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Effects of a multi-sensory environment on brain-injured patients: Assessment of spectral patterns

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ABSTRACT

Snoezelen® multi-sensory (SMS) environment has been commonly applied as a therapeutic strategy to alleviate the symptoms associated to a wide variety of pathologies. Despite most studies have reported a wide range of positive revealed short-term changes associated to SMS intervention, little has been done to systematically quantify its effects. The present study examined electroencephalographic (EEG) changes in 18 individuals with brain-injury and 18 healthy controls during SMS stimulation. The experimental design included a multi-sensory stimulation session carried out in a Snoezelen® room, preceded and followed by a 5 min quiet rest condition. Spontaneous EEG activity was analyzed by computing the relative power in conventional EEG frequency bands. The results suggest that SMS stimulation induces a significant increase ($p < 0.05$, Wilcoxon sign-ranked test) of relative power for low frequency bands (i.e., theta and alpha bands) and a significant decrease ($p < 0.05$, Wilcoxon sign-ranked test) for fast rhythms (i.e., beta1, beta2 and gamma bands). In addition, statistically significant differences ($p < 0.05$, Mann–Whitney U-test) between both groups were found in relative power of theta band. Our findings suggest that the slowing of EEG oscillatory activity may reflect the state of relaxation induced by the SMS stimulation. Furthermore, this study presents a new strategy to assess the short-term effects of SMS stimulation therapy in comparison to previous studies using subjective observations and qualitative data.

1. Introduction

Multi-sensory therapy is an activity which usually takes place in a specially equipped room aiming to stimulate the primary senses through light, sound, touch and smell. Snoezelen® multi-sensory (SMS) rooms contain tactile, visual, olfactory, auditory, vestibular and proprioceptive sensory equipment, such as mirror light balls, aromatherapy oils, optic fiber bundles, calming music, bubble tubes and other nominal sensory stimuli [1]. These stimuli can be presented in isolation or in combination, intensified or reduced and shaped for passive or active interaction [2]. A SMS environment is designed to create a feeling of comfort and safety, where the individual can relax, explore and enjoy the surroundings [3]. This environment has been applied to a wide range of conditions, such as aged people with dementia [4–7], mental health service recipients [8], adults with profound mental retardation [1,2], people with intellectual disabilities [9,10], individuals with autism [2,11], breastfeeding women [12] and children with Rett disorder [13] and severe brain injury [14], among others.

Although some authors have revealed negative outcomes when SMS therapy is applied [11], most studies have shown a wide range of positive effects. Preliminary investigations have suggested that multi-sensory therapy is beneficial for people with sensory and learning disabilities [9]. Moffat et al. revealed positive short-term benefits in people with dementia exposed to SMS environments, which experienced positive mood states such as happiness and calmness [5]. In other study, van Weert et al. observed that Snoezelen® rooms improved the nonverbal and verbal communication in nursing home residents with dementia during morning care [7]. Lotan and Shapiro suggested that regular visits to a SMS environment may provide a partial solution in management the difficulties of young children with Rett disorder [13]. Studies that measured physiological data also suggested the benefits of SMS therapy. In this sense, Hotz et al. analyzed the heart rate and muscle tone in children recovering from severe brain injury after SMS stimulation [14]. Their results revealed significant decreases in heart rate and muscle tone in all affected extremities for each subject, suggesting that SMS therapy produces a beneficial use in this population. Baillon et al. conducted a study to assess the effects of Snoezelen® intervention on the mood and behavior of people

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with dementia [15]. They observed that multi-sensory stimulation produced a reduction in agitation behavior and heart rate, though these effects were highly dependent on the analyzed subject. In sum, most of these studies have shown positive benefits of the SMS therapy, although the results are usually based on subjective observation or on qualitative data. These types of information do not provide an objective measure for understanding the mechanisms underlying SMS stimulation and therefore further efforts are required to systematically analyze and quantify the effects of SMS environments.

Multi-sensory stimulation is thought to affect central nervous system by inducing a state of relaxation in participants. This particular state of the brain alters the functional organization of cortical networks [16]. Therefore, the electroencephalographic (EEG) activity can be expected to quantify the changes induced in brain rhythms, since EEG oscillations measure the electrical field produced by the synchronous cortical network activity. To support this approach, several EEG studies have reported changes in the power spectrum during the exposure to a variety of relaxation and meditation techniques, though little is still known about the underlying neural mechanisms in stimulation therapies [16–18].

The purpose of this study was to describe the changes induced in the EEG brain oscillations by a SMS environment on individuals with brain-injury and healthy controls. The experimental protocol involved a multi-sensory stimulation session, where several auditory and visual stimuli were presented to the participants. In addition, a previous and a posterior 5 min quiet rest condition, where participants were asked to relax, close their eyes and remain awake, were applied. EEG activity was analyzed by computing the relative power in conventional EEG frequency bands before and after the multi-sensory stimulation session. The spectral patterns were compared to assess the spectral changes induced by a multi-sensory environment in brain dynamics. Furthermore, self-reported measures related to the level of relaxation and the global level of satisfaction with the SMS stimulation session were correlated with the observed changes in relative power. To sum up, we wanted to test the hypothesis that SMS stimulation elicits measurable changes in the EEG activity of brain-injured patients and to determine whether they can be related to a state of relaxation.

2. Materials

2.1. Participants

Informed consent was obtained from all participants and all patients' guardians prior to enrolling in the study. Likewise, all enrolled subjects and patients' guardians were previously informed about the background of the study, therapeutic techniques and experimental protocol. The study protocol was approved by the Ethics Committee at the "Centro de Referencia Estatal (CRE) para la Atención a Personas con Grave Discapacidad y Dependencia" (San Andrés del Rabanedo, Spain). A total of forty-one participants were initially selected to participate in the study. However, the final inclusion of participants was based on the following inclusion and exclusion criteria:

- Inclusion criteria: (1) age ranged between 25 and 50 years; (2) brain-injured patients showing evidence of pathologic condition on computed tomography (CT) or magnetic resonance imaging (MRI) scan; (3) Glasgow coma scale (GCS) score > 3; (4) collaborative in the EEG recording procedure; (5) ability to complete a full length neuropsychological evaluation; (6) ability to participate in the SMS stimulation session; (7) participants were not taking any drug that could affect the EEG recordings at the time of study.
- Exclusion criteria: (1) absence of neuroimaging data in patients; (2) secondary head trauma, penetrating brain injury or brain injury as result of child abuse; (3) psychiatric problems, neurological disorders, history of a chronic disease for the preceding 6 months, or pre-existing physical, neurological, psychiatric or developmental disorders; (4) mental retardation; (5) pregnancy; (6) presence of a pacemaker or other implanted medical device that may interfere with the EEG equipment.

Twenty-three participants with mild to severe brain injury from a National Reference Center for people with severe disabilities named "CRE para la Atención a Personas con Grave Discapacidad y Dependencia" (Spain) were initially included in the study. However, five of them were excluded due to excessive electromyographic activity and to the lack of attention during SMS stimulation session. Therefore, eighteen brain-injured patients (11 men and 7 women, age = 38.4 ± 5.1 (29–46) years, mean ± standard deviation M ± SD (range)) were finally included in the study.

Eighteen volunteers (9 men and 9 women, age = 37.6 ± 5.6 (30–48) years, M ± SD (range)) were also enrolled in the study as a control group among the staff of the "CRE para la Atención a Personas con Grave Discapacidad y Dependencia". They were cognitively normal controls with no history of neurological or psychiatric disorders. Additional sociodemographic data for brain-injured patients and controls are presented in Table 1. Non-significant differences were observed in the mean age ($p > 0.05$, Mann–Whitney U-test) or gender ($p > 0.05$, Mann–Whitney U-test) of both groups.

Brain injury diagnosis was made on the basis of exhaustive medical, physical and neuropsychological examinations, which were performed at the "CRE para la Atención a Personas con Grave Discapacidad y Dependencia" (Spain). Table 2 summarizes diagnostic information for the brain-injured patients. As indicated in Table 2, patients displayed a wide range of lesion distribution patterns, though a bilateral location of brain damage is the most common (61.1%). Nine of the patient's hospital records reported direct bilateral occipital lobe damage as part of their injury, whereas two indicated bilateral frontal lobe damage. Six patients also exhibited damage in frontal, parietal and occipital lobes (four in right hemisphere and two in left hemisphere), while one subject suffered damage in left temporal and parietal areas.

Neuropsychological testing was performed on all participants. A summary of test performance is presented in Table 3. Mini-Mental State Examination (MMSE) was used as the screening test to assess the cognitive deficit [19]. Brain-injured patients and controls obtained a mean MMSE score of 27.6 ± 0.7 points (range 27–29) and 30.0 ± 0.0 points (range 30–30), respectively. In addition, a neuropsychological examination was applied to analyze higher-level cognitive functions. For that purpose, 9 subtests of the Spanish

Table 1
Summary of the sociodemographic data of brain-injured patients and controls.

Characteristics	BI	C
Gender (no. of subjects)		
Male	11	9
Female	7	9
Age (years)		
Mean ± SD (range)	38.4 ± 5.1 (29–46)	37.6 ± 5.6 (30–48)
Occupation pre-injury (no. of subjects)		
Full time	8	14
Part time	0	2
Casual	5	0
No employment	5	2
Education (years)[a]		
Mean ± SD (range)	11.0 ± 2.3 (8–15)	16.8 ± 4.2 (10–21)

BI: brain-injured patients; C: controls; SD: standard deviation.
[a] Since 6 years.