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Research Report

Decision making after 50 days of simulated weightlessness

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ABSTRACT

By restricting physical activity levels, the bed rest simulation of weightlessness could be associated with changes in prefrontal cortex functioning that manifest as cognitive decrements, particularly for executive cognitive functions. We aimed to determine if performance on an executive function task was indeed affected by bed rest. The Iowa Gambling Task, a card game measuring real-life decision making processes, was administered to 25 healthy males (aged 21–45 years) selected to undergo 60 days of 6° head-down tilt bed rest for the 2nd Berlin BedRest Study (BBR2-2). Testing was conducted either 6 days before beginning bed rest ($n=13$) or on the 51st day of bed rest ($n=12$). The task performance scores of subjects tested before bed rest were not significantly different from those tested during bed rest. However, subjects tested during bed rest failed to adapt their card selection strategy as the Iowa Gambling Task progressed. This was unlike the subjects tested before bed rest, who switched between decks on consecutive card selections less frequently in latter stages of the task. An influence of prolonged bed rest on decision making could have implications for the planning of human spaceflights to Mars, or for any circumstance in which adequate physical activity levels are not achieved.

1. Introduction

In simulating the physiological effects of weightlessness, bed rest has proven useful for understanding how the human body responds to spaceflight, with changes in the cardiovascular system, body fluid regulation, skeletal muscle, and bone metabolism now well documented (Pavy-Le Traon et al., 2007). Also of interest has been the effects of bed rest on psychological functioning, including aspects of cognition that range between simple reaction time, mental arithmetic, short term memory and executive functions (high-order aspects of cognition involved in planning and carrying out goal-directed behaviour, Jurado and Rosselli, 2007). However, after reviewing 17 bed rest studies with cognitive variables we concluded that reliable effects of bed rest on either general cognition or particular types of cognitive functioning remain to be established (Lipnicki and Gunga, 2009). This is because of contrasting results, with reports of cognitive performance decreasing, increasing, and being unaffected by bed rest within each of the cognitive domains or test types that has been investigated. One reason for this variation across studies may be differences in experimental protocol, with the numerous test sessions of some studies potentially facilitating practice effects that could mask or overcome a theoretically plausible detrimental influence of bed rest on cognition.

A primary reason for expecting any true effect of bed rest on cognition to be detrimental is the severe restriction in normal physical activity levels associated with bed rest. It is known for all stages of the lifespan that participation in aerobic fitness training leads to gains in cognitive functioning

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(Hillman et al., 2008). The mechanisms underlying this effect await clarification, but are thought to include an array of changes in brain structure and function occurring across multiple levels, from the neurochemical to the gross structural (Hillman et al., 2008). For example, in older adults it has been shown that participation in aerobic exercise enhances task-related activity (Colcombe et al., 2004) and increases grey and white matter volume (Colcombe et al., 2006) in regions of the prefrontal cortex. Executive cognitive functions are heavily dependent on the prefrontal cortex (Jurado and Rosselli, 2007), and performance on executive function tasks is especially benefited by physical training in older adults (Colcombe and Kramer, 2003). Evidence for relationships between participation in physical activity, prefrontal cortex function and cognition also comes from studies with young adults. Cardiac vagal tone is a peripheral marker of prefrontal activity (Ahern et al., 2001; Gianaros et al., 2004; Lane et al., 2001) that increases with aerobic exercise training (Tulppo et al., 2003), and young men with higher cardiac vagal tone were found to outperform those with lower cardiac vagal tone on executive function tasks (Hansen et al., 2003; 2004). Cardiac vagal tone decreases during bed rest (Hirayanagi et al., 2004a, 2004b), suggesting the possibility of changes in prefrontal cortex functioning that manifest as cognitive performance decrements.

In simulating weightlessness, a detrimental effect of bed rest on cognitive functioning could have serious implications for the human missions to Mars being contemplated by both the European Space Agency (ESA) and NASA (2008). It is in this context that we are currently trying to determine if, as expected, bed rest does indeed have detrimental cognitive effects. Reported here are early results with the Iowa Gambling Task (IGT), an executive function test with a high sensitivity for detecting deficits in decision making associated with a vast array of neurological, psychological, and psychiatric conditions (see Brand et al., 2007). Performance of the IGT requires subjects to select one card at a time from any of four identical-looking decks, with each card having both a monetary gain and loss (potentially zero) that are revealed after selection and follow a schedule that differs across the decks. The aim of the task is to maximise overall gain, and to which end two of the decks are disadvantageous, with high gains overcome by large unpredictable losses that generate an overall loss with repeated selections. The other two decks are advantageous, with only a small gain per card but a loss schedule favouring a net gain. Normal, healthy subjects typically develop a preference for the advantageous decks as the task progresses (Bechara et al., 1994; 2000); they have also been shown to make less frequent switches between decks than patients with neurological conditions (Johnson et al., 2006; Sinz et al., 2008).

Our reasons for choosing to administer the IGT involve the ventromedial prefrontal cortex, with performance impaired by lesions of (Bechara et al., 1994), and correlated with activity in (Northoff et al., 2006), this region. Changes in activity of the ventromedial prefrontal cortex have also been correlated with changes in cardiac vagal tone (Gianaros et al., 2004; Lane et al., 2001). The decrease in cardiac vagal tone during bed rest (Hirayanagi et al., 2004a, 2004b) suggests that functioning of the ventromedial prefrontal cortex may be altered during bed rest. The IGT was also considered appropriate because it measures real-life decision making (Bechara et al., 1994), given the potential seriousness associated with making poor decisions in weightless environments. To avoid the practice effects that may have influenced the results of some previous bed rest studies, we administered the IGT before bed rest in some subjects and only after 50 days of bed rest in others. In doing this we tested the hypotheses that subjects administered the IGT before bed rest would perform the task better, and switch their choice of card less frequently, than subjects administered the IGT after 50 days of bed rest.

2. Results

Mean overall IGT performance scores were −3.50 ($SD=32.27$) for bed rest subjects and 4.15 ($SD=27.54$) for controls; performance scores for each 20-card selection block are shown in Fig. 1. IGT scores increased linearly across blocks 1–5, $F(1, 23)=11.974$, $p<.01$, though did not differ significantly between bed rest and control groups, $F<1$.

The mean number of switches between decks on consecutive card selections throughout the IGT was 62.50 ($SD=19.24$) for bed rest subjects and 56.85 ($SD=20.67$) for controls; Fig. 2 shows the number of switches per selection block. The number of switches did not differ significantly between bed rest and control groups or between blocks, $F<1$. There was however a group-by-block interaction, $F(2.38, 54.62)=3.465$, $p<.05$: in contrast to bed rest subjects, controls displayed a significant change in selection strategy as the

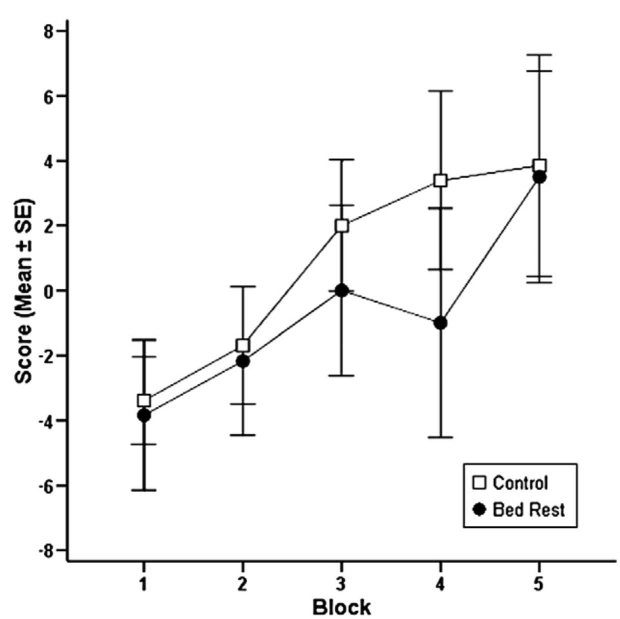

Fig. 1 – IGT performance scores for bed rest subjects and controls. Scores are the number of selections from advantageous decks (C′ and D′) minus the number of selections from disadvantageous decks (A′ and B′); higher scores indicate better performance. Data is shown in blocks of 20 consecutive card selections.