Effect of vestibular stimulation on spatial and verbal memory in college students

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ABSTRACT

Background. Excessive stress may have an adverse effect on learning and memory of students. It was reported that stimulation of the vestibular system enhances memory through its connections with the hippocampus, limbic system and neo cortex. This study aims to assess the effectiveness of vestibular stimulation in the modulation of memory in healthy human subjects.

Methods. For this longitudinal follow-up study, we assessed spatial and verbal memory of participants followed by vestibular stimulation. A total of 240 healthy college students of 18–24 years, of either sex were selected after obtaining written consent from them. Participants were randomly assigned into four groups—control male and female group and vestibular male and female groups. Vestibular stimulation was administered by making the participants swing on a swing, according to their comfort (back to front direction) as standardized by previous methods. Spatial and verbal memory tests were used to assess memory. Data were analysed using two-way ANOVA followed by the Bonferroni post-hoc tests to compare differences between groups.

Results. Baseline values of spatial and verbal memory scores were not significantly different between the control and intervention groups. Significant enhancement was observed in spatial memory following vestibular stimulation in males but not female subjects. Contrary to this, significant decrease in spatial memory was observed in both males and females due to pre-examination stress who did not receive any vestibular stimulation. Significant enhancement was observed in verbal memory scores in both males and females who received vestibular stimulation, whereas verbal memory was significantly decreased in males and females in the control groups during the pre-examination period.

Conclusion. Our study provides evidence to support vestibular stimulation as an efficient method to enhance memory and to prevent pre-examination associated stress-induced changes on memory. We recommend vestibular stimulation as a simple approach to improve verbal memory among students to cope with their pre-examination stress.

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INTRODUCTION

Memory is the storage of acquired information for later recall. Academic performance, the pressure to succeed and examinations for selection to postgraduate courses are common sources of excessive stress in college students.[1] Such stress may have an adverse effect on learning and memory of students. The vestibular system is sensory in nature and senses angular and linear acceleration of the head. It also generates vestibulo-ocular and vestibulo-spinal reflexes.[2] However, it is also essential for reading, writing and speech.[3] Vestibular lesions may cause impaired cognitive functions, including problems with learning, memory and attention.[4] Several studies have reported the effects of stress on learning and memory.[4] Animal studies have also reported that stimulation of the vestibular system enhances memory through its connections with the hippocampus, limbic system and neocortex.[5,6] We aimed to assess the effectiveness of vestibular stimulation in the modulation of memory in humans.

METHODS

Study design

In this longitudinal, follow-up study we assessed spatial and verbal memory of participants three times. The first assessment (baseline values) was done during regular classes (with no examination in the preceding and succeeding 2 weeks). The second assessment was done after the intervention and during regular classes, and the third assessment was done one week before university theory examinations (stressed state).

Setting

The study was done at the Little Flower Medical Research Centre and Little Flower Institute of Medical Sciences and Research, Angamaly, Kerala.

Study population

Two hundred forty healthy college students, 18–24-years-old of either sex were enrolled after obtaining written consent. Participants involved in drug/alcohol abuse, and those taking any kind of medication (including history of use of corticosteroids in the past year, antidepressants or on hormonal supplements including contraceptives) or suffering from any somatic or mental disorders, ear infections or any vestibular disturbances, and those with cardiorespiratory disorders were excluded. Participants were randomly assigned to four groups.

Control groups (no vestibular stimulation): 60 males and 60 females.

Intervention groups (vestibular stimulation administered): 60 males and 60 females.

After recording baseline values, vestibular stimulation was administered everyday to the intervention groups and post-intervention values were obtained during regular classes (mean [SD] duration of intervention was 146 [5.6] days in males and 147 [6] days in females) and during the pre-examination period (mean duration of intervention was 268 [5] days in males and 268

[6] days in females) followed by vestibular stimulation. However, values were recorded at the corresponding points in time.

Vestibular stimulation

Vestibular stimulation was administered by making the participants swing on a swing, according to their comfort (back to front direction) once in a day, for five days in a week during their leisure time (8:30–9:30 a.m., 11 a.m.–12 noon, 1–2 p.m. and 4–5 p.m. in four groups) as described previously.[7,8]

Assessment of memory

Spatial and verbal memory tests described in the literature were used and done in consultation with the psychiatrist of our hospital.[9–11] The test material was projected on a screen, allowing 10 seconds for each slide. After the 10 slides were shown, a mathematical problem (e.g. 2–7+5–1+10+11–2+5) was projected on the screen and the students were asked to immediately recall and write down (or in the case of spatial memory, to draw) within 60 seconds the 10 test items that had been shown to them. To test verbal memory, standard nonsense syllables of three letters, e.g. ZOL, were selected from a prepared list. The test for spatial memory consisted of 10 simple line drawings. Geometrical or other shapes that could be described verbally were not used, e.g. a square or a circle. The drawings were simple and easy to reproduce. For both verbal and spatial memory tests a correct answer was scored as '1' and a wrong answer was scored '0'. Different sets of 10 nonsense syllables and drawings were presented on different time periods of data collection.

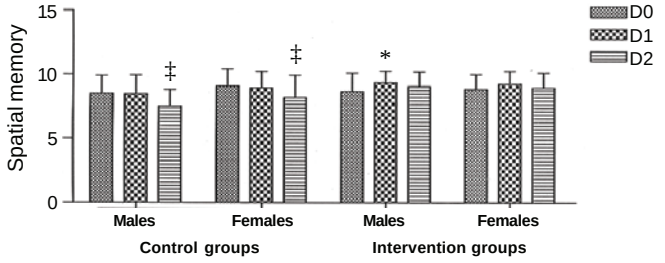

FIG 1. Mean (SD) spatial memory scores before and after vestibular stimulation

* p<0.05 ‡ p<0.001 D0 baseline (during regular classes) D1 post-intervention (during regular classes) D2 post-intervention (during pre-examination)

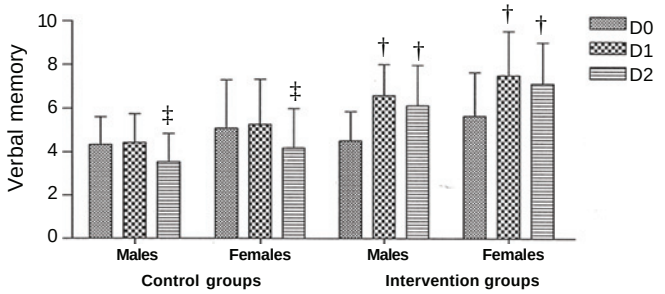

FIG 2. Mean (SD) verbal memory scores before and after vestibular stimulation

† p<0.01 ‡ p<0.001 D0 baseline (during regular classes) D1 post-intervention (during regular classes) D2 post-intervention (during pre-examination)

Ethical consideration

The study was approved by the Institutional Ethics Committee and done in accordance with the *Ethical Guidelines for Biomedical Research on Human Participants, 2006* by the Indian Council of Medical Research and the Declaration of Helsinki, 2008.

Data analysis

Data analysis was done using SPSS version 20.0. All data were expressed as mean (SD). Pre- and post-data were analysed using 2-way ANOVA followed by the Bonferroni post-hoc test to compare differences between groups. A value of $p<0.05$ was considered statistically significant.

RESULTS

Baseline values of spatial and verbal memory scores were not significantly different between the control and intervention groups. Significant enhancement was observed in spatial memory ($p<0.05$) following vestibular stimulation in males but not females. Contrary to this, a significant decrease ($p<0.001$) in spatial memory was observed in both males and females due to pre-examination stress among those who did not receive vestibular stimulation. Significant ($p<0.01$) enhancement was observed in verbal memory scores in both males and females who received vestibular stimulation, whereas verbal memory was significantly decreased ($p<0.001$) in the non-stimulation groups during the pre-examination period.

DISCUSSION

Existing neurobiological literature supports the association of vestibular system with memory.[12] Vestibular stimulation modulates the activity of place cells in the hippocampus, where integration of the sensory input and spatial memory occurs.[13] It has also been reported that lesions in the vestibular system can impair spatial memory.[14] The vestibular system improves cognition through its connections with the hippocampus, limbic system, neo-cortex and hypothalamic–pituitary–adrenal axis.[15–18] It was reported that otolith vestibular stimulation effectively modulates cognition and interestingly vestibular stimulation was found to improve spatial tasks significantly than non-spatial tasks.[19] This may be due to use of vestibular information by the hippocampus to form spatial memories.[20] Indeed low amplitude noisy Galvanic and caloric vestibular stimulation have been reported to enhance spatial and verbal memory.[21,22] We observed that pre-examination stress decreased spatial and verbal memory significantly in male and female students ($p<0.001$). Interestingly, vestibular stimulation significantly ($p<0.05$) improved spatial memory in males but not females. However, verbal memory was significantly ($p<0.01$) enhanced in both males and females following vestibular stimulation. The male-specific improvement in spatial memory observed in our study is indeed interesting and requires further research to understand this gender-specific beneficial effect of vestibular stimulation. However, this is not surprising as previous studies have reported gender differences in spatial and verbal memory.[23] As our study was designed to address aspects of pre-examination stress, wherein verbal memory may be more important than spatial memory, our observations on the beneficial effects of vestibular stimulation on improving verbal memory in both male and female students is interesting. It could be a simple but valuable method to help students cope with pre-examination stress and improve their performance in the examinations.

Pradhan *et al.* reported that pre-examination stress negatively effects cognitive functions in students and females were more affected than males.[24] This effect may be due to the release of excess epinephrine and glucocorticoids.[25] Glucocorticoids can cross the blood–brain barrier and bind with its type I and type II receptors located in the brain and modulate cognitive functions.[26] Our study provides further evidence of the deteriorating effects of pre-examination stress on cognition as we observed significant impairment of spatial and verbal memory in the control groups. However, this effect of stress was prevented by vestibular stimulation in the intervention groups. This may be due to inhibition of the HPA axis, the sympathetic–adrenal–medullary (SAM) axis and vagal stimulation by vestibular stimulation.[27,28]

Limitations

We did not have a control group to whom standard methods of relaxation could be given.

Conclusion

Our study provides evidence for vestibular stimulation as a method to enhance memory and prevent pre-examination stress-induced changes in memory. We recommend vestibular stimulation as a simple approach to improve verbal memory of students to cope with their pre-examination stress.

Conflicts of interest. None

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