HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

COLOR MODULATION IN NEUROPEDAGOGY: A TOOL FOR MITIGATING PREFRONTAL CORTEX LOAD AND COGNITIVE FATIGUE IN AUDITORY DEPRIVATION

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https://doi.org/10.5281/zenodo.20595515

Abstract:
This paper provides a neurophysiological rationale for the significance of visual color modulation in reducing cognitive listening effort and the subsequent functional load on the prefrontal cortex in individuals with hearing impairment and sensory deprivation.

Keywords:
neuropedagogy, auditory deprivation, cognitive load, prefrontal cortex, cognitive reserve, color modulation.

In individuals with hearing impairment, any daily audiological demand drastically escalates cognitive listening effort. Neurophysiological studies and linear mixed-effects models confirm that lower auditory acuity forces subjects to expend greater mental resources to perceive surrounding information. Rather than emotional distress, this condition primarily induces cognitive fatigue, thereby limiting human intellectual performance. Because auditory signals are degraded, the perceptual process demands higher cognitive resources. This forces a cognitive shift, diverting brain capacity from working memory, attention allocation, and executive functions toward listening effort. Prolonged exposure to this phenomenon leads to the complete depletion of cognitive reserves. Excessive cognitive load induces mild-to-severe structural changes in the brain, triggering neurodegeneration (the degradation of brain cells).

Color application can effectively reduce cognitive load and modulate neurophysiological activity. Studies by Al-Malky and Alsanosi (2025), as well as Peelle (2018), demonstrate that color coding and specific visual cues activate the prefrontal cortex, thereby mitigating auditory and perceptual fatigue (Peelle, 2018; ResearchGate, 2023). Obtained neurophysiological data indicate that in visual stimulation, colors serve not merely as aesthetic elements, but as cognitive modulators that accelerate information processing speed and conserve prefrontal cortex resources. The functional significance of colors in reducing cognitive load can be explained through several key neurobiological mechanisms.

First, research indicates that the probability of information retention depends on the depth of attention directed toward it. By capturing attention, colors increase the likelihood of information transitioning from short-term to long-term memory. According to a study conducted by Diachenko et al. (2022), seven distinct methods aimed at accelerating student mental activity were tested. The results revealed that highlighting critical text passages with colors (color coding) ranked first in memory retention and information systematization. Students who utilized specially designed "colored study guides" during lessons demonstrated an academic performance rate 11.5% higher than those

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who used standard materials. Color-enriched materials were found to be significantly more effective than monochrome, monotonous data. Students preferred the following formats for information retention:

• Video materials (~72%)
• Animations (~68%)
• Colored images, diagrams, and tables (~55%)

Second, neurotransmitter modulation and stress reduction: operating continuously in a "strained listening" mode increases stress hormones—such as cortisol and adrenaline—within the cerebral hemispheres, leading to general neuronal fatigue. Neurobiological analysis shows that specific wavelengths of the spectrum, particularly low-frequency green (520–570 nm) and cyan/light blue (450–490 nm), soothe the nervous system. This modulation suppresses hyperactivity in prefrontal networks, shifting the brain from anxious "Beta" waves to calm, deeply focused "Alpha" rhythms. Consequently, the subject's emotional homeostasis is restored, and auditory fatigue is neutralized. Therefore, appropriate color selection is crucial in classroom design. Utilizing light blue and green hues helps the brain perceive the environment as safe. Although yellow and orange tones induce an optimistic, motivational mindset, their excessive use can conversely lead to cerebral fatigue.

CONCLUSION

The human brain has a limited capacity for processing excessive information. The strategic application of color simplifies the visual structure of educational materials and reduces the cognitive load imposed on the brain. Thus, incorporating a targeted color spectrum when designing educational and rehabilitative materials for hearing-impaired individuals in neuropedagogical practice serves as an essential preventive strategy to preserve the subject's cognitive reserve.

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