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The effect of transient increase in oxygen level on brain activation and verbal performance

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Abstract

This study aimed to investigate the hypothesis that a transient increase in oxygen level administered to subjects increases the BOLD effect in brain regions associated with verbal cognitive functioning and enhances performance accuracy. A verbal task was presented while brain images were scanned by a 3T fMRI system. The accuracy rate on the verbal task was enhanced during 30% oxygen administration compared to 21% oxygen administration. The neural activations were observed at the occipital, parietal, temporal and frontal lobes, during both 21% and 30% oxygen administration. Increased brain activations were observed in the right middle frontal gyrus, right inferior frontal gyrus, right superior frontal gyrus, cingulate gyrus, left middle temporal gyrus, and left fusiform gyrus with 30% oxygen administration. These results suggest that a higher concentration of breathed oxygen increases saturation of blood oxygen in the brain, and facilitates verbal cognitive performance.

Keywords: Oxygen concentration level; Verbal performance; Brain activation; fMRI

1. Introduction

The brain is known as the most metabolically active organ for its size in the body. Similarly, the brain functions as remarkably dependent on the blood for its immediate and constant supply of oxygenated energy along with other essential energy substrates (e.g. glucose) (Peppiatt and Attwell, 2004). A number of brain imaging techniques have identified an enhanced intake of glucose and oxygen in brain areas that get activated differentially depending on the types of cognitive tasks involved (Horwitz et al., 1995). Oxygen is essential for physical and mental activities in humans, especially for brain function. However, it is partially known that oxygen administration improves memory performance and visuospatial cognitive performance. Sufficient glucose and oxygen can improve cognitive function while hypoglycemia and hypoxia result in reversible cognitive impairments (Noble et al., 1993; Gold et al., 1995). Administration of oxygen is reported to enhance cognitive performance. For example, it has been demonstrated that oxygen inspiration for 1 min prior to the presentation of a word list resulted in a significant increase in words recalled, after intervals of 10 minutes and twenty-four hours following oxygen administration. Undisputedly, external oxygen administration had positive effects on memory formation. Furthermore, the reaction time significantly decreased with additional external oxygen administration when responding to previously presented words (Scholey et al., 1999). Oxygen administration is found to improve many aspects of everyday memory, including shopping list items and matching names to faces (Winder and Borrill, 1998). However, there are few studies related to the effects of oxygen administration on language, learning, reasoning, and emotions using brain imaging methods, such as PET or fMRI.

We investigated the effect of 30% oxygen administration on visuospatial cognitive performance using fMRI (Chung et al.,

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Table 1
Verbal tasks and items

Origin of items	Type	
	A (55)	B (55)
Verbal analogy items from the GATB (25)	Common (25)	
Verbal analogy items from an intelligence test (30)	Odd number (15)	Even number (15)
Verbal antonym items from an intelligence test (30)	Even number (15)	Odd number (15)

(# of items).

2004). Increased activations in both the parietal, and frontal lobes with 30% oxygen administration were observed. Performance accuracy during 30% oxygen administration was also found to increase. It was assumed that the effect of a highly concentrated oxygen administration on the level of visuospatial cognitive performance might be attributed to an increase of brain activations associated with visuospatial processing. It is the purpose of the study to investigate the possible positive influences of oxygen administration on verbal cognitive performance and any concomitant brain function.

For this purpose, a comparison was made between the effect of an administration of air with 21% oxygen versus air with 30% oxygen on behavioral performance level and brain activations during a verbal task. Researchers also attempted to identify the neural substrates and the mechanism responsible for differences in behavioral performance produced by transient oxygen administration.

2. Methods

2.1. Participants and oxygen administration

Nine healthy right-handed male college students (25.1 ± 0.7 years old) participated in the study. Participants were screened to exclude a history of psychiatric or neurological disorders. The overall procedure was explained to all subjects. All subjects signed participation consent forms. All examinations were performed under the regulations of our Institutional Review Committee. The oxygen supply equipment (OxyCure Co. Korea), providing 21% and 30% oxygen concentration in the air at a constant rate of 8 L/min, was developed specifically for this study. In order to maintain the steady flow and constant level of oxygen concentration, oxygen was administered to subjects using masks. No information on oxygen concentration levels was provided to subjects. The oxygen level in the blood was ascertained to confirm changes in concentration level, when oxygen concentration was altered. Accordingly, SpO_2 was increased from 97.5% to 98.1% within 2 min after the administered oxygen level was changed from 21% to 30%.

2.2. Verbal performance task

Two subsets of a verbal cognition task (consisted of verbal analogy and antonym tasks) with similar difficulty were developed. Items were selected from Korean versions of an intelligence test and the General Aptitude Test battery (Lee, 1982; Park, 1985). A total of 85 items were selected from these tests. These items were then divided into two subsets (Type A and B) of 55 items each shown in Table 1. As shown in Fig. 1, the verbal analogy testing required the subject to select the word which had the same relationship as one of the given words. The verbal antonym testing required the subject to select the word which had a different meaning among 4 words. Group testing of the two subtests was administered to 263 college students. For verbal analogy testing, 40 items with a 37–89% accuracy rate were selected from 55 items. For verbal antonyms testing, 16 items with 31–80% accuracy rate were selected from 30 items. Finally 28 pairs of items with similar difficulty were selected.

2.3. Experimental procedure

The experiment consisted of two runs of the verbal cognition test. One run was performed under the condition of 21% level of oxygen and the other with 30% oxygen level. Every subject was to complete two runs and the order of 21% and 30% oxygen administration was counterbalanced. Each run consisted of 4 blocks; each block had both control and verbal items. Each run took approximately 8 min (2 min per block) as shown in Fig. 2. Five minutes prior to their run, each subject was supplied with oxygen of either a concentration of 21% or 30%. Subjects then were given time to adapt to the oxygen administration. Oxygen supply was stopped after the first run. During a resting period of 30 min following the first run, anatomical images were scanned. The second run was carried out with the opposite concentration of oxygen. The control and verbal tasks were presented using SuperLab 1.07 (Cedrus Co.). Items were projected onto a screen and subjects were instructed to provide the correct answers. In response to control tasks, subjects were instructed to press the button corresponding to the number (1, 2, 3, or 4) projected on the screen. In the verbal task, subjects were asked to press the button as quickly as possible to correctly identify the number of an item projected on the screen (7 items per block). The two verbal tasks were counterbalanced across high and low oxygen levels. Prior to the experiment, each subject was asked to listen carefully to procedural instructions. Subjects were trained to do

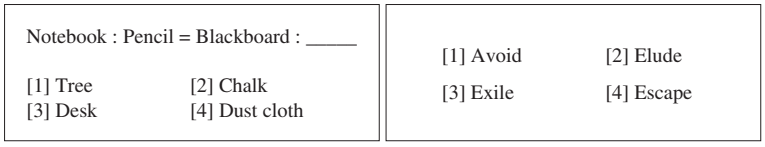

Fig. 1. Examples of items.