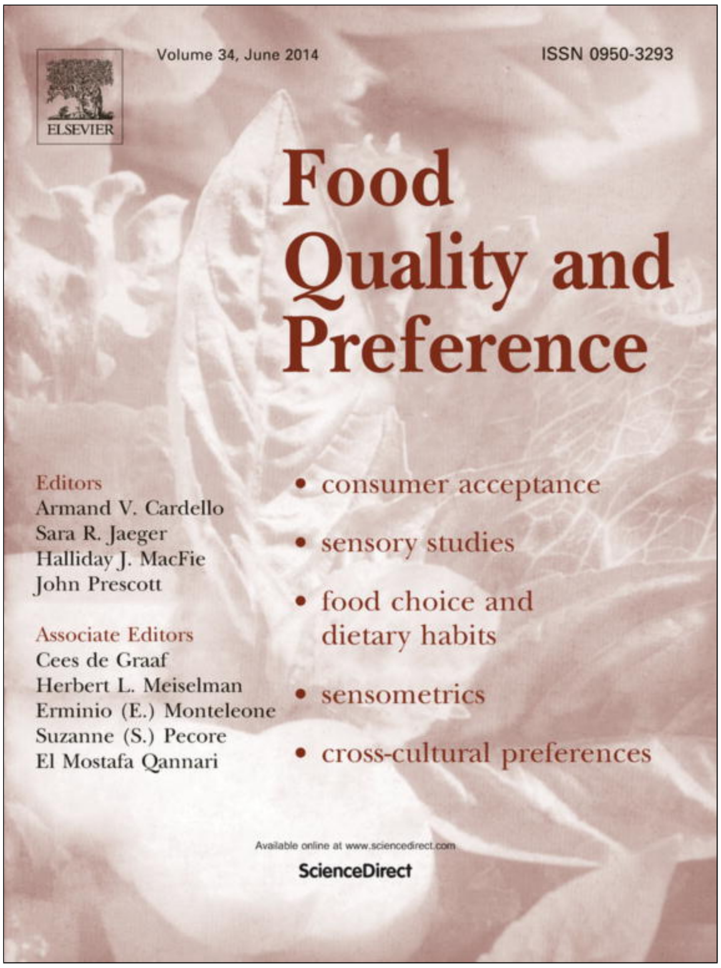
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Trained sensory panellists' response to product alcohol content in the projective mapping task: Observations on alcohol content, product complexity and prior knowledge

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ABSTRACT

Projective mapping has been validated as a practical tool for the rapid sensory profiling of brandy products, although repeatability concerns necessitate repeated measurements in larger sample sets. The reason for poor repeatability could be linked to the complexity of the product type, as well as the physical and possibly psychological factors associated with its high alcohol content. To date no information has been published that tested the effect of these specific factors on panellist performance in projective mapping tasks. This study tested the effect of sample complexity and alcohol content on sensory panel repeatability and accuracy in projective mapping, using six types of commercial alcoholic beverages. In a second objective, the study also tested the effect of prior knowledge of alcohol content of a given product set on panellist performance in projective mapping. The results showed that complexity had the biggest impact on panel performance, while alcohol content had a secondary but decisive influence, largely due to its chemosensory fatiguing nature. Knowledge of the product alcohol content appeared to affect individuals differently, and also had an effect on the terminology used by the panellists to describe the products. The study also introduces the Relative Performance Indicator (RPI) as a new panel performance monitoring tool for projective mapping.

1. Introduction

Brandy is a complex grape-based distilled beverage with an alcohol content of at least 36% ABV (alcohol by volume), as specified by EU regulations (European Union., 2008). Many different styles and types of brandy are produced across the globe. Well-known and protected styles include French cognac, Spanish Brandy de Jerez, Portuguese Lourinhã brandy, Chilean Pisco and South African potstill brandies (Robinson, 1999). Sensory evaluation of these products is important to ensure quality products that meet consumer demands.

Projective mapping, also known as Napping®, (Pagès, 2005; Risvik, McEwan, Colwill, Rogers, & Lyon, 1994) is a rapid sensory profiling method designed to obtain a holistic overview of the sensory differentiation between products in a given sample set, without the time- and cost impact of conventional sensory profiling methods such as quantitative descriptive analysis (QDA™) (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974). When it comes to alcoholic beverages, projective mapping has only been applied to wine (Hopfer & Heymann, 2013; Pagès, 2005; Perrin & Pagès, 2009; Perrin et al., 2008; Ross, Weller, & Alldredge, 2012; Torri et al., 2013). The wines tested included white wines from the Loire valley as well as red wines from France, Italy and the USA. Although the alcohol contents were not specified, the expected range for these wine styles is 11–15% ABV. One of these studies reported a maximum alcohol content of 15.3% ABV (Hopfer & Heymann, 2013; chemical analyses reported in related study in Hopfer, Ebeler, & Heymann, 2012). Spirit beverages, such as brandy, are typically diluted to 20–23% ABV before sensory evaluation (Louw & Lambrechts, 2012). Our earlier work was the first study on rapid sensory profiling of spirit beverages and projective mapping was validated as a suitable method for brandy evaluation (Louw et al., 2013). The results showed good accuracy and repeatability

Abbreviations: RPI, relative performance indicator; PPI, people performance indicator.

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for a small set of six brandies per evaluation. However, in comparison, when a larger set of ten brandies per session was evaluated, the repeatability of the method decreased, and repeated measurements were recommended to improve the quality of the results (Louw et al., 2013).

Considering the nature of brandy, we speculated in our earlier work that the decrease in panel performance could be due to sensory fatigue caused by the samples. Different types of fatigue relevant to sensory evaluation have been identified (Sauvageot, 1990). Those relevant to brandy evaluation include sensory and mental fatigue that may be induced by the inherent product properties and possibly psychological fatigue that may be induced by panellists' expectations of the product type and what the evaluation thereof, would involve. For high alcohol beverages, panellists may for example expect the product to elicit a stronger burning sensation than a low alcohol beverage or that it may cause them to tire more easily.

Alcohol is a chemosensory irritant which may cause sensory fatigue through continuous stimulation of the trigeminal senses (Green, 1988; Prescott & Swain-Campbell, 2000). As projective mapping relies on holistic, comparative product evaluation, sensory analysts are more restricted in the measures that can be taken to compensate for fatigue induced by high alcohol content than in conventional profiling where samples are presented one at a time. However, the effect of alcohol content on panel performance, and subsequently data quality, has not specifically been explored in literature.

Product complexity also complicates sensory evaluation, by leading to mental fatigue amongst panellists and hence poor performance. It has been suggested that a less analytical sensory approach is more suitable to complex samples than intensity scaling, based on the argument that the overall odour perception of complex products cannot be accurately broken down into independent, measurable attributes (Lawless, 1999). This often results in a sensory lexicon that is limited to a few descriptors that can be accurately scaled, ignoring many other attributes that may be present but for which panel consensus regarding their definition and intensity could not be achieved (Lawless, 1999). An approach that could deal with this issue would be to allow panellists to indicate, instead of quantify, which terms are important to describe the product by providing them with an extensive list of descriptors relevant to the product category (Campo, Ballester, Langlois, Dacremont, & Valentin, 2010; Lelièvre, Chollet, Abdi, & Valentin, 2008), or allowing them to supply their own words to describe the product, as is done in the Napping® procedure (Perrin et al., 2008). Product complexity has been implicated to impact on the quality of projective mapping results (Nestrud & Lawless, 2010), although this observation was based on fruit and dairy studies. The complex volatile structure of brandy elicits a considerable number of sensory perceivable nuances (Jolly & Hattingh, 2001), which can complicate the projective mapping task by making it more difficult for the panellist to decide which attributes are the most important. To date, there is no information available on the effect of the complexity of alcoholic beverages on panel performance in projective mapping.

As mentioned previously, panellists' assessment of spirit beverages may be influenced by their expectations of the product and the task of evaluating it. Panellists' expectations from information received or inferred prior to product evaluation are some of the many cognitive factors that can influence the way that trained panellists perceive and evaluate products (Lawless & Heymann, 1999; Schifferstein, 1996). Panellists may expect to perceive certain attributes based on verbal cues given by the panel leader, or from non-verbal cues obtained from the product itself. Qualitative judgments made on product information such as nutritional information has shown to also affect quantitative product assessment (Schifferstein, 1996). Confidence in task competency has been linked to motivation and performance of trained sensory panellists (Lund, Jones, & Spanitz, 2009). It is possible that panellists may form expectations around task difficulty based on product type and information; panellists may associate high alcohol beverages with sensory fatigue, mild intoxication and/or increased task difficulty. However, there is no information on whether sensory panellists' performance in the evaluation of spirit products is affected by their knowledge of the products' alcohol content.

Projective mapping studies tend to report on panel performance by comparing panellists with each other, but very few report on the individual panellists' internal consistency. Some researchers have used the panellists' physical projective maps to determine their task competency, i.e., whether samples were placed in straight lines, or scattered across the entire sheet (Nestrud & Lawless, 2008; Pagès, 2005). RV coefficients between data from repeated sessions have been used to determine the repeatability of individuals (Kennedy, 2010). Panellist performance has been evaluated by their ability to position two duplicated samples close to each other on the projective mapping sheet. This is expressed as a ratio of the Euclidean distance between the two duplicate samples and the maximum inter-sample Euclidean distance in the sample set. This ratio has been referred to as the People Performance Index (PPI) (Hopfer & Heymann, 2013) and also as a $D_{r\%}$ ratio (Torri et al., 2013). The drawback of this ratio is that it provides information on the panellists' consistency in positioning only one sample. Procrustes Analysis of Variance (PANOVA) has been used to determine panel consistency by evaluating total consensus variance for overall consistency and product residuals to determine whether there were any specific products that the panellists disagreed on (Nestrud & Lawless, 2008). Although this approach provides information the panel's consistency for all samples, it does not provide a single interpretable measure.

In this study it was of interest to gain better understanding of the sensory, mental and psychological fatigue causing factors that influence panel performance in projective mapping of spirit beverages, and two separate research objectives were identified. The first was to investigate the effects of alcohol content and product complexity, using an experiment design to vary these two factors, on panellist performance in the projective mapping task. The aim of this experiment was to evaluate which of these product characteristics would be the most important risk factor in brandy evaluation. The second objective was to determine to what extent panellists' performance is affected by prior knowledge of the alcohol content of a given sample set. In other words, the objective was to gain insight into the cognitive impact of high alcohol content on panellist performance. With panellist performance being a key concern in this study, a new performance monitoring measure, will be introduced.

2. Methods and materials

2.1. Panellists

The panels that participated in this study consisted of women between the ages of 23 and 60 that are employed as trained sensory panellists at Distell Ltd, South Africa. They were screened for sensory acuity according to the guidelines in Stone and Sidel (1992). The screening test included threshold testing for basic tastes, aroma identification, memory recall for aromas, discrimination ability, intensity ranking and participation in a mock panel situation. The panel was experienced in conventional sensory profiling as well as projective mapping of various types of alcoholic beverages, including brandy. Nine women participated in the study that investigated the effect of product alcohol content and complexity on panel performance, while ten women participated in the study investigating the effect of prior knowledge of alcohol content on panel performance.

2.2. Samples

2.2.1. Objective 1: the effect of product alcohol content and complexity on panel performance in projective mapping of alcoholic beverages

Six sets of commercial alcoholic beverages, ten products each, were presented to the panellists (Table 1). As the ultimate purpose of the study was to gain better understanding of the difficulties associated with brandy evaluation, it was decided to use ten samples per set, based on our previous work that showed that this number is challenging for the panel (Louw et al., 2013). The sets represented high alcohol products (20% ABV) and low alcohol products (≈7% ABV). Three levels of complexity were included in the design for each level of alcohol content. In this case, complexity was defined as the perceived complexity, i.e., the number of attributes used to describe the overall perception of the product, as well as the degree of homogeneity in the sample set, i.e., the ratio of the number of attributes per sample relative to the total number of attributes used to describe the whole product set. Data from previous sensory profiling studies on various types of alcoholic beverages, which were conducted at the sensory research facility at Distell Ltd, were evaluated to identify product types of varying complexity. These studies were conducted independently from the current study and from each other. The number of attributes for which a certain product scored higher than 0 on a 100 mm intensity scale was taken as an indication of perceived product complexity. This value was also divided by the total number of attributes measured in the study to give ratios of the number of attributes contributing to the overall perception of each product relative to the total number of attributes in the product set. This ratio can be regarded as an indication of sample set homogeneity. In each sample set, one product was presented twice as a blind duplicate to test for accuracy. The duplicated samples were chosen in such a way that they would not be obviously different from the others and therefor easily recognisable. Each sample set was presented twice to test repeatability. The panellists were not informed of the purpose of the study.

Standard serving practices were followed for each product type. The low alcohol products were refrigerated until 15 min prior to tasting. The high alcohol beverages were diluted with distilled, odourless water from their full alcohol strength (38% ABV to 43% ABV) to 20% ABV one hour prior to evaluation. The high alcohol products were served at room temperature.

2.2.2. Objective 2: the effect of prior knowledge of product alcohol content on panel performance in projective mapping of spirit beverages

Five sample sets, consisting of eight products each were served in this study (Table 2). Each set consisted of three brandy brands (B1–B3), diluted with three brands of non-alcoholic mixers of the same flavour (M1–M3). The B3M3 combination was served twice to test the panellists' ability to identify that the two duplicate samples are the most similar. In three of the sample sets, the brandies were diluted from their original alcohol strength (38% ABV–43% ABV) to 7% ABV (first three columns of Table 2). For these three, the panellists were either given no information (U), correct information (I) or incorrect information (M) regarding the alcohol strength. In the latter case (M) they were told that the samples were high in alcohol, when it was in fact low (7%). The remaining two sample sets were diluted to 20% ABV. For these, the panellists were given no information (U) or correct information about the alcohol content (I). It was not possible to create a credible misinformed scenario for the high alcohol content sample sets as the perceived alcohol burn would make it quite obvious that the samples are high in alcohol and not low alcohol as informed by the panel leader. Each sample set was presented twice to test repeatability.

Table 1
Six sets (10 samples each) of commercial alcoholic beverage of different levels of alcohol content and perceived complexity.

	Low complexity	Medium complexity	High complexity
High alcohol (20% ABV)	HaLc[a] 20[b]; 0.48[c]	HaMc 22; 0.56	HaHc 27; 0.71
Low alcohol (7% ABV)	LaLc 12; 0.31	LaMc 15; 0.50	LaHc 20; 0.57

[a] Abbreviation used in text.
[b] Sample complexity: average number of attributes recorded per sample.
[c] Sample set homogeneity: ratio of number of attributes present per sample relative to total number of attributes used to describe sample set.

2.3. The projective mapping task

The projective mapping task was performed in conjunction with ultra flash profiling as described by Perrin et al. (2008). Panellists were instructed to smell and taste all the samples in the order received and to position them on an A3 sheet of paper according to sensory similarity. Similar samples were to be positioned close together and very different samples, far apart. They were provided with scrap paper on which they could write down their perceptions. The panellists had to provide sensory descriptors for each sample. The samples were served in a randomised order, balanced across assessors, to avoid serving order effects.

2.4. Testing conditions

The tastings were conducted in white tasting booths under ambient lighting and controlled temperature. The samples were served in a random order with consideration for first order serving effects. The panellists received 30 ml of product in standard 250 ml tulip shaped tasting glasses. The panellists received all the samples at the same time.

2.5. Statistical analysis

All analyses were performed in XLStat version 2013.2.03. The projective mapping coordinates were measured relative to the centre of the tasting sheet. The coordinates were analysed with general procrustes analysis (GPA). RV coefficients were calculated as a measure of similarity between the repeated measurements of each panellist. During GPA, noise caused by rotation, translation and scaling are removed to generate an optimal consensus map. A Relative Performance Indicator (RPI), based on the variance explained by GPA after data transformation, was used as a measure of the similarity between the product maps generated in the replicated sessions for each panellist. Both RPI and the RV coefficients test repeatability, but RV coefficients are more relevant to the data structure before statistical analysis, RPI values are more relevant to the resulting product maps. It can be said that the RV coefficient tests repeatability of the panellists' actual measurements, while the RPI tests the repeatability of the panellists' resulting product maps.

Relative performance indicator

$$= \frac{\left(\text{sum of variances} - \frac{\text{SSQ}}{n_{\text{samples}} \times n_{\text{configurations}}}\right)}{\text{sum of variances}} \qquad (1)$$

Table 2
Abbreviations for samples tested at various alcohol strengths (L-low and H-high) and information regarding alcohol content given prior to evaluation (I-informed, U-uninformed, M-misinformed). In the sample abbreviations, the letters B1–B3 denote the brandy brands and the letters M1–M3 denote the mixer brands.

7% ABV (L) uninformed (U)	7% ABV (L) informed (I)	7% ABV (L) misinformed (M)	20% ABV (H) uninformed (U)	20% ABV (H) informed (I)
B1M1_L_U	B1M1_L_I	B1M1_L_M	B1M1_H_U	B1M1_H_I
B1M2_L_U	B1M2_L_I	B1M2_L_M	B1M2_H_U	B1M2_H_I
B1M3_L_U	B1M3_L_I	B1M3_L_M	B1M3_H_U	B1M3_H_I
B2M1_L_U	B2M1_L_I	B2M1_L_M	B2M1_H_U	B2M1_H_I
B2M2_L_U	B2M2_L_I	B2M2_L_M	B2M2_H_U	B2M2_H_I
B2M3_L_U	B2M3_L_I	B2M3_L_M	B2M3_H_U	B2M3_H_I
B3M3_L_U	B3M3_L_I	B3M3_L_M	B3M3_H_U	B3M3_H_I
B3M3_L_U	B3M3_L_I	B3M3_L_M	B3M3_H_U	B3M3_H_I

ABV: percentage alcohol per volume; Uninformed: no information was given; Informed: Correct information was given; Misinformed: panellists were told the products were strong in alcohol when it was not.

where SSQ = Residual Sum of Squares from Procrustes ANOVA after compensating for rotation, translation and scaling during GPA and n = number of samples or configurations, as annotated.

Higher RV and RPI coefficients indicate better similarity. RV coefficients of 0.700 have been suggested as a cut-off point for good similarity (Cartier et al., 2006). An appropriate cut-off point for the RPI has not been confirmed, but will for the present be evaluated against the same standard.

The panellists' accuracy was measured using the Peoples Performance Index (PPI) as suggested by Bertuccioli (2011) and applied by Hopfer and Heymann (2013). The index involves dividing the Euclidean distance between duplicated samples in a sample set by the maximum Euclidean distance in the sample set. Lower PPI values indicate better accuracy. The between treatment differences were tested for each performance indicator with ANOVA. Panellists were regarded as a fixed effect, since variance between panellists was a specific interest in this study. Significant differences were based on Type III Sum of Squares while individual differences were evaluated with the Fisher LSD post hoc test.

3. Results

3.1. Objective 1: the effect of alcohol content and complexity on panel performance in projective mapping of alcoholic beverages

3.1.1. Repeatability of measurements

Fig. 1 shows the effect of alcohol content and complexity on the RV coefficients between two repeated measurements by the same panellist. At low alcohol levels, sample set complexity did not appear to affect panellists' repeatability. However, at high alcohol levels, a significant step-wise decrease in repeatability was observed as the sample sets became more complex. In the high and medium complexity levels, alcohol content did not have a significant impact on repeatability. However, much higher RV coefficients was observed for HaLc than for LaLc.

3.1.2. Repeatability of product maps

At 20% ABV, complexity had a significant effect on the panellists' RPI values (Fig. 2). The panellists' produced the least repeatable product maps for the HaHc sample set. There were significant stepwise increases in the panellists' RPI values from HaHc to HaMc and finally to HaLc. At 7% ABV, an increase in complexity did not significantly affect the panellists' RPI values, although the panellists appeared to be somewhat less repeatable at high complexity than at medium and low complexity. Alcohol content did not appear to affect RPI values at the different levels

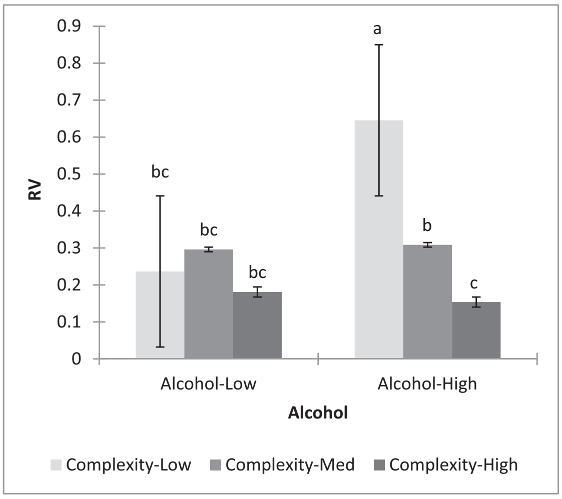

Fig. 1. Average RV coefficients showing trained panellists' repeatability in projective mapping for beverage sample sets of varying degree of complexity and alcohol content. Higher values indicate better repeatability. Letter notations denote Fisher LSD values as an indication of the observed effects. Error bars denote standard error.

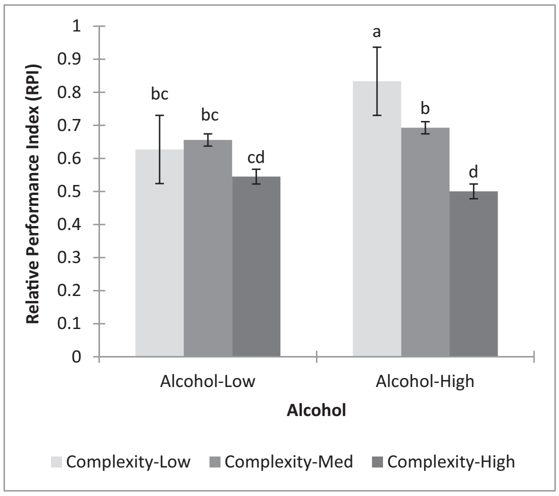

Fig. 2. Relative performance index showing trained panellists' ability to generate reproducible product maps with projective mapping for beverage sample sets of varying degree of complexity and alcohol content. Higher values indicate better performance. Letter notations denote Fisher LSD values as an indication of the observed effects. Error bars denote standard error.

of complexity. No difference was observed between HaHc and LaHc or between HaMc and LaMc. However, at low complexity, there was a significant difference between the alcohol levels, in favour of HaLc.

3.1.3. Accuracy in recognising duplicate samples

At both alcohol levels, the panellists' accuracy decreased as the sample sets became more complex (Fig. 3). At 20% ABV HaLc had significantly lower PPI values than HaHc and HaMc. At 7% ABV the difference was less pronounced; with LaLc being significantly lower than LaHc but not than LaMc. At all three complexity levels, the panellists were more accurate in the low alcohol sample set than in the high alcohol sample set. This difference was statistically significant at medium complexity.

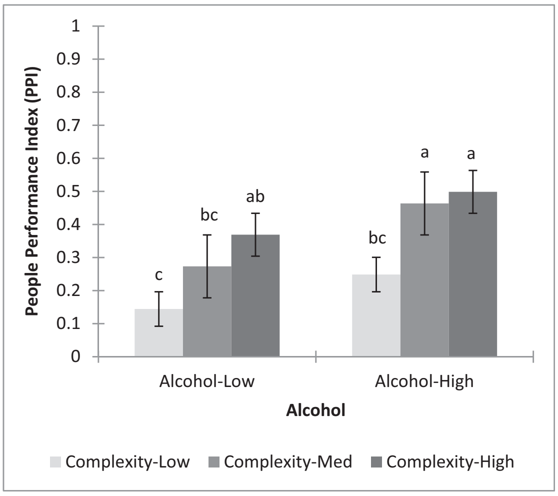

Fig. 3. People performance index (PPI) showing trained panellists' accuracy in projective mapping for alcoholic beverage sample sets of varying degree of complexity and alcohol content. Lower values indicate more accurate responses. Letter notations denote Fisher LSD values as an indication of the observed effects. Error bars denote standard error.

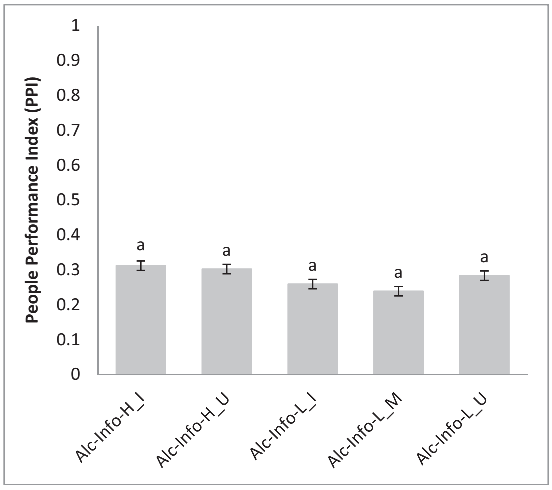

Fig. 5. Panellist accuracy in the projective mapping task for sample sets with high alcohol (H) and low alcohol content (L). Panellists were either given no information (U), correct information (I) or incorrect information (M) regarding the alcohol strength. Error bars denote standard error while letter notations on bars denote Fisher LSD values.

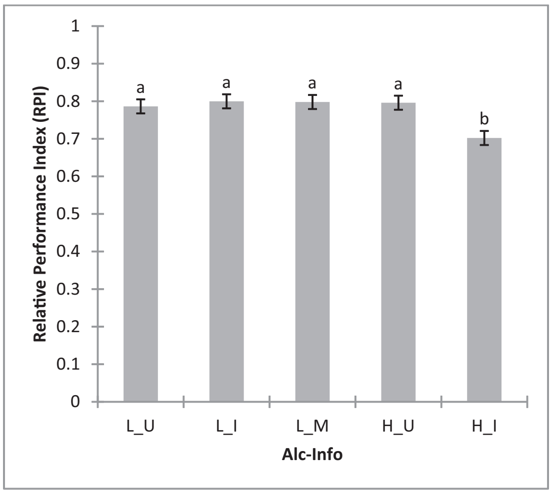

Fig. 4. Panellist repeatability in the projective mapping task for sample sets with high alcohol (H) and low alcohol content (L). Panellists were either given no information (U), correct information (I) or incorrect information (M) regarding the alcohol strength. Error bars denote standard error while letter notations on bars denote Fisher LSD values.

3.2. Objective 2: the effect of prior knowledge of alcohol content on panellist performance in projective mapping of spirit beverages

3.2.1. Repeatability of the measurements and product maps

In this case, there was a very high correlation between the RV coefficients and RPI values (Pearson correlation coefficient = 0.945; *p*-value < 0.0001) and the same conclusions can be drawn from the two coefficients. For the sake of brevity, only the RPI values will be discussed as an indication of repeatability (Fig. 4).

There was noticeably lower similarity between two replicate sessions when panellists were correctly informed that they were evaluating high alcohol products (H_I) compared to the other tasting conditions. The same effect was not observed in the case of L_M when panellists thought they tasted high alcohol beverages when they were in fact tasting low alcohol beverages. One could argue that the effect of the information served to strengthen the physiological impact of the high alcohol rather than reducing performance *per se*.

3.2.2. Accuracy in recognising duplicate samples

Information regarding the alcohol content did not significantly affect accuracy in this experiment (Fig. 5). However, a moderate panellist * treatment effect was observed ($p = 0.081$). Fig. 6 shows the average PPI score for three panellists for each treatment. Panellist 7 had very similar PPI scores over the different testing conditions, Panellist 6 performed better under low alcohol conditions, with her performance at L_M being more similar to H_I and H_U. In contrast, Panellist 2 performed better under high alcohol conditions, with her performance at L_M also being better than at L_I.

3.2.3. Use of alcohol related descriptors

Generally, the panellists used only one or two attributes relating to alcohol to describe the samples tested in this experiment. However, as a group, their use of alcohol related words was significantly more prevalent in the high alcohol conditions than in the low alcohol conditions (Fig. 7). Their word use in the L_M condition did not differ significantly from the high alcohol conditions, even though the samples were low in alcohol.

4. Discussion

4.1. The effect of alcohol content and complexity on panel performance in projective mapping of alcoholic beverage

The purpose of this part of the study was to gain a better understanding of the influence of high alcohol content and sample complexity on panel performance in projective mapping of brandy. Towards this end panellists' performance in projective mapping of six types of commercial beverages, including brandy, was compared. One must first consider the implications of the choice for evaluating commercial beverages over model beverages. Previous studies on wine suggest that alcohol content has a significant impact on the odour activity and perception of volatile compounds, but that the effect is not to the same for all compounds. Alcohol does not only affect the solubility of individual compounds, but also the perceptual synergy between compounds (Goldner, Zamora, Di Leo Lira, Gianninoto, & Bandoni, 2009; Le Berre,

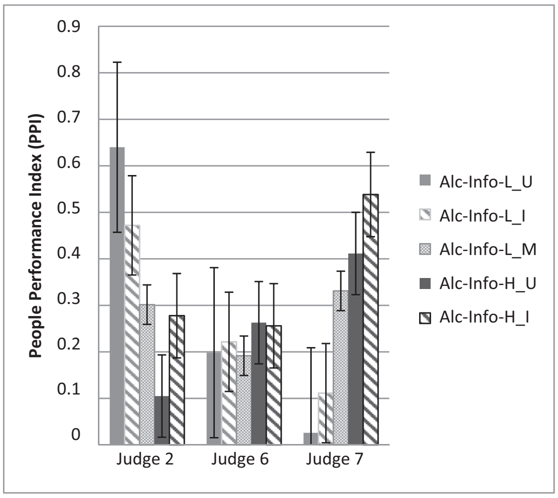

Fig. 6. Individual differences in accuracy with which panellists are able to perform the projective mapping task under two alcohol content conditions (High alcohol (H) and low alcohol content (L)) and three information conditions where panellists were either given no information (U), correct information (I) or incorrect information (M) regarding the alcohol strength. Error bars denote standard error while letter notations on bars denote Fisher LSD values.

Atanasova, Langlois, Etiévant, & Thomas-Danguin, 2007; Villamor, Evans, Mattinson, & Ross, 2013). Furthermore, it was also suggested that alcohol content can influence the extent to which other components such as glycerol and polysaccharides, influence aroma perception in wine (Jones, Gawel, Francis, & Waters, 2008). This implies that even if all other components remain constant, panellists' sensory perceptions of a set of products will invariably differ as soon as the alcohol content is adjusted. For this reason, it was decided not to use model beverages, but rather commercial beverages. However, this also means that conclusions drawn from the results of this study must take the variation of the product type into account.

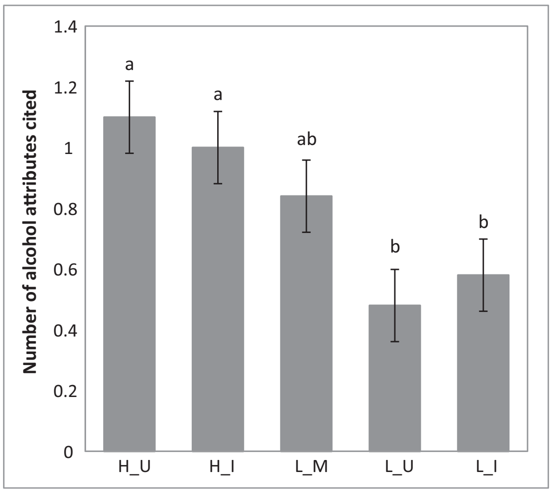

Fig. 7. Differences in the overall number of alcohol related attributes used in the projective mapping task under two alcohol content conditions (High alcohol (H) and low alcohol content (L)) and three information conditions where panellists were either given no information (U), correct information (I) or incorrect information (M) regarding the alcohol strength. Error bars denote standard error while letter notations on bars denote Fisher LSD values.

Keeping this information in mind, two key observations can be made regarding the effect of alcohol content and complexity on panel performance. The first is that the complexity of the sample set had a larger impact on panellist repeatability than alcohol content, in the range tested. In fact, despite some differences observed between LaLc and HaLc, alcohol content did not appear to have a significant effect on panellist repeatability at all. Considering the minimal effect at medium and high complexity, the difference observed at low complexity was likely due to the fact that the HaLc samples were more one-dimensional than the LaLc samples rather than the difference in alcohol content. It must be noted that the repeatability of LaMc was slightly lower than LaLc, although not significantly so. It is possible that the panellists changed their criteria on which they based their product positioning from one session to another, which could have a big effect if a sample set is very heterogeneous like LaLc. Shifts in projective mapping and sorting criteria have been reported in previous studies on sorting and projective mapping (Chollet & Valentin, 2001; Kennedy, 2010). Repeated measurements are recommended to compensate for criteria changes in projective mapping. Previous studies have also highlighted the value of repeated measurements towards ensuring valid results (Hopfer & Heymann, 2013; Louw et al., 2013).

The finding that sample set complexity proved to have a significant effect on panel performance, supports circumstantial evidence from other studies on the impact of product complexity on stability of results in rapid sensory profiling (Delarue & Sieffermann, 2004; Nestrud & Lawless 2010). The complexity of the sample set proves to be an important factor to take into account for the effective execution of projective mapping. Evaluating sample sets with a relatively low degree of differentiation in the set is a more complicated task with a higher risk of affecting panel performance than a sample set with a high degree of differentiation e.g., brandies compared to flavoured vodkas. If the samples are also perceptually complex, as is the case with brandy and wine, this can further complicate the task and increase the risk of poor panel performance. This supports Hopfer and Heymann's speculation that sample set homogeneity may be a contributing factor to high variability in panellist performance in projective mapping (Hopfer & Heymann, 2013).

A second important observation is that the effect of complexity on panellist repeatability was enhanced at higher alcohol content. Alcohol in itself can add to product complexity in the sense that flavoured vodkas can be perceived as more complex than flavoured waters. Among high alcohol beverages, different spirit product types can vary vastly in terms of volatile complexity. Vodka is by definition a neutral spirit with very few volatile components. In contrast, brandies have a very complex volatile structure, and even within the brandy category, product types can differ in complexity, depending on the percentage copper pot distilled content. Similar variations in compositional complexity can be found among low alcohol products such as spirit coolers, ciders and beers. Having a high alcohol content does not make a product set difficult to evaluate, as is indicated by HaLc. This study shows that the effect of complexity on task difficulty, as inversely expressed by panellist performance, is larger for spirit beverages than for low alcohol beverages. The enhancing effect of alcohol content could possibly be attributed to underlying sensory fatigue caused by the chemosensory irritation from the ethanol. Another hypothesis is that the perceived complexity of a compositionally complex spirit product is enhanced by its alcohol content and that this adds to task difficulty. The enhancing effect of alcohol content is likely due to a combination of these factors, although other explanations are not excluded.

4.2. The effect of prior knowledge of alcohol content on panellist performance in projective mapping of brandy

The second objective of this study was to determine whether sensory panellists' performance in brandy evaluation is influenced by their knowledge of the alcohol content. Although the panel leader can attempt to minimise the amount of information conveyed to the panel, the panellists are still able to infer information regarding the product. This is especially relevant in alcoholic beverage studies since the type of product can be a cue to the possible alcohol content, and also because alcohol itself is detectable with the senses. This part of the study investigated whether trained panellists' knowledge of the alcohol content of the products they evaluated affected their performance in projective mapping. It is uncertain exactly what information panellists would associate with high alcohol products. Panellists may expect that alcohol related attributes such as alcohol burn may be more prevalent in high alcohol beverages. This may influence their perception of the products and possibly the way in which they convey their perceptions in projective mapping. They may also expect, or at least be aware of the risk of the mild intoxication that may accompany the evaluation of high alcohol beverages. Such awareness may influence their expectation of the task difficulty and subsequently their performance.

Brandies mixed with different non-alcoholic mixers were chosen as stimuli as it would not be immediately obvious what the product type is and that the panellist could therefore not make any inferences regarding the alcohol content before tasting the product. Our results provide indicative information on the possible effect of panellists' expectation of alcohol content on their performance and approach to the projective mapping task.

Two important observations are highlighted in this study. Firstly, the effect of prior knowledge of a product's alcohol content on accuracy in the projective mapping task can differ from panellist to panellist as was illustrated in Fig. 6. The differences in their responses to the information given about the sample conditions could mean that the panellists formed different expectations from the information that they received. For instance, Panellist 6 had very similar PPI scores over the different testing conditions; she may not have had any expectations from her knowledge of the alcohol content of the beverages she had to evaluate. Panellist 7 performed much better under L_U and L_I conditions than under the H_U, H_I and L_M conditions. She may have expected that a low alcohol task will be easier than a high alcohol task based on previous experiences. The information provided about the alcohol content, whether true or false, may have influenced her confidence and motivation and subsequently her performance in the task. On the other hand, Panellist 2 had the exact opposite results, which is performing better under high alcohol conditions than low alcohol conditions. It may be that she also expected the high alcohol task to be more difficult, but instead of responding with demotivation, she responded by concentrating harder on the task. Collecting data from more than two sessions, as was done in this case, and perhaps also in different product types, would provide more insight into whether these tendencies persist.

A second important finding relates to the use of alcohol related characteristics to describe the differences they perceived between the products. In the low alcohol conditions, the panellists used significantly less alcohol related words than in the high conditions. However, for the L_M sample set, their use of alcohol related words did not differ significantly from high alcohol sample sets. A possible reason for this is that they may have allocated more value to the alcohol related attributes they perceived, thinking that the samples are high in alcohol than they may have felt necessary under the low alcohol conditions. It must be considered that the results of projective mapping rely on the relative value that panellists allocate to the different sensory attributes present in the products being evaluated. The results of this study provides reason for caution that alcohol content expectancies may influence which product attributes the panellists may consider as important or not. As with other stimulus errors, providing panellists with product information should be avoided.

4.3. The relative performance index (RPI) as a measure of panellist performance

A final observation must be made regarding the use of RPI versus RV coefficients to measure panellist repeatability. The conclusions drawn from RV coefficients and RPI values were largely similar. However, some important differences could be observed. Firstly, the panellists RPI values comparing sessions were consistently higher than their RV coefficients comparing sessions. Previous studies on projective mapping have also reported that, based on RV coefficients, that panellist repeatability can be poor despite stable overall configurations (Kennedy, 2010; Risvik, McEwan, & Rødbotten, 1997). In our study, the average RV coefficient between sessions was 0.402, also indicating quite poor repeatability. In comparison, the average RPI were much higher, around 0.702. In a study on granola bars, Kennedy speculated that poor panellist repeatability may be related to the possibility that panellists change their criteria by which they differentiate between samples (Kennedy, 2010). RPI is based on the optimal consensus between the replicate sessions after procrustes data transformation and therefore corrects for variation in the panellist's assessments, whether due to environmental factors or a conscious decision on the panellist's part. RPI may be a more realistic assessment of the panellist's perception of the products rather than the way that they approached the products and could be a very relevant panel management tool. Also, RPI values can be used as a single measure to determine consistency over several data configurations, whereas the RV coefficient only compares two data configurations. Therefore, if multiple repeated sessions are conducted, RPI values would provide a more comprehensive measure for panellist repeatability. In the case of brandy evaluation, where the risk of the product complexity to panel performance is enhanced by its high alcohol content, three replicate sessions may be more practical than two sessions, in which case RPI would be an especially useful measure of panel performance.

5. Conclusion

The high alcohol content and complexity of brandy has been identified as risk factors that can potentially affect panellist performance in the sensory evaluation thereof. Complexity appears to be the most important contributing factor, although alcohol content plays an important secondary role. From the preliminary results from this study, the role of alcohol content appears to be largely physiological through its chemosensory fatiguing effect. However, the performance of some individuals may also be influenced on a cognitive level by their knowledge of the products' alcohol content. As projective mapping is increasingly being used as an alternative to conventional profiling, it would be prudent to take all possible risk factors into account when applying the method to brandy. By using repeated measurements, restricting the amount of information given to panellists and using enough panellists to compensate for individual differences, many of the identified risks could be effectively addressed in future studies.

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