International Journal of Psychophysiology 89 (2013) 181–194

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

REM and NREM power spectral analysis on two consecutive nights in psychophysiological and paradoxical insomnia sufferers☆,☆☆

Geneviève St-Jean, Isabelle Turcotte, Alexandra D. Pérusse, Célyne H. Bastien *

École de psychologie, Université Laval, Québec, Québec, Canada, G1V 0A6
Laboratoire de neurosciences comportementales humaines, Centre de recherche de l'Institut universitaire en santé mentale de Québec, 2525 de la Canardière, Québec (Québec), Canada, G1J 2G3

ARTICLE INFO

Article history:
Received 5 November 2012
Received in revised form 30 May 2013
Accepted 3 June 2013
Available online 13 June 2013

Keywords:
Psychophysiological insomnia
Paradoxical insomnia
Power spectral analysis
Cortical activation
Sleep

ABSTRACT

The objectives of the study were to examine EEG activities using power spectral analysis (PSA) of good sleepers (GS), psychophysiological (PsyI) and paradoxical (ParI) insomnia sufferers on two consecutive nights. Participants completed three nights of PSG recordings in a sleep laboratory following a clinical evaluation. Participants were 26 PsyI, 20 ParI and 21 GS (mean age = 40 years, SD = 9.4). All sleep cycles of Nights 2 and 3 were retained for PSA. The absolute and relative activity in frequency bands (0.00 to 125.00 Hz) were computed at multiple frontal, central and parietal sites in REM and NREM sleep. Mixed model ANOVAs were performed with absolute and relative PSA data to assess differences between groups and nights. Over the course of the two nights, more absolute delta activity at F3, C3, and P3 was observed in ParI compared with PsyI suggesting deactivation of the left hemisphere in ParI and/or hyperactivation in PsyI. Further analysis on absolute PSA data revealed that differences between groups relate mostly to NREM. In REM, lower relative activity in slower frequency bands was found in ParI in comparison with GS and less relative theta activity was found in PsyI compared with GS implying higher activation in insomnia. In addition, between nights variability has been found in absolute powers of faster frequency bands (beta to omega). Signs of decreased cortical activity in absolute PSA in NREM combined with increased relative cortical activation in REM were found in ParI which might contribute to the misperception of sleep in ParI.

1. Introduction

Nearly 10% of the general population is suffering from chronic insomnia (Morin et al., 2006). In addition, a complaint of insomnia is expressed by one fifth of those who consult a generalist (Vgontzas and Kales, 1999). Associated daytime consequences are often the reason for medical consultation and treatment seeking (Morin et al., 2006). Chronic insomnia is defined by a complaint of difficulty falling asleep, awaking at night or too early in the morning, or of poor sleep quality for more than a month that conducts to significant distress or alters social or professional functioning (American Psychiatric Association and American Psychiatric Association. Task Force on DSM-IV, 2000; American Sleep Disorders Association. Diagnostic Classification Steering Committee, 1990). The International Classification of Diseases (Organisation Mondiale de la Santé, 1992) adds the criterion of three nights of sleep difficulty per week. Many studies have investigated the sleep macrostructure of insomnia sufferers although less work has been dedicated to the microstructure of their sleep.

Studies have found several differences in terms of physiological and cortical activation between chronic primary insomnia sufferers (PI) and good sleeper controls (GS). PI usually present greater metabolic rate as well as faster cardiac rhythm on a 24 h basis compared to GS (Bonnet and Arand, 1995; Monroe, 1967). Polysomnography (PSG) studies suggest that PI's sleep macrostructure is impaired, presenting longer sleep-onset latency (SOL), more stage 1 sleep and less stage 3 and 4 sleep (Merica et al., 1998; Gaillard, 1976; Frankel et al., 1976). Sleep microstructure, mainly assessed through the activity of different frequency bands at central sites with power spectral analysis (PSA), presents also particularities in PI compared to GS. At sleep onset, less delta power and more beta and alpha spectral powers are observed (Merica and Gaillard, 1992; Lamarche and Ogilvie, 1997; Staner et al., 2003). Altogether, results in non rapid eye movement (NREM) sleep suggest higher beta1, beta2 and gamma spectral power (Merica et al., 1998; Perlis et al., 2001a). Furthermore, elevated powers in alpha, sigma and theta frequencies have been reported (Krystal et al., 2002; Nofzinger et al., 1999). In rapid eye movement (REM) sleep, some studies have also

Abbreviations: BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; GS, Good sleeper controls; IDI, Insomnia Diagnostic Interview; ISI, Index of Severity of Insomnia; NREM, Non rapid eye movement; ParI, Paradoxical insomnia sufferers; PI, Primary insomnia sufferers; PSA, Power spectral analysis; PSG, Polysomnography; PsyI, Psychophysiological insomnia sufferers; REM, Rapid eye movement; SD, Sleep diary; SE, Sleep efficiency; SOL, Sleep onset latency; TST, Total sleep time.

☆ All authors have indicated no financial conflicts of interest.
☆☆ Research supported by the Canadian Institutes of Health Research (# 49500 and 86571) to C. H. Bastien.

* Corresponding author at: École de psychologie, FAS-Local 1012, 2325, rue des Bibliothèques, Université Laval, Québec (Qc), Canada, G1V 0A6. Tel.: +1 418 656 2131x8344; fax: +1 418 656 3646.
E-mail address: celyne.bastien@psy.ulaval.ca (C.H. Bastien).

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http://dx.doi.org/10.1016/j.ijpsycho.2013.06.004

reported increased activity in the beta frequency band (Merica et al., 1998; Freedman, 1986; Perlis et al., 2001b). These increased activities in faster frequency bands, suggesting increased cortical activation, support theories stating that insomnia is linked to emotional and physiological hyperactivation as predisposing, precipitating, and maintaining factors (Bonnet and Arand, 2010).

PI sufferers represent a heterogeneous group of individuals. Subclassifications of the diagnosis of chronic insomnia exist (Organisation Mondiale de la Santé, 1992) and include, among others, psychophysiological insomnia sufferers (PsyI) and paradoxical insomnia sufferers (ParI). The former relates to a condition where the difficulties are caused by a conditioned aroused state at bedtime and the latter where objective reports do not corroborate the patient's complaint of sleep difficulty. Edinger et al. (2004) proposed that the privileged interpretation of ParI would be the absence of sleep pathology while a complaint is expressed. The following criteria were suggested: it is necessary that the absence of sleep pathology be shown as expressed by a total sleep time (TST) of more than 6.5 h and sleep efficiency (SE) of at least 85% at night PSG recordings. Moreover, important sleep difficulties should be reported. As such, it may be the report of a subjective impression of little or no sleep most of the time and rare normal nights. Otherwise, the average sleep time, in at least a week of sleep logs, is well below normative values, often with several sleepless nights and no daytime naps. In addition, a consistent and marked difference between PSG data and subjective sleep estimates is present. Since these guidelines are recent, few research protocols have used them to examine possible discrepancies between types of insomnia. Although seemingly thorough, these guidelines are nonetheless lacking operationalization. We intend to remedy to this lack of operationalization in the present paper.

Among studies that did categorize PI in PsyI and ParI, although ParI were then called 'sleep state misperception', larger absolute spectral amplitude in NREM in frequency bands from 14 to 54 Hz (beta and gamma bands) in ParI than GS (Perlis et al., 2001b) was reported. On the other hand, Krystal et al. (2002) observed larger absolute spectral amplitude in frequency bands ranging from 8.5 to 30 Hz (sigma, alpha, and beta bands) in stages 2 and 4 of ParI compared to PsyI and GS. These interesting results suggest higher activation in ParI than PsyI. These authors have also found trends for relations between NREM spectral power in ParI and subjective rest, TST and SE, three variables that can be related to sleep quality. As such, the differences in absolute spectral power observations between PsyI and ParI are not necessarily or only attributable to group belonging, but could also reflect a difference in the perceived sleep quality. This information is meaningful in view of the many studies that have used only one night of PSG recording, this procedure leading to the possible observation of a first night effect where participants' sleep does not represent their usual sleep because of the unfamiliar experimentation setting (Hauri and Olmstead, 1989). Moreover, previous studies did not assess the natural fluctuation of sleep difficulties in insomnia, instability of sleep quality (Vallieres et al., 2005), while collecting PSA data. Consequently, laboratory settings and sleep variations are to be considered.

In addition to the above mentioned variations in studies' protocols, some authors have reported absolute, and others relative PSA measures. Such inconsistencies in PSA literature make it even more laborious to compare and relate the conclusions of each study so to brush a comprehensible picture of cortical activation in insomnia. Whereas absolute PSA is the measure of the actual power in the designated frequency bands, relative PSA refers to the proportion of the power in a frequency band in relation with the power in all other frequency bands. Thus, these two measures offer different viewpoints of the activity in frequency bands and are both of interest. As relative power calculation reduces the variance between subjects due to individual anatomical differences and tissue conductance found in absolute power, it has the inconvenience of distorting the data interpretation by creating dependencies between bands as an increase of one frequency band is understood as a decrease of other bands. Still, the evaluation of relative power spectra is indicated for the detection of subtle shifts in brain function over time by normalizing fluctuations in total power seen across individuals or within one individual across several recordings (Chen and Black, 2005). Unfortunately, cortical activation at other sites than central, such as frontal and parietal regions, has been poorly explored. The comparison of multiple sites in statistical models certainly contributes to burden the interpretation of the results and seems unappealing. On the other hand, if not studied, it will limit the cortical mapping of activity of insomnia and its cognitive underpinnings. To our knowledge, only one study has compared multiple sites while studying ParI ($n = 10$) and GS ($n = 10$) (Marzano et al., 2008). Although this study targeted sleep-onset only, 1 Hz binned preliminary results showed local functional impairment in the synchronization process of ParI compared to GS. In this regard, ParI tended to display more beta and less delta and sigma relative power on anterior scalp locations (mainly centroparietal). Although these preliminary findings are interesting, we still do not know about nightly sleep/awakenings. Furthermore, it is now recognized that frontal regions are associated with planning, judgement and memory, among others, and parietal regions with sensory information processing (Purves et al., 1999), which could explain the subjective recall of the night, e.g. in sleep diaries.

Therefore, the aim of this study is to examine the sleep microstructure (absolute and relative PSA) differences between GS, PsyI and ParI on the second and third night of a three night protocol at multiple scalp sites (frontal, central and parietal). It is hypothesized that previous results will be replicated i.e. elevated activity in alpha, sigma and beta frequency bands in ParI compared to GS and PsyI will be found at central sites. As for frontal and parietal sites, far less explored in PSA studies, the objective is to provide a description of the cortical activity in those regions although they should also show signs of elevated activity in ParI. Finally, it is expected that more PSA variability between nights in insomnia sufferers (INS) will be observed since they might also display a variation in their objective sleep quality and report a variation in their subjective sleep quality over the course of the two nights of recording, as for diagnostic criteria permit such observation in sleep difficulties.

2. Method

2.1. Participants

Volunteers from 25 to 55 years of age were recruited through local newspaper advertisement. On the basis of the three group criteria, 26 PsyI (14 females, 12 males), 20 ParI (14 females, 6 males) and 21 GS (12 females, 9 males) participated in this study. Participants had a mean age of 40.21 (9.38) years.

2.1.1. Control group

GS must have shown, on the two week sleep diary completed before laboratory nights, less than three nights with sleep difficulties (i.e. SOL or awakenings of more than 30 min or a TST of less than 6.5 h) per week, as well as a SE of 85% or more, and a mean TST between 6.5 to 8.5 h per night. On the Insomnia Severity Index, ISI (Morin, 1993), GS had to report no sleep difficulty and no complaint of daytime difficulty related to sleep and a score less than 8. During laboratory nights, participants who showed an objective sleep efficiency of less than 85% on nights 2 and 3 were discarded from the study.

2.1.2. Insomnia group

Insomnia participants had to report at least three nights per week of sleep difficulty (i.e. SOL or awakenings of more than 30 min or a TST of less than 6.5 h) as well as SE of less than 85%. Moreover, they had to report at least one moderate negative daytime consequence attributed to the loss of sleep and a score over 15 on the ISI. The difficulties lasted more than six months and were not secondary to another medical, psychological or sleep disorder or to medication.