Role of the music therapy in neurorehabilitation of patients with disorders of consciousness – looking for rules of evidence based practice

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ABSTRACT

Neurological early and long-term rehabilitation plays a crucial role in the therapy of patients with disorders of consciousness (DOC) such as unresponsive wakefulness syndrome or minimally conscious state. Neuroscience tries to explain the effect of music therapy on all levels of the nervous system = activity in patients with DOC, but full understanding is still incomplete. This paper attempts to answer how current clinical outcomes may reflect the influence of various factors including music's capacity. Based on their interdisciplinary perspective and previous experiences, the authors try to investigate the extent to which current occupations have been explored. The authors analyzed the literature data concerning the results of the studies published until the first half of 2016, to sum up the current state of research. Research in the main databases: PubMed, PEDro, Health Source: Nursing/Academic Edition was made using specified keywords and inclusion and exclusion criteria. Next, the authors sorted them all out into a coherent view of the current state. Music listening may constitute a part of an enriched environment setting. However, due to weak evidence, the therapeutic value of music-based interventions in patients with DOC is uneven or limited. The role of music therapy is thus complementary. Standardized clinical settings, protocols, and behavioral measures should be developed to increase its clinical validity, reliability, sensitivity, and objectivity. There is a reasonable hypothesis that music may produce a high level of diagnostic and therapeutic outcomes as stimuli usually reflecting strong personal meaning in patients with DOC.

Keywords: Neurorehabilitation, consciousness, arousal, disorders of consciousness, music, evidence-based medicine

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INTRODUCTION

Disorders of consciousness (DOC) such as vegetative state also called unresponsive wakefulness syndrome (VS/UWS), minimally conscious state (MCS) and locked-in syndrome (LIS) are not the illnesses, but the sets of symptoms associated with many various diseases, cerebrovascular accidents and injuries, such as stroke, traumatic brain injury (TBI), severe poisonings or metabolic diseases. Prevalence of VS/UWS is assessed from 0.1 to 6.1 cases per 100 000 inhabitants, but we should be aware of diverse methodologies and possible misdiagnosis of VS/UWS and MCS [1,2]. Prevalence of MCS is assessed to 1.5 cases per 100,000 inhabitants. The prevalence of trauma cases among MCS patients varies from 21.9% to 53.8% [3]. Prevalence of LIS is unknown but is assessed as much lower than the prevalence of VS/UWS or MCS [4].

Neurological early and long-term rehabilitation plays a crucial role in the therapy of patients with DOC such as UWS or MCS. Model of care and neurorehabilitation in DOC is still being developed. Neurorehabilitation in DOC should be early, continuous, comprehensive and multidisciplinary. It should cover all stages of patient therapy and care, involving both DOC patients (taking into consideration possible transitions among DOC states during therapy), and post-DOC patients. Such neurorehabilitation is usually provided by various specialists called multidisciplinary therapeutic team. Such a therapy, neurorehabilitation and care cover i.a. care, hydration, nutrition, pain management, tools and technologies increasing objectivity of the clinical diagnosis, supporting of patients' responsiveness and its individual variability, at least several subsequent stages of the therapy (acute, early rehabilitation, chronic, long-term inpatient, long-term outpatient), and continuous monitoring of the heath status (usually semi-automated). Thus mortality and life quality indicators have significantly improved during recent twenty years [5-9].

There is a reasonable hypothesis that music may produce a high level of diagnostic and therapeutic outcomes as stimuli usually reflecting strong personal meaning in patients with DOC. Thus music therapists are members of the multidisciplinary therapeutic teams, especially in wards treating patients with DOC and post-DOC patients.

This paper attempts to answer how current clinical outcomes may reflect the influence of various factors including music's capacity. Based on their interdisciplinary perspective and previous experiences, the authors try to investigate the extent to which current occupations have been explored.

REVIEW

The authors analyzed the literature data concerning the results of the studies published until the first half of 2016, to sum up the current state of research. Research in the main databases: PubMed, PEDro, Health Source: Nursing/Academic Edition was made using specified keywords (music therapy, vegetative state, unresponsive wakefulness syndrome, minimally conscious state, locked-in syndrome and similar), inclusion and exclusion criteria (Table 1). Next, the authors sorted them all out into a coherent view of the current state.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Original papers published in journals, conference proceedings and books, reviews, case studies	Editorials, letters, etc.
Language of publication: Polish, English	Language of publication: other
Peer-reviewed	Non peer-reviewed

Results of the review are decribed below.

Multidisciplinary neurorehabilitation and music therapy

Music-stimulated activation is regarded as very beneficial to the treatment of several syndromes and diseases, mainly in young developing brain and by stimulating altered (e.d. due to trauma) neuronal connections. Thus musical tools and activities may support and facilitate neurorehabilitation. Mechanisms of the music-induced brain plasticity are rather well known but need for integration of neurobiological, cognitive, emotional, and behavior levels for general, multidimensional view. It may influence e.g. reorganization of language function, mirror neuron system, multimodal integration, motivation, and mood in selected cases [10,11]. However, these mechanisms are not always the same - there are many various interventions such as melodic intonation therapy and music-supported motor rehabilitation. Its application in the particular patient depends on many factors, including co-

occurrence with other modalities used within the neurorehabilitation process. Moreover neurorehabilitation plan may be modified in time. Pace and direction of the modifications above depend on the primary patient assessment, changes in the patient' clinical status, results of cyclic reassessment, and subsequently modified aims of the rehabilitation (wich may depend on rehabilitation stage: acute, post-acute, long-term, etc.). We are aware that rhythmic auditory stimulation may influence neurorehabilitation of stroke, Parkinson's disease, dementia, traumatic brain injury (TBI), cerebral palsy (CP), and other movement disorders, as far as hemispatial neglect and aphasia [12-17].

Approach to the music therapy in patients with neurological disorders is so diverse that we can perceive neurologic music therapy as a separate set of music therapists abilities. In such patients, music is used as alternative/supplementary way for stimulation of CNS functions unavailable in the normal way. During a special set of exercises music-based stimulation is generalized and transferred into non-musical functions (e.g. within a prime, cue, or coordinate movement, synchronization of biological rhythms, affective/ motivational system, etc.) [18].

Neurorehabilitation is useful in patients in every posttraumatic stage: physiotherapy is useful even in patients with mechanical ventilation (MP) or prolonged mechanical ventilation (PMV). DOC are cause of 15% of mechanical ventilation (MV) cases [19,20].

The effect of music and engaging sound on consciousness in healthy people and patients with disorder of consciousness

Music and engaging sound constitute a powerful multimodal (visual, auditory, and motor) stimulus. It is present in our life from the earliest ages, transmitting information to our brain, causing emotional responses, what may engage diverse and wide interconnected brain areas. Research on this phenomenon is still challenging to scientists and clinicians [21,22].

Neuroscience tries to explain the effect of music therapy on all levels of the nervous system = activity in patients with DOC, but full understanding is still incomplete. Music listening may constitute a part of an enriched environment setting. However, due to weak evidence, the therapeutic value of music-based interventions in patients with DOC is uneven or limited. The role of music therapy is thus complementary. Standardized clinical settings, protocols, and behavioral measures should be developed to increase its clinical validity, reliability, sensitivity, and objectivity [23-32].

The impact of the music and generally the sound on the consciousness depends on many factors, including not only music/sound complexity (rhythm, melody, etc.), and their familiarity to the listener, and associated emotions. Preferred music and engaging sound may modulate cognitive processes stronger than neutral music or sound. Self-related autobiographical features of the sound may be critical in severe cases, such as patients with DOC. Increased overall cortical arousal and awareness may influence networks responsible for the level of consciousness. Selected mechanisms may provide an increased level of consciousness [33-38]. Further therapeutic properties of music therapy shifted recently from psychosocial aspect toward the application of the structural elements of music (engaged sounds) within recovery of the motor control, speech, and language, and cognitive functions (attention, memory, etc.) [12,39].

Soria-Urios et al. studied musician's brain. Theses outcomes showed how the brain adapts to the needs of musical performance' improvement [22].

Own research

Authors are scientists, engineers, and clinicians with over ten years of experience in neurorehabilitation, psychology, and cognitive sciences, including patients with DOC. Experience above also covers the technical support of patients with DOC, post-DOC patients, and their families/caregivers.

Current clinical scores and scales, such as JFK Coma Recovery Scale-Revised or Reuth DOC Response Assessment (RDOC-RA) [40], are strongly addicted to the behavioral observation. More advanced and deeper solutions are needed, such as systems engaging brain-computer interfaces (BCI) with temporally, spatially, and semantically congruent audiovisual stimuli [41].

Neurocognitive Laboratory of Interdisciplinary Center for Modern Technologies at Nicolaus Copernicus University in Toruń participates in InteRDoCTor (International Interdisciplinary Research on Disorders of Consciousness) project. This project aims at:

- intensification of the interdisciplinary cooperation in order to conduct advanced research aimed at patients with DOC,
- providing integrated scientific and research support for diagnostic and neurorehabilitation processes.

Integrated therapy and specific medical care for patients with DOC should be provided through whole therapy: from proper diagnostical process to improved quality of patient's life during long-term care and rehabilitation.

An important part of research on music therapy in DOC patients constitute emotional effects of the music. Own breath sensor allows not only for novel applications of traditional breath

analysis technologies (including flow measurement and gasometry), but also breath-based emotions detection, and affective computing (automated emotion recognition and shaping) applied using own pulmonary biofeedback system [42]. Thus the emotional status of DOC-patient may be recognized and stabilized using various stimuli: auditory, visual or multimodal. The most important scientific problems are twofold:

- diagnosis of a patient with DOC is able to process whole aspects of the stimuli,
- validation of the stimuli set (i.e. which stimulus should cause particular emotion or sets of emotions).

Validity and reliability of our solutions are still limited for this moment.

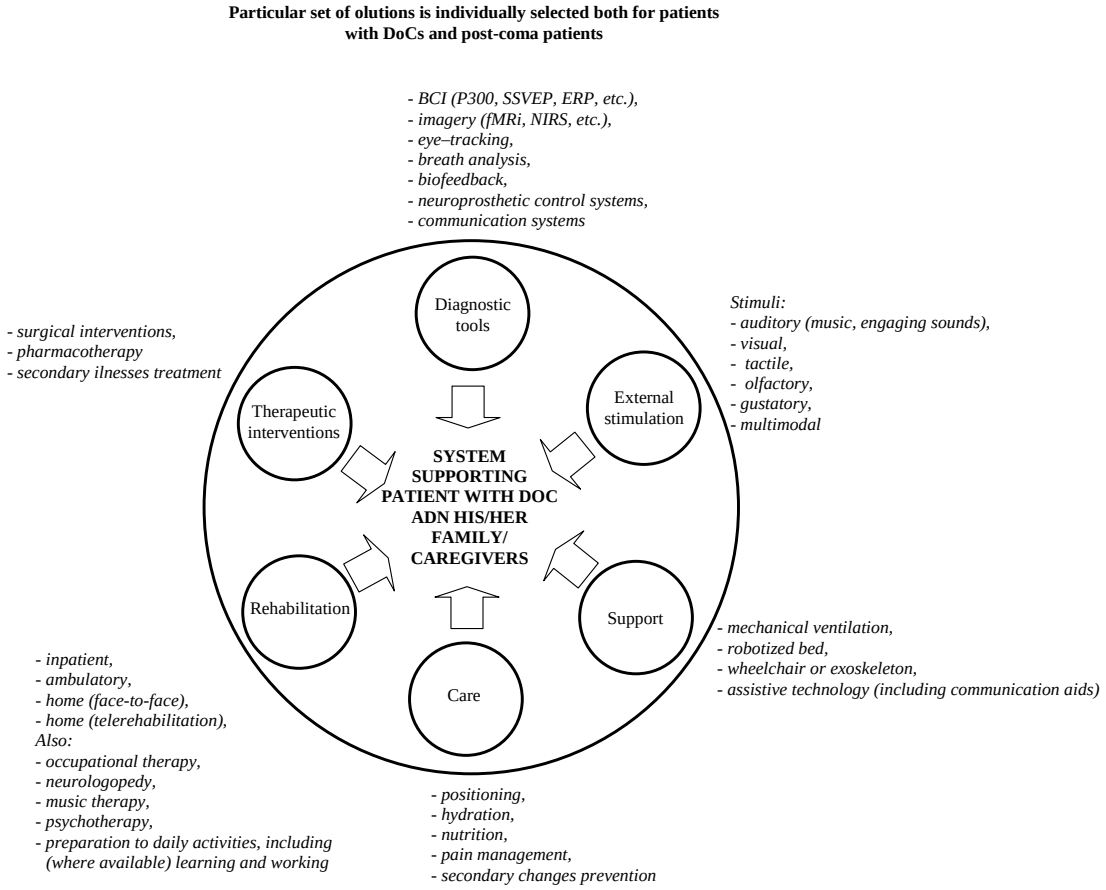

Figure 1. Music/sound stimuli within system supporting patient with DoC and his/her family/caregivers (own concept)

In our studies, we discuss previous hypotheses that beyond the phenomenon above there is a co-operation of two cortical networks: external fronto-parietal network and internal network. Based on our previous research we try to analyze possible engagement of the lower mechanism associated with brain stem function. This approach, based on own computational models, is original and was not published elsewhere. Coupling of low-level brain stem mechanisms and high-level cortical mechanisms may reflect further mechanisms, unknown yet. Hypothesis above may be associated with diagnostic and therapeutic outcomes in patients with DOC.

Brainstem function computational simulations showed that it is possible to reflect both conscious states and DOC within one computational model. Stimuli processing depends on such level of consciousness as far as kind and level of pathology. Now we work on a multilevel (tiered) model of brain stem activation through various stimuli, including music and sounds. Ascending reticular activating system (ARAS) regulates the level of consciousness and thus promotes various processing of the stimuli. Higher levels of processing (subcortical and cortical) link kind nad level of the stimulus, its direction, with context and associated meaning. Internal coupling within cortical areas shows linking with individual memory and emotional processes. The model above

is too general to link it with individual preferences and processes of the particular patient but shows general mechanism and CNS area involved in sound (or multimodal, such as auditory-visual) processing. This model creates the basis for more advanced, detailed models describing the whole causal chain of the particular DOC, e.g. auditory malfunction.

The research above is still pending. General conclusions from current outcomes concern high flexibility in the general structure of such systems, as far as planning and organization of the staff engaged. Changes in the clinical status of the patient are often unpredictable. Thus quick adaptation to the changes in the patients' clinical needs and goals is mandatory.

DISCUSSION

Despite long-term research way to the ultimate consensus concerning the way of diagnosis, neurorehabilitation in DOC- and post DOC–patients is still challenging. Approximately 40% of patients in VS are still regarded as misdiagnosed [8]. Combined prognostic factors (including i.e. music stimulus) may provide both better prediction accuracy and better clinical outcome in selected DOC patients.

Neurorehabilitation is individualized and multidisciplinary. Thus every intervention should be adapted to the particular patient needs and aims, other applied therapeutic modalities, and applied within cyclic reassessment of each patient's unique capacities and problems. Thus thinking about neurorehabilitation process we should take into consideration whole subsequent interventions, modified in time. The aforementioned situation makes difficult not only a clinical practice but also a scientific research. It is hard to gather a coherent group of patients with therapy evolving at the same pace. It is hard to compare two or more diverse patients with a similar disease since we know that differences within their central nervous system (CNS) and CNS damages may be critical for planning further rehabilitation way and pace. Randomized controlled trials are the only model of the therapy, useful in a limited group of patients. The importance of clinical guidelines and recommendations increases. There is a need to admit that selected ways of the music therapy belong to the "self-managed" (i.e. patient-managed or caregivers-managed) therapeutic methods, easy to administer within e-Health approach – as a part of telerehabilitation. Such approach decreases the influence of distance to the hospital or shortages of specialists, and may be useful within long-term neurorehabilitation. Moreover, they are easier to automate within the therapeutic patient environment. Compartmental studies concerning the efficacy of the traditional “face-to-face”, distant, and hybrid (partially traditional, partially telemedical) approaches are still needed [43-45].

Limitations of previous studies cover the lack of comprehensive approach to the whole multidisciplinary therapeutic process (from acute stage to the long-term home-based neuro-rehabilitation). There is lack both theoretical assumptions and clinical research, except the recent AmI-based concept of Dolce et al. [5] and our earlier proposal of integrated IT environment of disabled person [46].

Limitations of own studies still constitute a transfer of the most promising advanced technological solutions to a stage of regular operation in the neurorehabilitation wards. Rehabilitation robots, robotic beds, and adaptive technologies are still supportive solutions (not even substitutes), while core therapy, including decision-making process, is human-based. Despite the interdisciplinary team gathered within Neurocognitive Laboratory and InteRDoCTor project, there is still a limited support from clinicians (even within scientific research). Contrary to patients expectations, the traditional therapy is still a basis, despite accessible novel technologies. Common awareness of the occupations achieved due to the technical advancement of the DOC care and neurorehabilitation may change this situation.

Main limitation of the review constitutes few randomized controlled trials (RCTs) on bigger samples of patients with DOC as far as diverse methodologies of the assesment.

Directions for further research cover search for factors influencing the efficacy of the music therapy in patients with DOC and post-DOC, especially its application in pediatric neuro-rehabilitation [47]. Due to a variety of different patient stages, associated with diverse areas, kinds, and levels of disorders, there is a wide spectrum of possible stimuli and responses combinations indicating presence or absence of awareness [48]. Huge variety of applied tools need an agreement (correlation) in their diagnostic outcome and require a level of interrater reliability. The sensitivity of various tools may be nonlinear, and diverse for each domain (auditory, visual, motor, etc.). The multidisciplinary process of neuro-rehabilitation may “disturb” selective efficacy, but general (holistic, long-term, for all domains) efficacy may be much higher. The cause of such situation may be the fact that high quality and adequate (even low) pace of stimuli may be prevalent over a high number of stimuli. Dedicated protocols for validation of assessment tools are still needed.

Neurologic music therapy has to develop coherently with other parts of the EBM-based clinical practice within the multidisciplinary therapeutic team. Common goal setting, therapeutic

co-operation, effectivity through synergy, cyclic reassessment and discussions are a key part of teamwork abilities. RCTs covering clinical outcome studies (including music therapy) should provide evidence if there may be observed the significant superiority of neurorehabilitation with music over the one without music [18].

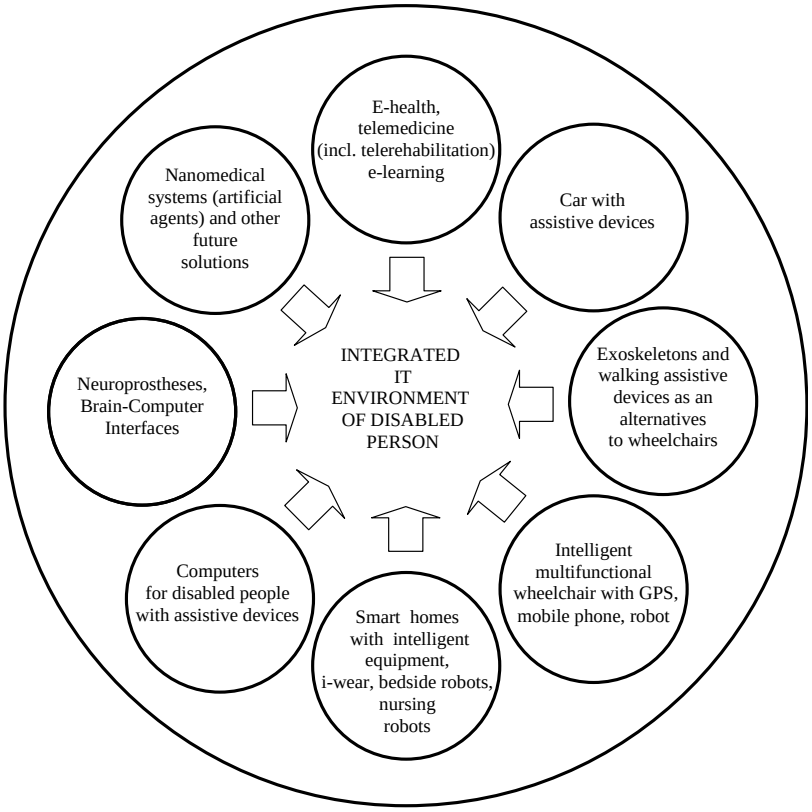

Figure 2. Integrated IT environment of disabled person (own concept) [46]

CONCLUSIONS

Music therapy constitutes important adjunctive therapeutic method within contemporary neurorehabilitation, including patients with DOC and after DOC. There is a deep belief that further understanding of music-associated CNS processes and a multidisciplinary clinical perspective of the neurorehabilitation allow to apply it to the therapy of a much wider range of symptoms and conditions. Activation of the brain as a result of music and/or engaging sounds stimulation still requires further research, but its explanation on the ground of neuroscience seem to be easier due to relatively novel solutions: computational models of multistage brain processing based on recent EEG and MRI outcomes. There is a need for further education of specialists in music therapy, dedicated to hard clinical work with DOC and post-DOC patients. One of the most important clinical tasks is the coherent application of music therapy by the multidisciplinary therapeutic team to achieve common goals.

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Conflicts of interest

None declared.

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