Influence of Red and Blue Virtual Environments During a Listening Evaluation: A Preliminary Study of Academic Performance and Subjective Self-Perception

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Abstract. Color and lighting have been shown to influence human physiology and may affect cognitive performance. Some theories suggest that blue background colors promote relaxation and concentration, whereas red colors induce arousal and alertness. However, empirical evidence remains inconclusive due to variations in experimental designs and task types, making it unclear how color ultimately affects cognitive performance. The aim of this preliminary study is to compare performance and subjective self-perception throughout a listening evaluation and to determine whether red or blue colors yield differences in performance. We conducted a study in which university students completed five listening tests within a red or blue virtual environment and answered questions about their subjective self-perception at the beginning and end of the experiment. Our results showed that: i) students in an environment characterized by a blue color obtained higher median performance (6.8 vs. 6.0) as time progressed during the evaluation; ii) medium positive correlations were found in the blue group (0.36 and 0.36) between the performance-attention and performance-relaxation that exceeded that of the red group; iii) a medium negative correlation was discovered in the red group (-0.48) between the performance-mental effort that exceeded that of the blue group. The preliminary findings of this study could suggest that a blue environment may facilitate relaxation and attentional focus, which could enhance performance. Despite the modest sample size, these findings underscore the necessity for additional research to determine the true impact of color on academic performance, with potential implications for educational settings and academic institutions.

Keywords: Red · Blue · Listening evaluation · Academic performance · Virtual Reality (VR)

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1 Introduction

It is hypothesized that color influences cognitive processes. In our previous study [1], we analyzed brain signals using EEG and found that red and blue colors induced distinct patterns of cerebral activity. Additionally, Elliot et al. posits that red color engenders a state of alertness due to its association with blood, and its historical utilization in danger signals across various cultures. Conversely, both blue and green have been linked with positive emotions, such as peace and calm, due to their association with nature [2].

Several studies have reported divergent findings regarding color effects. For instance, red backgrounds have been linked to improvements in short-term memory compared to blue or white backgrounds [3], while other study have shown that blue color enhance performance in an attention task compared when compared to a white background [4], suggesting that color may exert differential effects relative to neutral color. Nevertheless, due to the diverse range of experiments carried out under varying conditions, there remains no consensus regarding the specific impact of each color [5].

Some research suggests that warm colors may be more effective for detail-oriented or simple cognitive tasks, whereas cold colors enhance performance in more complex or demanding tasks [6, 7]. For example, Liu et al. found that cold-colored walls were more effective for relaxation, but yellow walls yielded the highest performance scores on the Stroop task, mental arithmetic and reading, followed by red, green, blue, and white walls [8]. Conversely, Llinares et al. reported that cold hues improved auditory attention and memory tasks more effectively than warm colors [9], reinforcing the notion that task complexity and modality may mediate color effects on cognition.

The aim of this preliminary study is to extend our previous study by comparing performance and subjective self-perception throughout a listening comprehension task, designed to closely resemble an authentic academic setting requiring sustained attention, and to determine whether blue or red colors present differences.

2 Methods

2.1 Participants and Experimental Design

Fourteen students (four females and ten males; 20.4 $\pm$ 2.4 years) from the University of Granada participated in the study. After providing informed consent, the Ishihara test was administered to all the participants due to the color-based nature of the experiment. One participant was excluded for expressing discomfort during the test. The study was approved by the Research Ethics Committee of the University of Granada (3702/CEIH/2023) and conducted at the Research Centre for Information and Communication Technologies (CITIC-UGR).

Participants fitted with a virtual reality headset and initially immersed in a fully white environment. The experiment started with a subjective questionnaire designed to assess the participants' state, consisting of five items evaluating attention, stress, interest, mental effort, and relaxation on a scale from 1 to 5. Participants were assigned to a red or blue group, and the virtual environment was adjusted accordingly. After a 3-min relaxation in the colored environment, participants completed five C2 Spanish audio tests (six questions, two options each), followed by another relaxation period and subjective questionnaire. Further details are in our previous study [1].

2.2 Statistical Analysis

A dataset was constructed by combining the responses to the subjective questionnaires, listening tests, and the assigned color background to each participant.

Firstly, performance was analyzed using the median scores (scaled to 10) due to the small sample size, and median absolute deviation for uncertainty. Subsequently, cumulative performance, calculated individually for each participant before computing the median, was analyzed across the tests.

Secondly, subjective questionnaires were analyzed using the median for each group. Both absolute self-perception states (responses at the beginning and end) and relative self-perception states (difference between them) were examined. The relative state may differ slightly from the absolute difference due to individual calculation before computing the median.

Finally, the correlation between performance and self-perception relative state was assessed using Kendall's Tau correlation [10], suitable for non-Gaussian data and small samples. Only medium (0.3–0.49) and large (0.5–1) correlations, as defined by Cohen [11], were considered.

3 Results

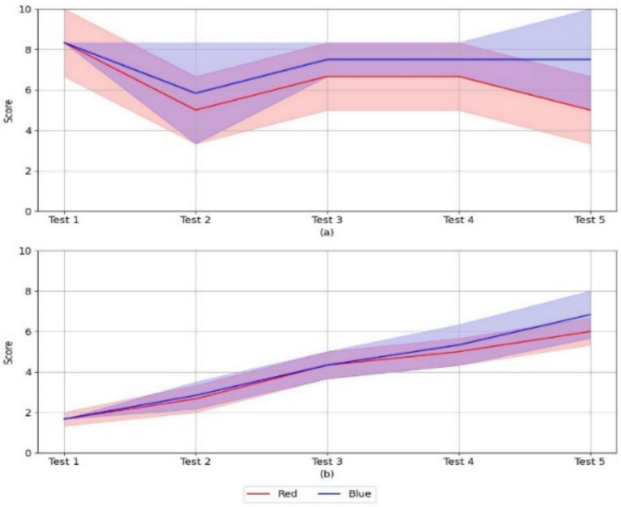

Fig. 1. Median performance (0–10 points) throughout the listening tests for each group. Red and blue represent the group's virtual environment color. Colored shadows represent the median absolute deviation. (a) Scores from each test (medians). (b) Weighted cumulative scores throughout the tests (median of the sum).

Figure 1 shows the median performance throughout all the listening tests for each group. Red and blue colors represent the median for the students within a red and blue virtual environment respectively. Colored shadows represent the median absolute deviation as

an indicator of uncertainty for each group. Figure 1a represents the median scores from each test, scaled to 10; Fig. 1b represents the weighted median for each group of the cumulative scores from each participant. In other words, we first sum the scores for each participant and then the median is computed.

Table 1. Median of the answers to the first and second subjective questionnaires (SQ) and the difference between them for each group and question.

Question	*Red Median*			*Blue Median*		
	1st SQ	2nd SQ	Diff SQ	1st SQ	2nd SQ	Diff SQ
What has your level of attention been so far?	5	4	−1	5	5	0
What is your stress level right now?	2	3	1	1.5	2.5	0.5
What is your level of interest so far?	5	4	0	5	5	0
What has your level of mental effort exerted so far?	1	4	2	1	4	3
What is your level of relaxation?	3	2	−1	3.5	2.5	0

Table 1 shows for each group the median of the answers in the five questions of the first and second subjective questionnaires (SQ), along with the difference between them. The 'Diff SQ' columns do not correspond to the subtraction of '2nd SQ' minus '1st SQ' columns, since the difference was calculated for each subject individually, and the median was computed afterward.

Table 2. Kendall's Tau correlation coefficient between performance and subjective self-perception for each group and question. Bold values correspond to medium level correlations.

Questions	*Red*	*Blue*
What has your level of attention been so far?	−0.23	0.36
What is your stress level right now?	−0.05	0.08
What is your level of interest so far?	0.06	0.16
What has your level of mental effort exerted so far?	−0.48	−0.16
What is your level of relaxation?	−0.21	0.36

Table 2 shows the Kendall's Tau correlation coefficient between performance and the median difference of the responses to the subjective questionnaires for each group and question. Bold values correspond to medium level correlations.

4 Discussion

In this study we explored the influence of red and blue virtual environment on performance and subjective self-perception during a sustained auditory attention task, simulating a realistic academic context. Preliminary results would suggest that a blue environment may facilitate relaxation and attentional focus, which could enhance performance.

Figure 1.a shows a trend in which the blue group begins to outperform the red group from the second test onward, maintaining a relatively stable performance level until the end of the experiment. In contrast, the red group exhibits a final decline in performance. This final divergence (Test 5) is echoed in the cumulative analysis (Fig. 1.b), where the shaded regions representing the median absolute deviation reveal that the blue group's variability band still overlaps the red group's median, whereas the red group's band does not extend into the blue group's median range. This asymmetry suggests a potential divergence in performance trajectories between the groups. While these patterns may indicate a performance advantage in blue environments, the degree of statistical uncertainty prevents any definitive conclusion. Therefore, the results should be interpreted as preliminary and hypothesis-generating rather than confirmatory regarding the effects of red or blue color on sustained cognitive performance.

Table 1 shows that both groups experienced increased stress and reduced relaxation; however, the blue group reported more favorable absolute values in both dimensions. These findings suggest that participants perceived themselves to be in a more relaxed state when immersed in a blue environment, consistent with prior studies indicating that blue color generated a more relaxed state [2, 4, 5, 8]. In fact, in our previous study [1] where brain signals were analyzed, participants in the blue condition exhibited higher alpha power levels (an electrophysiological marker traditionally linked to relaxed mental states) at the end of the session. This convergence between neurophysiological signals and self-reported measures supports the interpretation that blue environments may facilitate relaxation.

Table 2 shows a positive medium correlation for attention and relaxation in the blue group, suggesting that the enhanced attention and relaxation fostered by the blue environment may have improved performance. In contrast, a negative medium correlation for mental effort was found in the red group, indicating that reduced mental effort may have facilitated better performance. This correlation in the red group could reflect differences in academic level among participants, which were not present in the blue group.

5 Conclusions and Future Work

This study has several limitations. First, the small sample size (seven in the red group and six in the blue group) led to large error margins and necessitated using the median as the central tendency measure. Second, while we measured performance and subjective states like relaxation and mental effort through listening tests, we did not assess participants' cognitive capacity, which is closely linked to performance.

Although the present results are not conclusive, they offer preliminary insights that justify further investigation. The trends identified suggest that environmental color, particularly blue, may influence self-perceived cognitive states and sustained performance

during attention-demanding tasks. However, the findings should be interpreted with caution and regarded as hypothesis-generating rather than confirmatory. Replication of this study with a larger and more diverse sample is essential to validate these patterns. While incorporating cognitive capacity measures could help control participant heterogeneity, a sufficiently large sample may itself dilute the effect of outliers and allow for more reliable group-level inferences.

Additionally, it may be valuable to include other color conditions, such as green or yellow, and to combine behavioral analysis with complementary methods (e.g., EEG) to better understand the mechanisms underlying color-related cognitive effects.

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