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Supine posture affects cortical plasticity in elderly but not young women during a word learning-recognition task

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ABSTRACT

The present research investigated the hypothesis that elderly and horizontal body position contribute to impair learning capacity. To this aim, 30 young (mean age: 23.2 years) and 20 elderly women (mean age: 82.8 years) were split in two equal groups, one assigned to the Seated Position (SP), and the other to the horizontal Bed Rest position (hBR). In the Learning Phase, participants were shown 60 words randomly distributed, and in the subsequent Recognition Phase they had to recognize them mixed with a sample of 60 new words. Behavioral analyses showed age-group effects, with young women exhibiting faster response times and higher accuracy rates than elderly women, but no interaction of body position with age group was found. Analysis of the RP component (250–270 ms) revealed greater negativity in the left Occipital gyrus/Cuneus of both sitting age-groups, but significantly left-lateralized RP in left Lingual gyrus only in young bedridden women. Elderly hBR women showed a lack of left RP lateralization, the main generator being located in the right Cuneus. Young participants had the typical old/new effect (450–800 ms) in different portions of left Frontal gyri/Uncus, whereas elderly women showed no differences in stimulus processing and its location. EEG alpha activity analyzed during a 3 min resting state, soon after the recognition task, revealed greater alpha amplitude (i.e., cortical inhibition) in posterior sites of hBR elderly women, a result in line with their inhibited posterior RP. In elderly women the left asymmetry of RP was positively correlated with both greater accuracy and faster responses, thus pointing to a dysfunctional role, rather than a compensatory shift, of the observed right RP asymmetry in this group. This finding may have important clinical implications, with particular regard to the long-term side-effects of forced Bed Rest on elderly patients.

1. Introduction

Past literature on body posture provided evidence that many psychophysiological processes, including cortical activity and cognitive functioning, are significantly altered during space-related microgravity condition, Head-Down and horizontal Bed Rest (Fritsch-Yelle, Charles, Jones, Beightol, & Eckberg, 1994; West, 2000). According to Vaitl, Gruppe, Stark, and Possel (1996), Head-Down as well as horizontal Bed Rest compared with standing and seated position elicited an increase of low-frequency EEG rhythms, i.e., the delta and theta bands, in an open-eyes, resting-state task. Since delta band typically marks cortical inhibition and is considered a marker of brain sufferance or pathological condition when it appears in the adult waking brain (De Jongh et al., 2003; Gloor, Ball, & Schaul, 1977; Penolazzi, Spironelli, & Angrilli, 2008; Spironelli & Angrilli, 2009a; Spironelli, Penolazzi, Vio, & Angrilli, 2006; Spironelli, Penolazzi, & Angrilli, 2008; Spironelli, Angrilli, Calogero, & Stegagno, 2011), authors suggested that the Bed Rest body position induced a cognitive impairment (Vaitl et al., 1996). Consistent with this result, recent studies in male participants submitted to 3-h Head-Down position revealed a lack of startle reflex habituation, and therefore reduced reflex plasticity (Messerotti Benvenuti, Bianchin, & Angrilli, 2011), and a significant inhibition of cortical emotional responses (i.e., P3 and Slow Positive Potentials) elicited by pleasant and unpleasant *vs.* neutral IAPS slides (Messerotti Benvenuti, Bianchin, & Angrilli, 2013). Furthermore, young healthy males laid in a 6° Head-Down Bed Rest position for 2 h exhibited significantly reduced, subjective pain perception and the amplitude of the P1, N1 and P2 pain-related ERP components (Spironelli & Angrilli, 2011). Interestingly, also the horizontal body position – i.e., a less extreme and more ecological position – was able to influence pain-related somatosensory processing in healthy women, supporting the hypothesis that posture alters sensory thresholds (e.g., Fardo, Spironelli, & Angrilli, 2013) and, more in general, EEG activity (Chang et al., 2011; Rice, Rorden, Little, & Parra, 2013). Chang et al. (2011) investigated the association

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between autonomic response (using the HRV index) and cortical activity (measured with EEG) by manipulating participants' body position (supine vs. upright) in resting state. After changing position from upright to supine, authors found both a significant increased amplitude of slow frequency (i.e., delta and theta) rhythms – in line with past studies on simulated microgravity (e.g., Vaitl et al., 1996) – and a significant decrease of activity in high-frequency (i.e., beta and gamma) bands. Also Thibault, Lifshitz, Jones, and Raz (2014) found significant decrease of high-frequency bands in supine rather than upright posture, regardless of task (resting state or mental counting) and eyes (open or closed). All these studies agreed on the general effects of body position on brain functioning, showing a selective inhibition of complex perceptual/cognitive abilities, and suggesting that body posture alters cortical functioning, by involving different neural networks (or the same neural network, but in a different way) during lain supine *vs.* seated upright. In general, real or simulated microgravity induce accelerated aging and represents at physiological level an interesting model of human aging (see, for a review, Vernikos & Schneider, 2010), however the cognitive and psychophysiological domains of the hypothesized posture-related decline and its possible interaction with natural aging have been relatively neglected, so far. Concerning the possible physiological mechanisms which might link horizontal posture with cortical inhibition, arterial baroreceptor reflex – adjusting blood pressure in relation with body posture – may represent the most probable system which is involved in short/mid-term effects of postural change. Although the neural circuit connecting posture-related baroreceptor firing to cortical inhibition is still not well known, the effects of postural/blood pressure changes on cortical inhibition are well documented (Angrilli, Mini, Mucha, & Rau, 1997; Dworkin et al., 1994; Fardo et al., 2013; Spironelli & Angrilli, 2011). Among the many methods available for measuring brain functioning, the EEG technique appears particularly suited, as it allows to study cortical brain activity in different conditions and body positions. Indeed, although upright MRI scanners exists, they are rare and use only low magnetic fields which do not allow a good fMRI sequencing with respect to that achieved by standard scanners, in which, however, participants necessarily laid supine during task execution and data acquisition.

The effects of body position on cortical functioning becomes even more important in view of its possible implications for bedridden patients. Indeed, a long-term hospitalization, in which patients are necessarily confined to bed, could significantly alter their cognitive and perceptual functioning, in particular within the elderly age. Indeed, bedridden patients – that usually lie for long time on the bed – are often elderly individuals with age-related cognitive decay. To the best of our knowledge, there were so far no studies which investigated the effects of body posture on cognition and cortical activity in healthy elderly participants. To this end, we carried out an experiment in which two different age-groups, i.e., young and elderly adults, were assigned to sitting or horizontal Bed Rest position for 2-h, and the electrophysiological correlates underlying learning and recognition skills were analysed. In this view, one of the most common paradigms for investigating short-term memory-related plastic changes requires a stimulus learning phase followed by a recognition judgment task. Typically, participants have to study a list of stimuli, usually written words, afterward, in a recognition task presenting both old and new words, they have to decide whether a given stimulus belongs to the studied list or not. This, at behavioral level, typically results in the well known "old/new effect" (Chee, Goh, Lim, Graham, & Lee, 2004; Curran & Dien, 2003; Evans & Federmeier, 2007; Rugg & Doyle, 1994; Spironelli, Galfano, Umiltà, & Angrilli, 2011). At the electrophysiological level, the old/new effect develops 400–800 ms after stimulus onset (Friedman & Johnson, 2000), is marked by increased positivity for old vs. new stimuli, and reaches the peak amplitude over parietal sites (implicit memory component; e.g., Rugg et al., 1998) or frontal locations (familiarity component; e.g., Curran, 2000). However, Spironelli, Galfano et al. (2011) showed that the Recognition Potential (RP) – a negative component which occurs in left occipito-temporal sites and reaches the maximum amplitude in an interval between 130 and 260 ms after word onset (Cohen et al., 2000; Dehaene, Le Clec'H, Poline, Le Bihan, & Cohen, 2002; Martín-Loeches, Hinojosa, Casado, Muñoz, & Fernández-Frías, 2004; Spironelli & Angrilli, 2007, 2009b; Spironelli, Penolazzi, & Angrilli, 2010; Spironelli, Penolazzi, Vio, & Angrilli, 2010) – represents the first marker of the old/new stimulus recognition. With respect to the plastic word learning task, a simple lexical decision task shows a solid and well preserved mechanism of automatic written word detection, the typical RP which is left-lateralized also in pathological neurodegenerative disorder (i.e., mild/moderate AD patients, Spironelli, Bergamaschi, Mondini, Villani, & Angrilli, 2013). Furthermore, after a 5-week cognitive training, the RP component of AD patients showed an increased amplitude over left posterior locations, revealing the possibility of a neural reorganization even in a neurodegenerative disease like dementia. For all mentioned characteristics, using the linguistic version – i.e., the Word task, with only word presentation – of the paradigm validated by Spironelli, Galfano et al. (2011), the RP represents a good ERP candidate to test the effects of body posture in different group-age. Based on past findings on Bed Rest effects (e.g., Fardo et al., 2013; Messerotti Benvenuti et al., 2013; Vaitl et al., 1996), we expected to detect a typical left posterior RP in both young and elderly participants assigned to sitting position (control) groups, and a lack of posterior left RP lateralization for the horizontal bedridden (experimental) groups, especially in the elderly group, in which natural decline is expected to interact with bed-rest induced cortical inhibition.

2. Material and methods

2.1. Participants

Thirty young women (age: mean = 23.2 years, Standard Deviation [SD] ± 1.4 years) and twenty elderly women (age: mean = 82.8 - years, SD ± 8.0 years) were enrolled in the experiment. All participants were fully right-handed (scores at the Edinburgh Handedness Inventory: mean = 90.5%,SD ± 12.75%; Oldfield, 1971) Italian native speakers, and had normal or corrected-to-normal vision. For elderly participants, a complete assessment of an ophthalmologist ensured that all women had good eyesight, and this was an inclusion criterion for experiment participation. In addition, none of participants had been treated for neurological or psychiatric disorders, nor were they under psycho-pharmacological treatment at the time of testing.

All women gave their written informed consent to the study, according to the Declaration of Helsinki. The experimental procedures were approved by the Ethics Committee of the Department of General Psychology (University of Padova, Italy).

2.2. Stimuli, tasks, and procedure

Stimuli consisted of 120 polysyllabic Italian, highly concrete and imaginable words (mean written word frequency = 137.02, SD ± 28.29, range = 100-200; Bertinetto et al., 2005; average word length = 6 letters/2.5 syllables, SD ± 1.68/0.77 respectively, range = 3-9 letters/2-4 syllables). Two lists of 60 words[1] were generated and pre-tested in order to rule out differences in word frequency. Statistics confirmed no significant differences between the two samples (136.98 ± 28.96 vs. 137.07 ± 27.86; $t_{128} = -0.02$, *n.s.*), and lists were counterbalanced between participants so that across the experiment identical words appeared in each Visual Field (VF) for each

[1] With respect to our past work (Spironelli, Galfano et al., 2011), in the present experiment we have reduced the number of words to be memorized from 125 to 60, because the elderly sample included 80-years-old women, and their learning skills were relatively reduced compared with those of participants of the past study (Spironelli, Angrilli et al., 2011; Spironelli, Galfano et al., 2011).