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The effect of 30% oxygen on visuospatial performance and brain activation: An fMRI study

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Abstract

This study aimed to investigate the hypothesis that administration of the air with 30% oxygen compared with normal air (21% oxygen) enhances cognitive functioning through increased activation in the brain. A visuospatial task was presented while brain images were scanned by a 3 T fMRI system. The results showed that there was an improvement in performance and also increased activation in several brain areas in the higher oxygen condition. These results suggest that a higher concentration of breathed oxygen increases saturation of blood oxygen in the brain and facilitates performance.

Introduction

The brain is the most metabolically active organ in the body. This almost exclusively consists of the oxygen-dependent breakdown of glucose. A number of brain imaging techniques have identified that there is an enhanced intake of glucose and oxygen into brain areas that are differentially active depending on the types of cognitive tasks involved (Horwitz, McIntosh, Haxby, & Grady, 1995). Sufficient glucose and oxygen can improve cognitive functioning while hypoglycemia and hypoxia results in reversible cognitive impairments (Gold et al., 1985, Noble et al., 1993). Similarly, an aging-related cognitive decline is attributed to the compromised delivery of oxygen and glucose through the cerebral vasculature (Eustache et al., 1995).

The administration of a glucose drink has been found to enhance memory performance (Craft, Murphy, & Wernstrom, 1994). This phenomenon is observed in all ages and is greater in the elderly (Benton, Owens, & Parker, 1994). Like glucose, oxygen is also reported to enhance the cognitive performance. Oxygen inspiration for 1 min prior to the presentation of a word list resulted in a significant increase in the number of words recalled 10 min or 24 h after the presentation (Moss and Scholey, 1996, Scholey et al., 1999). From these results, it is concluded that external oxygen administration has positive effects on memory formation. Furthermore, reaction time is much faster with external oxygen administration when responding to previously presented words (Scholey et al., 1999). Oxygen administration is found to improve the aspects of everyday memory, including shopping list items and matching names to faces (Winder & Borrill, 1998). The studies on the effects of oxygen administration have focused on cognitive functioning and not the direct effects on the brain. As a result, research is necessary to identify the underlying brain mechanism that accounts for these behavioral effects produced by increased oxygen administration.

We should note that not all cognitive measures are improved by oxygen administration. For example, the level of working memory on a computerized test was unaffected by oxygen administration (Moss et al., 1998, Scholey et al., 1998) and induced hyperoxia had not effect on forward nor backward digit span performance (Scholey et al., 1998), which is consistent with the results reported on glucose (Fox, Raichle, Mintum, & Dence, 1998). While there are these studies on the effects of external oxygen administration on memory, there are few studies concerning the effects of oxygen on other cognitive functions, such as language, learning, reasoning, and visuospatial processing.

We hypothesized that transient administration of highly concentrated oxygen activates

energy production and enhances neural activation in the brain during a cognitive task, which in turn improves performance. To test this hypothesis, we simultaneously measured the level of visuospatial performance and neural activation in the brain with functional magnetic resonance imaging (fMRI).

In the late 1980s, functional imaging started to be used to study brain activity using electroencephalogram and positron emission tomography (PET). FMRI as measured by the changes in the blood oxygenation level-dependent (BOLD) signal was introduced as a non-invasive method with an accurate spatial and relatively high temporal resolution (Ogawa et al., 1992).

The first purpose of this research was to compare the effect of administration of air with 30% oxygen to that of air with 21% oxygen on behavioral performance and neural activation in the brain during a visuospatial task. Second, based on these results, we attempted to identify the neural substrates and mechanism responsible for the behavioral effect produced by the transient oxygen administration.

Section snippets

Participants

Eight healthy right-handed male college students (23.5 ± 3.2 years old) participated in the study. None of the participants reported having a history of psychiatric or neurological disorders. The overall procedure was explained to all subjects who released consent for the procedure. All examinations were performed under the regulations of our Institutional Review Committee. …

Oxygen administration

The oxygen supply equipment (OxyCure Co. Korea), providing 21 and 30% oxygen in the air at a constant rate of 8 L/min, was …

Behavioral performance

The response accuracy rate of the task items was analyzed to identify the effect of oxygen on the visuospatial performance. Seven out of eight subjects showed a higher mean accuracy rate in the visuospatial task under administration of 30% oxygen than with 21% oxygen (Table 2), while the other one subject showed the same mean accuracy rate in both experimental conditions. The mean accuracy rate was 50.63 ± 8.63 (mean ± *SD*) and 62.50 ± 9.64 for 21 and 30% oxygen administration, respectively, with a …

Discussion

The results showed that the mean response accuracy rate for the visuospatial task increased significantly under the administration of the air with 30% oxygen when compared to that of the normal air condition. This suggests that 30% of oxygen administration also has a positive effect on visuospatial performance as it does on memory as reported by others (Moss and Scholey, 1996, Scholey et al., 1999, Winder and Borrill, 1998).

Studies of neural networks and brain function related to visuospatial …

Acknowledgment

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>
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