2

Female, 41 years.
Family/social status: Single. *Work*: specialized nurse. Sick listed 100% from this employment, however, works 80% in a special arranged position in reference to her cognitive and somatic deficits.
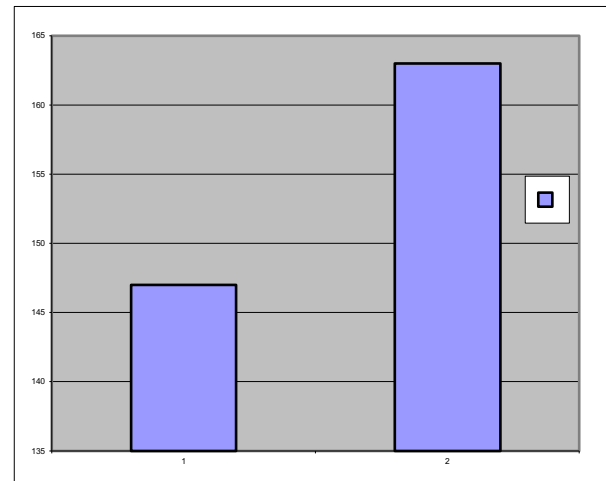*Injured at work.*
Reports:
Cognitive problems with attention and concentration, memorization problems, forgets semantic words.
Somatic: fatigue, sleep-disturbances, headache, sensitive to light and sound, vertigo, and nausea.
Social interaction: Due to sensitivity to sound, she avoided social gatherings

CVLT scores pre-post intervention: 147-163.

Training time piano total 8 weeks: 36 hours 45 minutes.

Subjective report: At the beginning of the intervention, often tired after music-lessons.
A demanding task, however, very enjoyable. Played more than instruction of 15 minutes every day. Increased well-being during intervention, especially after 4 weeks of intervention. Less headache and better sleep patterns.
Motivational factors during intervention: "I was looking forward to each lesson, which I enjoyed very much. I also liked practicing at home. A fantastic method for cognitive improvement."
Work post-intervention: 100% return to work as specialized nurse.

Case 3

Male, 31 years.
Family/social status: Not married but lives with his partner.
Work: planner office. 100% sick-listed for a period after injury, however, at time of intervention back at work, but with cognitive and somatic problems preventing him from satisfactory work-performance.
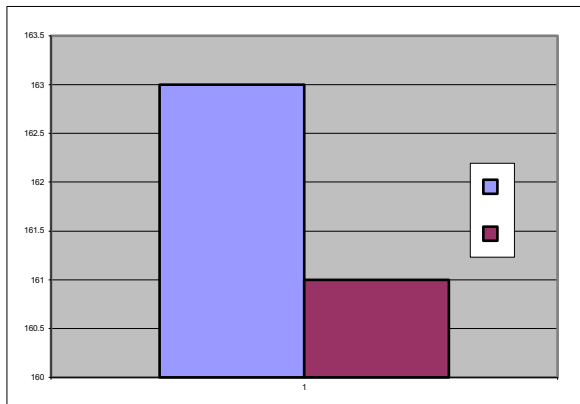*Injured at a social gathering outdoors*. Fell downhill.
Reports:
Cognitive problems with attention, concentration, memorization.
Somatic: Fatigue, vertigo, sensitive to sound and light.
Social interaction: Irritable. Reduced function at work.

CVLT scores pre-post intervention: 163-161.

Training time piano total 8 weeks: 8 hours.

Subjective report: The CVLT test was well known to the participant. He scored high pre-intervention, however, did not concentrate due to fatigue at post testing which resulted in a lower score. He reports lack of time to practice at home, and he often forgot to participate in piano-lessons. He enjoyed the lessons. Reports vertigo during lessons.

    Motivational factors during intervention: "Enjoyable and I believed in the method. However, I forgot to meet up several times. I did not follow practice instructions at home due to fatigue."

    Work post-intervention: 100 %. Report improvement of attention and concentration.

Case 4.

Female, 52 years.
Family/social status: Married. *Work*: Leader of health department. Reduced work post injury.
Injured at home. Fall.
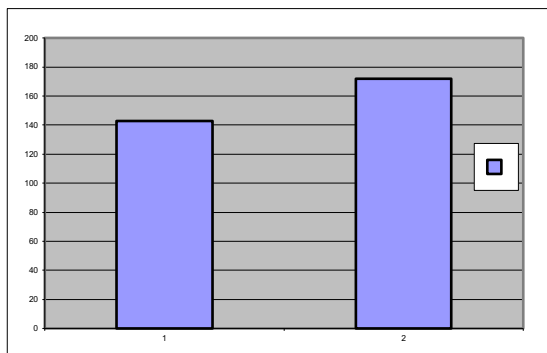*Reports:*
Cognitive problems: Low stamina.
Somatic: Sensitive to sound and light, headache, a burning feeling in her head. Fatigue. Vertigo, problems walking.
Social interaction: Due to sensitive to sound and light, she avoids gatherings.

CVLT scores pre-post intervention: 143-172.

Training time piano total 8 weeks: 28 hours 35 minutes.

Subjective report: Patient reports of increased well-being during the intervention period. Less fatigue and headache. Less "burning-feeling" in head. Better stamina during working days. Noticed improvement half way in the intervention.

    Motivational factors during intervention: Enjoyable, however challenging due to headache and sensitive eyes, fatigue.

    Work post-intervention: Return 100% back to work as before injury.

Case 5.

Female, 55 years.
Family/Social status: Widow. *Work:* Sick-listed from work within health-sector.
Injured: Bike accident.
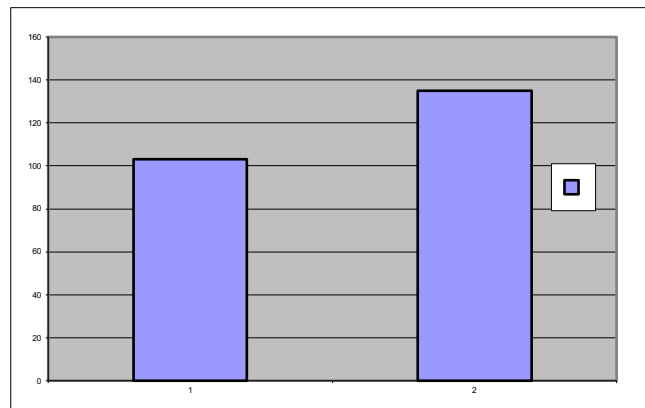*Reports:*
Cognitive: Attention and concentration problems, problems in memorizing. Slow thinking.
Somatic: fatigue, sensitive to sound, vertigo.
Social interaction: Irritable

CVLTscores pre-post intervention: 103-135.

Training time piano total 8 weeks: 23 hours 55 minutes.

Subjective report: A positive experience. An enjoyable activity, which also convinced me that I can still memorize and have the ability to learn after my accident. Improved attention and concentration. Less fatigue. Would like to continue to play the piano. Noticed a positive change halfway in the intervention.

    Motivational factors during intervention: Looked forward to the lessons, discovered I could concentrate and memorize and learn something new. That made me relax and enjoy piano-lessons.

    Work post-intervention: She changed her workplace and started to work 100%.

Case 6.

Male 30.
Family/Social status: Single.
Work: 100% sick-listed.
Injured: He has had two accidents: the first accident when he was 7 years old and fell down a hillside, 14 meters.
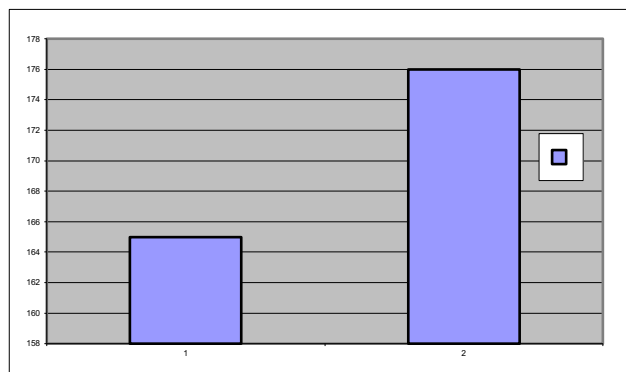Second injury, traffic accident when he was 28.
Reports:
Cognitive: Cognitive: slow thinking, concentration deficits.
Somatic: Headache, vertigo, gait problems.
Social interaction: Cannot read other people's intention and therefore feel "outside" together with other people.

CVLT scores pre-post intervention: 165-176.

Training time piano total 8 weeks: 21 hours 20 minutes

Subjective report: Enjoyed piano-lessons. Better concentration so as he could think of a subject for a longer time and reflect. Felt his brain was able to a more "clear" thinking. Noticed an improvement half way in the intervention.

   Motivational factors during intervention: Believed in the method, enjoyed the lessons.

   Work post-intervention: Due to his vertigo, he changed his profession and works 100%.

Case 7.

Male 19 years.
Family/Social status: Single
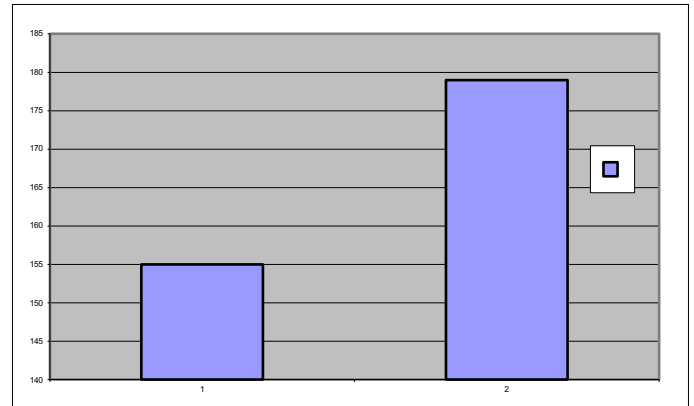*Work:* Student
Injured: Traffic accident.
Reports:
Cognitive: Problems with attention and concentration.
Somatic: Headache, fatigue, sleep disturbances. Problem with falling asleep during school-lessons.
Social interaction: No report.

CVLT scores pre-post intervention: 155-179.

Training time piano total 8 weeks: 15 hours 20 minutes

Subjective report: Enjoyed very much piano-lessons, happy to learn to play the piano. "The whole process was enjoyable and I learned a lot. My problems with concentration have been reduced, I have improved my attention and can read and write for longer period of time. I do not fell asleep during school-hours any more." Noticed improvement after 4-5 weeks of intervention.

   Motivational factors during intervention: Enjoyed learning to play the piano, enjoyed piano-lessons.

   Work post-intervention: He took his final school exams two months post intervention with high marks. Present: University student.

Table 2

Variables	P1	P2	P3	P4	P5	P6	P7
Concentration pre-interv.	x	x	x	x	x	x	x
Post-interv.							
Memorization pre-interv.	x	x	x	x		x	x
Post interv.							
Headache pre-interv.	x	x	x	x	x	x	x
Post- interv.	x						
Vertigo pre-intervention		x		x	x	x	
Post-interv.							
Balance pre-interv.				x		x	
Post-interv.						x	
Nausea pre-interv.				x			
Post-interv.							
Fatigue pre-interv.	x	x	x	x	x	x	x
Post-interv.	x						
Sleep disorders pre-interv.	x	x	x	x	x	x	x
Post-interv.	x						
Double vision pre-interv.				x			
Post-interv.							
Blurred vision pre-interv.				x			
Post-interv.							
Irritable mood pre-interv.	x	x	x	x	x	x	x
Post-interv.	x						
Depression pre-interv.	x	x	x	x	x	x	x
Post-interv.	x					x	
Response inhibition pre-intervention	x	x	x	x	x	x	
Post-interv.	x					x	

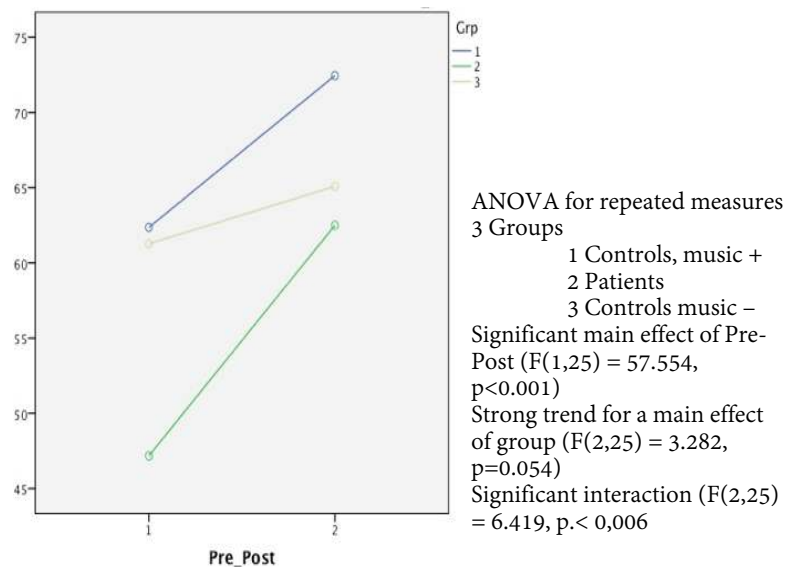**Table 2** displays 3 groups of post-concussion symptoms following TBI, divided into cognitive problems (two first variables, somatic symptoms (8 next variables) and behavioural problems (last 3 variables). The data are obtained from semi-structured interviews pre- and post intervention.

Table 3.

Results from neuropsychological tests, California Verbal Learning Test 2(CVLT), pre-post intervention, and total training time during 8 weeks of music-intervention.

Patient	CVLT 2 Pre-interv.	CVLT2 Post-interv.	Total training-time.
P 1 42M	17	60	7h.45 min.
P 2 41F	58	65	36h.45min
P 3 31M	60	60	8h.
P 4 52F	54	70	28h.35min.
P 5 55F	32	48	23h.55min.
P 6 30M	62	74	21h.20min.
P 7 19M	60	75	15h.20min.

Fig.1. ANOVA repeated measures for all 3 groups. Patient group (no.2 green line) show a normalization of cognitive performance up to the level of control group. Control group with music (no 1 blue line) has a significant increase of cognitive performance. Control group without music (no 3 yellow line) has a slight increase that is considered a usual increase of 10 % second testing.

ANOVA for repeated measures 3 Groups
1 Controls, music +
2 Patients
3 Controls music –
Significant main effect of Pre-Post $(F(1,25) = 57.554, p<0.001)$
Strong trend for a main effect of group $(F(2,25) = 3.282, p=0.054)$
Significant interaction $(F(2,25) = 6.419, p.< 0,006)$

Results

The present study is restricted to an examination of the patient group. Data from the control group of healthy participants are not included.

The above Figure 1 shows results from the CVLT test between the three groups. These results clearly reflect the enhancement of cognitive control in both music groups. However, we did not collect behavioral data from the healthy control group with music as we were interested in clinical and behavioral data from the patient group only. Our aim was to detect a positive change in their PCS problems as described within the single cases that followed.

As displayed in Figure 1, both music groups had a significant increase in cognitive performance. The patient group achieved scores up to the level of the two control groups. In other words, we see a normalization of cognitive performance. Individual differences between the patients were presented in the following cases.

Data from fMRI are described in Vik et al. [1] and data from resting state fMRI are also described [19]. The changes in orbitofrontal networks (OFC) were concordantly seen both in a simple task fMRI and also in resting-state fMRI.

As the present study applies a qualitative methodology with an analyzing of data which has not previously been reported, the study will be restricted to an exploration of these data.

All patients achieved enhanced cognitive performance post-intervention in accordance with the neuropsychological test-results shown in Table 2. However, only 6 out of 7 patients returned to work. Behavioral data in reference to clinical data and semi-structured interviews, which may have an impact on the final results, will be further discussed in the following paragraphs.

Similarities

According to Table 2 most PCS-symptoms were common between the 7 participants. This Table displays 3 groups of PCS following TBI, divided into cognitive problems (two first variables, somatic symptoms (8 next variables) and behavioral problems (last 3 variables). Common PCS are described in table 2 and more in detail within the single case reports.

Divergencies

P1 (see Table 2), did not return to work and reported no increase of wellbeing on factors related to depression and response inhibition. P6 returned to work, but reported no change in difficulties with social interaction. Training time is a variable of interest. There were extensive individual differences. Mean training time was 3 hours per week. P7, (Table 3), played the minimum time per week during 8 weeks, namely 15 hours, 20min. This patient was present at all lessons. Participating in all lessons is a variable because neuroplasticity in the brain's neural networks is dependent on

repetition which supports the firing of new neural connections [20].

Discussion

All participants in the patient group had problems with concentration and memorization as described in the single case-reports. In addition, they reported PCS which includes complaints of somatic and behavioral problems. These may have had an impact on the recovery process. It was therefore of interest to investigate more in-depth, the similarities and divergencies between participants in the patient group only, which enabled a look at factors that could predict a positive or negative outcome of the intervention.

Although all patients in the present study are diagnosed mTBI, the consequences of the injury may have affected each patient differently. Post-concussion syndrome (PCS) can be divided into somatic, cognitive and emotional complaints [20], and as seen in Table 3, the patients reported PCS problems within all categories. The patients display common PCS, however, there are differences in reference to clinical and self-reports that may predict a negative outcome of intervention.

Two patients, P1 and P6, differed from the group as seen in Table 2. P1 achieved significant enhancement of CVLT results but did not return to work. Clinical data revealed a previous depression condition before the accident. P1 did not attend all piano-lessons due to fatigue. P6 had significant positive results of CVLT post intervention, returned to work, but did not report improvement in social behavior. P6 reported to have problems with social interaction before the accident. P6 had experienced TBI twice, the first injury was probably moderate or severe. A confounding variable to give an exact level of TBI may be an intubation for a week during first injury. The first accident may have influenced his social behavior being a persistent problem before the second accident. To emphasize the divergencies, of P1 and P6 from the rest of the group, these two patients had clinical factors pre-intervention that could have an impact on the outcome of the intervention.

Factors that may predict a positive outcome of the intervention is first of all the strong effect of neural activation during playing which may reorganize the brain's neural network and link up broken connections [10]. Secondly, a motivational factor of playing the piano may also open up for a positive outcome. The nature of learning to play the piano is goal-oriented and for most people, can be a pleasent experience [21] They looked forward to learning to play as reported in the case-reports. The enjoyment of playing the piano may have a possible dopamine-releasing effect [22], thereby increasing the neuro-transmitter effect between the neural networks affecting OFC and executive functions, followed by the normalization of emotional reactions that are fundamental in social interactions. Also the fact that the

participants registered improvement of their deficits after approximately 4 weeks was encouraging (see P6 for details). However, clinical issues that has been registered before the accident may play an important factor in evaluating and predicting the patients' potential positive results of an intervention. It is well-known that a pre-injury depression may predict a poor rehabilitation outcome for patients with TBI [23]. A multidisciplinary approach may thus be the avenue to a successful result for patients with a complex clinical history.

Conclusion

The present case-reports investigated factors that could predict a positive or negative outcome of the music-supported intervention (1). The aim of this study was to refine a systematic treatment strategy of music training to improve both cogntive and behavioural domains of functioning in patients following mTBI. I emphasized elements which may play a key role in designing an effective music-supported intervention for patients with mTBI. Apart from the fact that playing an instrument is a strong stimulus for neuroplastic changes in the brain and a possible means for re-connecting broken circuits, I would suggest that a positive factor of motivation and thereby dopamine-release, can activate OFC toward an increase of cognitive performance and behavioral interaction. Negative risk-factors may be multiple head injuries and pre-injury depression as described in the literature and replicated in this study. I would argue that a multidisciplinary outpatient program should be added to the music-supported intervention to catch patients that otherwise would be drop-outs or influence those prone to negative outcomes. Implementation of clinicians in the intervention protocol may strengthen the method. The results of the present article may expand understanding of cognitive and social processes during the intervention period and thus promote possible refinement of the method for future application. A broader understanding of music-supported therapy in general within cognitive rehabilitation of patients with mTBI may thereby be provided and lead to improved clinical outcomes.

References

1. Vik, B., Skeie, G.O., Vikane, E., Specht, K., *Effects of Music Production on Cortical Plasticity within Cognitive Rehabilitation of patients with mild Traumatic Brain Injury*. Brain Injury, 2018. **32**(2).

2. Tagliaferri F, C.C., Korsic M, Servadei F, Kraus J., *A systematic review of brain injury in Europe.* Acta Neurchir (Wien), 2006. **148**: p. 255-268.

3. Hegde, S., *Music-based cognitive remediation therapy for patients with traumatic brain injury.* 2014, http://journalfrontiersin.org/article/10.3389/fneur.2014.00034/full.

4. Sigurdardottir, S., *A prospective study of Traumatic Brain Injury*, in *Department of Psychology. Faculty of Social Sciences.* 2010, University of Oslo: Oslo.

5. Warden DL, F.L.M., Shupenko, L., Fargus J, Riedy G, Erickson M.E., Jaffee M.S., Moore D.F., *Case report of a soldier with primary blast brain injury.* NoroImage, 2009(47): p. 152-53.

6. Vikane, E., *Effect of multidisciplinary outpatient treatment after mild traumatic brain injury. A randomised controlled trial and prognostic factor for return to work.* 2016, University of Bergen, Norway: University of Bergen, Norway.

7. Heskestad, B., *Minimal, mild and moderate traumatic brain injury in Rogaland; guidline compliance and early intervention*, in *Faculty of Medicine.* 2017, Universty of Oslo, Norway: Oslo.

8. Thaut, M.H., Hoemberg, V., *Handbook of Neurologic Music Therapy.* 2016, Oxford: Oxford University Press.

9. Goldberg, E., *The executive brain: frontal lobes and the civilized brain.* 2009, New York: Oxford University Press.

10. Särkamö, T., et al., *Structural changes induced by daily music listening in the recovering brain after middle cerebral artery stroke; a voxel-based morphometry study.* Frontiers in Human Neuroscience, 2014.

11. Jäncke, L., *Music drives brain plasticity.* Floor Reports Biology, 2009.

12. Schlaug, G., *Music,musicians, and brain plasticity.* , in *The Oxford Handbook of Music Psychology.*S. Hallam, I. Cross, and M.H. Thaut, Editors. 2009, Oxford University Press: New York. p. 197-207.

13. Pantev, C., *Musical Training and Induced Cortical Plasticity*, in *The Neurosciences and Music III*, S.K. Dalla Bella, N., Overy, K., Pantev, C., Snyder, J.s., Tervaniemi, M., Tillmann, B., Schlaug, G., Editor. 2009, Annals of the New York Academy of Sciences: New York.

14. Thaut, M.H., *Therapy in Cognitive Rehabilitation.* Music Perception, 2010. **27**(4): p. 281-285.

15. Altenmüller, E., *Music as a driver for brain plasticity.* Clinical Neurophysiology, 2016. **127**: p. e22-e22.

16. Thaut, M.H., *Music Therapy and Medicine: From Social Science to Neuroscience.* 2005, New York: Routledge; Taylor and Francis Group.

17. Agnestig, C.-B., *Vi spiller Piano.* 1958, Stockholm: AB Carl Gehrmans Musikforlag.

18. Hebb, D., *Distinctive features of learning in the higher animal*, in *Brain Mechanisms and Learning*, J.F. Delafresnaye, Editor. 1961, Oxford University Press: London.

19. Vik B, S.G.O., Specht K., *Neuroplastic Effects in Patients with Traumatic Brain Injury After MusicSupported Therapy.* Frontiers in Human Neuroscience, 2019. **13**(177).

20. Potter S, L.E., Wade D, Fleminger S., *The Rivermead Post Concussion Symptoms Questionnaire: a confirmatory factor analysis.* JNeurol 2006; 253:1603-14., 2006.

21. Lehrer, J., *The Neuroscience of Music*, S. 01.19.11., Editor. 2011, www.wired.com/2011/01/the-neuroscience-of-music.

22. Brodal H.P., O.B., Specht K., *Listening to Rhythmic Music Reduces connectivity within the Basal Ganglia and the Reward System.* Frontiers in Human Neuroscience, 2017.

23. Finch, E., Copley, A., Cornwell, P., Kelly, C., *Systematic Review of Behavioural Interventions Targeting Social Communication Difficulties After Traumatic Brain Injury.* Archives of Physical Medicine and Rehabilitation, 2016. **97**: p. 1352-65.

Biographical Statements

Berit Marie Dykesteen Vik, Department of Biological and Medical Psychology, University of Bergen, Norway. Freelance PhD researcher.