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The Influence of Classroom Illumination Environment on the Efficiency of Foreign Language Learning

Ting Liu [1,2,*], Takaya Yuizono [2], Zhisheng Wang [2,3] and Haiwen Gao [3]

[1] School of Foreign Languages, Dalian Polytechnic University, Dalian 116034, China
[2] School of Knowledge Science, Japan Advanced Institute of Science and Technology, Nomi 923-1292, Japan; yuizono@jaist.ac.jp (T.Y.); wangzs@dlpu.edu.cn (Z.W.)
[3] Research Institute of Photonics, Dalian Polytechnic University, Dalian 116034, China; Gao_haiwen@126.com
* Correspondence: s1820031@jaist.ac.jp; Tel.: +81-139-0408-6146

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Abstract: This paper investigated foreign language learning efficiency in four different illumination environments (in different illuminance and color temperatures), focusing on the influence of the illumination environment on foreign language learners' sentimental status, by means of foreign language skills testing in mind-map, objective evaluation of physiological reaction, and subjective evaluation of psychological reaction. It was shown that in different illumination environments, the language skills of foreign language learners were different, and their psychological and physiological reactions varied, which influenced the efficiency of foreign language learning. The results indicated that the ideal learning space was in high illuminance and low color temperature, which increased the stimulation in foreign language learners; promoted the formation of optimistic sentiment; and enhanced their interest in, and the quality and efficiency of, foreign language learning.

Keywords: illumination environment; illuminance; color temperature; sentiment; foreign language learning

1. Introduction

Sentiment factor in language learning is attracting more and more attention with the emergence and development of humanistic psychology. In language teaching, "sentiment" refers to the learners' emotions, feeling, mood, and attitude, among other factors in learning process [1]. Foreign language learning is closely related to sentiment, as sentimental factors can not only reflect the learners' physiological and psychological status but also influence their learning efficiency [2]. Human acquisition of external information is derived 80% or more from vision [3], thus foreign language learners' sentimental factors may, to a certain degree, be stimulated or induced by classroom learning conditions.

In classrooms, illumination is a very important design factor [4]. Illumination affects not only visual response but also nonvisual reactions, such as performance, mood, and attention [5–8]. Improvements in the quality of illumination environments increase productivity in students and teachers [9]. Different illumination environments in a classroom will trigger different sentiments, which may influence learners' ability to concentrate and attendance [10]. Indoor illumination will cause the following reactions generally: it will affect information processing, result in physiological change, and affect psychological reactions of sentiment or mood [11]. In this paper, the influence of indoor illumination on foreign language learning efficiency was researched in the following three aspects: foreign language skills testing, the objective evaluation of physiological reaction, and the subjective evaluation of psychological reaction (Figure 1). The three aspects were correlated, and formed a reaction process that influenced the sentimental status of foreign language learning and, finally, influenced the efficiency of foreign language learning.

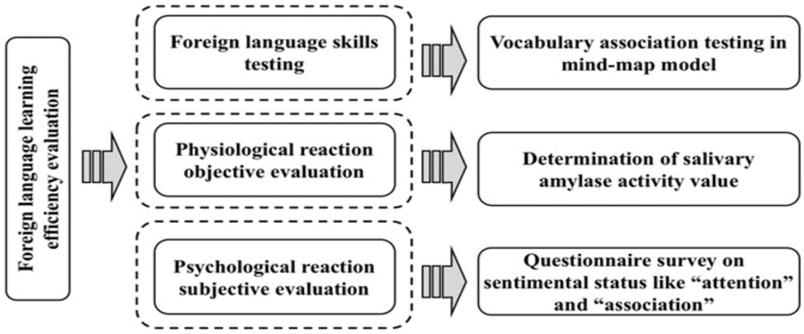

Figure 1. Evaluation modes on the efficiency of foreign language learning in different illumination environments.

This paper set up four illumination environments by different illuminance and color temperatures, tested foreign language learners' language skills, and made subjective and objective assessments of their physiological and psychological reactions through foreign language vocabulary association skills testing in mind-map, stress value determination by salivary amylase activity, and questionnaires on sentimental status related to "concentration" and "association". In addition, this paper analyzed the influence of illumination environment on foreign language learning efficiency, in order to recommend what kind of illuminating condition might best improve foreign language learners' optimistic sentiment, create their perfect learning status, and increase their learning efficiency.

Lighting arrangements can be used to enhance the clarity, relaxation, and pleasantness of a room [12]. In recent years, it has been considered to be an effective method to define the "pleasing zone" of lighting environments in terms of the combination of illuminances and color temperatures. The Kruithof curve indicates that combinations at high (low) illuminances and high (low) color temperatures could be pleasing zones [13]. Figure 2 shows the pleasing zone defined by Kruithof. Feeling comfortable is the primary condition for the ideal classroom lighting environment. This paper assumes that Kruithof 's pleasing zone is a comfortable classroom lighting environment, and the experiment was conducted based on different combination of illuminances and color temperatures within Kruithof 's pleasing zone in order to determine a sound classroom lighting environment for foreign language learning.

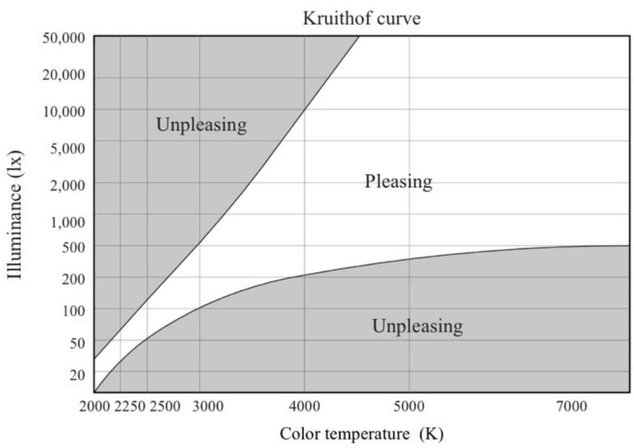

Figure 2. The Kruithof curve.

2. Methods

The participants consisted of 50 2nd-year university students in the Japanese department of a language institute in Dalian city (five groups, 10 students per group). These students were all comparable in Japanese language skills and were all holders of an N2 certificate for Japanese as a foreign language. The laboratory was four classrooms of this university, which were all designed to be closed spaces without natural light, with all the windows covered by curtains.

The duration was four weeks, and the working hours were from 13:00 to 15:00. Table 1 shows the four illumination environments. The average illuminance value of the classroom should not be less than 300 lx, and the appropriate color temperature range of light source should be 3300 K–5500 K [14]. In this paper, we set a high (low) illuminance of 650 lx (325 lx) and a high (low) color temperature of 5000 K (4000 K). The four different combinations of illuminance and color temperature were all within the range of Kruithof's pleasing zone. In all four conditions, the testing sequence was the same: quiescence for 5 min, salivary amylase activity testing for 2 min, Japanese vocabulary association testing in mind-map for 5 min, and subjective questionnaire survey on "concentration" and "association" for 3 min. In avoidance of any visual impact of cumulative lighting conditions, every group took a rest of 10 min between cases to relax or relieve their visual fatigue before changing into another illuminating condition so that they could test in the next step with a brand-new visual status.

Table 1. Illumination environments.

Case	Illuminance/lx	Color Temperature/K
Case 1	650	5000
Case 2	650	4000
Case 3	325	5000
Case 4	325	4000

3. Japanese Vocabulary Association Test in Mind-Map

Mind-map is an association tool that develops thinking by using free association. It is useful for the development of creative thinking skills and the application of foreign language knowledge [15]. Japanese vocabulary association testing may determine Japanese language learners' linguistic information processing capability and reflect the application or practice of linguistic knowledge. This paper analyzed Japanese language learning efficiency by investigating the efficiency of Japanese vocabulary free association. Within 5 min, all participants wrote down words connected to the Japanese words offered in the mind-map; the more words they wrote down, the more efficient they were. For the minimization of varied linguistic difficulty in different illumination environments, the words offered in mind-map were all general terms like foods and lifestyles.

3.1. Results

Table 2 and Figure 3 show every group's averages for the quantity of words written down. The results show that in different illumination environments, the quantity of associated Japanese words was different. The sequence from the largest quantity to the least quantity was Case 2 (4000 K, 650 lx), Case 1 (5000 K, 650 lx), Case 4 (4000 K, 325 lx), and Case 3 (5000 K, 325 lx).

Table 2. Quantity of associated Japanese words of every group in different illumination environments.

Group	Case 1	Case 2	Case 3	Case 4
Group 1	35	40	27	30
Group 2	30	35	20	23
Group 3	28	36	25	28
Group 4	33	38	22	25
Group 5	25	34	19	24

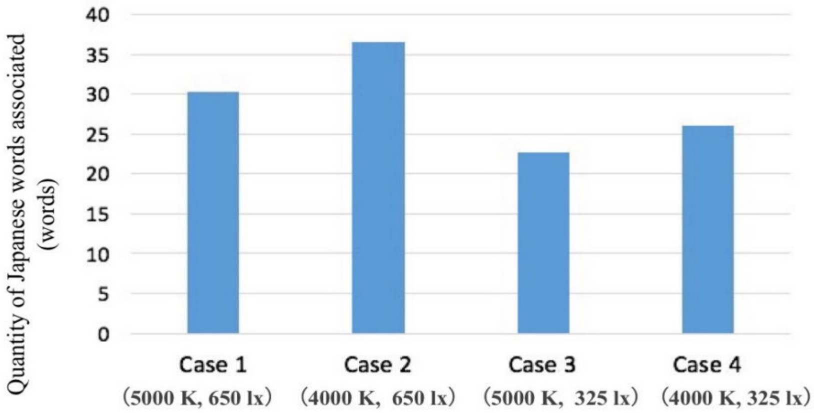

Figure 3. Average quantity of associated Japanese words in different illumination environments.

3.2. Evaluation and Analysis

Based on the comparison of every group's quantity of associated Japanese words in four illumination environments (Figure 4), a t-test was made (Table 3). In 5000 K high color temperature conditions, Case 1 efficiency of Japanese vocabulary mind-map association in high illuminance was obviously higher than Case 3 efficiency in low illuminance (t = 5.295, df = 4, $p = 0.006$ ($p < 0.01$)); in the 4000 K low color temperature conditions, Case 2 efficiency in high illuminance was obviously higher than Case 4 efficiency in low illuminance (t = 12.159, df = 4, $p = 0.000$ ($p < 0.01$)).

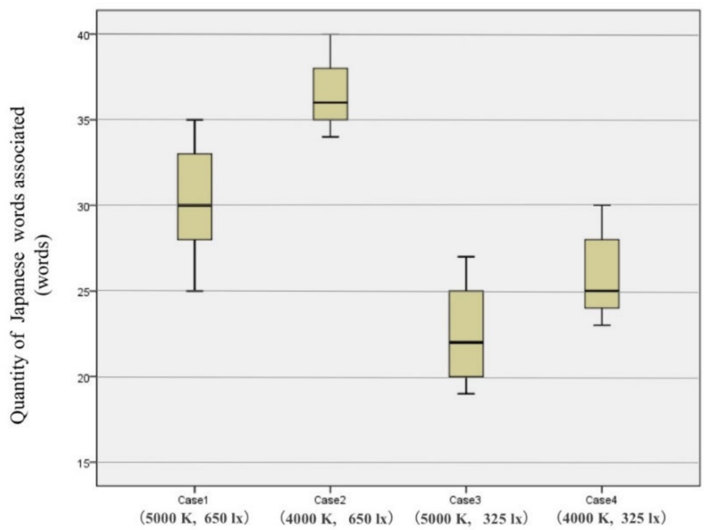

Figure 4. Comparison of the quantity of associated Japanese words in different illumination environments.

It is shown that no matter the difference in color temperature, the variation of illuminance caused obvious difference in the efficiency of Japanese vocabulary association, for example, Case 1 and Case 2 in high illuminance showed higher efficiency of Japanese vocabulary mind-map association, in particular Case 2 in high illuminance and low color temperature (4000 K, 650 lx). The illuminating condition of high illuminance and low color temperature was more helpful to Japanese vocabulary association in mind-map, which developed linguistic information processing and practice and improved the learning efficiency.

Table 3. T-test results.

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-Tailed)
				Lower	Upper			
Pair 1 (Case 1–Case 2)	−6.400	1.949	0.871	−8.820	−3.979	−7.341	4	0.002
Pair 2 (Case 1–Case 3)	7.600	3.209	1.435	3.615	11.584	5.295	4	0.006
Pair 3 (Case 1–Case 4)	4.200	3.563	1.593	−0.224	8.624	2.635	4	0.058
Pair 4 (Case 2–Case 3)	14.000	2.000	0.894	11.516	16.483	15.652	4	0.000
Pair 5 (Case 2–Case 4)	10.600	1.949	0.871	8.179	13.020	12.159	4	0.000
Pair 6 (Case 3–Case 4	−3.400	0.894	0.400	−4.510	−2.289	−8.500	4	0.001

4. Determination of Salivary Amylase Activity

Traditional illumination research focused on subjective evaluation experiments, whose flawed data repetition, accuracy, and traceability have impaired the universality of results; therefore, objective physiological evaluation is becoming the mainstream in illumination testing [16]. Different illumination environments will have different influences on human sympathetic nerves; when the sympathetic nerves are excited, salivary amylase secretion will increase, salivary amylase activity will increase, and stress will increase [17]. The salivary amylase activity value detected by salivary amylase meter may observe the participants' stress status under different illumination environments, to objectively evaluate the participants' physiological reactions.

A moderate stress status may be achieved through the creation of an ideal illuminating condition, to form a certain momentum for learning and increase learning efficiency.

In this experiment, before entering into the designed illuminating condition, participants were first kept static for 5 min in a (3000 K, 200 lx) illuminating condition, and tested for salivary amylase activity, whose value would be used to evaluate the stress in quiescence. Later, participants entered into the designed four illumination environments; were kept static for 5 min; and then tested for salivary amylase activity, whose value would be used to evaluate the stress in different illumination environments.

4.1. Results

Table 4 shows every group's salivary amylase activity in different illumination environments, whose value was measured in KU/L, where KU/L = 1000 U/1000 ML = 1 U/ML, representing how active the amylase was in saliva. The stress evaluation depended on the change rate of salivary amylase activity.

$$N = \frac{A - B}{A} \times 100\% \quad (1)$$

where N is the change rate (%) of salivary amylase activity, A is the value measured before entry into the designed illuminating condition, and B is the value measured after entry into the designed illuminating condition. After entry into the designed illuminating condition, the change rate is positive when the salivary amylase activity is lowering, indicating relieving stress (sympathetic nerves are static); on the contrary, in the designed illuminating condition, the change rate is negative when the salivary amylase activity is rising, indicating increasing stress (sympathetic nerves are excited).

Table 4. Salivary amylase activity level in different illumination environments (KU/L).

Group	Quiescence	Case 1	Case 2	Case 3	Case 4
Group 1	53	65	41	57	43
Group 2	38	42	35	51	36
Group 3	48	49	45	62	36
Group 4	46	48	34	53	44
Group 5	34	53	32	46	30

Due to individual difference of participants, the maximum difference of salivary amylase activity values between different participants was nearly 80 KU/L, so every group's measured values were averaged (Table 4). According to these statistics, in different illumination environments the salivary amylase activity value was different, in a sequence from high to low: Case 3 (5000 K, 325 lx), Case 1 (5000 K, 650 lx), Case 4 (4000 K, 325 lx), and Case 2 (4000 K, 650 lx), i.e., higher values appeared in higher stress while lower values appeared in lower stress (Figure 5). The change rate of salivary amylase activity was positive in Case 2 (4000 K, 650 lx) and Case 4 (4000 K, 325 lx), respectively, and 0.09% in Case 2 and 0.13% in Case 4, which meant that in these two illumination environments, Japanese language learning stress was reduced; the change rate was negative in Case 3 (5000 K, 325 lx) and Case 1 (5000 K, 650 lx), respectively, and −0.24% in Case 3 and −0.19% in Case 1, which meant that in these two illumination environments, Japanese language learning stress was increased.

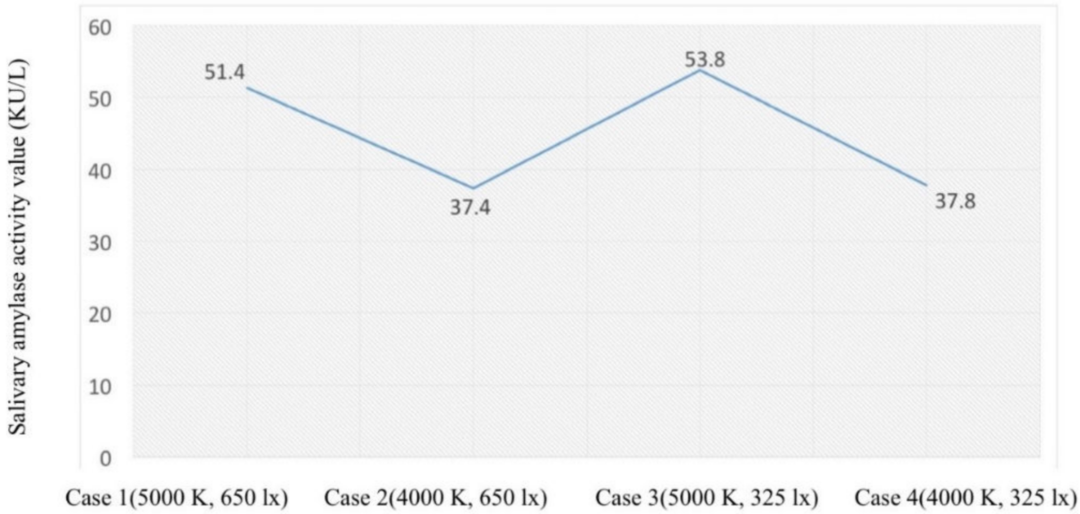

Figure 5. Averages of salivary amylase activity values in different illumination environments.

4.2. Evaluation and Analysis

The results of comparison in Figure 6 are subject to t-test (Table 5). In terms of color temperature, in high color temperature (5000 K) conditions, there was no significant difference between Case 1 in high illuminance and Case 3 in low illuminance. Similarly, in low color temperature (4000 K) conditions, there was no significant difference between Case 2 in high illuminance and Case 4 in low illuminance. On the other hand, in high illuminance (650 lx) conditions, the salivary amylase activity value was significantly higher in high color temperature Case 1 than in low color temperature Case 2 (t = 3.627, df = 4, $p = 0.022$ ($p < 0.05$)). In low illuminance (325 lx) conditions, the activity value was significantly higher in high color temperature Case 3 than in low color temperature Case 4 (t = 3.451, df = 4, $p = 0.026$ ($p < 0.05$)). It was indicated that the salivary amylase activity value varied with color temperature, and the effect of illuminance was minimal. Especially in high color temperature Case 1 and Case 3 conditions, salivary amylase activity values were very high.

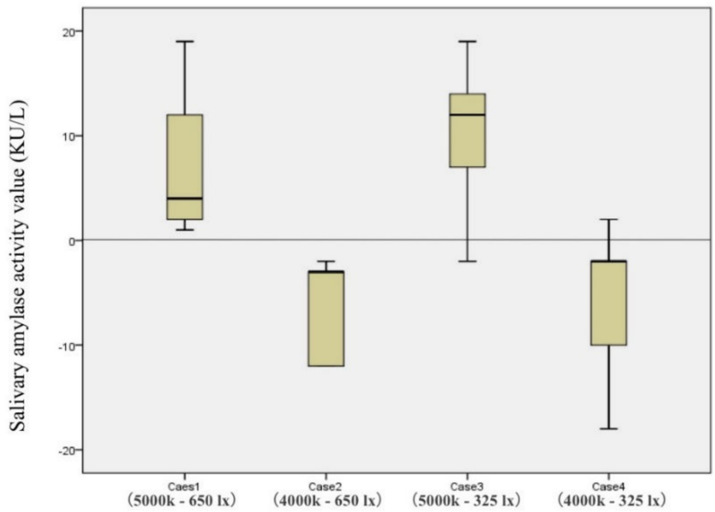

Figure 6. Comparison of salivary amylase activity values in different illumination environments.

Table 5. T-test results.

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-Tailed)
				Lower	Upper			
Pair 1 Case 1–Case 2	1.400	8.631	3.860	3.282	24.717	3.627	4	0.002
Pair 2 Case 1–Case 3	−2.400	12.601	5.635	−18.046	13.246	−0.426	4	0.692
Pair 3 Case 1–Case 4	13.600	8.080	3.613	3.566	23.633	3.763	4	0.020
Pair 4 Case 2–Case 3	16.400	4.615	2.063	−22.130	−10.669	−7.946	4	0.001
Pair 5 Case 2–Case 4	−0.400	9.289	4.154	−11.934	11.134	−0.096	4	0.928
Pair 6 Case 3–Case 4	16.000	10.368	4.636	3.126	28.873	3.451	4	0.026

In different illumination environments, stress varied in the process of Japanese vocabulary association. It was shown that the low color temperature illuminating condition of Case 2 (4000 K, 650 lx) generated moderate stress. Instead, the high color temperature illumination environments of Case 1 (5000 K, 650 lx) and Case 3 (5000 K, 325 lx) were prone to generate high stress due to cold light. An ideal illuminating condition, with moderate stress, may form a certain momentum and enthusiasm for Japanese language learning and generate an efficient learning outcome.

5. Subjective Evaluation Questionnaire on “Concentration” and “Association”

Cognition and sentiment are inseparable in foreign language learning [18,19]. In the view of educational psychology, one of the most important influencers in the learning process is the learner's sentiment [20]. A high concentration of “concentration” and “association” may lead to superb learning sentiment. The highest score of the questionnaire in this paper was 5, which. allowed the participants to make self-assessment subjectively on “concentration” and “association”, respectively, right after Japanese vocabulary association testing in different illumination environments, which surveyed the participants' psychological reactions and sentimental feelings and explored the influences of different illumination environments on learning efficiency.

5.1. Results

The results are shown in Figures 7–9. Figure 7 shows the average values of subjective evaluation on "concentration" and "association", and Figures 8 and 9 show the comparisons of scores on "concentration" and "association" of every group in four different illumination environments.

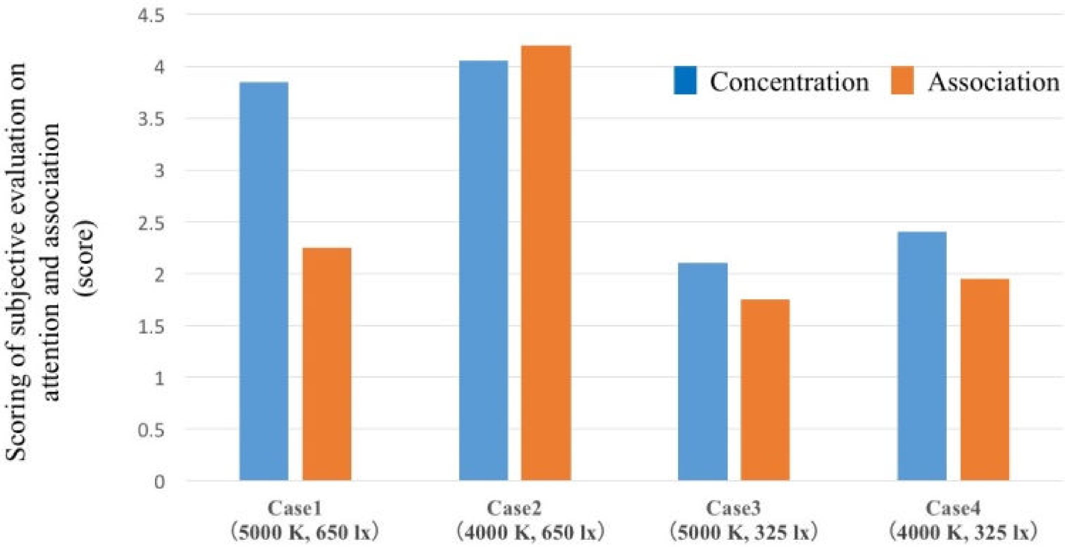

Figure 7. Average scores of evaluation on "concentration" and "association" in different illumination environments.

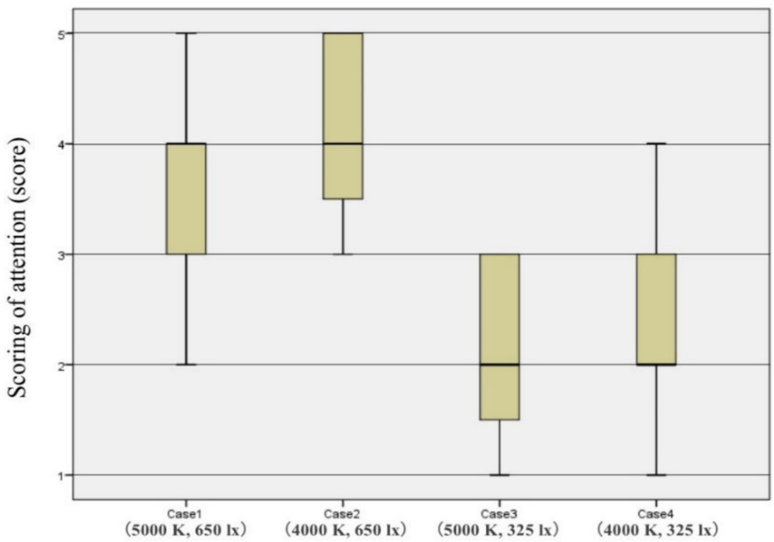

Figure 8. Comparison of subjective evaluation on "concentration" in different illumination environments.

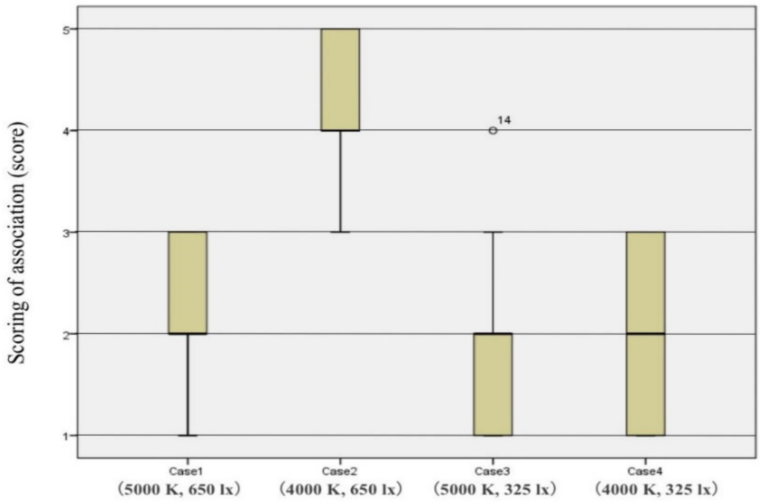

Figure 9. Comparison of subjective evaluation on "association" in different illumination environments.

5.2. Evaluation and Analysis

Through comparison, it is shown that "concentration" and "association" varied in different illumination environments. The scoring sequence from high to low was Case 2 (4000 K, 650 lx), Case 1 (5000 K, 650 lx), Case 4 (4000 K, 325 lx), and Case 3 (5000 K, 325 lx).

Both "concentration" and "association" were largely influenced by illuminance. In high illuminance condition, the scores were higher, while in low illuminance condition, the scores were lower, a tendency that was similar to the Japanese vocabulary mind-map association efficiency in different illumination environments. High illuminance condition brought about broad vision, which promoted learners' attentiveness in Japanese language learning, drove their associative development, and helped to increase Japanese language learning efficiency.

6. Conclusions

The creation of a sound classroom illuminating condition is an efficient way to increase learners' enthusiasm and optimism toward learning. This paper analyzed the influence of different illumination environments on Japanese language learners by testing and verifying their Japanese language skills, physiological reactions, and psychological reactions, through Japanese vocabulary mind-map association testing, salivary amylase activity determination, and a questionnaire on "concentration" and "association" evaluation. Specifically, the mind-map association efficiency of Japanese vocabulary was largely influenced by illuminance but only slightly influenced by color temperature, with the Japanese vocabulary association efficiency being especially high in the illuminating condition of high illuminance and low color temperature. The salivary amylase activity values detected in different illumination environments showed that in the high color temperature illuminating condition, Japanese language learners' stress was increased, while in the low color temperature illuminating condition, the stress was moderate. In high illuminance and low color temperature conditions in particular, Japanese language learners showed moderate stress, formed certain momentum for learning, and increased their Japanese language learning efficiency. According to subjective evaluation results, Japanese language learners' "concentration" and "association" were greatly influenced by illuminance, and in high illuminance condition the efficiency of "concentration" and "association" were even higher. Overall, the current results showed that the illuminating condition of high illuminance (650 lx) and low color temperature (4000 K), which is in the range of Kruithof's pleasing zone, was the most ideal classroom illuminating condition for Japanese language learning efficiency. It indicated that the findings in this paper match Kruithof's rule well.

However, certain limitations should be noted. First, the experimental subjects were limited only to Japanese language learners in China. Although the sample size was sufficient to investigate the influence of illumination environment, it is still a small number for the generalization of results. In the future, it will be necessary to conduct an experiment with a larger number of subjects of foreign language learners and to analyze the results further. Second, the ideal illumination environment may vary depending on culture or geographical location because people in different cultures and regions of the world will have different emotional responses to the same color temperatures and illuminance. For foreign language learners in different cultures and regions, further investigation and verification are required to confirm whether ideal foreign language learning effects can also be achieved under the illumination environment found in this paper. Third, this study has limited implications for the classroom illumination environment, as this study is still considered exploratory. In future work, color rendering index, uniformity in ratio of illuminance, and glare may be considered for the determination of an ideal illumination environment for foreign language learning.

Author Contributions: T.L. proposed the methodology and did the theory architecture; T.Y. did the research direction; Z.W. did the experiment design and draft writing; and H.G. did the SPSS analysis and validation. All authors have read and agree to the published version of the manuscript.

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