# 딥러닝 기반 뉴로사이언스 마이닝 기법을 이용한 고객 매력/유용성 인지 (CAUP) 예측 성능에 관한 탐색적 연구: Dark vs Light 사용자 인터페이스 (UI)를 중심으로

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# Exploring the Performance of Deep Learning-Driven Neuroscience Mining in Predicting CAUP (Consumer's Attractiveness/Usefulness Perception): Emphasis on Dark vs Light UI Modes

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● 요 약 ●

In this work, we studied consumers' attractiveness/usefulness perceptions (CAUP) of online commerce product photos when exposed to alternative dark/light user interface (UI) modes. We analyzed time-series EEG data from 31 individuals and performed neuroscience mining (NSM) to ascertain (a) how the CAUP of products differs among UI modes; and (b) which deep learning model provides the most accurate assessment of such neuroscience mining (NSM) business difficulties. The dark UI style increased the CAUP of the products displayed and was predicted with the greatest accuracy using a unique EEG power spectra separated wave brainwave 2D-ConvLSTM model. Then, using relative importance analysis, we used this model to determine the most relevant power spectra. Our findings are considered to contribute to the discovery of objective truths about online customers' reactions to various user interface modes used by various online marketplaces that cannot be uncovered through more traditional research approaches like as surveys.

**키워드:** Neuroscience mining, Electroencephalogram,
Consumer's attractiveness/usefulness perception, 2D-ConvLSTM, User Interface Mode

## I. Introduction

It is a well-established fact that how products are shown in marketing has an effect on consumers' perceptions [1]. The effect of physical product display varied according to brand and product characteristics, and this marketing strategy resulted in the rise of online shopping. Online shopping malls have modified their websites and user interfaces and have lately expanded their offerings to include mobile commerce. Mobile shopping malls, on the other hand, have more consistent features than online shopping malls, and access may vary according to customer preferences. In mobile shopping, the most clearly


Fig. 1. Dark UI and light UI stimuli used to represent online iPad shopping

recognized element is the UI's background color. The backdrop color of web services running in a mobile environment varies in response to the setting of a dark or light background, referred to as "dark mode" and "light mode," respectively. Then, users can choose between light mode (LUI) and dark mode (DUI) depending on their device and operating system. Both UI techniques have advantages; for instance, the LUI mode enhances readability [2]. On the other side, the DUI produces less light, which benefits the eye's health and visual perception in general. Additionally, dark mode has been demonstrated to consume less power than bright mode and extend the battery life of devices. The current surge in consumers preferring dark mode to bright mode has resulted in a high usage rate. According to an Android poll, 81.9 percent of 2,514 respondents indicated that they utilize dark mode on their devices whenever it is available. In comparison, only 9.9 percent indicated that they utilize both modalities. As a result of dark mode's emergence, some crucial questions about its impact on user behavior when using a smart device arise. With the growing usage of personal smart devices and computers for everyday chores, the digital design, experience, and user interface all have a considerable impact on customer perception and decision-making processes [3]. The brain has been demonstrated in research to be an excellent predictor of motivations, particularly behaviors such as approach motivation toward products. For instance, earlier research has discovered that when people are exposed to promotional content, the alpha band of the EEG positively corresponds with product like assessments [4]. Following Vecchiato et alinvestigation .'s [4], we intended to explore the brainwave band of the EEG to determine whether such sensations exist. We anticipate that by utilizing neuroscience mining techniques, we will discover that brain data has a greater predictive power than customer opinions of attractiveness/usefulness (CAUP). As a result, the following research question is proposed:

*Research Question 1: Which type of UI is more accurate in predicting CAUP?*

*Research Question 2: Which AI model is more accurate in predicting CAUP?*

## II. Methodology

### 1. Experiment

Twenty-eight South Korean undergraduates (mean age = 24.61; 18 males) participated in the experiment for a fee after seeing a notice on the college's homepage. In addition, approval was obtained from the IRB ethics committee before the experiments began. Participants were randomly assigned to one of two conditions: DUI or LUI. A 29-inch computer screen was used to present the stimuli in the form of a tablet to mimic shopping on a tablet. To run the stimuli on a computer, we used the software PsychoPy [5]. Each condition had the same stimuli design except for the different UI types. In total, four product categories (fashion, electronic home appliances, computers, jewelry) were used for the test (see Fig. 1).

### 2. Neuroscience Mining Models Used

In this study, we analyzed EEG data using the Emotive EPOC+ Model 2.0 (Fig. 2). The electrode signals were passed through a high-pass filter with a cutoff frequency of 0.16 Hz, a preamplifier, and a low-pass filter with a cutoff frequency of 83 Hz. Finally, the alpha band was extracted from the data. After preprocessing the EEG data, they were used for neuroscience mining.

Neuroscience mining helps to explore unseen patterns in neurobiological data to predict the meaning of these data. Usually, neurobiological data are studied based on areas of interest and traditional statistics. However, this neglects the fact that the brain works synchronously across multiple domains in many tasks. The he use of neuroscience mining allowed for an unbiased

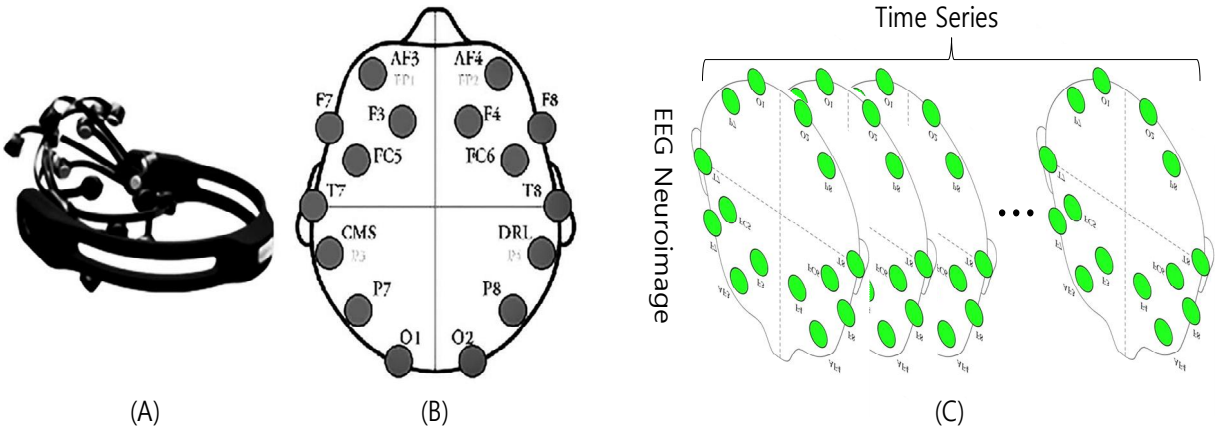


Fig. 2. (A) Emotiv device; (B) EEG channel placement; (C) EEG Neuroimage structure

analysis of participants as they performed the experiment.

We used the following models in our analysis: Random Forest (RF), Support Vector Machine (SVM), Convolution Neural Network (CNN), Bi-Directional Long Short-Term Memory (Bi-LSTM), 2-Demensional Convolutional LSTM(2dConvLSTM).

Table 1. Prediction Performances

| Attractiveness Prediction Performance for the Dark UI | | | | |
|---|---|---|---|---|
| *Model* | *Acc%* | *Pre%* | *Rec%* | *F1%* |
| RF | 37.08 | 34.32 | 33.61 | 33.96 |
| SVM | 35.52 | 32.91 | 32.90 | 32.91 |
| CNN | 37.17 | 35.11 | 33.63 | 34.35 |
| Bi-LSTM | 42.28 | 43.52 | 47.52 | 45.43 |
| 2dConv-LSTM | **57.56** | **51.52** | **67.14** | **58.30** |
| Usefulness Prediction Performance for the Dark UI | | | | |
| *Model* | *Acc%* | *Pre%* | *Rec%* | *F1%* |
| RF | 36.96 | 36.68 | 32.89 | 34.68 |
| SVM | 35.46 | 35.26 | 31.76 | 33.42 |
| CNN | 37.85 | 37.08 | 33.78 | 35.35 |
| Bi-LSTM | 43.99 | 44.41 | 48.64 | 46.43 |
| 2d Conv-LSTM | **60.10** | **53.22** | **68.29** | **59.82** |
| Attractiveness Prediction Performance for the Light UI | | | | |
| *Model* | *Acc%* | *Pre%* | *Rec%* | *F1%* |
| RF | 34.62 | 33.79 | 33.32 | 33.56 |
| SVM | 34.83 | 33.30 | 31.22 | 32.23 |
| CNN | 34.99 | 34.76 | 33.57 | 34.16 |
| Bi-LSTM | 40.15 | 39.96 | 49.65 | 44.28 |
| 2d Conv-LSTM | **54.89** | **50.15** | **63.22** | **55.93** |
| Usefulness Prediction Performance for the Light UI | | | | |
| *Model* | *Acc%* | *Pre%* | *Rec%* | *F1%* |
| RF | 34.72 | 33.25 | 31.66 | 32.44 |
| SVM | 33.92 | 31.34 | 30.88 | 31.11 |
| CNN | 35.64 | 33.89 | 32.21 | 33.03 |
| Bi-LSTM | 40.18 | 40.10 | 47.27 | 43.39 |
| 2d Conv-LSTM | **58.07** | **52.16** | **62.58** | **56.90** |

## III. Result

The prediction results are shown in Table 1. Each prediction result represents a result validated by 5 cross-validations. Looking first at the prediction results for customer attractiveness detection in DUI, RF was able to predict 37 percentage points, while SVM showed the lowest prediction performance of 35.52. When comparing CNN and LSTM, the Deep Learning comparison groups, the prediction results were 37.17% and 42.27%, respectively. These results show about 15% lower performance than the 2dConvLSTM model proposed in this study. SVM had the lowest prediction performance (35.46%) and 2dConvLSTM performed the best with 60.1% in prediction results for usability perception. Next, if we consider the prediction results on LUI, the prediction performance of RF was lower than that of SVM (attractiveness), in contrast to the results considered previously, and the highest prediction performance was still observed for 2dConvLSTM.

Each UI mode was separated for analysis to make a comparison. As seen, the brain data from the participants that were conditioned in the DUI showed overall higher predictive CAUP. As seen in the prior paragraph, 2dConvLSTM for the DUI showed the greatest performances of all the models, and when compared with the light mode's most accurate results from the 2dConvLSTM model. Thus, the neuroscience mining results added further evidence of the effect of the DUI. And the AI model suitable for CAUP prediction was found to be 2dConvLSTM

## IV. Conclusions

The purpose of this work was to examine customers' price perceptions under two different conditions: DUI and LUI. We analyzed the neuronal data generated from the EEG investigation using a unique neuroscience method. We discovered that by

fitting a 2dConvLSTM model to the brain data of subjects altered in the DUI condition, we were able to predict much higher CAUP. Additionally, 2dConvLSTM was found to be a viable AI model for CAUP prediction. Because the EEG data are in the form of brain pictures and are time series in nature, it can be assumed that these results will improve performance when examined with a combination model of 2dCNN and LSTM.

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