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Two Preliminary Studies on the Effects of Multisensory Stimulation on Working Capacity and Stress Reduction

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Abstract: This paper reports the results of two separate experiments on the effects of multisensory stimulation on working capacity and stress reduction. The first experiment, employing auditory stimulation and lighting stimulation, revealed that multisensory stimulation, a combination of green light, and the sound of a murmuring stream, had a greater stress-reduction effect than single-sensory stimulation. The second experiment, which employed smell and lighting stimulation, revealed that a peppermint scent reinforced working capacity during arithmetic calculation. Green light combined with a peppermint scent also supported working capacity. Such multisensory interaction cannot be accounted for as merely the cumulative effect of a combination of single-sensory stimuli.

Keywords: *Multisensory stimulus, Peppermint scent, Murmuring stream sound, Green light, Arithmetic calculation*

1. INTRODUCTION

This paper presents two preliminary studies on the effects of single-sensory and multisensory stimulation on human intellectual and physical activities, one of the most important research topics in affective science. Single-sensory stimulation, such as sound, light, haptic, smell, taste or thermal stimulation, triggers cognitive and affective effects. Multisensory stimulation may cause the same effects, but it is expected to trigger different or reinforced effects. The effects of multisensory interaction cannot be explained as simply the combined effects of multiple types of single-sensory stimulation. Therefore, it is important to study the effects of multisensory stimulation on human intellectual and physical activities provided by comparing them to those of single-sensory stimulation.

A goal of this research is to determine whether multisensory stimulation reinforces working capacity and reduces stress. The cognitive and affective effects of single-sensory stimulation, such as sound, light, and smell, have been extensively studied. For example, Mishima et al. [1] investigated the effects of auditory stimulation using the sound of a murmuring stream. Electroencephalogram (EEG) and blood pressure measurements from experiment participants revealed this sound brought about a relaxed state in participants. Koshisaka et al. [2-3] found that blue LED light, and also green LED light yielded a relaxed state in humans. Mizunoya et al. [4] investigated the effect of the background colors of a PC screen set in front of experiment participants using the PC to take the Uchida-Kraepelin test. They found that blue and magenta improved working capacity, but red weakened it. Kumagai & Nagayama [5] found that a peppermint scent reduced errors made in arithmetic calculations and improved the mood of participants. Using the semantic differential method for their investigation of multisensory effects, Nagano et al. [6] reported the comfort of several environmental sounds perceived by participants under pleasant or unpleasant thermal and lighting conditions.

These studies did not address whether multisensory stimulation reinforces working capacity or reduces stress. Thus, we decided to investigate the working capacity and stress-reduction effects using multisensory stimulation.

2. MULTISENSORY EXPERIMENT 1: SOUND AND LIGHTING

2.1 Methods

A total of eight Japanese college students (six males and two females, aged between 21 and 22 years) with normal visual acuity and color vision participated in the study. Throughout the experiment, participants were asked to perform arithmetic subtraction tasks and give their answers verbally. The arithmetic tasks were expected to cause the participants stress; their stress levels were measured by the ratio of low-frequency to high-frequency heart-rate variability (LF/HF), which reflected activity of the sympathetic nerve[7]. A lower LF/HF ratio reflected a state of relaxation while a higher LF/HF ratio reflected higher stress. We used a MEG-6108 heart rate meter by Nihon Kohden and recorded and analyzed the measurement data using a Vital Recorder and BIMUTAS II by Kissei Comtec.

The sound of a murmuring stream has a stress-reducing effect, as reported by Mishima et al. [1]. Based on Mishima's report, we used the sound of a murmuring stream as an auditory stimulus, and experimental conditions were either the sound of a murmuring stream at 45 dB or the absence of sound. Green light has also been found to have a stress-reduction effect, as reported by Koshisaka et al. [2–3]. In this experiment, we used green light and normal white light as lighting stimuli. These stimuli were presented to eight participants by using an LED desk lamp placed in front of each participant at 300 lumens. We used a color-changeable LED lamp, PLAYBULB Color, provided by MIPOW.

For multisensory stimulation, we combined lighting with auditory stimulation, and set up three experimental conditions and a control condition: green light and a murmuring stream, green light and no sound, normal white light with a murmuring stream, and normal white light and no sound. The time length for each condition was three minutes. We provided rest intervals, equivalent to two minutes of the normal white light and no sound condition, between each of the four conditions. To avoid order effects, the presentation order of the four conditions was counterbalanced.

2.2 Results

Table 1 shows the LF/HF ratio values for the four conditions; A—H indicate each of the eight participants.

The experimental results revealed that the LF/HF rations during the green light with no sound condition were significantly higher than during the green light with a murmuring stream condition ($p < .05$).

However, no significant difference emerged between the other conditions. There was also no correlation between the degree of stress (values of LF/HF ratio) and performance on the arithmetic task (percentages of correct answers).

Table 1: Comparison of LF/HF ratio

	Subject								
	A	B	C	D	E	F	G	H	Average
Green/Sound	0.573	0.157	0.112	0.0653	1.33	0.365	0.789	0.0923	0.435
Green/None	1.66	0.555	0.231	0.0822	2.79	2.83	1.25	0.155	1.19
White/Sound	4.84	0.160	0.155	0.133	0.507	0.498	0.967	0.874	1.02
White/None	0.911	0.148	0.439	0.229	0.846	1.45	0.837	0.100	0.620

3. MULTISENSORY EXPERIMENT 2: SCENT AND LIGHTING

3.1 Methods

The participants were eight Japanese college students (aged from 21 to 23 years) with normal visual acuity and color vision.

We used a peppermint scent as the smell stimulus. Experimental conditions were tests with and without a peppermint scent. The peppermint scent was generated by an aroma diffuser with peppermint oil. We used peppermint oil (product number: 08-440-3720, lot number: 16) produced by TREE OF LIFE Co. Ltd. and an Aromax aroma diffuser produced by Air Aroma. The peppermint scent was expected to reduce mistakes in arithmetic calculation and to improve participant mood, as reported by Kumagai & Nagayama [5].

We used the same color-changeable LED lamp used in experiment 1, PLAYBULB Color, provided by MIPOW. As a pre-experiment, participants adjusted the LED color to match the peppermint scent as they imagined it. Then, a green light at R=0, G=255, and B=43 in 8-bit color notation of color-changeable LED lamp was selected, based the result of the above mentioned pre-experiment. The lighting stimuli were the green light and normal white light and were presented to the eight participants via the LED desk lamp, which was set in front of each participant.

For multisensory stimulation, we combined the lighting stimulation with smell stimulation, and employed three experimental conditions: green light with a peppermint scent, green light with no scent, and normal white light with a peppermint scent, and a control condition: normal white light with no scent. To avoid order effects, each condition was conducted on different days.

Each condition lasted 10 minutes, and throughout each condition, participants were asked to do *100-masu keisan*, simple 100-cell arithmetic calculations, as shown in figure 1. This task was expected to cause stress among the participants. Their stress levels were measured at the beginning and the end of each condition by using flicker fusion frequency (FFF), the flicker-perception threshold at which an intermittent light stimulus appears to be completely steady to an observer. Davis [8] reported that physiological factors such as fatigue may decrease FFF.

At the end of each condition, participants evaluated their psychological states using a visual analog scale (VAS). The VAS was used to evaluate the degrees from 0% to 100%, of the following mental states for the four conditions: 1) preference, 2) being irritated, 3) mental concentration, 4) mental composure, 5) being motivated, and 6) being refreshed.

+	1	9	5	2	7	4	8	3	10	6
1										
4										
6										
8										
2										
7										
10										
3										
9										
5										

Figure 1: *100-masu keisan*: a 100-cell arithmetic calculation

3.2 Results

Figure 2 shows the mean numbers of arithmetic answers given in 10 minutes during each of the four conditions. A statistical test based on multiple comparisons revealed that the mean value of answers during the green light with a peppermint scent condition was significantly larger than that of the normal white light with no scent condition ($p < .01$). In addition, the mean value during the normal white light with a peppermint scent condition was significantly higher than that for the normal white light with no scent condition. ($p < .01$). The mean value for the green light with a peppermint scent condition was significantly higher than that for the green light with no scent condition ($p < .05$). In contrast, there was no significant difference between the mean values of incorrect answer rates in the four conditions.

Table 2 shows the mean VAS values (the degrees of mental states from 0 to 100). VAS values for the mental state of being refreshed differed significantly between normal white light with a peppermint scent and normal white light with no scent ($p < .01$).

There was no significant difference between the mean FFF values before and after 10 minutes of arithmetic calculation.

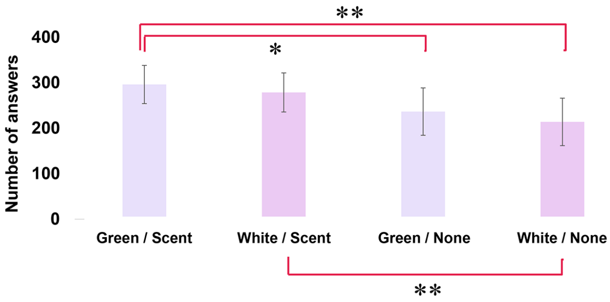

Figure 2: Number of answers for four conditions

Table 2: Mean of VAS values from 0 to 100

Mental states	Green / Scent	White / Scent	Green / None	White / None
1) Preference	61.0	81.6	50.3	69.9
2) Being irritated	39.3	38.8	40.1	40.9
3) Mental concentration	79.5	82.6	58.1	62.3
4) Mental composure	72.6	82.9	56.8	72.5
5) Being motivated	81.8	78.1	64.0	67.1
6) Being refreshed	78.3	82.6	55.9	48.5

4. DISCUSSION

Experiment 1 showed the murmuring stream sound seems to reduce stress, as expressed by the LF/HF ratio values, and green light may reinforce the effect of this sound. In contrast, green light without the murmuring stream sound seems to increase stress, rather than reduce it. This phenomenon can be explained as follows: Human color vision cannot adapt to green light and white appears green under green light. Therefore, participants were forced into the uncomfortable experience of reading and doing calculations under green light. These findings suggest that the effects of multisensory stimulation cannot be explained as simply the cumulative effects of single-sensory stimulation.

Experiment 2 found a peppermint scent seemed to reinforce working capacity and green light seemed to play a supportive and independent role, albeit with a smaller effect on working capacity than the peppermint scent. It is also interesting that the peppermint scent alone and the combined peppermint scent and green light both reinforce working capacity while in experiment 1, the murmuring stream and green light do not have the same effect on working capacity as the peppermint scent alone. In contrast, the peppermint scent does not seem to be effective for reducing stress. Experiment 2 thus suggests that the peppermint scent strongly reinforces working capacity, whether combined with a green light or not. The effect of the green light is supplementary.

The results of experiment 1 and 2 are difficult to compare directly because they were conducted independently by different experimenters. Nevertheless, it is noteworthy that green light plays quite different roles in experiments 1 and 2 according to the stimulant with which it is combined: sound or scent.

5. CONCLUSIONS

We conducted this study to confirm whether the affective effects of multisensory stimulation differ from the cumulative effects of combined forms of single-sensory stimulation, and found the reinforced affective effects cannot be explained simply as the combined effects of multiple types of single-sensory stimulation.

Experiment 1 revealed that a combination of green light and murmuring stream sounds reduces stress. It was also found that green light alone could increase stress. In contrast, experiment 2 found that a peppermint scent reinforce working capacity during arithmetic calculation. In addition, green light combined with a peppermint scent supports the reinforcement of calculation-capacity.

Comparing experiment 1 and 2, murmuring stream sounds seemed not to reinforce working capacity during arithmetic calculation, while the peppermint scent did. The murmuring stream sound seemed to reduce stress while the peppermint scent did not. This study is just the beginning of exploration of the effects of multisensory stimulation on human intellectual and physical activities. A limitation of these studies is their lack of strict and reliable control and statistically reliable evaluation. Resolving these shortcomings will be our next task.

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