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Enhancing Academic Performance and Psychological Well-being Through Sound Vibration Reading: An Experimental Study

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Abstract

This study investigates the development and application of monitoring equipment for sound vibration in neuroscience, focusing on its effects on high school students' academic performance and psychological well-being. The premise of the research is based on the phenomenon where sound vibrations from speech induce vibrations in the cranial bones, which is hypothesized to improve cerebrospinal fluid circulation, thus enhancing nutrient exchange within brain tissues. This enhancement could potentially elevate cognitive capabilities, academic achievements, and reduce psychological stress among students.

To verify the effects of sound vibration on learning outcomes, controlled experiments were performed in schools located in Beijing and Henan, China. The study divided participants into groups based on their habit of reading aloud. In Beijing, an experimental group engaged in scheduled reading sessions was compared to a control group that did not practice reading aloud. The participants were students without a pre-existing habit of reading aloud, and the reading material covered subjects like language arts and English. The sessions were integrated into the school's daily schedule. A novel, wearable head-mounted device developed in collaboration with Tsinghua University's Architectural Acoustics Laboratory measured the sound vibration levels during these sessions.

The research findings reveal a significant correlation between the quantity of cranial vibration from reading aloud and improvements in students' academic performances. The experimental group exhibited notable grade improvements, especially in the subjects included in the reading sessions. Furthermore, the study examined the relationship between sound vibration from reading aloud and psychological stress by assessing changes in saliva cortisol levels before and after the reading activities. Results demonstrated a negative correlation between sound vibration levels and cortisol levels, indicating that increased cranial vibration from reading aloud could potentially lower psychological stress.

In conclusion, the study provides evidence that sound vibration reading positively influences high school students' academic achievements and reduces psychological stress. The development of a portable, head-mounted sound vibration monitoring device presents a new avenue for leveraging the benefits of sound vibration in educational and psychological interventions. This research contributes to the understanding of how physiological processes influenced by external physical stimuli, like sound vibration, can impact cognitive and psychological outcomes, offering a novel approach to improving student performance and well-being.

Keywords: *Sound Vibration, Academic Performance, Psychological Well-being, Cerebrospinal Fluid Circulation*

Principles of Sound Vibration Neuroscience

The cranial bone has a unique anatomical structure, playing a crucial role in the life of vertebrates and supporting various sensory organs in mammals, including those for hearing, smell, vision, and taste [1] . In 2014, Tsinghua University experimentally confirmed the phenomenon of cranial sound vibration during speech. For instance, one can feel the vibrations by touching the top of the skull while pronouncing the "ee" sound [2].

The cranial bone consists of 23 bones, with the mandible being the only one articulating with the cranial bones; the rest are interlocked like a jigsaw puzzle. Inside the cranial bone and up to the cerebral cortex, there are three membranous structures: the dura mater, arachnoid mater, and pia mater. The dura mater is rich in blood vessels and nerves, and its inner layer has folds forming septa like the falx cerebri and tentorium cerebelli, which extend into the brain's gaps. When the cranial bone

vibrates, the dura mater closely attached to it also vibrates, transmitting these vibrations deeply into the brain.

The subarachnoid space between the arachnoid mater and pia mater, filled with cerebrospinal fluid, occupies the entire subarachnoid space, ventricular system, and subarachnoid space of the spinal cord [3]. Since the brain is immersed in Cerebrospinal Fluid (CSF), this fluid is crucial for brain metabolism. Lacking a lymphatic system and with underdeveloped veins, the CSF takes on a lymphatic role, being the primary pathway for clearing brain waste [4].

Neurons in the brain, totalling hundreds of billions, are not welded together but have microscopic gaps. During the transmission of nerve impulses, neurotransmitters are released into these gaps and quickly diffuse into neighbouring neurons for information transfer. Frequent brain activity leads to inevitable accumulation of metabolic waste in these gaps, which needs to be removed via CSF circulation. Although the brain weighs less than 2% of body weight, it consumes 20% of oxygen and 15% of cardiac output, indicating its high metabolic rate [5].

CSF is produced by the brain's ventricles and flows over the surface of the brain's gyri and sulci, collecting in the subarachnoid space, and finally exiting the brain through arachnoid granulations and the olfactory nerve pathway into venous blood or lymph. Vibrations enhance the outflow of CSF from the arachnoid granulations and olfactory nerve passage, akin to how shaking a sieve facilitates material passing through it. This accelerates CSF circulation and brain metabolism.

Given this theory, in this project, we used MRI scans to observe this phenomenon. The brain's fixed structure within the cranial cavity limits nutrient diffusion efficiency, but vibration enhances nutrient and waste exchange deep within the brain, much like shaking a glass of water speeds up sugar diffusion . Thus, reading aloud aids brain metabolism, enhancing brain vitality, promoting academic performance, and fostering a positive psychological state. Numerous studies corroborate these effects of reading aloud [1].

Development of Sound Vibration Testing and Head-Mounted Monitoring Devices

Before this experimental research, we utilized professional vibration testing equipment (Fig. 1), attaching test probes to the centre of the cranial bone using ear clips. However, such equipment is costly, challenging to use simultaneously with many students, requires AC power, and has many wires, making it impractical for daily monitoring of students' sound vibration levels. After surveying teachers and students from several middle schools and gathering feedback, we developed a more suitable testing device for high school students. Different designs were tested, including hat, glasses, and hairpin styles, but due to varying development stages among high school students, differences in head size, limited space for large testing equipment, and the need for a snug fit and comfort, we finally settled on a portable headband-style monitoring device, co-developed by the Tsinghua University Architectural Acoustics Laboratory and related electronics laboratories.

Figure 1: Professional Vibration Testing Equipment

Figure 2: Portable Head-Mounted Monitoring Device

Students from various schools and grades were invited to try on the device, and their feedback on wearability and measurement effectiveness was collected, leading to the completion of the portable head-mounted monitoring device.

Experiment on the Relationship Between Sound Vibration from Reading and Academic Performance

At Beijing Changping No.2 High School of Beijing, we randomly selected four classes (each with equal

teacher allocation and curriculum) and divided them into two groups (classes 1 and 4 with 80 students as the experimental group, and classes 2 and 3 with 76 students as the control group). These students did not have a prior habit of reading aloud. The experimental group engaged in daily reading sessions for one semester, while the control group did not participate in reading aloud. The reading materials included Chinese and English, alternating during the school's self-study periods totalling 50 minutes a day. A head-mounted sound vibration instrument was used to measure the students' cranial vibrations. The amount of cranial vibration over 50 minutes varied among students, approximately between 10,000 to 70,000 vibrations ("vibrations" as a unit proportional to vibration intensity over the measurement period).

Figure 4: Students' result on non-speaking subjects

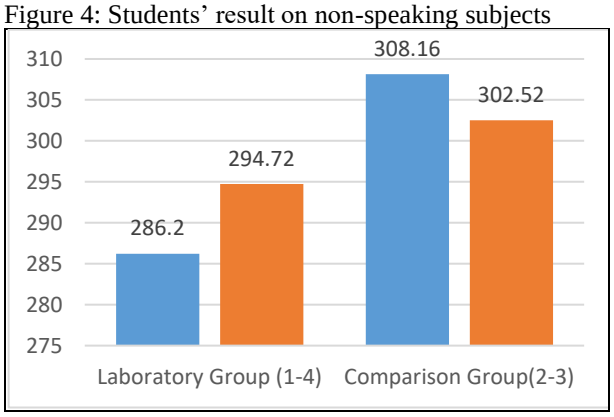
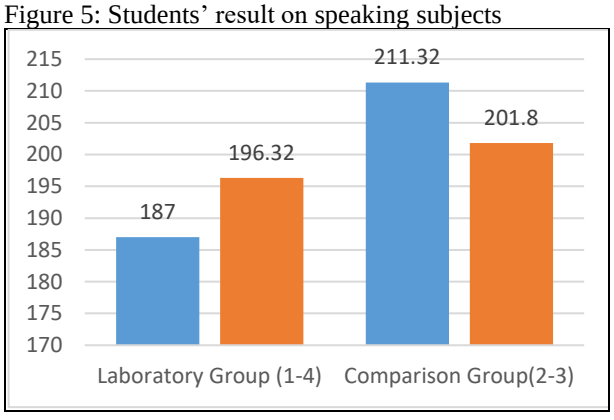


Figure 5: Students' result on speaking subjects

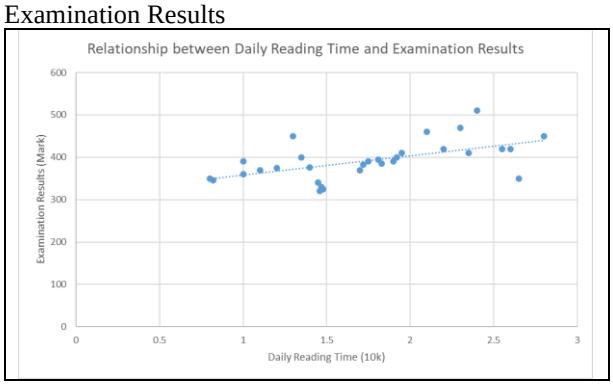


At the beginning of the experiment, all students took a baseline test to assess their initial performance. A midterm and a final exam were conducted during the semester, and the final score was the average of these two exams [6]. Comparing the performance changes between the experimental and control groups, we observed the effects of sound vibration reading. Due to variations in test scope and difficulty, direct comparisons of raw scores are not scientific. Therefore, the Ministry of Education's standard scoring conversion method was used to standardize scores [7].

As shown in Figures 4 and 5, after the sound vibration reading experiment, the experimental group's academic performance improved, with reading subjects showing a 4.6% increase and non-reading subjects a 2.2% increase.

An investigation revealed that Nanyang Nanshao High School in Henan province has a tradition of reading aloud. A randomly selected class with a habit of reading was monitored for cranial sound vibration during daily reading sessions for one semester. Pre-reading, mid-semester, and end-of-semester exams were conducted, with scores converted to standard scores to demonstrate performance changes. The relationship between daily average cranial vibration from reading and average exam scores is depicted in the following figure.

Figure 6: Relationship between Daily Reading Time and Examination Results



Experiment on the Relationship Between Sound Vibration from Reading and Psychological Stress

Psychological health issues in high school students are a growing concern. Positive psychology research shows that lively, talkative students experience less psychological stress, whereas those with depressive tendencies are often silent. Sound vibrations promote CSF circulation, balancing brain hormone levels and metabolism, potentially reducing psychological stress and fostering positive psychology [8]. Professor Peng Kaiping, Dean of the School of Social Sciences at Tsinghua University, advocates positive psychology, studying positive emotional experiences, personality traits, and interpersonal relationships [9].

Saliva cortisol, an easily measurable stress hormone, typically rises under physiological and psychological stress. Higher cortisol levels indicate negative psychological states (stress, anxiety, depression). At Changping No.2 High School of Beijing, 56 students participated in a 42-day sound vibration monitoring study, reading the same content daily. Daily sound vibrations were monitored using a head-mounted device, and saliva cortisol levels were compared before and after reading sessions to analyse the relationship between sound vibration and psychological stress.

Figure 7: Relationship Between Post-Reading Saliva Cortisol Levels and Daily Sound Vibration

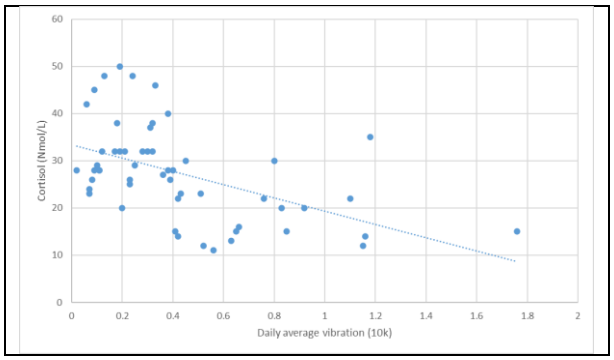
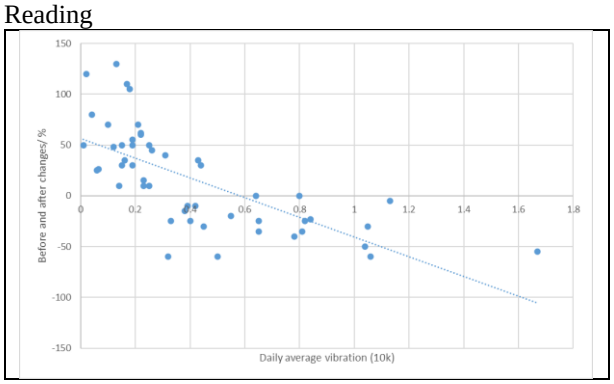


Figure 8: Change in Cortisol Levels Before and After Reading



Studies indicate that patients with generalized anxiety disorder have significantly higher saliva cortisol levels than healthy individuals [10]. Saliva cortisol levels are classified as follows: 5-15 nmol/L indicates low stress and relaxed psychology; 20-30 nmol/L indicates normal psychological stress; 35-50 nmol/L indicates high stress, requiring more active emotional regulation; and >50 nmol/L suggests a depressive tendency.

Figures 7 and 8 show that the cortisol concentration is negatively correlated with the amount of sound vibration, meaning the greater the daily cranial sound vibration from reading, the lower the psychological stress.

Conclusion

Through the development of monitoring equipment and the experiment on sound vibration reading, results indicate that sound vibration reading positively impacts improving high school students' academic performance and reducing psychological stress. Sound vibration reading enhances brain development and cognitive abilities, serving as an effective method to aid students in improving academic performance and reducing stress. Further enhancing reading methods to increase sound vibration efficiency may lead to even greater academic improvements and maintain a healthy psychological state.

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