"I started to feel again."

An Individually Guided Dance Rehabilitation Intervention May Enhance Mood, Abstract Reasoning, and Quality of Life in Traumatic Brain Injury: A Pilot Study

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Abstract

Objective: Traumatic brain injury (TBI) is a major public health issue leading to long-term cognitive, emotional, and physical impairments. New, effective, multimodal and multidisciplinary rehabilitation practices are needed. Dance is a multimodal activity that engages several brain regions simultaneously and, therefore, might be ideal for enhancing complex functions. Dance also combines physical exercise and the use of music, both of which positively affect healthy and neuropathological populations. The aim of the research project was to develop a multidisciplinary dance rehabilitation method and to evaluate its feasibility and effectiveness in chronic severe TBI. The current study investigates the intervention's effects on cognition, depressive mood, and health-related quality of life. The feasibility of the intervention is also discussed.

Methods: The current study had 11 participants with severe TBI; four women and seven men, 19 – 45 years old, with an average time of 7.6 years from the acquisition of the injury. A two-group crossover design with random allocation was used. The intervention (three months, two weekly sessions) was carried out together by a dance instructor and a physiotherapist. Neuropsychological assessments were conducted at the beginning of the study (t0), and twice after that every three months (t3 and t6). Performance before and after the intervention in general cognition, frontal lobe functions, abstract reasoning, visuo-spatial reasoning, working memory, mood, health-related quality of life, and executive functions were compared with paired sample t-tests. Time and group interactions were studied by repeated measures analyses of variance.

Results: Abstract reasoning, health-related quality of life, and most saliently, mood improved significantly during the intervention. Qualitative findings also indicated enhanced mood. One of the participants described being reconnected to emotions for the first time a after the acquisition of the TBI and several other participants expressed positive feelings and experiences during the intervention.

Conclusions: The current study suggests that dance rehabilitation may improve mood, abstract reasoning, and quality of life in the chronic state of severe TBI. These results are tentative and more research with larger samples is needed to verify the findings.

Tiivistelmä

Tutkimuksen tarkoitus: Traumaattinen aivovamma on merkittävä kansanterveysongelma, jolla on pitkäaikaisia kognitiivisia, emotionaalisia ja fyysisiä seurauksia. Aivovammakuntoutukseen tarvitaan uusia, vaikuttavia, multimodaalisia ja monialaisia kuntoutuskäytäntöjä. Tanssi on multimodaalista ja aktivoi useita aivoalueita yhtä aikaa ja saattaa siten myös kuntouttaa monimutkaisia toimintoja. Tanssi myös yhdistää liikunnan ja musiikin, joilla kummallakin on positiivisia vaikutuksia sekä terveisiin että neuropatologisiin kohderyhmiin. Tutkimushankkeen tavoite oli kehittää monialainen tanssikuntoutusmenetelmä ja arvioida sen käytettävyyttä ja vaikuttavuutta vakavan aivovamman kroonisessa vaiheessa. Tässä tutkimuksessa tarkastellaan intervention vaikutuksia kognitioon, masentuneeseen mielialaan ja terveyteen liittyvään elämänlaatuun sekä arvioidaan menetelmän käytettävyyttä.

Menetelmät: Tutkimukseen osallistui 11 vakavan traumaattisen aivovamman saanutta 19 – 45 -vuotiasta henkilöä, joista neljä oli naisia ja seitsemän miehiä. Tutkimuksen alkaessa vammautumisesta oli kulunut keskimäärin 7,6 vuotta. Tutkimuksessa käytettiin crossover-asetelmaa, jossa osallistujat satunnaistettiin kahteen ryhmään. Interventio kesti kolme kuukautta, sisälsi kaksi viikottaista tanssituntia ja sen toteuttivat yhdessä tanssinopettaja ja fysioterapeutti. Neuropsykologiset tutkimukset tehtiin tutkimuksen alussa (t0) ja kahdesti sen jälkeen kolmen kuukauden välein (t3 ja t6). Suoriutumista yleisen kognition, otsalohkotoimintojen, abstraktin päättelyn, visuospatiaalisen päättelyn ja työmuistin tehtävissä sekä itsearvioitua mielialaa, terveyteen liittyvää elämänlaatua ja toiminnanohjausta ennen interventiota ja sen jälkeen tutkittiin parittaisilla t-testeillä. Ryhmien eroavaisuuksia tutkittiin toistettujen mittausten varianssianalyyseillä.

Tulokset: Abstrakti päättelykyky, terveyteen liittyvä elämänlaatu sekä merkittävimmin mieliala paranivat intervention aikana. Laadulliset löydökset kertoivat myös mielialan kohentumisesta. Eräs osallistujista kertoi saaneensa yhteyden tunteisiinsa ensimmäistä kertaa vammautumisen jälkeen ja useat muut osallistujat kuvasivat positiivisia tuntemuksia ja kokemuksia intervention aikana.

Johtopäätökset: Tanssikuntoutus näyttää vaikuttavan positiivisesti mielialaan, abstraktiin päättelykykyyn sekä elämänlaatuun vakavan aivovamman kroonisessa vaiheessa. Tulokset ovat alustavia ja tarvitaan lisää tutkimuksia suuremmilla otoksilla vahvistamaan löydökset.

Contents

Abbreviations

ANOVA	Analysis of variance
BDI-II	Beck depression index II
BDNF	Brain-derived neurotrophic factor
BRIEF	Behavior rating inventory of executive function
CT	Cat scan
DAI	Diffuse axonal injury
DMT	Dance and movement therapy
EE	Enriched environment
EEG	Electroencephalography
FAB	Frontal assessment battery
FIM	Functional independence measure
GCS	Glasgow coma scale
GOSE	Glasgow outcome scale extended
LOC	Loss of consciousness
MNS	Mirror neuron system
MOCA	Montreal cognitive assessment scale
MRI	Magnetic resonance imaging
QOLIBRI	Quality of life after brain injury scale
RCT	Randomly controlled trial
PD	Parkinson’s disease
PTA	Post-traumatic amnesia
SART	Sustained attention to response test
TBI	Traumatic brain injury

1 Introduction

Traumatic brain injury (TBI) is a major public health issue changing, touching, and ending a multitude of lives every day. Over 50 million people suffer a TBI each year (Maas et al., 2017), 10 million of which are serious enough to result in death or hospitalization (Langlois, Rutland-Brown & Wald, 2006). According to some estimates, half of the world's population will have one or more TBIs during their lifetime (Maas et al., 2017). In Finland, over 5000 people acquire TBI annually and the incidence of hospitalized TBI is 101/100 000 (Koskinen & Alaranta, 2008). In the United States, the incidence of TBI goes up to 200/100 000 (Chua, Ng, Yap & Bok, 2007) and in both countries, the incidence is probably even higher due to underreporting and misdiagnosing mild injuries. TBI is the leading cause of mortality in young adults (Maas et al., 2017) and a significant cause of disability across all ages.

Advances in legislation, prevention, first-aid, and neurosurgery have helped more and more TBI patients survive previously fatal injuries (Chua et al., 2007; Ghajar, 2000). In Finland, approximately 20 % of severe injuries lead to death and 1 – 3 % to a vegetative state, as 20 – 25 % of severely injured patients make a good recovery, up to 21 % of them are permanently severely disabled, and 5 – 26 % moderately disabled (Brain injuries: Current Care Guidelines, 2017). As the chances of survival and number of people with long-term consequences of TBI have increased, effective rehabilitation plays a crucial role in improving the lives of TBI survivors - or vice versa, ineffective rehabilitation may hinder more and more people from achieving the best possible outcomes post-injury.

Due to the complexity of the brain and various brain injury mechanisms, the symptoms of TBI can be any combination of neurological, physical, cognitive, behavioural, social, or emotional deficits (Brain injuries: Current Care Guidelines, 2017; Chua et al., 2007; Langlois et al., 2006; Maas et al., 2017). Severe and extremely severe TBI more often cause dysfunction in multiple domains at the same time than milder injuries. The goal of TBI rehabilitation is to help the person regain as much of previous functioning as possible (Khan, Baguley & Cameron, 2003), and according to the NIH consensus panel, to address the full complexity of TBI, various rehabilitation strategies are needed (Ragnarsson et al., 1999). TBI rehabilitation should be delivered by a specialized multidisciplinary team in close liaison with the patient and their family (Togher et al., 2014).

The incidence and prevalence of TBI globally, along with the increased survival rates of those with severe TBI, and symptom heterogeneity call for new and effective, multimodal and multidisciplinary rehabilitation practices (Maas et al., 2017). Since some degree of contact with medical and rehabilitation services will often be required for the rest of the person's life, (Khan et al., 2003) continuity of care is vital. Thus, an important feature of rehabilitation is to be engaging and motivating in order to foster adherence and long-term commitment.

Dance rehabilitation is a new multimodal and multidisciplinary method for the chronic state of severe TBI. Dhami, Moreno, and DeSouza (2015) propose dance as a potential method in neurorehabilitation to aid both physical and cognitive impairments. Dance is a multimodal activity that combines physical exercise and the use of music, both of which have positive effects on both healthy and neurological populations. There is some evidence for the efficacy of using dance in the rehabilitation of Parkinson's disease (PD) (Foster, Golden, Duncan & Earhart, 2013, Hackney & Earhart, 2009; Hackney & Earhart, 2010; Heiberger et al., 2011), and dementia (Hokkanen et al., 2003; Hokkanen et al., 2008), but no evidence for the use of dance in TBI rehabilitation.

The aim of the current study is to assess the effects of a multimodal, multidisciplinary, individually guided dance rehabilitation intervention on cognitive and psychological functioning in the chronic state of extremely severe TBI. The feasibility of the intervention is also discussed. Based on the study, the purpose is to further develop the intervention and to conduct a wider study on the clinical effectiveness of the intervention.

1.1 Traumatic brain injury (TBI)

TBI is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force (Menon, Schwab, Wright & Maas, 2010). Alteration in brain function refers to loss or decrease in the level of consciousness, memory loss of events immediately before or after the injury, neurological deficits, and alterations of mental state at the time of the injury. Other evidence could be detected visually, neuroradiologically, or in laboratory settings (Menon et al., 2010).

Different types of TBI are classified by the severity of the trauma (table 1), injury mechanism or the nature of the tissue damage (Brain injuries: Current Care Guidelines, 2017). Severity is evaluated by the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974; Teasdale & Jennett, 1976) that estimates the level of consciousness based on eye opening, motor and verbal functions, and length of post-traumatic amnesia (PTA) (Brain injuries: Current Care Guidelines, 2017).

Table 1

Defining the acute severity of TBI (modified from Brain injuries: Current Care Guidelines, 2017).

Severity	**GCS**	**PTA**	**LOC**	**Brain imaging findings**
Mild	**13-15**	< 24 h	< 30 min	a minor intracranial finding in a CT or MRI
Moderate	9-12	1-7 d	30 min - 24 h	**an intracranial finding in a CT or MRI**
Severe	3-8	> 7 d	> 24 h	**an intracranial finding in a CT or MRI**

The bolded section on each row is the mandatory criterion, on top of which at least one of the other three criteria must be met for the TBI to be defined as mild, moderate, or severe. The Glasgow Coma Scale, GCS score is defined immediately after the acquisition of the injury. Post-traumatic amnesia, PTA is defined to last until the moment when the patient starts having continuous memories. Loss of consciousness, LOC cannot be stated without an eye-witness.

The criteria for severe TBI are an intracranial brain imaging finding caused by the TBI, and at least one of the following: 1) a GCS score of eight or less within 30 minutes of the injury or at some point after the injury, 2) loss of consciousness of over 24 hours, and 3) PTA of over seven days (Brain injuries: Current Care Guidelines, 2017).

1.1.1 Sequelae

Instead of a single event, TBI can be viewed as a collection of different and often chronic disease processes with varying clinical manifestations and long-term outcomes (Maas et al., 2017; Masel & DeWitt, 2010). TBI involves multiple interrelated components that have primary and secondary effects on individual neurons, neuron networks, and cognition (Ragnarsson et al., 1999), and it is often accompanied by vast physical deficits such as fractures, spinal cord injuries and peripheral nerve injuries. Typical long-lasting symptoms of TBI are dysfunctions in executive functions and behavior, fatigue, reduced stress resistance, and difficulties in concentration and memory, none of which are specific solely to brain injuries (Brain injuries: Current Care Guidelines, 2017).

The cognitive, psychological, behavioural and emotional deficits pose a heavy psychosocial and economic burden (Chua et al., 2007; Langlois et al., 2006). TBI poses a high risk for persistent cognitive impairment (Schretlen & Shapiro, 2003), depression (Bombardier et al., 2010; Dikmen, Bombardier, Machamer, Fann & Temkin, 2004), dementia (Gardner et al., 2014), stroke (Burke et al., 2013), PD (Gardner et al., 2015; Lee, Bordelon, Bronstein & Ritz, 2012) and epilepsy (Lowenstein, 2009) and severe TBI has a high mortality rate (Maas et al., 2017). TBI has massive consequences for the individuals, their families and society.

1.1.2 Outcomes

Late outcomes, and factors determining the late outcomes, of TBI are reported only by a few studies. Often, the consequences of TBI remain in original or altered forms across the lifespan, with new challenges likely to occur due to new situations and complications and the aging process (Ragnarsson et al., 1999). A high proportion of TBI survivors continue to suffer from disability 5 – 7 years after TBI, even when the injury has been first classified as mild, and the overall rate of disability remains similar to that observed at one year post TBI (Whitnall, McMillan, Murray & Teasdale, 2006). The majority of survivors may reach a good functional outcome 10 years after TBI measured by the Glasgow Outcome Scale Extended (GOSE) (Ponsford, Draper & Schönberger, 2008), and despite persisting difficulties 10 years after severe TBI, most survivors experience generally high satisfaction in life (Koskinen, 1998).

TBI severity measured by length of PTA is a significant predictor of functional outcome (Brown et al., 2005; Ponsford et al., 2008) and it accounts for a great proportion of variance in psychosocial outcomes (Tate et al., 2005; see Ponsford et al., 2008). TBI severity assessed within 24 hours of injury is related to neuropsychological and functional outcomes 3 – 5 years after the injury (Dikmen, Machamer, Powell & Temkin, 2003), and initial GCS scores in the range of severe TBI are linearly related to poor outcomes (Ghajar, 2000). Older age is related to worse outcomes (Brain injuries: Current Care Guidelines, 2017; Hukkelhoven et al., 2003).

There is a link between adverse self-reported emotional well-being and moderate or severe disability both when disability persists from the acute phase and when it develops in the long-term phase of TBI (Whitnall et al., 2006). Since TBI is often followed by depression, many survivors are at risk of overestimating their dysfunction. Anxiety in TBI survivors 10 years after the injury is also linked to poorer global outcomes (Ponsford et al., 2008).

1.1.3 Rehabilitation

TBI rehabilitation is a continuum from the acute (0 – 3 months post-injury) into the post-acute (3 – 12 months post-injury), and chronic (over 12 months post-injury) phases (Frasca, Tomaszczyk, Bradford, McFadyen & Green, 2013). Thus, the acute phase starts immediately after the acquisition of the TBI and the need for chronic rehabilitation may continue for the rest of the affected person's life. Post-acute and chronic rehabilitation may include: home-based, outpatient, community re-entry, comprehensive day treatment, residential community re-integration, and neurobehavioral programs (Ragnarsson et al., 1999).

Rehabilitation protocols may focus on restitutional, compensatory or adaptive mechanisms, or combine them (Maas et al., 2017). Restitutional strategies focus on relearning specific pre-existing behaviors through repetition and rehearsal, whereas compensatory training aims to use intact abilities to substitute for impaired functions. Adaptive rehabilitation refers to mechanisms aiming for psychosocial adjustment to residual impairment by cognitive restructuring.

Evidence supports the use of structured, systematic, goal-directed and individualized interventions that involve learning, practice and social contact in a personally relevant context (Ragnarsson et al., 1999). In their brief review of TBI rehabilitation, Chua and colleagues (2007) conclude that promising approaches include the following: multidisciplinary community-based rehabilitation; targeted therapies specific to sustained, selective and divided attention; task-specific training of attention; memory retraining focused on prospective memory and errorless learning. In a review of evidence-based cognitive rehabilitation (Cicerone et al., 2011), direct attention training and metacognitive training were found to be beneficial in the development of self-directed strategies. The use of these strategies was recommended for the remediation of mild memory deficits. Direct attention training and metacognitive training were also found to enhance generalization to real-world tasks during post-acute rehabilitation. Interventions that focus on self-monitoring and self-regulation are recommended in rehabilitation of deficits in executive functions and other higher cognitive functions, including self-awareness (Cicerone et al., 2011).

The general consensus is that most TBI patients improve during the first few years after the injury, after which the progress plateaus. Perhaps for this reason, research on TBI rehabilitation is prominently focused on acute and post-acute phases, whereas less research on rehabilitation in the chronic phase has been conducted. Despite of this imbalance, there is accumulating evidence for the effectiveness of cognitive rehabilitation during the post-acute and chronic phases of TBI (for review see Cicerone et al., 2011). Two RCTs support the effectiveness of holistic neuropsychological rehabilitation for TBI (Cicerone et al., 2008; Vanderploeg et al., 2008). These comprehensive interventions may improve post-acute participation and quality of life after moderate or severe TBI (for review see Cicerone et al., 2011). In addition, interventions tapping into psychological factors even late after injury, are potentially beneficial (Fordyce, Roueche & Prigatano, 1983).

There are individual differences in how or whether rehabilitation affects the rehabilitees. Because of unawareness of symptoms, some patients benefit from rehabilitation only at a later stage of recovery, and some do not benefit from conventional therapies at all (Brain injuries: Current Care Guidelines, 2017). Three different recovery paths have been recognized (Robertson & Murre, 1999). Some patients recover spontaneously, and no structured rehabilitation is needed, while some show little or no progress even after long periods of time and attempts at rehabilitation. The third path is recovery dependent on rehabilitation attempts. For all patients, functional outcomes may improve regardless of rehabilitation efforts through adaptation (Brain injuries: Current Care Guidelines, 2017). Deficits in executive functions may moderate responses to treatment, but further research is needed to clarify how patient characteristics influence treatment effectiveness (Cicerone et al., 2011).

Evidence of patient outcomes after TBI rehabilitation is scarce due to challenges in using randomized controlled trials (RCT) to study TBI (for review see Chua et al., 2007; Maas et al., 2017). Small patient numbers and heterogeneity of symptoms, injury types, interventions and outcomes make the results ambiguous, which doesn’t necessarily mean that the interventions do not benefit the patients, but that group level effects are difficult to observe (Chua et al., 2007). A host of other factors complicate the use of RCTs in TBI rehabilitation research. One is the expanding body of evidence in favor of multidisciplinary approaches in other types of neurorehabilitation, which additionally makes it ethically and practically difficult to randomize TBI patients into treatment and control groups, and lack of resources hinders assignment of different systems of care to different groups (Chua et al., 2007; Maas et al., 2017). TBI patients may also lack the mental capacity to give their fully informed consent for participation or have problems in treatment compliance (Chua et al., 2007).

TBI is the starting point of an ongoing and often lifelong process that has wide impacts within the body and may cause and accelerate other diseases, and thus it should be managed as a chronic disease (Masel & DeWitt, 2010). The chronic nature of TBI calls for discovering and researching therapies that may influence the disease process even years after the initial event. Current guidelines promote a one-size-fits-all approach without addressing the heterogeneity of TBI (Maas et al., 2017), although the remarkable individuality of TBI should be taken into consideration in all treatment and rehabilitation (Brain injuries: Current Care Guidelines, 2017).

1.2 The potential of dance in TBI rehabilitation

The limbs move, but it is the brain that dances - if we are to believe the Dutch choreographer and researcher Ivar Haageerndoorn (2003). The potential of dance in TBI rehabilitation is still unknown, but dance is the target of a growing neuroscientific interest. Despite the increasing interest and awareness of the potential benefits of dance, in a meta-analysis of the neurological impacts of dance in elderly people Kshtriya, Barnstaple, Rabinovich, and DeSouza (2015) mentioned only one study using dance in brain injury or stroke rehabilitation. In this study, Berrol, Ooi and Katz (1997) used a 5-month dance and movement therapy (DMT) intervention for elderly people as a part of their normal treatment curriculum. The treatment groups participated in a 45-minute long DMT session twice a week. The control group didn’t participate in a DMT intervention but continued their usual treatment regime. After the intervention, statistically significant differences between the treatment and control groups favoring the treatment group were found in cognitive performance (decision making, ability to make oneself understood, and short-term memory), motor ability and social interaction. Their qualitative analysis also pointed towards improved mood in the treatment group (Berrol et al., 1997).

A recent case study found that a 20-week individualized goal-directed dance rehabilitation intervention had positive effects on multiple areas of motor, cognitive and functional measures in the chronic state of severe TBI 6,5 years after the injury (Kullberg-Turtiainen, Vuorela, Huttula, Turtiainen & Koskinen, 2019). The rehabilitee was a former semi-professional dancer and the intervention was incorporated in his normal rehabilitation curriculum. The 60-minute sessions were guided by a professional dance teacher and a physiotherapist provided manual instruction facilitating correct execution of movement and body positioning. Short movement sequences were learned, repeated, recited and combined, and the selected movements kinematically resembled movements that the subject had performed before the accident. The intervention's highly motivating goal was to perform in a dance competition. Observational results indicated improvements in balance, posture, mobility and endurance, increased sense of security, independence and self-control, improved self-awareness, self-reflection, alertness level, attention and coping as well as episodic and working memory. The subject's functional independence measure (FIM) score increased by 29 % compared to the measurement before the intervention and stayed at the new elevated level for 2 years. The positive changes were apparent mostly in motor components of the FIM as the cognitive components showed only slight improvement. EEG studies described elsewhere (Fingelkurts & Fingelkurts, 2017) showed results that were correlated with the FIM results.

In a systematic review of the evidence for the effectiveness of DMT (Strassel, Cherkin, Steuten, Sherman & Vrijhoef, 2011), it was concluded that dance has multisensory, emotional, cognitive, and somatic characteristics that are therapeutically valuable in multiple conditions. Although DMT and dance rehabilitation differ from each other in many ways, the underlying mechanisms of dance are the same.

Using and studying dance as a rehabilitation method matches the recommendations of the NIH consensus development panel (Ragnarsson et al., 1999) about TBI rehabilitation in many ways. According to the panel rehabilitation must be matched to the individual needs, strengths and capacities of each rehabilitee and rehabilitation services should be accessible through the entire course of recovery; rehabilitation of persons with severe TBI should be interdisciplinary and include both cognitive and behavioral interventions; patients should have the opportunity to participate in planning and design of the rehabilitation programs and; innovative rehabilitation interventions for TBI should be developed and studied.

In the following sections, various mechanisms involved in dance and current evidence of their use in neurorehabilitation, and dance therapy, and how they can be utilized in dance rehabilitation, are shortly discussed. Due to the lack of empirical studies on the neuroscience of dance, and the poor scientific quality of the studies on dance therapy (Strassel et al., 2011), theoretical formulations are also considered. Since dance combines the use of music and physical exercise, evidence of the effectiveness of music and physical exercise are considered aswell.

1.2.1 Mechanisms involved in dance

1.2.1.1 Multimodality

Dance is a multimodal activity that involves sensory, motor, emotional, and cognitive systems (Kullberg-Turtiainen, 2013). In dance, visual and auditory information is incorporated with proprioception – the sense of the relative position of one's own parts of the body and strength of effort being employed in movement (Poikonen, 2018). The body is perceived and moved in relation to itself, the environment, music and possibly other dancers. Dancers learn single movements and movement sequences of growing complexity and length and shift between imitation of the dance teacher, execution of verbal and sometimes tactile cues and performance without instruction. Choreography is often created around a theme and a piece of music fitting to that theme is selected to support the movement and, thus, dance is emotionally charged. Dance is intrinsically both physical and cognitive and, as Bläsing and colleagues (2012) conclude, the dimensions can hardly be evaluated separately.

Due to its multimodal nature, dance has the capability of activating several brain regions at the same time (Kullberg-Turtiainen, 2013) and, therefore, it might be ideal for enhancing similarly complex functions. In line with this hypothesis, Hamacher and colleagues (2015) found that dance improves motor-cognitive dual-task capability in healthy elderly people. Their study was a parallel group design with random allocation and a blind observer. One group participated in a dancing intervention and the other in a health-related physical exercise group that also listened to music while training. The training conditions were nearly identical in terms of intensity, frequency and duration. In the pre- and post-intervention measurements, the participants were made to walk continuously and simultaneously do serial subtractions, and while they were doing this, various aspects of their gait and the average time to recite the subtractions and the percent of correct answers were measured. A significant interaction of group and time, to the benefit of the dancing group was found in the average recitation time. This was interpreted as a result of the dual task nature of dance and that it trains both executive and attentive functions (Hamacher, Hamacher, Rehfeld, Hökelmann & Schega, 2015), and this was seen to confirm results from other studies (Jovancevic, Rosano, Perera, Erickson & Studenski, 2012; Kattenstroth & al., 2011) where dance improved cognitive functioning.

Functioning in everyday life is not reliable only on the effectiveness of cognitive, motor and sensory processes in isolation, but even seemingly simple tasks require seamless cooperation of these systems (Hamacher et al., 2015). Therefore, the finding of Hamacher and colleagues might be indicative of the potential of dance to improve cognitive functioning in a way that translates into everyday life.

Berrol and Katz (1985) suggest that the diffuse damage and dysfunction following traumatic brain injury require a multimodal treatment approach where several sensory modalities are stimulated simultaneously. The approach; tapping into cognitive, psychosocial and physical domains via sensory systems; may access patient's areas of strength which may help activate a weaker area (Berrol & Katz, 1985). There is also a general consensus that learning is enhanced by cross-modal presentation of information. All this suggests that dance may have some advantages as a rehabilitation tool that should be studied.

1.2.1.2 Embodiment

Embodiment is a concept of growing popularity and scientific interest. It goes against the Descartesian notion that minds and bodies are separate entities (Block & Kissell, 2001), and that mental and neuronal processes may only be related to each other, leading to a short-circuit of mind and brain (Fuchs, 2009). Embodiment referes to the embedding of cognition in brain circuitry and to the origin of these processes in an individual's sensory–motor experience (Fuchs, 2009). Neural and cognitive functions, perception and emotion are seen as rooted in and integrated throughout the body – not just the brain. The brain becomes the location of the mind not as a separate entity but only in connection to the living being (Fuchs, 2009). Embodiment approaches also see individuals as embedded in the physical and social world around them (Block & Kissell, 2001; Fuchs, 2009). The neurocognitive system cannot be grasped separately; it exists enmeshed in the world in which we move and live with others through our bodily existence.

Embodiment is a useful concept in TBI rehabilitation since professionals deal with individuals – not just brains. According to Fuchs (2009), a neurobiological paradigm may generate a restricted perspective on mental illness in three distinct ways: 1) by reducing subjectivity into a by-product of brain activity, 2) by reification, as in by localizing mental and subjective states into the brain which results in the belief that brain images may show the cause of a mental illness or even the illness itself, and 3) by isolating the individual and their illness from the interconnections with their environment, and treating them as separate. These same functions seem plausible for the TBI rehabilitation and treatment context.

Dance is profoundly oriented to a bodily way of being through movement (Block & Kissell, 2001). In dance, movement is connected to and influenced by meaning on a personal and private, or a social and public level in addition to spatial, temporal and perceptual factors. A critical evaluation of the embodied cognition hypothesis is beyond the scope of this study, and is available elsewhere (see Mahon & Caramazza, 2008), but the notion that there is a two-way connection between the body and the mind, and thus one can be influenced through the other, is essential in the dance rehabilitation approach.

1.2.1.3 The mirror neuron system

The discovery of the mirror neuron system (MNS; Di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992) and vast research into the topic thereafter, is the most direct kind of evidence in support of the embodied cognition hypothesis (Mahon & Caramazza, 2008). Mirror neurons are a class of visuomotor neurons that were originally found in the monkey premotor cortex area F5 to respond to the meaning of a specific movement (Di Pellegrino et al., 1992). These neurons activated both when the monkey was performing an object-related action and when observing the experimenter perform the same action – mirroring or reflecting the observed action in the motor representation of the same action in the observer's premotor cortex. The first evidence of mirror neurons in humans came from a magnetic stimulation study (Fadiga, Fogassi, Pavesi & Rizzolatti, 1995), in which the motor cortex was stimulated and the same motor evoked potentials that are observed during executing certain movements significantly increased during observing those same movements.

The human MNS might be sensitive to the degree of the correspondence between the observed action and the motor capability of the observer (Buccino et al., 2004). Expert ballet dancers and expert capoeira dancers showed stronger responses in the MNS areas when observing dance movement from their personal repertoire, than when observing kinematically comparable dance movement not included in their repertoire, while non-dancers showed no activation of the MNS areas while watching either repertoires (Calvo-Merino, Glaser, Grèzes, Passingham & Haggard, 2004). This finding is consistent with another fMRI finding (Buccino et al., 2004) indicating that a person must have personal knowledge of a certain movement for it to activate the MNS. Other movement, that the observer has no direct experience of, will be recognized as biological movement, but there will not be similar cortical resonance.

According to Rizzolatti (2005), the MNS doesn't have a specific functional role, but it may underlie a multitude of functions, depending on what aspect of action is coded, which circuits mirror neurons are included in, and the connectivity of the MNS with other systems. The MNS is central in both in visual and auditory action recognition (Buccino, Binkofski & Riggio, 2004). In addition to action recognition, the MNS is involved in understanding the intentions of others' actions (Iacoboni et al., 2005), empathy (Wicker et al., 2003) and imitation (Buccino et al., 2004).

The activation of motor representations through observation could have important applications in motor rehabilitation (Calvo-Merino et al., 2004). A 4-week action observation therapy combining observation of daily actions with physical training of those actions, was found to significantly improve motor functions of stroke patients and increase activity in the bilateral ventral premotor cortex, bilateral superior temporal gyrus, the supplementary motor area and the contralateral supramarginal gyrus (Ertelt et al., 2007). These results show that the positive impact of action observation on motor functions happens through reactivation of motor areas that contain the MNS. In dance, learning happens through action observation and imitation (Bläsing, Puttke & Schack, 2018) and thus, the MNS is actively engaged.

1.2.1.4 Brain plasticity

Brain plasticity is structural change in the brain at the cellular, molecular, and system levels, that ultimately supports behavioral plasticity (Cotman & Berchtold, 2002). There is an induction-feedback loop between experience, plasticity and behavior: brain plasticity is induced by behavioral, sensory, and cognitive experiences and there is robust evidence that neural connectivity is remodeled to encode experience (Kleim & Jones, 2008). The neural changes associated with experience vary from increases in brain size, cortical thickness, neuron size, dendritic branching, spine density, synapses per neuron, and glial numbers (Kolb & Whishaw, 1998).

Plasticity is the mechanism by which the injured brain relearns behavior in response to rehabilitation (Kleim & Jones, 2008), and a damaged brain is reorganized by plasticity spontaneously even without rehabilitation (Kleim & Jones, 2008). Berrol and Katz (1985) point out that the plasticity of the brain often facilitates the process of recovery that may continue for many years post injury. According to the review of Kullberg-Turtiainen (2013) brain plasticity can be utilized in dance rehabilitation.

Dance (Rehfeld et al., 2017), physical exercise (Cotman & Berchtold, 2002; Rehfeld et al., 2017) and skill learning (Doyon & Benali, 2005; for review see Kolb & Whishaw, 1998) promote brain plasticity especially in the hippocampus (for review see Thomas, Dennis, Bandettini & Johansen-Berg, 2012). A cognitively stimulating context may maximize the impact of physical exercise on neuroplasticity (Fabel & Kempermann, 2008). The hippocampus is central in learning novel information and skills, and rapid formation of comprehensive associations between events to create declarative memories (for review, see McClelland, McNaughton & O'reilly, 1995). A group of professional dancers, ice dancers and slackliners (trained group) outperformed matched controls in a hippocampal formation dependent configural learning task and there were significant differences in bilateral grey matter volumes between the groups (Hüfner et al., 2011).

1.2.1.5 Enriched environment

Enriched environments (EE) can be broadly defined as 1) an environment that provides enhanced cognitive, physical and social stimulation (Frasca et al., 2013; Voss, Vivar, Kramer & van Praag, 2013), and 2) a condition that encourages participation (Frasca et al., 2013). Dance combines these elements in a complex way, and thus the context of dance can be considered an EE (Kattenstroth et al., 2010).

In rodents, EEs enhance spatial memory (Meshi et al., 2006; Nilsson, Perfilieva, Johansson, Orwar & Eriksson, 1999), and hippocampal plasticity (Brown et al., 2003; Kempermann, Kuhn, & Gage, 1997; Meshi et al., 2006; Nilsson et al., 1999). Animal studies have shown that the intensity and duration of EE are critical for producing beneficial effects (for review see Frasca et al., 2013). The effects of EE have been found to endure time at least partially, and the longer the exposure to EE, the more persistent the effects are (Amaral, Vargas, Hansel, Izquierdo & Souza, 2008).

There are positive correlations between EEs and cognitive and neuronal status, and some findings suggest that EEs curb post-acute cognitive and neuronal decline (for review see Frasca et al., 2013). In healthy older adults, participation in intellectual and social leisure activities was associated with less cognitive decline and a lower incidence of dementia (for review see Scarmeas & Stern, 2003). This finding supports the importance of EE in the chronic phase of rehabilitation as a potential buffer against decline (Frasca et al., 2013). Scarmeas and Stern (2003) proposed three potential mechanisms by which EE may buffer against cognitive decline: 1) increasing synaptic density, 2) more efficient use of the same neuron networks, and 3) more efficient use of alternative networks.

EEs are essential for maximizing the potential for recovery (Bach-y-Rita, 1980; see Berrol & Katz, 1985). There is an increased risk for reduced enrichment in the chronic phase of rehabilitation as the amount of therapeutic activity decreases (Frasca et al., 2013). Even when TBI survivors return to environments that are stimulating and complex, they may be unable to engage without the expertise and support of the therapists.

1.2.2 Dance and cognition

Both the physical and artistic demands of dance require cognitive abilities that can be studied using behavioral and neuroscientific methods (Bläsing et al., 2018). Learning to dance requires imitation, combining visuo-spatial perception and proprioception, memorizing and executing movement sequences, synchronizing movement with music and sometimes with other dancers, translating verbal instructions into movement, and physical execution of movement is preceded and accompanied by ideomotor execution of movement (Bläsing et al., 2012). All of this engages a vast range of cognitive functions and so, it is reasonable to look at how dance affects cognitive functioning and hypothesize that it might.

The few existing empirical studies looking at the cognitive benefits of dance on healthy adults, show somewhat mixed results. A 6-month dance intervention for healthy elderly people had positive effects on cognition, attention, reaction time, motor, tactile and postural performance, subjective well-being and cardio-respiratory performance (Kattenstroth, Kalisch, Holt, Tegenhoff & Dinse, 2013). The individuals who benefited most from the intervention, were the ones showing lowest performance in the pre-tests. In a study comparing a dance intervention to a walking intervention on healthy elderly people (Merom et al., 2016) no support was found for the hypothesis that dance elicits greater changes in executive function, learning and memory than a functionally simpler activity. The only aspect that the dance group seemed to improve more in than the walking group, was visuospatial learning and memory. It was hypothesized that the sample consisted of people more active than average and thus no effect was found. Taking into consideration the finding of Kattenstroth and colleagues (2013), that the positive changes were greatest on the ones with lowest performance at first, it seems coherent that in a sample of healthy and active people dancing didn't have significantly better outcomes than walking (Merom et al., 2016).

In neurological patients, dance and music may have positive effects on cognition. In the current research group's previous studies, dance and movement therapy improved the cognitive state of dementia patients (Hokkanen, Rantala & Remes, 2003; Hokkanen, Rantala & Remes, 2008). Active music listening was found to improve verbal memory recovery and focused attention recovery in stroke patients (Särkämö et al., 2008), and preliminary results indicate that music therapy may improve executive function in the form of mental flexibility in traumatic brain injury patients (Thaut et al., 2009).

Physical and cognitive training have been shown to be useful to some extent in improving cognition, but there may be added benefits to combining the two into a single activity (Dhami et al., 2015). Music may enhance the effects of physical exercise on cognitive function and especially visuospatial functioning (Satoh et al., 2014) and exercise may need to be done in a cognitively stimulating context in order to maximize its impact on cognition (Fabel & Kempermann, 2008). This is supported by the finding that out of two aerobic dance programs on healthy and fit older adults, the intervention with increasing difficulty level enhanced executive function more than the repetitive program (Kimura & Hozumi, 2012).

1.2.3 Dance and mood

Dance expertise consists of physical virtuosity and other components, such as aesthetic, affective, communicative and social elements. The latter distinguish dancers from other motor experts. Not only do dancers strive to be in control of their body movement and to develop their physical capabilities throughout their training, but they learn to perform movement with their chosen aesthetic quality or a range of different kinds of qualities. These qualities reflect both the technique of given styles and the emotional states that the dancers choose to perform.

Dance may decrease depression in psychiatric patients more than music or movement alone (Koch, Morlinghaus & Fuchs, 2007). In a three-group repeated-measure study comparing dance, music-only, and movement-only treatments on depressed subjects, there was a significant decrease of depression in the dance condition, whereas the scores did not change in the two other conditions. Participants both in the dance and music-only conditions showed increased vitality but the increase was significantly higher for the dance condition.

Physical exercise may improve mood after TBI: a 10-week exercise intervention, consisting of a weekly supervised 60-minute session and unsupervised 30-minute aerobic exercises 4 times a week, increased physical activity and reduced scores on the Beck Depression Index (BDI) in participants who had suffered a TBI six months to five years prior to the study (Wise, Hoffman, Powell, Bombardier & Bell, 2012). The acquired improvements in mood maintained over time and the participants that exercised over 90 minutes a week, had lower scores in the BDI compared to the participants that exercised less at the 10-week and 6-month assessments.

Music has well documented effects on the listener's emotional states, and positive responses to music correlate with activation in brain areas related to reward and emotion (Blood & Zatorre, 2001). Music therapy may support emotional adjustment after TBI by decreasing sensation seeking, anxiety, and depression (Thaut et al., 2009), and active music listening may improve depressed mood and diminish confusion in stroke patients (Särkämö et al., 2008). As stated in the previous section, dance and cognition, music has positive effects on cognitive function, but according to Schellenberg (2012), it is the mood enhancing capability of music that positively affects cognitive functioning rather than listening to music *per se*.

1.2.4 Dance and quality of life

As defined by experts, TBI survivors, and family members, the quality of life of TBI survivors has three central components: 1) interpersonal relationships and a sense of community, 2) a sense of productivity, and 3) a sense of self-control, self-efficacy, or self-competency (Bergquist et al., 1994). In a study on quality of life in the chronic state of severe TBI (Koskinen, 1998), friendship, sexuality, and leisure activities – all of which relate to interpersonal relationships and community – were found to be the most dissatisfactory domains of life satisfaction.

The social and interactive nature of dance taps directly into the issue of reduced satisfaction in friendship, intimacy, and connectedness. As Poikonen (2018) describes, embodied communication, touch, and self-awareness are at the core of dance, and vital for individuals and communities. Throughout human history, in various cultures dance has had a role as a ritual, a rite of passage, and an emotionally expressive form of communication (Block & Kissell, 2001). Active music therapy may also positively influnce interactive abilities of patients with severe TBI (Formisano et al., 2001).

Residual motor deficits of severe TBI negatively influence quality of life (Klonoff, Costa & Snow, 1986), and physical exercise may increase perceived quality of life and mental health in TBI patients (Wise et al., 2012). Physical training in a social context may be especially beneficial: fitness center -based physical training resulted in better adherence, achieved more goals, and was found more motivating by TBI patients than home-based training (Hassett et al., 2009), and a guided dance intervention resulted in good adherence in PD patients (Westheimer et al., 2015). The PD patients also expressed willingness to keep attending the dance class if it were ongoing. In an RCT study comparing physical training to relaxation, significant improvements in physical fitness, but not in functional independence, mobility or psychological functions were found in the exercise group compared to the relaxation group (Bateman et al., 2001).

1.3 Research questions and hypotheses

The aim of this research project is to present an individually guided dance intervention as a new tool for neuropsychological, psychological and motor rehabilitation in the chronic state of severe TBI. In the current study, the intervention's feasibility and effectiveness in the neuropsychological and psychological rehabilitation of chronic severe TBI is assessed. The research questions are, whether the intervention affects cognitive function, mood, and quality of life. The study is exploratory and the purpose of the assessment of effectiveness is to guide future research and to generate further and more precise hypotheses.

The hypotheses are similar on cognition, mood, and quality of life. If the rehabilitation dance intervention has the presumed positive effects, the following hypotheses are accurate on all outcome measures: 1) performance of group A improves more between t0 – t3 than performance of group B, 2) performance of group A improves more between t0 – t3 than t3 – t6, and 3) performance of group B improves more between t3 – t6 than t0 – t3. If the rehabilitation dance intervention has long term effects, the following hypothesis is accurate: 4) performance is better in group A at t6 than at t0.

2 Methods

2.1 Participants

A total of 11 participants (table 2), four women and seven men, participated in the study. One male participant discontinued after health complications at t5, but he was still included in the study due to the small sample size. The remaining ten participants finished the intervention according to the schedule. The participants were 19 – 45 years old with an average age of 35.7 years (SD = 9.9). Before the occurrence of the TBI, seven participants reported no health issues or good health, two reported long-term illnesses, and one reported having been in a car accident that had caused fractures in the spinal cord. No participants had a history of neurological or psychiatric illness.

The inclusion criteria were: 1) a diagnosed severe traumatic brain injury 2 – 4 years ago (chronic long-term consequences), 2) no prior severe neurological or psychiatric illness or drug abuse, 3) sufficient motor function to enable participation in the intervention: activity in both arms, walking/standing while supported or aided, and no severe ataxia, 4) age 20 – 50 years, 5) living in Uusimaa and 6) ability to understand the purpose of the study and to decide about participation themselves. All other inclusion criteria were met on all participants, but the youngest participant was 19.2 years old at the beginning of the current study and had suffered a TBI 1.5 years earlier.

The average time from the injury was 7.6 years, with a minimum of 1.5 and a maximum of 13.5 years (SD = 3.2). All participants had been in inpatient rehabilitation and received physiotherapy, neuropsychological rehabilitation, speech therapy and occupational therapy due to the TBI according to their individual needs and resources. PTA length could be defined from the medical records of eight participants and it varied from 35 days to 180 days (M = 124; SD = 53). GCS score could be defined from the medical records of seven participants and varied between 3 and 5 (M = 3.6; SD = 0.8). A neurosurgical operation had been performed on eight participants. All participants filled the criteria for a severe TBI with a loss of consciousness of over seven days or a PTA of over four weeks. One participant, ID 3, had acquired the TBI in the United States and thus, her clinical reports could not be accessed but an experienced clinical neuropsychologist inferred the severity of the TBI based on the participant's case history and considered the inference very reliable.

Table 2

Subjects and background variables.

ID	**Group**	**Gender**	**Age at t0 (y)**	**Time since injury (y)**	**Length of PTA (d)**	**Length of LOC (d)**	**GCS**	**GOSE**	**Neurosurgical operation**
1	*A*	*Female*	33.9	13.5	120	30	*unknown*	4	*yes*
2	*A*	*Male*	41.1	7.5	90	28	*unknown*	4	*yes*
3	*A*	*Female*	34.8	9.4	*unknown*	*unknown*	*unknown*	4	*yes*
4	*A*	*Male*	37.4	9.2	*unknown*	28	4	5	*yes*
5	*B*	*Male*	20.5	4.1	180	42	3	3	*yes*
6	*A*	*Female*	26.1	6.0	180	150	5	4	*yes*
7	*B*	*Male*	48.5	6.5	35	21	4	4	*no*
8	*B*	*Female*	43.8	7.6	*unknown*	14	*unknown*	4	*yes*
9	*B*	*Male*	42.0	9.4	180	2	3	3	*yes*
10	*A*	*Male*	45.0	9.4	90	30	3	3	*no*
11	*B*	*Male*	19.2	1.5	120	56	3	3	*yes*
		min	19.2	1.5	35	2	3	3	
		max	48.5	13.5	180	150	5	5	
		Mean	35.7	7.6		40.1	3.6	3.7	
		SD	9.9	3.2		41.3	0.8	0.6	

T0 refers to the starting point of the study. Length of post-traumatic amnesia, PTA, and length of loss of consciousness, LOC, after the TBI, are reported in days and were obtained from clinical reports. Glasgow coma scale, GCS, score is the score immediately after the TBI. PTA, LOC, and GCS were obtained from clinical reports. The Glasgow Outcome Scale Extended, GOSE, score is defined by an experienced clinical neuropsychologist based on interviews, clinical reports, and the data.

The participants were randomized into two groups, A and B. The groups were compared with an independent samples t-test on the background variables age at t0, time since injury at t0 in years, length of PTA in days, length of loss of consciousness in days, the GCS score, and the GOSE score. No significant differences emerged between the groups (table 3). Time since injury at the beginning of the current study was approaching significance but since all participants were in the chronic state of TBI, this was not seen as a problem when outliers would be inspected with regards to each analysis.

Table 3

Comparison of groups.

	Group A	**Group B**	***t***	**df**	**sig**
N	6	5			
Males	3	4			
Females	3	1			
N neurosurgical operation	4	4			
Age at t0	36.4	34.8	.197	5.437	.851
Time since injury at t0	9.2	5.82	1.985	9	**.078***
Loss of consciousness	53.2	27	1.004	8	.345
GCS	4	3.25	1.324	5	.243
GOSE	4	3.4	1.662	9	.131

**** significant at the p < .01 level, ** significant at the p < .05 level, * approaching significance*

T0 refers to the starting point of the study. Length of post-traumatic amnesia, PTA, and length of loss of consciousness after the TBI, are reported in days. Glasgow coma scale, GCS, score is the score immediately after the TBI. The Glasgow Outcome Scale Extended, GOSE, score is defined by an experienced clinical neuropsychologist based on interviews, clinical reports, and the data.

2.2 Intervention

The intervention was implemented according to the rehabilitation dance concept manual (Kullberg-Turtiainen, Forsbom & Molander, 2015) as an individually guided combination of dance instruction and physiotherapy (figure 1). A dance teacher gave verbal instructions and visual cues through their own movement which the participant imitated to their best ability. A physiotherapist helped the participant in executing the movements correctly in a way that the participant could not on their own, giving them sensory (tactile) information of their body position. The starting position was either sitting down or standing up, depending on the motor abilities of the participant. The physiotherapist helped the participant maintain an optimal position of the body, execute movement in rhythm of the music, and start, continue and finish movement when needed. If the participant could not keep up to the pace of music or lost track of movement, the physiotherapist would guide them to follow the dance teacher's movement.

Each session had the same content: 1) concentration to the body, 2) finding rhythm and tempo, 3) isolations, 4) choreography, and 5) ending. In the beginning of the sessions, the participant was verbally guided to mentally scan their body and pay attention to different body parts. If necessary, the dance teacher gave a tactile cue to the body part in question. The rhythm and tempo section consisted of different clapping and stomping exercises. Isolations mean separated movement of body parts; a certain body part was to be moved in isolation, while other parts of the body would be actively kept still with the help of the physiotherapist. The aim is to increase awareness of the body and to warm up. In the choreography section, movements from all the sections of the session were combined with reaching, looking, facial expressions, pauses, and other rhythmic variations. Depending on the fitness of the participant, also large circular movements, level changes, and steps could be included. The choreography was built by putting together 2 – 3 elements which were then repeated until the participant remembered the combination and was able to execute it without modeling the dance teacher, after which another 2 – 3 elements would be added. There were two different choreographies that varied in energy. One was calm and the other more rhythmic. Both were done to music of the participant's choice. The ending of the session included stretching and relaxation.

2.3 Outcome measures

2.3.1 Neuropsychological assessment

A comprehensive neuropsychological test battery was employed, and the tests were administered at all instances by the same blinded, well-trained, pre-graduate MD student of psychology. Each assessment session lasted 1.5 – 2 hours and short breaks were taken when necessary. The neuropsychological test battery consisted of the Montreal Cognitive Assessment Scale (MOCA; Nasreddine et al., 2005), the Frontal Assessment Battery at Bedside (FAB; Dubois, Slachevsky, Litvan & Pillon, 2000), the Number Letter Task (adapted from Rogers & Monsell, 1995), three subtests (S, BD and DS) of the Wechsler Adult Intelligence Scale IV (WAIS-IV; Wechsler, 2008) and the Sustained Attention to Response Test (SART; Robertson, Manly, Andrade, Baddeley & Yiend, 1997). The Number Letter Task turned out to be too difficult for many of the subjects for it to be included in the final selection of outcome measures. All these tests were presented so that the subject and the interviewer sat facing each other at a table, some subjects sitting in a wheelchair. The SART and the Numer Letter Task were administered via a HP computer, programmed with Presentation software, and modified to record the responses with a button box for precise response timing.

The MOCA is used to screen for mild cognitive impairment and has 11 items measuring various aspects of cognition. Some items are presented and responded to in a paper-and-pen manner and some in a question-response manner. In the current study the MOCA was used to assess general cognition. The FAB consists of 6 items assessing frontal lobe function. All items are presented verbally by the interviewer and responded to either verbally or by following the interviewer's instructions of various motor tasks. The similarities and digit span subtests of the WAIS-IV are presented and responded to verbally, and the block design involves manipulation of small objects and arranging them according to a visual cue. The SART error score is a measure of sustained attention ability.

2.3.2 Questionnaires

The participants filled questionnaires at home with the help of their family or personnel of a supported housing establishment, if needed. The questionnaire battery consisted of the Behavior Rating Inventory of Executive Function (BRIEF) (Roth, Isquith & Gioia, 2014), the Beck Depression Index II (BDI-II; Beck, Steer & Brown, 1996), the QOLIBRI (von Steinbuchel et al., 2010), and the Patient Competency Rating Scale (Prigatano, 1986). The BRIEF was filled out by the subjects and separately by their close others, whereas the BDI-II and the QOLIBRI were filled out only by the subjects.

The outcome measures used in the current study were depressive mood (total score of the BDI-II), quality of life (total score of the QOLIBRI), general executive function (the general executive composite subscale of the BRIEF), metacognition (the metacognition index of the BRIEF), and behavioral regulation (the behavioral regulation index of the BRIEF). Single items were not evaluated in the current study.

Table 4

Assessment methods and outcome measures.

Assessment method	Outcome measure
MOCA total score	General cognition
FAB total score	Frontal lobe function
WAIS-IV Block Design	Visuo-spatial reasoning
WAIS-IV Digit Span	Working memory
WAIS-IV Similarities	Abstract reasoning
SART error score	Sustained attention
BDI-II total score	Depressive mood
QOLIBRI total score	Quality of life
BRIEF General Executive Composite	Executive function
BRIEF Metacognition Index	Metacognition
BRIEF Behavioral Regulation Index	Behavioral regulation

2.4 Study design

The present study was a two-group crossover study lasting six months. In a crossover design, each participant is their own control which reduces error variance. The neuropsychological assessments were done three times within the six-month period with 3-month intervals at t0, t3, and t6. During the first half of the research (t0 to t3), group A participated in the dance rehabilitation intervention, whereas group B functioned as a control group. Group B participated in the intervention during the second half of the research (t3 to t6), and group A did not. Both groups maintained their usual rehabilitation curriculum according to their individual needs throughout the six months. All questionnaires were also filled at t0, t3 and t6, and in addition, at t18. At t18, 4 subjects in total did not respond to the questionnaires, and there was a remarkable amount of missing data even within the subjects who had responded to the questionnaires at that time point. Because of the vast missing data in the small sample, t18 was left out of the current study.

The statistical analyses were done in a progressive sequence (table 5). To study the efficacy of the intervention, the first step was to conduct paired samples *t*-tests to compare the scores before and after the intervention on the whole sample for all outcome measures. For the measures showing statistically significant differences, relevant subscales were studied with paired samples *t*-tests to define more precisely, how the intervention affected the outcome measure in question. In step 3, comparisons between performance before and after the control period were conducted as paired samples *t*-tests for all variables with significant results in steps 1 and 2. The significance level was set to .05 and no adjustments to the significance levels were made while conducting the analyses due to the exploratory nature and the purpose of the study to guide future research and create more precise hypotheses for a wider effectiveness study. Thus, avoiding type 2 errors was prioritized. The Holm-Bonferroni method (Holm, 1979) for counteracting the problem of multiple comparisons was used to evaluate the results.

To investigate if the groups differed from each other in the controllable section of the study (t0-t3), a repeated measures ANOVA with time as a 2-level within subject factor and group as a 2-level between subject factor was conducted on all outcome measures. To investigate if there were differences between the groups at the three different time points, a repeated measures ANOVA with time as a 3-level within subject factor and group as a 2-level between subject factor was also conducted on all outcome measures.

Table 5
Sequence of statistical analyses.

Step	Method	Variables	Model
Step 1	paired samples t-tests	All	the whole sample before and after the intervention
Step 2	paired samples t-tests	Relevant subscales if significant in step 1	the whole sample before and after the intervention
Step 3	paired samples t-tests	If significant in step 1 or 2	the whole sample before and after the control period
Step 4	repeated measures ANOVAs	All	time (2) × group (2): t0 – t3
Step 5	repeated measures ANOVAs	All	time (3) × group (2): t0 - t6

The study was approved by the Helsinki University Hospital ethics committee on October 15, 2014, and each participant provided written informed consent before participating in the study. Both the neuropsychological and the motor tests were administered at Validia Rehabilitation Helsinki and travels by taxi were arranged for all, except for one physically fit participant. The present study was funded by the Finnish Cultural Foundation, Emil Aaltonen Foundation, and The Social Insurance Institution.

3 Results

Results of the paired samples t-tests of step 1 are shown in table 6. Three outcome measures had significant results and one was approaching significance. The results are reported in more detail in the following sections with the step 2 and 3 results.

Results of step 4 and 5 ANOVAs are shown in table 7. Only one time and group interaction emerged supporting the hypothesis that group A would improve more between t0 and t3 than group B. Time × group interactions for all outcome measures with significant results at any step of the analyses are shown in figure 1.

3.1 Cognition

General cognition (MOCA total score) did not change during the intervention, but it improved both from t0 to t3, $F_{1, 9} = 7.582$, $p = .022$, and t0 to t6, $F_{1, 9} = 6.051$, $p = .010$, but no significant time × group interactions emerged. The pairwise comparisons implied that both t3 and t6 differed from t0, but there was no difference between t3 and t6. Thus, general cognition improved during the entire course of the study, but the change cannot be attributed to the intervention.

Time had a significant main effect on frontal lobe function (FAB total score) between t0 and t3: group B improved more than group A between time points t0 and t3, $F_{1, 9} = 5.867$, $p = .038$. The time (2) × group (2) interaction was also significant $F_{1, 9} = 5.867$, $p = .038$. A significant time main effect, $F_{2, 18} = 4.581$, $p = .025$, and a time (3) × group (2) interaction, $F_{2, 18} = 4.017$, $p = .036$, were found. The pairwise post hoc comparisons implied that there was a difference between t0 and t3 but not between t0 and t6, or t3 and t6.

Abstract reasoning (WAIS-IV Similarities) was better after the intervention (M = 21.546, SD = 11.457) than before the intervention (M = 19.364, SD = 11.030), $t_{10} = -2.564$, $p = .028$, $d = .773$. The effect size was at the upper limit of the medium range. Neither visuo-spatial reasoning nor working memory changed significantly during the intervention. Self-assessed metacognition approached significance, $t_9 = 2.127$, p = .062, but all other scales of the BRIEF, both self- and other-assessed, had nonsignificant results in all analyses.

3.2 Mood

Depressive mood (BDI-II total score) after the intervention (*M* = 9.3, *SD* = 6.70) was better than depressive mood before the intervention (*M* = 14.3, *SD* = 9.3), $t_9 = 3.682$, $p = .005$; $d = 1.16$. The effect size was large which implies possible clinical significance. Depressive mood showed nonsignificant results when comparing the scores before and after the control period. A significant main effect of time, $F_{2, 16} = 5.070$, $p = .020$, and a time (3) × group (2) interaction were found in depressive mood, $F_{2, 16} = 3.718$, $p = .047$.

In both groups A and B, depressive mood changed as predicted by the hypotheses: group A improved more than group B between time points t0 and t3, group A improved more between t0 and t3 than t3 and t6, group B improved more between t3 and t6 than t0 and t3, and mood was better in group A at t6 than at t0.

3.3 Quality of life

One participant was excluded from the analysis of quality of life as an outlier. The quality of life of this participant decreased dramatically during the intervention: the QOLIBRI total score dropped from 103 to 56. For the remaining participants, the total score of QOLIBRI was higher after the intervention (M = 95.78) than before the intervention (M = 88.33), $t_8 = -2.698$, $p = .027$, $d = .899$. In analyses of the subscales, no individual subscale reached significance but most improvement was made in scale A, cognition, and F, physical problems.

In the repeated measures ANOVAs, there were no significant main effects of time or time × group interactions for quality of life. Quality of life in group A seemed to improve steadily throughout the study, while decreasing in the beginning of the study and remaining unchanged during the intervention in group B.

3.4 Adjustmen for multiple comparisons

No adjustments to the significance levels were made while conducting the analyses. In order to control the problem of multiplicity, the Holm-Bonferroni method was adopted. The method adjusts the rejection criteria of the individual hypotheses in a step-wise manner.

Table 6

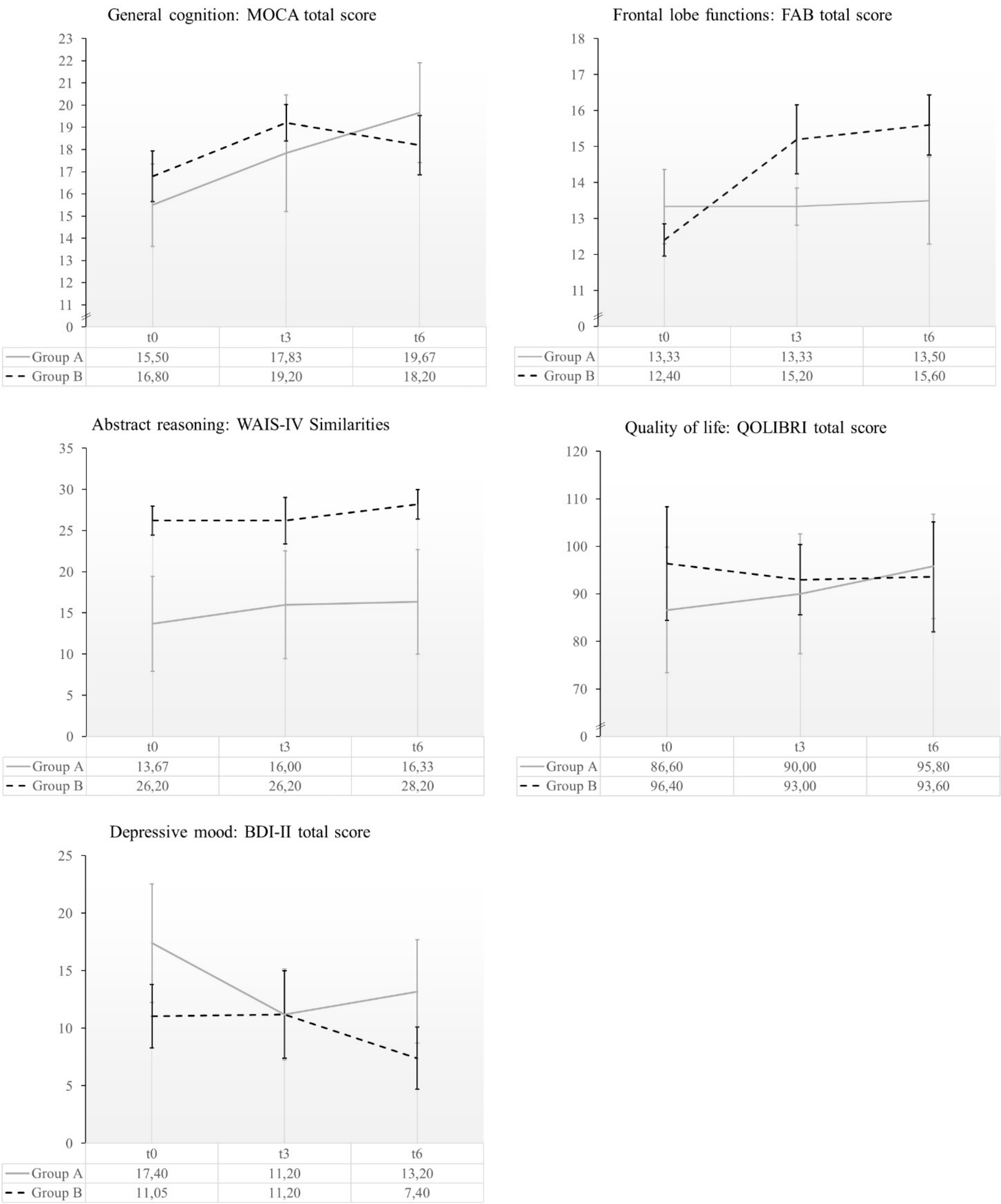
Paired samples t-tests on all outcome measures before and after the intervention.

Outcome measures			**95% confidence interval for the difference**					
	Mean	**SD**	**Upper**	**Lower**	***t***	**df**	**sig.**	**Cohen's *d***
Neuropsychological tests								
MOCA total score	-.181	2.316	1.374	-1.739	-.260	10	.800	
FAB total score	-.182	1.537	.851	-1.215	-.392	10	.703	
WAIS-IV Digit Span	-1.272	2.936	.699	-3.245	-1.438	10	.181	
WAIS-IV Similarities	-2.182	2.822	-.286	-4.078	-2.564	10	**.028****	.773
WAIS-IV Block Design	-3.182	6.780	1.373	-7.736	-1.557	10	.151	
SART error score	.545	9.863	7.171	-6.080	.183	10	.858	
Questionnaires								
BDI-II	5.000	4.294	8.072	1.928	3.682	9	**.005*****	1.164
QOLIBRI	-7.444	8.278	-1.081	-13.808	-2.698	8	**.027****	.899
BRIEF self assessment								
General executive	8.060	15.187	18.924	-2.804	1.678	9	.128	
Behavioral regulation	3.980	9.798	10.989	-3.029	1.285	9	.231	
Metacognition	4.080	6.064	8.419	-.259	2.127	9	**.062***	
BRIEF other assessment								
General executive	.725	2.351	2.304	-.855	1.022	10	.331	
Behavioral regulation	.422	1.380	1.350	-.505	1.015	10	.334	
Metacognition	.302	1.160	1.081	-.477	.864	10	.408	

**** $p < .01$, ** $p < .05$, * approaching significance*

Figure 1

Time × group interactions of all outcome measures that had significant results at any stage of the analysis sequence.



In the MOCA, the FAB, and the WAIS-IV Similarities higher scores imply better performance. In the QOLIBRI higher scores imply higher life satisfaction. In the BDI-II, lower scores imply better mood (less depressive mood).

Table 7
Repeated measures ANOVAs for all outcome measures.

Outcome measure	time (2)			time (2) × group (2)	
	df	***F***	**sig**	***F***	**sig**
Neuropsychological tests					
MOCA total score	1, 9	7.582	**.022****	.002	.970
FAB total score	1, 9	5.867	**.038****	5.867	**.038****
WAIS-IV Digit Span	1, 9	.885	.372	.885	.372
WAIS-IV Similarities	1, 9	2.179	.174	2.179	.174
WAIS-IV Block Design	1, 9	.043	.841	1.427	.263
SART error score	1, 9	.054	.821	.584	.464
Questionnaires					
BDI-II	1, 8	3.215	.111	3.551	**.096***
QOLIBRI	1, 7	.057	.818	1.570	.250
BRIEF self assessment					
General executive	1, 8	.432	.529	1.773	.220
Behavioral regulation	1, 8	.092	.770	1.064	.333
Metacognition	1, 8	1.490	.257	2.949	.124
BRIEF other assessment					
General executive	1, 9	1.645	.232	.372	.557
Behavioral regulation	1, 9	2.299	.164	.134	.722
Metacognition	1, 9	.411	.538	.618	.452
	time (3)			**time (3) × group (2)**	
	df	***F***	**sig**	***F***	**sig**
Neuropsychological tests					
MOCA total score	2, 18	6.051	**.010****	7.130	.201
FAB total score	2, 18	4.581	**.025****	4.017	**.036****
WAIS-IV Digit Span	2, 18	1.406	.271	.313	.735
WAIS-IV Similarities	2, 18	5.492	**.014****	1.457	.259
WAIS-IV Block Design	2, 18	1.711	.209	.498	.616
SART error score	2, 18	.550	.586	.890	.428
Questionnaires					
BDI-II	2, 16	5.070	**.020****	3.718	**.047****
QOLIBRI	2, 16	.228	.798	.605	.558
BRIEF self assessment					
General executive	2, 16	.941	.411	1.306	.298
Behavioral regulation	2, 16	.273	.765	.768	.480
Metacognition	2, 16	2.462	.117	2.036	.163
BRIEF other assessment					
General executive	2, 18	.632	.543	.191	.828
Behavioral regulation	2, 18	1.209	.322	.192	.827
Metacognition	2, 18	.124	.884	.190	.828

**** significant at the p < .01 level, ** significant at the p < .05 level, * approaching significance*

All significant results that supported the original hypotheses, were arranged from the lowest *p*-value to the highest, and the significance level was first adjusted for the lowest *p*-value. The procedure is step-down and should be continued until a failure to reject a null hypothesis occurs.

In the current study, only the first null hypothesis was rejected. In other words, mood was significantly better after the intervention than before the intervention in the whole sample when the significance level was adjusted for multiple comparisons.

4 Discussion

On a theoretical level, dance has been presented as a viable new tool for TBI rehabilitation (Berrol & Katz, 1985; Dhami et al., 2015). Music (Särkämö et al., 2008; Thaut et al., 2009) and movement (Hassett et al., 2009; Wise et al., 2012) have been used in the rehabilitation of neuropathological patients. Nevertheless, there has been basically no empirical research on the usefulness of dance in TBI rehabilitation, even though dance has been used successfully in treatment of neurological disorders like dementia (Hokkanen et al., 2003; Hokkanen et al., 2008) and PD (Foster, Golden, Duncan & Earhart, 2013, Hackney & Earhart, 2009; Hackney & Earhart, 2010; Heiberger et al., 2011). In the current study, an individually guided dance rehabilitation intervention had positive effects on mood, overall quality of life, and abstract reasoning, all of which improved in the whole sample during the intervention. These results had medium or large effect sizes which may implicate clinical significance, but in the current study, the effect sizes must be interpreted with caution.

Adherence in the current study was excellent, and when the participants and their close others were asked to freely comment on the intervention and describe their experiences, nine out of eleven participants provided written comments and seven of them reported positive experiences. All but one participant had either neutral or positive responses to the intervention. One participant dropped out of the study due to epilectic seizures that the participant had not had earlier. The participant was 49 years old, the oldest in the current study, and had suffered the TBI 6.5 years before the study in a traffic accident. Prior to the injury, the highest level of education he had finished was primary school and he reported having had good health and functional capabilities. LOC after the TBI lasted for 21 days, PTA for over a month (approximately 35 days), and the GCS score was 4. The most plausible explanation for the dropout in the current study is the participant's contusion in the left frontal thalamus. Shortly put, the thalamus operates as a relay center for sensory and motor mechanisms and its lesions may cause a variety of somatosensory symptoms (Herrero, Barcia & Navarro, 2002). It is possible that the intervention's multimodal stimulation overloaded the lesioned thalamus with too much input, which lead to the seizures. With one dropout, the attrition rate was 9 %. The response rate to the questionnaires varied between the different questionnaires and time points from 82 % to 100 %. No unusual difficulties or particular challenges arose during the dance sessions. All in all, the rehabilitation dance concept seems to provide a feasible method to be used in the rehabilitation of chronic severe TBI with the possible exception of patients with thalamic lesions.

4.1 Effectiveness of the intervention

4.1.1 Cognition

The effects of dance on cognition have been mixed in previous studies (Kattenstroth et al., 2013; Merom et al., 2016). In a case study using a conceptually similar dance intervention as the current study on a severely brain injured patient, the cognitive components of the FIM showed only slight improvement even though the physical components improved remarkably (Kullberg-Turtiainen et al., 2018). In the current study, a similarly mixed pattern was observed: the intervention did not seem to affect general cognition or frontal lobe function, but reasoning and, more precisely, abstract reasoning seemed to improve during the intervention, although none of the findings on cognitive functioning survived the Holm-Bonferroni adjustment.

In the current study, the intervention had no effect on visuo-spatial reasoning, although in some previous studies, physical exercise (Satoh et al., 2014) and dance (Merom et al., 2016) had positive effects on visuo-spatial functions. In the current study, the Block Design subtest of the WAIS-IV was used as a measure of visuo-spatial functioning. However, the question arises, if the Block Design subtest measures the kind of visuo-spatial functioning required in dance. In the intervention, the goal is three-dimensional visuo-spatial execution of verbal, visual, auditory, and tactile cues. In the Block Design task, the participant recreates a two-dimensional visual cue by manipulating and arranging small three-dimensional objects. The key differences seem to be how the cues are presented (multisensorially or visually) and whether the execution of the cues involves 1) fine motor skills or broad motor skills, and 2) manipulation of objects or bodily positions and movement. Since dance has had positive effects on visuo-spatial functions, and enriched environments are known to enhance spatial memory (Meshi et al., 2006; Nilsson, Perfilieva, Johansson, Orwar & Eriksson, 1999), alternative measures of visuo-spatial functions could be considered in future studies. Spatial memory has been studied for instance with a virtual human analog of the Morris water maze (Cornwell, Johnson, Holroyd, Carver & Grillon, 2008; Newman & Kaszniak, 2000) even in TBI patients (Skelton, Ross, Nerad & Livingstone, 2006).

Engaging in mentally stimulating activities has been found to enhance fluid intelligence performance (Tranter & Koutstaal, 2008), and thus, the complex cognitive stimulation that dance provides (Voss et al., 2013) may enhance fluid reasoning – the ability to "creatively and flexibly grapple with the world in ways that do not explicitly rely on prior learning or knowledge" (Tranter & Koutstaal, 2008, p. 2). In the current study, abstract reasoning – a cognitive function that requires fluid intelligence (Weiss et al., 2010) – improved during the intervention. Music has been found to improve mental flexibility in TBI patients (Thaut et al., 2009), and it seems like dance may have a similar effect.

The findings of a study comparing a dance intervention to a walking intervention did not indicate that dance would positively affect executive function (Merom et al., 2016). In another study, it was found that a dance intervention with an increasing difficulty level could enhance executive function (Kimura & Hozumi, 2012). In the current study, executive function (and frontal lobe functions) remained unaffected, although the change in self-assessed metacognition during the intervention approached significance. Thus, the effect of dance on executive function remain ambiguous.

Socially and intellectually engaging activities and EEs may act as a buffer against cognitive decline (Frasca et al., 2013; Scarmeas & Stern, 2003). Based on the current study, it is impossible to say, if dance can curb cognitive decline in TBI patients but the results do not rule out the possibility. Since TBI is often followed by persistent cognitive impairments (Schretlen & Shapiro, 2003), the potential buffering effect of dance on cognitive decline may be of great importance.

4.1.2 Mood

The most salient effect of the intervention seemed to be on mood. Mood improved in both groups during the intervention and stayed at the elevated level in group A three months after the intervention. The findings were supported by the subjective experiences and stories of the participants many of whom described positive emotions and willingness to continue dancing after the intervention was over. One participant described not having felt emotions since the acquisition of the TBI, but during the intervention: "I started feeling again."

We used the BDI-II to assess depressive mood rather than depression, which is justified by the finding of Homaifar and colleagues (2009). In their study on the sensitivity and specificity of the BDI-II in persons with TBI, it was concluded that the BDI-II can be used as a screening tool for depression in the TBI population. The sensitivity and specificity of the BDI-II were optimized with a cutoff point of 35 for moderate or severe TBI, meaning that total scores below 35 most likely do not indicate depressive symptoms (Homaifar et al., 2009), and none of the participants of the current study had total scores of 35 or more at any assessment point.

The current study and the study of Berrol and colleagues (1997) together suggest that dance can be used to improve mood and depressive symptoms in TBI patients. The findings are further supported by previous findings of how music (Blood & Zatorre, 2001; Forsblom et al., 2009) and movement (Wise at al., 2012) enhance mood, and music may decrease depression after TBI (Thaut et al., 2009) and stroke (Särkämö et al., 2008). Dance may enhance mood more than music or movement alone in psychiatric patients (Koch et al., 2007). All in all, the support for the mood-enhancing capability of dance is persuasive.

4.1.3 Quality of life

In the current study, self-assessed overall health-related quality of life improved during the intervention. Most improvement seemed to happen *in how satisfied the participants were with their cognitive and physical abilities*, although none of the subscales of the QOLIBRI showed statistically significant changes. Physical exercise has been found to increase perceived quality of life in TBI patients (Wise et al., 2012), and it seems like dance may have a similar effect.

We assumed that deterioration processes would not affect the participants' performance in the assessments in the current study due to the short intervention period. We also assumed that spontaneous recovery did not affect the participants' performance since the participants were in the chronic state of TBI. This may not be true for one participant, ID 11, for whom the TBI had occurred 1.5 years before the study. For this participant, quality of life seemed to decrease remarkably, and increased awareness of disability may have negatively affected the subjective experience of quality of life. When asked to describe their experiences, thoughts, and feelings of the intervention, one of the other participants also reported being more aware of the physical impairments caused by the TBI.

Five of the participants in the current study reported willingness to continue dancing and seven expressed positive views on their experience of the intervention. A similar qualitative finding was reported in a study on a dance intervention for PD (Westheimer et al., 2015) where all participants expressed their willingness to keep attending the dance class if it were ongoing. A social context for training has been found more motivating by TBI patients than home-based training (Hassett et al., 2009), and both physical training in a social context for TBI patients (Hassett et al., 2009) and a dance intervention for PD patients (Westheimer et al., 2015) result in good adherence.

Attending the dance intervention may have provided the participants interpersonal relationships, a sense of productivity, and a sense of self-control, self-efficacy, and self-competency, which are the three central components of quality of life for TBI patients (Bergquist et al., 1994). In their reports of their experiences, the participants described positive feelings during the intervention, and liking the intervention, the dance teacher, and the physiotherapist. Improvements in self-control, self-awareness, sense of security, and independence were found after a dance intervention in a case study using a conceptually similar intervention as in the current study (Kullberg-Turtiainen et al., 2018), and in another study a DMT intervention had a positive effect on social interaction (Berrol et al., 1997). Learning new skills could affect self-competency and participating in an activity that focuses on individual strengths and emotional expression may be more meaningful than problem-focused approaches. Since leisure activities have been found to be one of the most dissatisfying domains in life for TBI patients (Koskinen, 1998), participating in the intervention may have been satisfying in itself.

4.2 Strengths and limitations of the current study

The participants in the current study were among the most severely brain injured and in the chronic state of TBI. While the initial status at the beginning of the TBI sequelae was similar for all participants, by the time of the current study, there were remarkable differences in functional capabilities. It is typical for TBI that there are vast individual differences in outcomes (Maas et al., 2017), but the current status of each participant should be taken into consideration in the study for example as a predictor in the measurement model.

Recruiting participants from TBI populations is challenging and even more so among the severely injured. Small sample sizes are a common challenge in TBI research making the generalizability of results difficult (Chua et al., 2007). Compared to more traditional RCT designs with experimental and control groups, a strength of the crossover design is that each participant is their own control, which reduces error variance. This was a major advantage in the current study where the total number of participants was small. In such a small sample, the error variance that may occur despite randomization might affect the results more than in a larger sample.

In clinical studies, the crossover design is presumably more equal and motivating for the participants than designs with treatment and control groups. During the first half of the study (t0 – t3), a comparison between the experimental group (then, group A) and the control group (then, group B) was possible without the ethical concern of leaving subjects completely outside of treatment. The test batteries in the current study were comprehensive and time-consuming, and it seems implausible that TBI patients who often suffer from fatigue, lack of motivation, lack of awareness of their symproms, irritability, and impatience (Brain injuries: Current Care Guidelines, 2017; Maas et al., 2017), would have volunteered for such a study without the reward of possibly benefiting from the intervention.

A limitation of the crossover design is that only the immediate effectiveness of the intervention between groups can be studied, and the long-term effectiveness can be evaluated only within groups. In the current study, since the observations at t18 were left out due to major missing data, the only long-term effects that could be assessed were for group A (t0 – t6). We regarded the benefits of the design greater than the limitations, especially for a pilot study.

Another important feature of the current study was successful blind testing, which hasn't been reported adequately in many earlier papers on dance (Strassel et al., 2011). In future research, blinding must be addressed, and it would be recommendable to have more than one blind assessor conducting the neuropsychological assessments in order to minimize the possible influence of human factors.

The questionnaire battery in the research project (6 questionnaires) and the neuropsychological assessment (up to 2 h) were vast and possibly burdening even for participants without verbal limitations. Three participants had major difficulties in verbal commucation. Two participants suffered from global aphasia and were not able to fill the questionnaires on their own and some creativity had to be used in order to get them to understand instructions. One participant communicated using a tablet and a paper and pen method. In future studies, the number of questionnaires should be considered more carefully, keeping in mind that subjects with TBI are prone to fatigue and cognitive difficulties.

All findings in the current study are tentative for a few different reasons. First, the small sample may not be representative of the target population which makes it challenging to generalize the findings. Secondly, a small sample size may be adequate for assessing the usefulness of a study design or an intervention protocol but not truly the effectiveness of the intervention (Hertzog, 2008). Thirdly, due to the exploratory nature of the current study, no corrections for multiple comparisons were made within the analyses which means that the findings may arise from chance or measurement errors. To take this into consideration, the Holm-Bonferroni method was adopted, and the only rejected null hypothesis was that mood was similar before and after the intervention for all participants. This is unsurprising, considering the limitations of the current study, but does not diminish the importance of the results. Since the purpose of the study was to assess the effectiveness of the dance intervention in order to guide future research, rather than to make affirmative statements of the effectiveness on the various outcome measures, it is encouraging that significant results emerged even in such a small sample.

4.3 Future considerations

No cost-effectiveness evaluations can be made based on the current study, but such an evaluation should be made in the future. The intervention was rather expensive to implement, since two trained professionals per rehabilitee were required, and transportation was arranged and payed for to all assessments and intervention sessions. Despite being costly, the arranged transportation was an important feature of the current study since it made participation as easy as possible for all participants.

Since dance may combine the benefits of movement and music, adding control groups C and D, that would have participated in movement-only and music-only interventions, would allow inferences of whether the positive effects of the intervention were a consequence of music, movement, or dance. A study with three different intervention groups would be expensive to implement, but important in studying the specific effects of dance. Application of two other experimental groups would also enable double-blinding which would further increase the scientific quality of the study.

Another factor that the current study was unable to control, was the alertness levels of the participants at the time of the neuropsychological assessments. Alertness may affect performance in various tasks that require attention, processing speed, working memory, and mental flexibility, and in TBI patients, alertness levels may vary remarkably even within the assessment session and between the different assessments. It may be impossible to schedule the assessments in a way that would remove the effect of alertness and thus, alertness level should be controlled in the analyses. In future studies, larger samples and more careful control of possible predictors are needed in order to reduce error variance.

Based on the current study, future studies should aim to confirm or contest the findings on abstract reasoning, depressive mood, and overall health-related quality of life. In general, the scientific quality of dance-related research is poor (Strassel et al., 2011) and no studies have been replicated, which means that all results are tentative and more basic and applied research into the field is needed. An important goal is to conduct scientifically high-level research by addressing blinding, including necessary predictors into the statistical models, and by considering carefully to which degree TBI patients can engage in the assessments.

5 Conclusions

TBI is a pervasive cause of disability worldwide. The survivors suffer from a vast range of cognitive, physical, emotional, and social symptoms and the heterogeneity of the symptoms is a great challenge for rehabilitation (Maas et al., 2017: Chua et al., 2007). New, innovative, and multimodal treatment approaches are needed (Maas et al., 2017), and dance is such a potential new tool for TBI rehabilitation.

Our research project, “Moving the brain! Dance in the extensive rehabilitation of severe traumatic brain injury” aimed at developing the rehabilitation dance concept (Kullberg-Turtiainen, Forsbom & Molander, 2015) that addresses crucial issues in TBI rehabilitation (Ragnarsson et al., 1999). The interdisciplinary, multimodal, and multisensory intervention includes cognitive and behavioral elements, encourages patient participation, and it is individually customized to match the needs, strengths and capacities of each patient. The intervention is also targeted to the chronic state of TBI and using music, movement and social interaction, it is hypothesized to affect psychological factors.

It seems like the rehabilitation dance concept (Kullberg-Turtiainen et al., 2015) is applicable in TBI rehabilitation and may enhance mood, abstract reasoning, and quality of life in the chronic state of severe TBI. The results of this study are tentative and more research with larger groups of subjects is needed to replicate our findings and to draw solid conclusions. Thus, the research project that the current study is a part of, was called for and fulfills an important purpose of guiding future research on the feasibility and effectiveness of dance as a tool in TBI rehabilitation.

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