Evaluation Method of e-Learning Materials by α-Wave and β-Wave of EEG

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Abstract. In e-Learning study, the materials are the only environment. Therefore, the influence which these have on a students' emotion has big influence on progress of study. The purpose of this study, from a standpoint of making easy-to-follow e-Learning materials, is to construct the foundation for a methodology to evaluate the materials from emotional aspect. At first we re-corded the basic EEG during mental calculation. Second, we tested two different levels of materials which had 3 important learning points. We recorded subjects' EEG, then analyzed and compared with the basic EEGs. The result suggested us that at the learning point, where the α-wave power was greater than the basic one and the β-wave was less than it , the content was not able to understand.

1 Introduction

Instructional Design (ID) that is a guideline to prepare materials defines two-step evaluation of e-learning materials. The first is the formative evaluation for im-proving materials in the development phase and the second is the overall evaluation for evaluating the effect of education in a comprehensive way after completing the development phase.

The purpose of this study is to select user-friendly materials that with higher learning effect among e-learning materials already developed and to lay the foundation for a method for evaluating materials from a viewpoint of affective aspect considering storyline. Kirkpatrick's four-level model is the most widely used and popular model for the evaluation of training and learning. The four levels of Kirkpatrick's evaluation model essentially measure: 1) reaction of student - what they thought and felt about the training, 2) learning - the resulting increase in knowledge or capability, 3) behavior - extent of behavior and capability improvement and implementation/application and 4) results - the effects on the business or environment resulting from the trainee's performance. They are calculated from the results of test, questionnaire and interview (Japan Society for Educational Technology ed., 2000). If classified roughly, 2) Learning can be evaluated by the results of tests, and 1) Reaction of student, 3) Behavior and 4) Results may be hardly evaluated from the viewpoint of affective aspect. Conventionally, information based on the subjective of learners has been used for evaluating the affective aspect. However, it is nonobjective because the criteria are un-clear.

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Therefore, researchers began to use biological information. Biological information is operant responding of learners. Biological information provides objective and quantitative data (Nakayama, Shimizu, et al., 2003). Meanwhile, the questionnaire and interview survey hardly evaluate materials considering change over time because they are performed after learning. Therefore, they are not appropriate for performing overall evaluations on materials completed including story line. In that respect, EEG that is one of the biological information is excel-lent in time resolution.

The purpose of higher education targeted in this study is to learn basic knowledge first and to understand and apply knowledge in a comprehensive way. Affective effect is highly requested in the higher education. Therefore, a method for evaluate materials from a viewpoint of affective aspect is important. As just mentioned, the affective aspect can be evaluated through an objective perspective by using EEG among biological information. Additionally, storyline can be also evaluated because EEG has better time resolution.

Previous works suggest that learners dedicate themselves to learning in comfortable atmosphere (learners learn deliberately in a relaxed and comfortable environment, make advances in their learning and are hardly distracted) when learners advance in knowledge at the essential points of learning (basic knowledge is out-lined and learners are made to apply knowledge). At the time, alpha wave is ob-served significantly (Murakami, 2003).

In this study, two materials with different difficulty levels were used for evaluating the affective aspect. EEG was measured over time for each material. The relationship between EEG change and final achievement of learning target was made clear in order to evaluate materials from a viewpoint of affective aspect. Each material had 3-graded learning targets. Essential points of learning are indicated at the end of each grade.

The evaluating method is as follows: 1) A reference status for evaluating the affective aspect (atmosphere in which learners learn deliberately in a relaxed and comfortable manner, make advances in their learning and are hardly distracted) is created. EEG is measured to determine the basic EEG. 2) Subjects are made to learn with e-learning materials. EEG at that time is measured. 3) Subjects take an exam for evaluating achievement of learning target. Verbal reports about materials are collected. 4) EEG at each phase of learning is calculated from the EEG during learning. Calculated EEG is compared to the basic EEG (matching level). 5) An evaluation method is obtained from the relationship among the matching level, examination and matching level.

2 Method

Basic EEG value is determined from the EEG when learners dedicate themselves to learning in order to evaluate the affective aspect during learning based on EEG. Then, EEG during learning by using materials with essential learning point known is measured. The EEG value calculated from EEG at the essential point of learning is cross-checked with the basic EEG value in order to evaluate the affective aspect of learning. Subjects are made a verbal report and take an examination in order to support the result. The procedure is shown below:

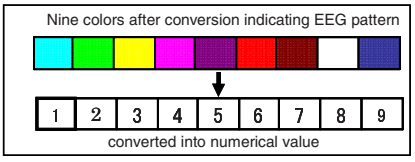

Fig. 1. Conversion of EEG pattern to numerical values

STEP1: The EEG when learners dedicate themselves to learning in comfortable atmosphere is recorded to obtain the basic EEG value. Topography of alpha and beta wave in the occipital region is prepared from the EEG. The pattern is converted into a numerical value with a digitizing program (Fig. 1). "Basic EEG value" is obtained from the average of processing results from 5 subjects.

STEP2: EEG of multiple subjects, who learn by two materials (different difficulty levels), is measured. After completing learning, verbal reports are recorded in order to capture subjective impression of the lesson, and subjects are made to take an examination in order to explore their level of understanding. Topography of alpha and beta wave in the occipital region is prepared for three essential points of learning. The pattern is converted into a numerical value with a digitizing program.

STEP3: The matching level of EEGs of the three essential points of each material is calculated on the basis of the basic EEG value. The denominator of the matching level is the basic EEG value obtained in STEP1. The numerator of the matching level is the EEG value during learning obtained in STEP2. The matching level is expressed in percentage.

STEP4: The relationship among the matching level and scores of the verbal report and examination is discussed.

3 Experimental Result

Subjects include master course students and senior students in this department. Five subjects do mental calculation in order to obtain the basic EEG value. E-learning materials during learning include two materials (referred to as material P and Q) with different difficulty levels from problems of production scheduling that is a part of "production management technology" in which more than 80% of subjects par-ticipate. Each experimental group consists of five subjects. The prepare of the mate-rials made material P and Q so that they included three grades respectively. As a re-sult of analyzing each material, subjects reach the essential point of each grade at 3:20, 5:51 and 16:20, and 5:30, 10:30 and 21:10 after starting learning (Fig. 2). The EEG at the point where the amount of beta wave becomes maximum within 30 seconds of the essential point of each grade is considered to be the data of the essential point. After that, the essential point is called "evaluation point" because the essential point is considered to be a point for evaluating the material.

After completing the experiment, subjects take an examination in order to explore their level of understanding each material. Additionally, a verbal report is obtained in order to (1) understand the subjective impression of the whole lesson and each

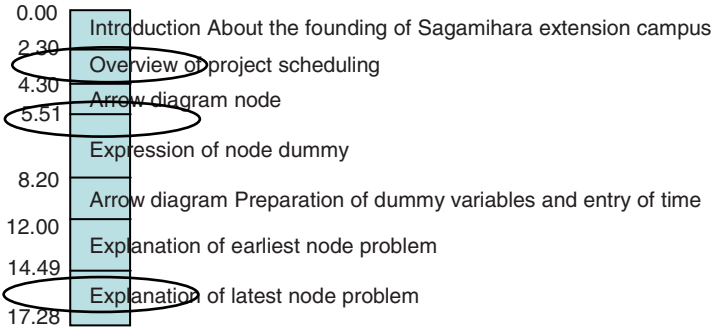

Fig. 2. Configuration of material P and three points

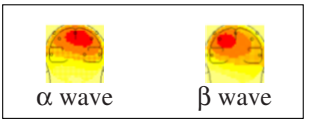

Fig. 3. Topographies of occipital region during mental arithmetic (subject a, maximum potential: alpha wave: 1.6μV, beta wave: 1.1μV)

Table 1. Basic EEG value

Subject	a	b	c	d	e	Average
a wave	1470	1265	1259	1536	1207	1347
b wave	1441	1607	1532	1500	1676	1551

chapter, (2) to confirm that subjects consider the evaluation points to be essential points, and determine evaluation points based on a series of EEG data.

3.1 Basic EEG Value

Subjects do mental arithmetic (integer addition: 1+2+3, 3+3+6, 6+4+10, 10+5+15…) keeping their eyes open for two minutes. Based on the verbal report of subjects, they are dedicating themselves to learning in comfortable atmosphere when the sum is approximately 100. Therefore, the EEG of their occipital region (Fig.3) is FFT-analyzed at this point for two seconds to obtain a topography of wave and wave (Fig. 3). The topography is converted into a numerical value with a digitizing program (table 1).

3.2 EEG Value During Learning with e-Learning Materials

Figs. 4 and 5 show topographies of alpha and beta wave in occipital region for three essential points in material P (basic problems) and Q (applied problems) respectively.

As shown in Fig.4, alpha wave is dominant over beta wave at each evaluation point of subject a for the material P. As shown in Fig.5, beta wave is dominant over alpha wave at each evaluation point of subject a for the material Q.

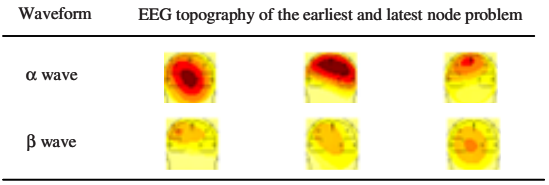

Fig. 4. Topographies at three essential points of material P (subject a, maximum potential: alpha wave: 1.6μV, beta wave: 1.1μV)

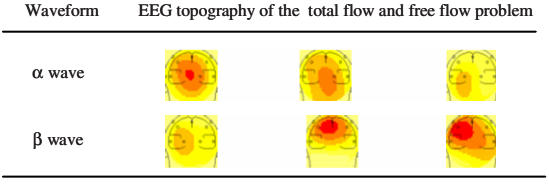

Fig. 5. Topographies at three essential points of material Q (subject a, maximum potential: alpha wave: 1.6μV, beta wave: 1.1μV)

Potential of each point of topography (maximum potential is indicated as level 9) of brain alpha and beta wave in the occipital region obtained by this method is converted into values shown in Fig. 1. The summation is calculated to obtain the EEG value at the evaluation point.

3.3 Cross-Check Between the Basic EEG Values and Numerical Values Converted from the EEG During Learning with Materials

The matching level is defined in order to indicate the learning status of an evaluation point by using the "basic EEG value" established as a criterion of agreeable advancement of learning. The matching level is defined by the following equation:

$$\text{Matching level} = \text{EEG value at evaluation point} / \text{basic EEG value} \times 100 \quad (1)$$

Figure 6 shows the matching level of material P and Q at evaluation points. In both materials, the matching level of alpha wave decreases and beta wave increases as learning advances. However, the matching level of beta wave exceeds 100 for material Q.

As shown in table 2, one-way analysis of variance showed that the matching levels of alpha wave were different between evaluation points for both material P and Q (significant level: 5%). Additionally, as shown in tables 3, the matching levels of beta wave were different between evaluation points for both materials (significant level: 1%).

The relationship between the matching levels of alpha and beta wave for material P and Q, and evaluation points of materials will now be discussed. X axis is alpha wave matching level. Y axis is beta wave matching level.

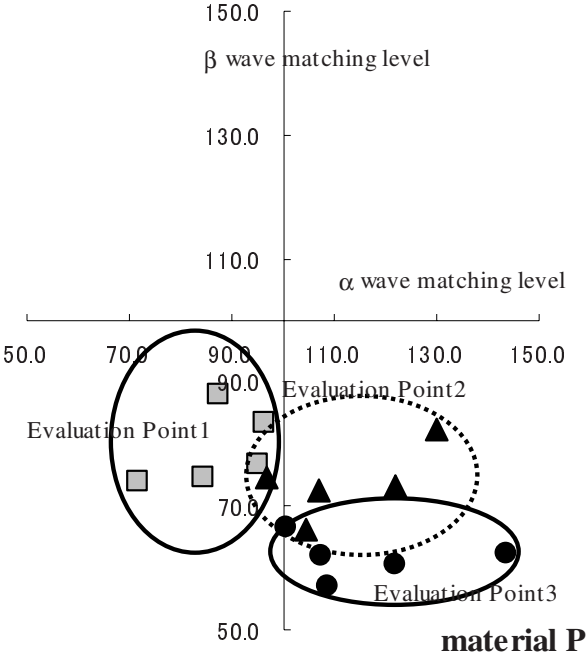

Fig. 6. Matching level of evaluation point 1, 2, 3 of material P and Q

Table 2. ANOVA on the difference of α and β wave power at evaluation point for material P

wave form	Factor	s.s	d.f	d.f	F_0
α wave	Between evaluation points	2525.93	2	1262.97	6.56*
	Within evaluation point	2311.80	12	192.65	
β wave	Between evaluation points	811.37	2	405.68	14.99**
	Within evaluation point	324.69	12	27.06	

Table 3. ANOVA on the difference of α and β wave power at evaluation point for material Q

wave form	Variation factor	s.s	d.f	d.f	F_0
α wave	Between evaluation points	564.60	2	282.30	6.08*
	Within evaluation point	557.19	12	46.43	
β wave	Between evaluation points	2129.95	2	1064.97	18.92**
	Within evaluation point	675.29	12	56.27	

3.4 Results of Examination and Verbal Report by Material

The average score of examination for the material P was 97.2. For the material Q, the average scores were 78.9 and 44.4 for the middle and final point respectively. These values show that the general cognitive assessment of the material Q is higher than Q.

In verbal reports, some subject mentioned that they could focus on the evaluation point 3(last) of the material P and thought it was not so difficult. With regard to the material Q, some subjects said that the material got more difficult from the middle of it and they could not understand it because the narrator spoke too fast.

4 Discussion

The relationship among evaluation points, and alpha and beta wave shows that (1) the matching level of beta wave gets higher and that of alpha wave gets lower at evaluation points in latter part. The brain is activated, alpha wave is suppressed and beta wave increases as learning advances. (2) with regard to the evaluation point 3 of the material Q where beta wave exceeded 100, some subjects mentioned in the verbal reports after learning that (a) pacing of learning was too intense to understand it. (b) The test score was 44. So, it seemed that subjects could not understand the material because it was too difficult.

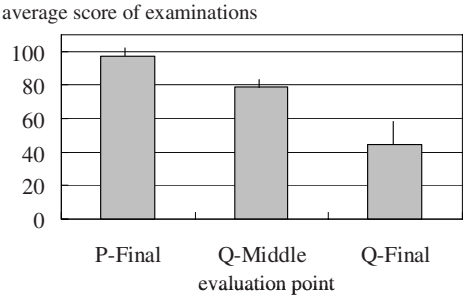

Fig. 7. Test score by material(by evaluation point

The results shown above suggest that combination of alpha and beta wave provide us with information for making a decision of the state of learning where learners can advance the study agreeably and judging the difficulty level of materials. The method may be used for evaluating cognitive aspect. Therefore, also for affective aspect, it is supposed that materials with which alpha wave decreases and matching level of beta wave exceeds 100% (the second quadrant in Fig. 7) after combining alpha and beta wave are not appropriate.

5 Summary

As a result by advancing this research, it was confirmed that that the matching level of alpha wave tended to fall and that of beta wave tended to rise when the brain was activated. Additionally, the accuracy rate and verbal reports showed that learners could not understand the material enough at the points of materials in which the matching level of the beta wave exceeded 100 because the narrator spoke too fast or the difficulty level of problems was too high. When evaluating a material by using

biological information, if there were multiple essential points in the material, it was suggested that all evaluation points could be evaluated in a comprehensive manner.

After this, the state of understanding during learning will be clarified by using the simultanagnosia chart, and EEG changes generated before and after "understanding" and the state within the brain will be made clear through experiments and analyses.

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