Vector Auto-Regression Model of Temporal Perceptual and Affective Responses Towards Food

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***Abstract*—Although human perceptual and affective responses triggered by the exposure to sensory experiences are dynamic, their temporal evolution has not been intensively investigated. In this study, we aimed to construct a mathematical model of such dynamics. The perceptual and affective responses while eating strawberries were measured using the temporal dominance of sensations method. We modeled them with a vector auto-regression (VAR) model based on Granger causality between perceptual and affective responses.**

I. Introduction

Our affective experiences are changed by stimuli perceived via our senses. For example, once we perceive the characteristic taste or smell of food, this sensory information is integrated into affective sensations like satisfaction, or evaluations such as like/dislike. In this way, the sensory information caused by the exposure to stimuli changes our affective feelings in a dynamical process. However, methods to mathematically model these dynamic affective responses have not been established.

Some researchers specified the semantic causal relationships among adjectives used in sensory evaluation [1], [2], [3], [4], and identified the causalities from the sensory adjectives expressing physical characteristics of the stimuli to the affective adjectives representing their affective characteristics. The causalities from the sensory or affective adjectives to the evaluative adjectives expressing preference were also observed.

This multi-layered causal structure among senses, affects and preferences implies that our affect and preference dynamically change, being triggered by the stimuli perceived via our senses. In these experiments, however, subjects were allowed to evaluate each adjective at any time in sensory evaluation, that is, the causalities between perceptual and affective feelings were not investigated in their temporal aspect.

In this research, we focus on taste and affective feelings and aim to establish mathematical models of perceptual and affective responses experienced immediately after starting to eat. We measure the temporal change of taste and affective feelings using the temporal dominance of sensations method, and demonstrate that the resulting multivariate time series can be treated with a vector auto-regression (VAR) model.

II. Measurement of Perceptual and Affective Responses Towards Foods

The temporal dominance of sensations (TDS) method [5] is a sensory evaluation technique that can be used to efficiently measure multiple sensations caused by eating food. In the TDS method, a graphical user interface such as the one shown in Fig. 1 is used. On the computer screen, some buttons with adjectives such as “sweet” or “sour” are displayed. Firstly, the panelists push the start button as soon as they put food into their mouth. While eating the food, they select and push the button with the sensation which they dominantly feel at the moment. They push a button every time the dominant sensation changes until the food varnishes in the mouth, and then push the stop button. The changes in perceptual and affective responses are recorded as the sequence of dominant sensations.

Fig. 1. A graphical user interface used in the TDS method.

III. Experiment

We performed a TDS experiment using strawberries. The panelists were 7 males and 1 female.

A. Choice of adjectives

We selected the adjectives to be used in the experiment through a preliminary experiment performed by 7 participants. As a result, 14 words, suitably representing the taste or affective characteristics of strawberries, were selected out of the 137 candidates we had prepared. Seven of them are sensory adjectives which express the characteristics of food perceived via senses; “Sour,” “Sweet,” “Juicy,” “Melty,” “Refreshing,” “Soft,” and “Watery.” The other 7 were affective/evaluative adjectives representing affective or preferential feelings; “Like,” “Elegant,” “Natural,” “Delicious,” “Happy/Satisfied,” “Fresh,” and “Flavorous.” In the TDS experiment, adjectives belonging to one type (sensory or affective/evaluative) at a time were displayed on the screen.

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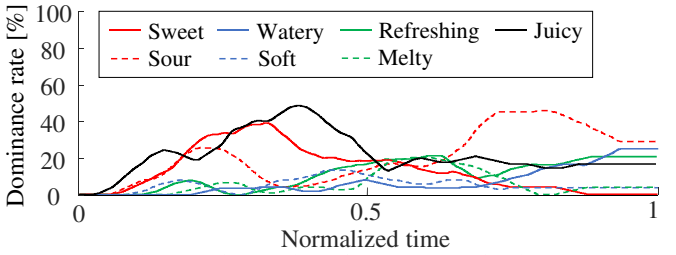
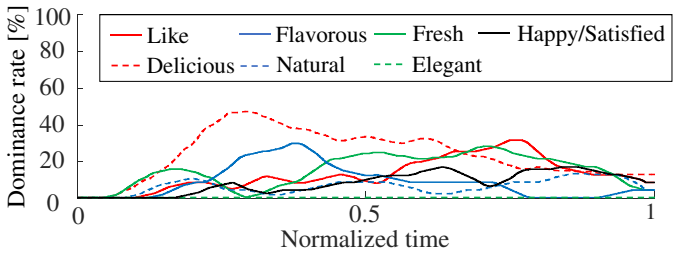


(a) Change of sensations for sensory adjectives.



(b) Change of sensations for affective/evaluative adjectives.

Fig. 2. Temporal change of perceptual and affective responses while eating food. The horizontal axis represents normalized time, spanning from the intake of a strawberry (0) to the end of perceptions (1). (a) Results for sensory adjectives. (b) Results for affective/evaluative adjectives.

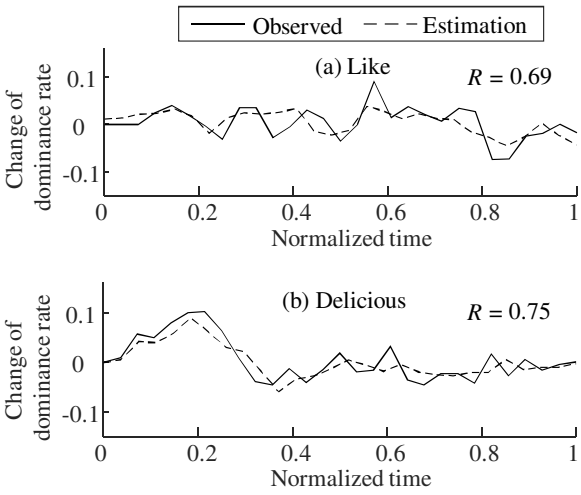


Fig. 3. Results of the estimation of affective responses using the VAR models. (a) Estimation of "Like" by (1). (b) Estimation of "Delicious" by (2).

B. Task

One strawberry was used for each trial. In each trial, the panelists first rinsed their mouth with water. Immediately after they put a strawberry in their mouth, they started the task of pushing buttons. Each panelist performed this task three times for each type of adjective alternately. The locations of adjectives on the screen were randomized for each panelist.

C. Results

The graphs shown in Fig. 2 show the perceptual and affective responses obtained in the experiment. The vertical axis shows the dominance rate, which is the ratio of total number of trials to the number of times each sensation was selected. For sensory adjectives (Fig. 2(a)), the dominant sensations were "Juicy" and "Sweet" in the first half and "Sour" in the second half. For affective/evaluative adjectives (Fig. 2(b)), "Delicious" was the most dominant sensation during a large part of the trial. Among other adjectives, "Flavorous" was dominant in the first half of the trial and "Like" and "Fresh" in the second half. On the other hand, "Soft," "Melty," "Elegant," "Happy/Satisfied," and "Natural" were excluded from the analysis of taste and affective feelings since they were infrequently selected throughout the experiment.

IV. Mathematical Model of Affective Dynamics

A. VAR model

We used vector auto-regression (VAR), often applied in economics and neurosciences to describe the evolution of multivariate time series, to model the perceptual and affective responses. In a VAR model for n variables with a model order q, one of the variables at time t is expressed as the linear function of the past q lags of the n variables, including itself. Since the VAR model is applied to discretized data, the continuous data obtained by the TDS method were discretized into 30 equally spaced time points (sampling period $\Delta t \simeq 1$s).

In order to select the explanatory variables in the VAR model, we used Granger causality, which can statistically test causal relationships between time series. As explanatory variables in a VAR model to estimate a certain sensation, we elected only those sensations from which the causality to the target sensation was significantly supported ($p < 0.10$). We analyzed the time series shown in Fig. 2 after removing their trend by differencing, since the Granger causality test assumes stationarity of the data. The model order of the VAR model was selected based on information criterion to each estimated variable.

B. Result

We report the results for two affective/evaluative adjectives, "Like" and "Delicious". The results of the Granger causality test suggested that "Like" was negatively affected by "Watery" (sensory) and positively affected by "Fresh" (affective) and "Flavorous" (affective). The results also suggested that "Delicious" was positively affected by "Sweet" (sensory). Some previous researches [1], [2] also suggested that preferential adjectives such as "Like" were affected by not only sensory adjectives but also affective ones. Figure 3 shows the changes in "Like" and "Delicious" estimated by the VAR models including only the variables for which causality to each sensation was supported. The correlation coefficients between estimated and observed values were $R = 0.69$ and $R = 0.75$ respectively. The VAR models ($q = 1$) for "Like" and "Delicious" are the following:

$$y_{\mathrm{like},t} = 0.011 - 0.99y_{\mathrm{watery},t-\Delta t} + 0.15y_{\mathrm{fresh},t-\Delta th} + 0.25y_{\mathrm{flav},t-\Delta t} + 0.17y_{\mathrm{like},t-\Delta t}, \quad (1)$$

$$y_{\mathrm{del},t} = 0.0026 + 0.43y_{\mathrm{sweet},t-\Delta t} + 0.41y_{\mathrm{del},t-\Delta t}. \quad (2)$$

These results show that the change in the feeling of "Delicious" was mainly caused by the sense of sweetness. Although model (1) had two more explanatory variables than model (2), the correlation coefficient between observed and estimated values was larger for (2), implying that "Like" is a sensation more complex and difficult to predict compared to "Delicious."

V. Conclusion

We measured perceptual and affective responses while eating food using the TDS method and mathematically estimated the affective responses from the perceptual ones. Simple and effective models of affective responses were established by selecting the explanatory variables included in a VAR model considering Granger causality in the choice of variables. Mathematical models of affective responses may enable us to design the changes in the affective feelings of consumers.

Acknowledgment

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