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Short Communication

Decomposition of the level effect into overall and descriptor-specific components

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ABSTRACT

Despite training, subjects in a descriptive panel can still differ in their use of the scale. Some subjects can score higher or lower than others (level effect) or spread more or less their scores on the scale (scaling effect). The scaling effect, as calculated in Brockhoff, Schlich, and Skovgaard (2015), was recently decomposed into an overall and a descriptor-specific component (Peltier, Visalli, & Schlich, 2015b). It was suggested that the overall component was related to psychological effect whereas the specific one was more related to a physiological one.

This paper aims to extend this decomposition to the level effect. The ***overall level effect*** gives indications about the psychological component of the scoring level, which is obtained by averaging the level effects of all the descriptors, whereas the ***descriptor-specific*** component can reveal a subject's hyper- or hyposensitivity to a given descriptor and thus is related to the individual's physiological response. The relevance of this decomposition was demonstrated by a meta-analysis of 419 sensory profiling datasets.

Finally, the summary table of performances MAM-CAP Table (Peltier, Brockhoff, Visalli, & Schlich, 2014) was improved in order to show both level and scaling effects (overall and specific) for facile monitoring of individual differences in the use of sensory scales by a panel.

1. Introduction

In sensory profiling, a panel uses a list of descriptors (such as sweetness, crunchiness, etc.) to describe the sensory characteristics of food products and rates the perceived intensities. Then, the performances of the panel members in terms of repeatability (giving the same score to the same product repeatedly presented), discrimination (perceiving differences between different products) and agreement with the panel should be monitored by the panel leader.

These performances can be affected by differences in the subjects' use of the scale. For example, some subjects can spread more their scores on the scale than the rest of the panel. Brockhoff and Skovgaard (1994) first described this effect (the so-called scaling effect) in their Assessor Model. However, this statistical model did not test for the product effect and was consequently not used in sensory analysis. Therefore, Brockhoff, Schlich, and Skovgaard (2015) proposed a model that accounts for the scaling effect and tests for the product effect, namely the Mixed Assessor Model (MAM).

This model was used by Peltier, Brockhoff, Visalli, and Schlich (2014) to produce the MAM-CAP table, a visual tool for monitoring the panel and subject performances (including scaling effects) for each descriptor. Peltier, Visalli, and Schlich (2015b) later proposed decomposing the MAM scaling effect of all the descriptors to differentiate between the following two scaling components:

- the **overall scaling**, which is independent of the descriptors. This scaling coefficient is calculated based on assessor's scores for all the descriptors. It can be interpreted as the "psychological part" of the scaling effect.
- the **corrected scaling,** which depends on the descriptors. This scaling effect is used to evaluate an assessor's sensitivity to specific descriptors and can be interpreted as the "physiological part" of the scaling effect.

This "psychological/physiological" decomposition of scaling was illustrated by a meta-analysis of 189 datasets. Relations between individual subject characteristics and the overall scaling and between the attribute modality and specific scaling were observed. These results were consistent with experimental results showing that taste sensitivity decreases with age (Mojet, Christ-Hazelhof, & Heidema, 2001).

However, the scaling effect is not the only factor influencing the use of the scale: some subjects might consistently give higher (or lower)

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scores than other subjects. This effect was studied in docimology (science of evaluation). For example, Bacher (1969) claimed that some examiners spread their scores more or less around a certain average. Leclerq, Nicaise, and Demeuse (2004) went even further, saying that an examiner tends to adjust the scores of his students in order to have a Gaussian distribution of the scores (with a specific mean and a specific standard deviation). The differences between the specific means of different examiners were illustrated in an experiment where 150 mathematic teachers in secondary cycle corrected the same paper. The scores given to the paper varied between 0.5 and 11.5 with a mean of 5.70/20 (De Landsheere, 1980). Transposed to sensory science, examiners are panellists evaluating products instead of students' works, their scale being theoretically provided with references during the training.

Besides, in psychology, the term "response style" refers to a respondent's tendency to provide a systematic response to questionnaire items regardless of their contents. The most common response styles are acquiescence (ARS) or disacquiescence (DRS) (tendency to agree or disagree with an item regardless of its content), and extreme response style (ERS) versus middle response style (MRS): that is the tendency to use the extreme or middle response categories on rating scale (Harzing, Brown, Köster, & Zhao, 2012). Cross-cultural differences about ARS were observed: hispanics were found more acquiescent than non-hispanic (Marin et al., 1992).

Back to sensory analysis, regarding only one specific attribute, the fact to score higher or lower than the panel was called **level effect** in Naes (1990) and occurs – as scaling effect – during the sensory process (Næs & Langsrud, 1998; Romano et al., 2008). Level effect can occur in different steps of the sensory process.

Indeed, Meilgaard, Gail Vance Civille, and Carr (1999) describes the chain of sensory perception as a three-step process: the stimulus is converted to a nerve signal that travels to the brain, this signal is interpreted as a perception, and finally a response is formulated. Lim (2011) also decomposed the sensory process into a physiological step (transduction of stimulus into internal representation) and a psychological step (including evaluative and decision making process). Thus, differences between two people's verdicts can be caused either by a difference in their sensations or in their mental treatments of the sensation. Different cognitive factors affecting the psychological step (factors due to the task, to the subject expectations…) were listed by Schifferstein (1996).

These authors agreed on a bias due to mental treatments during sensory profiling. As the aim of this task is to describe a sensory reality of the products, this description should be freed from any bias due to differences in the use of the scale between subjects.

This paper aims to extend the decomposition of the scaling effect (Peltier et al., 2015b) and the MAM-CAP table (Peltier et al., 2014) to the level effect. Therefore, the level effect was decomposed into overall (more psychological) and descriptor-specific (more physiological) components. The MAM-CAP table was revised to include these new indicators. Finally, they were evaluated using 419 datasets from the SensoBase in order to study relations between the level and scaling effects and impacts of gender, age and smoking status on level effect.

2. Materials and methods

2.1. Overall and descriptor-specific decomposition of the level effect

2.1.1. Usual level

The usual ***level of scores*** $l_{i,d}^{usual}$ is defined as the difference between the subject mean score and the panel mean for a given descriptor. For subject i and descriptor d, this variable can be written as

$$l_{i,d}^{usual} = y_{i..}^{d} - y_{...}^{d}$$

where $y_{i..}^{d}$ and $y_{...}^{d}$ are the average scores given by subject i and by the entire panel, respectively, for descriptor d.

A level higher (resp. lower) than 0 indicates that subject i tends to give higher (resp. lower) scores than the panel. It should be noted that the subject effect calculated in the two-way ANOVA is based on the sum of squares of the level effect, i.e. $\sum_{i=1}^{I}(y_{i..}^{d} - y_{...}^{d})^2$.

As with the scaling effect, the level effect could be due to either physiological or psychological factors. In the former case, one descriptor is perceived more intensely by the subject than by the panel, whereas in the latter case, the subject tends to consistently score all the descriptors higher (or lower) than the panel (whatever the descriptors).

Although the level effect is usually corrected in statistical analysis by using such ANOVA, the reason of its heterogeneity should be investigated. Indeed, it could highlight potential individual differences in sensory perceptions of some attributes.

2.1.2. Overall level

The **overall level** $l_i^{overall}$ is the average level effect of all the attributes in the dataset.

$$l_i^{overall} = \frac{1}{D}\sum_{d=1}^{D} l_{i,d}^{usual}$$

This overall level mathematically corresponds to the subject's average tendency to score higher or lower than the panel whatever the descriptor. A high overall level results in the combination of two causes:

- The subject is an "high-scorer" whatever the scale (pure psychological effect due to the use of the scale)
- The subject has perceived most of the descriptors more intensively than the panel, and scored high as a consequence (hyper-sensitivity to most of the descriptors of the study)

2.1.3. Specific level

The **specific level** $l_{i,d}^{specific}$ is the average usual level effect minus the overall level effect:

$$l_{i,d}^{specific} = l_{i,d}^{usual} - l_i^{overall}$$

The usual level effect is consequently decomposed into a sum of the overall and the specific level components. The specific level represents the level effect corrected from the overall effect.

It enables the detection of a potential hyper- or hyposensitivity to a given descriptor. As an example, assume that a subject systematically scores one point higher than the panel ($l_i^{overall} = 1$) but scores sweet exactly the same in average as the panel ($l_{i,sweet}^{usual} = 0$). When the usual level is used, no hyper- or hyposensitivity is detected. However, the use of the specific level corrects for the bias due to the scale use, allowing the hyposensitivity to sweet to be detected ($l_{i,sweet}^{specific} = -1$). This information could be relevant to the panel leader during the training phase.

2.2. Significance of the overall level and presentation of the results

The significance of the overall level was determined by a two-sided t-test of the differences between the scores of a subject and the rest of the panel (for all attributes together). When the overall level is significant ($p = 0.05$), the sign of the level indicates whether the subject tended to score higher or lower than the panel.

The same kind of t-test was used to assess the significance of the specific and usual level effects for each attribute individually.

2.3. Presentation of the results

The MAM-CAP table (Peltier et al., 2014) summarizes classical performance indicators (discrimination, agreement and repeatability) with a colour code (green for good performances, red for bad performances).

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