THESES OF DOCTORAL (PHD) DISSERTATION

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INVESTIGATING THE EFFECTS OF SENSORY STIMULI USING NEUROMARKETING TOOLS

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Table of contents

1. BACKGROUND OF THE WORK, OBJECTIVES

Understanding and deciphering the behaviour of others is a fundamental part of human development and nature. This is particularly true in business and customer behaviour, where assessing and understanding the behaviour of others is a way of predicting the market and increasing profits. Neuromarketing is an interdisciplinary branch of science based on the use of neuroscientific concepts, theories and methods (or tools and techniques for recording brain and neural activity during behaviour). It does this by focusing on the study of the brain and nervous system, understanding instinctive (or natural) human behaviour and emotions in response to some marketing stimulus, whereby the knowledge gained from neuromarketing research contributes to the development and advancement of marketing theory (LIM 2018; Internet 1). Neuromarketing was developed to measure the emotions, feelings and perceptions that arise during consumer decision-making, thereby moving closer to understanding the process. With its tools it enables the examination of the unconscious parts of the human brain, providing insights that traditional marketing and research methods cannot achieve.

There are countless factors that influence our everyday choices and decisions. The realm of unspoken thoughts is much wider than spoken and known thoughts, and this is where neuromarketing comes in. Furthermore, there are many factors that can alter and distort human perception, many of which individuals are unaware of. However, neuromarketing can identify and measure these factors, making it a highly effective tool.

Food choice is a seemingly simple, but in fact very complex process, influenced by many interacting factors (KÖSTER 2009). Therefore, my PhD thesis aimed to investigate the impact of certain factors such as scent, music and nutrition labelling on consumer choice.

In my PhD thesis, I investigated some of the factors influencing consumer decision making (scent, music and nutrition labelling), so I grouped my objectives according to these factors. My aims and theses are below:

My aim in studying the effect of scent was to investigate

(1) four categories of foods (chocolate, tea, muesli bar and yoghurt), whether participants chose the product they looked at most often and

(2) whether the presence of the strawberry scent influenced consumer decision-making, i.e., the strawberry scent made more consumers to choose the strawberry-flavoured product.

In examining the effect of music, my aim was to investigate whether

(3) the music of different nations influenced consumer choices, i.e. whether music caused more people to choose a particular national food;

(4) music has an effect on visual attention;

(5) there is an interaction between music and food choice; and

(6) there are parallels between similar cultures.

In examining the different front-of-pack (FoP) labels, I aimed to investigate

(7) the impact of different labels on visual attention;

(8) which of the FoP labels studied received the most visual attention, and

(9) whether there is a difference in the ranking of products before and after the eye-tracking measurement, i.e., whether there is a difference in the ranking of products before participants are not familiar and familiar with the FoP label of the products, and hence their nutritional value.

In examining each of the menu alternatives, my aim was to investigate

(10) whether the area of a menu that attracts the most visual attention;

(11) which menu alternatives, after visual inspection, are the ones that consumers choose to eat with lower kilocalorie (kcal) value;

(12) which labelling method is most likely to attract consumers' visual attention and

(13) whether there is a relationship between choice and self-report for each menu alternative.

In examining the Nutri-Score labelling system, my goal was to examine whether

(14) there is an interaction between the products included in the study and the emotions expressed by the participants, and

(15) the fixation duration (FD) value of the eye-tracking parameters can predict a participant's choice.

2. MATERIALS AND METHODS

2.1 Tools used in the research

I have followed the guidelines published by FIEDLER et al. (2020) for information on eye-tracker studies. During my research, eye movements were tracked and recorded using desktop eye-trackers from Tobii (Tobii Pro AB, Danderyd, Sweden). Eye movements were tracked using a Tobii Pro X2-60 eye-tracker when investigating the effects of scent and music, a Tobii Pro Nano eye-tracker when investigating different front-of-pack (FoP) labels, and a Tobii Pro Fusion eye-tracker when investigating menu alternatives and the Nutri-Score labelling system. The image sequences in each study were displayed using Tobii Pro Lab (Tobii Pro AB, Danderyd, Sweden) software.

In addition to the eye-tracker, the Nutri-Score labelling system was tested using Noldus Information Technology FaceReader version 9.1 software (Wageningen, The Netherlands). FaceReader is a facial analysis software that can recognise facial expressions. It is trained to classify the participant's facial expressions into one of the following categories, which Ekman described as basic emotions: happy, sad, angry, surprised, fear, disgusted and neutral (EKMAN 1970).

I used questionnaires to collect demographic data for each survey, as well as other questions related to the research.

2.2 Visual stimuli used in the measurements

I have defined the area of interests (AOIs) according to the formal characteristics of the products presented. The distance between AOIs was maximised to avoid overlaps. I applied an Identification by Velocity Threshold (I-VT) filtering method that used interpolation between gaps (75 ms), noise reduction (median), a velocity threshold of 30°/s, merged adjacent fixations (<0.5°) between fixations (<75 ms), and discarded short fixations (<60 ms).

2.2.1 Visual stimuli used to examine the effect of scent

I showed the participants five different series of images, the first of which were practice exercises, rehearsal images. The rehearsal images contained

products different from the subject of the measurement and were used to understand the task, so I did not use them in the data analysis. The structure of the remaining four choice sets was identical, but the order of product groups and products was random. The image sets presented four product groups - muesli bar, chocolate, tea and yoghurt - and there were always four product alternatives to choose from. The visual stimuli consisted of product alternatives from the same brand, with only one strawberry flavour. Each variation was preceded by a slide with a fixation cross presented in the middle of the screen for two seconds, so that the gaze was always directed from the centre. As the research was aimed at investigating the effect of strawberry scent on decision making, a pleasant strawberry scent was sprayed into the air using MAYAM elements essential oil and a Sencor SHF 920BL (Ricany, Czech Republic) humidifier.

2.2.2 Visual stimuli used to examine the effect of music

To investigate the effect of the music, I showed the participants four different sets of images, the first of which were the rehearsal images. I also excluded the rehearsal images from the data analysis. The structure of the remaining three choice sets was identical, but the location of the products was random. The image sets included starters/soups, main courses and desserts, which were traditional dishes from four different nations (Hungarian, German, Italian and Spanish).

As the aim of the research was to investigate the effect of music on decision making, I played music from the four nations (Hungarian, German, Italian and Spanish). I found the music tracks using an app called Spotify (Stockholm, Sweden) (Internet 2).

2.2.3 Visual stimuli used to examine the effect of visuality

2.2.3.1 Visual stimuli used to examine the liking of different FoP labels

I also started with the different front-of-pack (FoP) labels, using the same design as for the music effect. Five breakfast cereals were included in the study, some of which were easy to incorporate into a healthier lifestyle and some of which were less so. The products included in the study were: Nestlé Fitness (P1), Kellogg's Coco Pops (P2), Nestlé Cornflakes (P3), Bona Vita Spelt Wheat Flakes (P4) and Nestlé Cini Minis (P5). For each of the five products, I created three to three front labels, which were as follows: Nutri-

Score, GDA (guideline daily amount) and MTL (multiple traffic light). For each of these products, I created labels per 100 grams based on the nutrition facts table on the back. I placed each label under the product during the measurement so that all information was clearly visible. No FoP label was visible on the packaging of the products at this time.

2.2.3.2 Visual stimuli used to examine menu alternatives

In the menu alternatives study, a total of three different but identical menus of starters/soups, main courses and desserts were examined using an eye-tracker. Each category included 9-9 dishes. Compared to traditional menus, the alternatives in the study differed in that they contained some information on the energy content of each dish. I marked the energy content of each food in three different ways. The first alternative was the GDA-type menu, where the kilocalorie (kcal) values for each dish were indicated numerically in black. The second alternative was based on the principle of MTL labelling, where three colours (red, yellow and green) were used. For those dishes with a high value, the kcal value was indicated in red. For lower kcal values, the colour green was used. The kcal values per serving were determined using NutriComp nutrient calculation software (NutriComp Bt., Budapest, Hungary). For the third alternative (symbolic menu), instead of quantified information, I used a battery to indicate to the participants how energy-dense or energy-poor the food was. I assigned a red battery to foods with a high kcal value and a green battery to foods with a low kcal value.

2.2.3.3 Visual stimuli used to examine Nutri-Score labelling system

In total, twenty commercially available foods were tested. During the measurement, video recordings were made in order to be able to perform the analysis using the Noldus FaceReader software (Wageningen, The Netherlands). The participants agreed to the video recording by signing a declaration. The products included in the measurement were the following: Alpro NOT MILK oat drink; Venus light salted margarine; Garden Gourmet soy protein based bundt vegan bar; Gullón ZERO fibre-filled sugar-free biscuits; ZOTT Jogobella strawberry yoghurt; Venus natural baking margarine; HELIOS strawberry extra jam; Hungarian ESL fresh milk; Nescafé Dolce Gusto Latte Macchiato coffee capsules; Coca-Cola Light carbonated soft drink; Nestlé Chocapic cereal; Alpro sugar-free almond drink; Knoppers Nut Bar chocolate bar; Eisberg French-style garlic salad dressing;

Diablo white chocolate cream; Nesquik Extra Choco cocoa drink powder; Nescafé Dolce Gusto Flat White coffee capsule; Kania ketchup with basil and oregano; Nestlé Fitness strawberry cereal bar and Ritter Sport milk chocolate with whole hazelnuts.

2.3 Data analysis

For the data analyses, I used the following eye-tracking parameters (DANNER et al. 2016):

- time to first fixation (TTFF, time in seconds between stimulus presentation and the first fixation of the user's gaze on the alternative);
- first fixation duration (FFD, duration of first fixation on the alternative in seconds);
- fixation duration (FD, total duration of fixations on the alternative in seconds);
- fixation count (FC, number of fixations on the alternative in units);
- dwell duration (DD, the time in seconds between the user's first fixation on a product and the next fixation outside the product), and
- dwell count (DC, number of 'visits' to an alternative, pieces).

2.3.1 Methods used to examine the effect of scent

I have examined the frequencies of elections using the Chi-square statistic. I tested the effect of choice and scent on gazing behaviour using repeated measures analysis of variance (RMANOVA), with eye-tracking variables as within-subjects factors and choice and odour as between-subjects factors. Data analysis was performed using IBM SPSS Statistics version 16.0 (SPSS Inc., Chicago, USA).

2.3.2 Methods used to examine the effect of music

The data analysis was performed using principal component analysis (PCA), t-test and analysis of variance using XLSTAT version 16.0 (Addinsoft, Paris, France). Classification models were trained using the R project version R-4.2.1 and the following packages: linear discriminant analysis: `MASS` (RIPLEY et al. 2024), artificial neural network: `nnet` (RIPLEY & VENABLES 2023a), random forest: `randomForest` (BREIMAN et al. 2001), support vector machine: `e1071` (MEYER et al. 2024) and k-nearest neighbour classifier: `class` (RIPLEY & VENABLES 2023b). Performance

measures were computed using the `caret` (KUHN et al. 2023) package. Models were created using eye-tracking data obtained on the control group (without music) and the music group. I defined the eye-tracking parameters as independent variables and used choice as the dependent class. Therefore, I trained and tested a total of eight models, four on the control group data and four on the music group data. I compared the models using the sum of ranking differences (SRD) method.

2.3.3 Methods used to examine visuality

2.3.3.1 Methods used to examine different FoP labels

Before and after the eye-tracking measurement, I also used questionnaires, which was necessary to rank the products. The results from this were evaluated using the Kruskal-Wallis test, while the results of the product and label evaluations were evaluated using analysis of variance (ANOVA).

In addition to these, I used choice-based conjoint analysis (CBCA) to examine consumer preference. I created the conjoint maps using the R project (ver. 4.2.1) (R DEVELOPMENT CORE TEAM 2023) `choicetools` package (CHAPMAN et al. 2022). After the eye-tracker measurement, I evaluated the response data using the R-project and the `choicetools` package. I used multinomial logistic regression to evaluate the part-worth utilities.

2.3.3.2 Methods used to examine menu alternatives

Multiple correspondence analysis (MCA) and two-way analysis of variance were performed using XLSTAT v.2023.2.1414 (Lumivero LLC., Denver, Colorado, USA) software. To investigate how the TTFF value varies among the three menu alternatives, I used Kruskal-Wallis test and plotted the mean values using STATISTICA v10 (StatSoft Inc. Tulsa, Oklahoma, USA) software for better comparability.

2.3.3.3 Methods used to examine the Nutri-Score labelling system

Of the data extracted from the FaceReader software, I only analysed the data retrieved from the post-selection page, i.e. the results. First, I analysed the data using analysis of variance (ANOVA), which allowed me to filter out which emotions showed significant differences. This analysis was carried out for each of the 20 products measured. In the following, I only examined the emotions that showed a significant difference. Then I conducted with a

repeated measures analysis of variance (RMANOVA) to examine the interaction between the products and the emotion. The two analyses (ANOVA, RMANOVA) were performed using XLSTAT v.2023.2.1414 (Lumivero LLC., Denver, Colorado, USA) software. The software was used to test whether there is a correlation between the FaceReader and the eye-tracking data. Subsequently, I also performed an analysis of the eye-tracking parameters FD (fixation duration) data for choice prediction using a random forest (RF) method. Last but not least, I also investigated the proportion of participants who made the correct decision regarding the Nutri-Score label of each product.

3. RESULTS AND THEIR DISCUSSION

3.1 The effect of scent

Each of the products included in the study was chosen at least eight times by my participants, and for two of the four product groups (chocolate, tea) I found statistically significant differences in the frequency of choice.

The results of the repeated measures analysis of variance (RMANOVA) (Table 1) showed that for the tea product group, the product had a significant effect on eye movement. Product choice showed no significant effect for any of the four categories, while scent also showed no significant effect for any of the product categories. A significant interaction between product and choice was found for all four product categories. This indicates that the product of choice was viewed differently than the product not of choice.

Table 1: Results of repeated measures analysis of variance (RMANOVA) showing the F-values of the three main effects and their two interactions for the four product categories

Effect	Chocolate	Yoghurt	Muesli bar	Tea
Product	3.068	1.057	3.999	**5.181***
Choice	0.854	0.974	0.923	1.919
Scent	6	1.762	1.908	0.533
Product × Choice	**1.673***	**1.527***	**1.723***	**1.134***
Product × Scent	0.702	**2.667***	0.78	1.329

*Bold and * indicate significant effect at $p<0.05$ significant level.*

Analysing the significant effects in more detail, univariate tests show that the product had a significant effect on FC in the muesli bar category and DC in the chocolate category. TTFF and FFD showed no significant effect between product and choice, supporting appropriate randomization. Significant interaction was found for FD, FC and DD values for all four product categories and for the DC eye-tracking parameter for chocolate, yoghurt and muesli bars. There was also no significant interaction between product and scent for TTFF, but a significant interaction for FFD for the yoghurt, muesli bar and tea product categories. For the DC value, significant results were obtained only

for the yoghurt product category. RMANOVA gave similar results for all four product categories. The results indicate whether participants chose the product to which they paid the most visual attention.

3.2 The effect of music

The Spanish starter received the highest visual attention for FD, FC, DD and DC, while the Italian starter received the lowest average TTFF score. For main courses, the Spanish starter received the highest visual attention for FD, FC and DD, while FFD and DC showed no significant difference between the four nations. However, the highest scores were observed for FFD for the Hungarian main course and DC for the Italian main course. For desserts, FD, FC and DD values showed that the Hungarian dessert received the highest visual attention.

After ANOVA analysis of the type of music (Table 2), I found that for all dishes, Spanish music received the highest scores for almost all parameters, meaning that each dish received the most visual attention when Spanish music was playing. Italian music had the highest number of visits, but there was no significant difference for Spanish and Italian music for DC. With the exception of TTFF, visual attention was lowest when Hungarian music was played. Looking at the starter/soup results separately, we see that FD, TTFF and DD scores were highest for Spanish music, but no significant difference between the music of the four nations. Looking at the main courses, we can say that Spanish music influenced the dishes with the highest visual attention for FD, TTFF and DD, while Italian music did for FC and DC, although there was no significant difference between the music of the four nations. With the exception of the FD value, Spanish music was the most visually appealing to desserts for all parameters.

Table 2: Analysis of variance on the effect of different national music on visual parameters for all dishes (starter/soup, main course and dessert)

Dish category/ eye-tracking parameter		FD	FC	TTFF	FFD	DD	DC
All dishes	Esp_z	0.813^{b}	3.157^{b}	1.026^{b}	0.259^{b}	0.963^{b}	1.562^{b}
	Ita_z	0.708^{b}	$3.134a^{b}$	0.855^{ab}	0.246^{ab}	0.780^{b}	1.599^{b}
	Ger_z	0.802^{b}	2.947^{ab}	0.771^{a}	0.236^{ab}	0.878^{b}	1.512^{ab}
	Hun_z	0.516^{a}	2.587^{a}	0.859^{ab}	0.213^{a}	0.585^{a}	1.305^{a}
Starter/soup	Esp_z	0.946^{a}	3.133^{ab}	1.028^{a}	0.228^{ab}	1.047^{a}	1.422^{ab}
	Ger_z	0.940^{a}	3.220^{ab}	0.904^{a}	0.222^{ab}	0.993^{a}	1.520^{ab}
	Ita_z	0.842^{a}	3.981^{b}	0.772^{a}	0.178^{a}	0.954^{a}	1.827^{b}
	Hun_z	0.588^{a}	2.489^{a}	0.934^{a}	0.246^{b}	0.666^{a}	1.234^{a}
Main course	Esp_z	0.761^{b}	3.034^{a}	1.012^{b}	0.225^{ab}	0.960^{b}	1.610^{a}
	Ita_z	0.694^{b}	3.057^{a}	0.760^{ab}	0.271^{b}	0.742^{ab}	1.623^{a}
	Ger_z	0.640^{ab}	2.600^{a}	0.682^{a}	0.248^{ab}	0.789^{ab}	1.542^{a}
	Hun_z	0.489^{a}	2.586^{a}	0.862^{ab}	0.202^{a}	0.549^{a}	1.329^{a}
Dessert	Esp_z	0.752^{b}	3.327^{b}	1.042^{b}	0.329^{c}	0.890^{c}	1.633^{a}
	Ger_z	0.797^{b}	2.958^{ab}	0.708^{a}	0.242^{ab}	0.834^{bc}	1.479^{a}
	Ita_z	0.590^{ab}	2.365^{a}	1.033^{b}	0.288^{bc}	0.646^{ab}	1.346^{a}
	Hun_z	0.488^{a}	2.680^{ab}	0.782^{a}	0.198^{a}	0.559^{a}	1.340^{a}

Symbols: Esp: Spanish music; Ita: Italian music; Ger: German music; Hun: Hungarian music; z: music; FD: fixation duration; FC: fixation count; TTFF: time to first fixation; FFD: first fixation duration; DD: dwell duration; DC: dwell count. Letters indicate homogeneous subgroups defined by Tukey HSD test.

In the choice, I looked at the relationship between food and music of nations. Figure 1 shows the frequency of choice as a function of music. The figure clearly shows that the four nations can be divided into two groups, i.e. similar cultures such as Hungarian-German and Spanish-Italian are clearly distinct from the other two nations in terms of both music and frequency of choice. When Hungarian or German music was played, participants tended to choose Hungarian or German food. The same was found for Spanish and Italian food choices and music.

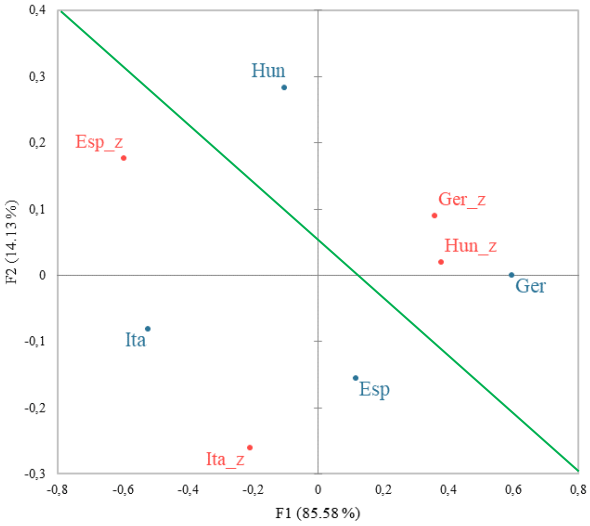

Figure 1: Correspondence analysis BiPlot showing the frequency of choice as a function of music. The "z" denotes the music. The straight green line is arbitrarily drawn.

3.3 The effect of visuality

3.3.1 The preferences of different FoP labels

Table 3 presents the results of the analysis of variance (ANOVA). In the analysis of effects, univariate tests show that the product had a significant effect on the parameters FD, FC, FFD and DD. As can be seen from the table, the P3 product attracted the least visual attention based on the FD value, which was also true for the FC and DD parameters. From the table it is clear that P1, P4 and P2, P3 products belong to the same group, the two groups are significantly different from each other, with two and three products within the groups receiving almost the same visual attention. Based on eye-tracking parameters, products P1 and P4 received the highest visual attention.

Table 3: Average values of the eye-tracking parameters calculated for the five products. The letters behind the means indicate the results of the Tukey post hoc test. The last row in the table shows the p-value obtained in the analysis of variance.

Product code/ eye-tracking parameter	FD	FC	TTFF	FFD	DD	DC
P1	2.900^{b}	6.509^{ab}	1.838^{a}	0.327^{a}	2.931^{b}	3.421^{a}
P2	2.379^{ab}	5.930^{ab}	1.008^{a}	0.244^{a}	2.244^{ab}	3.404^{a}
P3	2.204^{ab}	5.281^{a}	1.422^{a}	0.318^{a}	2.302^{ab}	3.109^{a}
P4	3.093^{b}	7.444^{b}	1.172^{a}	0.252^{a}	3.248^{b}	3.651^{a}
P5	1.542^{a}	5.169^{a}	1.497^{a}	0.288^{a}	1.623^{a}	2.763^{a}
Pr > F	**0.003***	**0.012***	0.227	**0.032***	**0.003***	0.225

*Bold and * indicate a significant effect at p<0.05. TTFF: time to first fixation; FFD: first fixation duration; FC: fixation count; FD: fixation duration; DC: dwell count; DD: dwell duration; P: product designation; P1: Nestlé Fitness breakfast cereal; P2: Kellogg's Coco Pops; P3: Nestlé Cornflakes; P4: Bona Vita Spelt Wheat Flakes; Nestlé Cini Minis. Letters indicate homogeneous subgroups as defined by Tukey HSD test.*

For the label, I observed significant effects for FD, FC, DD and DC (Table 4). For those parameters where a significant difference was observed, the GDA label received the most visual attention in all cases. However, for all eye-tracking parameters, there was no significant difference between the GDA and MTL labels. After statistical analysis of all parameters, it can be seen that the NS label received the least visual attention. This in turn confirms that the low information content of NS requires shorter visual attention, while GDA and MTL labels require more time to process the information and thus receive more visual attention.

Table 4: ANOVA results of visual parameters for labels

Type of label/eye-tracking parameter	FD	FC	TTFF	FFD	DD	DC
GDA	4.004[b]	7.441[b]	2.134[a]	0.663[a]	4.130[b]	3.549[b]
MTL	3.355[b]	7.074[b]	2.110[a]	1.164[a]	3.442[b]	3.495[b]
NS	1.605[a]	4.087[a]	2.006[a]	0.334[a]	1.584[a]	2.796[a]
Pr > F	**<0.0001***	**<0.0001***	0.847	0.477	**<0.0001***	**0.014***

*Bold and * indicate a significant effect at p<0.05. TTFF: time to first fixation; FFD: first fixation duration; FC: fixation count; FD: fixation duration; DC: dwell count; DD: dwell duration; GDA: guideline daily amount; MTL: multiple traffic light; NS: Nutri-Score. Letters indicate homogeneous subgroups defined by Tukey HSD test.*

Before the eye-tracker measurement could start, participants had to rank the products in the questionnaire. Products P1 and P4 received the best ratings, with these products finishing in first place the most often. P3, with few exceptions, was in the middle of the ranking, while P2 and P5 came last. The results of the Kruskal-Wallis test showed that P1 was significantly different from P2, P3 and P5, while P4 was not. Product P2 showed a significant difference from two products, P1 and P4. Product P3 did not show a significant difference, only compared to product P2. After the eye-tracker measurement, the ranking was repeated. By this time, the participants were more familiar with the products and their nutritional value, so I wanted to see if there had been any change in their perception of the healthiness of the products. The results showed that the perception of P2 had changed in a positive direction, and the results of the Kruskal-Wallis test showed that there was only one significant effect: the difference between P3 and P5 was significant. The ranking did not change compared to before the measurement.

Table 5 shows the partial coefficients of benefit obtained from the choice-based conjoint analysis (CBCA). The highest partial coefficient of benefit is obtained for the front label by GDA (L3), followed by MTL (L2). For products, the highest value is P1 followed by P4. For products, P3 comes last.

Table 5: Results of the analysis on labels and products

L1	L2	L3	P1	P2	P3	P4	P5
-0.002909	0.825416	1.577450	1.051825	-1.940835	-3.0524418	0.825378	-2.469662

Labels: L: label; L1: Nutri-Score label, L2: multiple traffic light (MTL) label; L3: guideline daily amount (GDA) label; P: product; P1: Nestlé Fitness Breakfast Flakes; P2: Kellogg's Coco Pops; P3: Nestlé Cornflakes; P4: Bona Vita Spelt Wheat Flakes; P5: Nestlé Cini Minis.

3.3.2 Menu alternatives

The results of the Kruskal-Wallis test showed a significant difference ($p<0.05$) between the TTFF (time to first fixation) data for each meal, except for the fourth ($p=0.411$) and seventh ($p=0.32$) meal on the menu.

The results of the MCA analysis are illustrated in Figure 2. The figure shows that the low kcal starters/soups were most often chosen by participants who selected a menu alternative that contained symbols, while the high kcal dishes were most often chosen by participants who selected a dish from the menu alternative that contained black kcal values. This was only true for the choice of desserts. Medium kcal foods were chosen most often for main courses, but it is difficult to isolate which menu alternative the statement is true for, but the one marked in black is the closest.

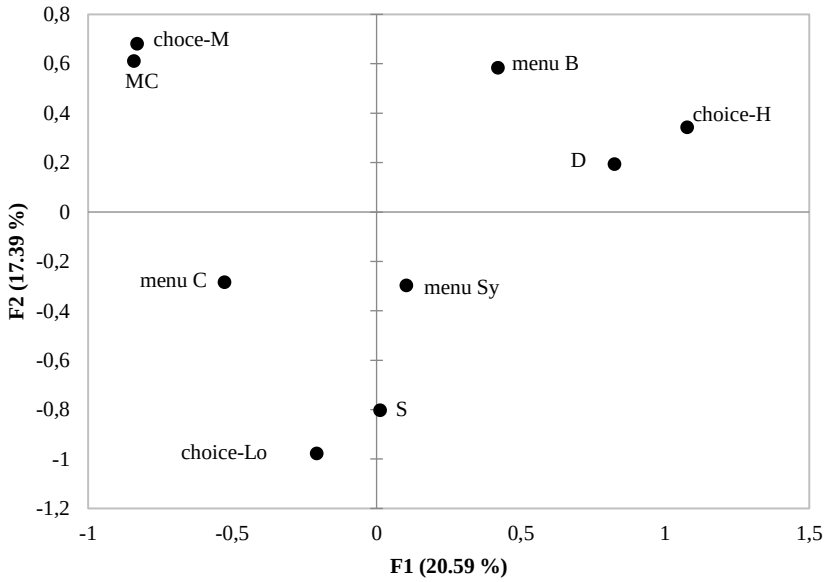

Figure 2: Results of the multiple correspondence analysis (MCA) for menu alternative, calorie content and food category

Labels: Lo: low-calorie meal; M: medium-calorie meal; H: high-calorie meal; S: starter/soup; MC: main course; D: dessert; B: black menu; C: MTL/colour menu; Sy: symbol menu.

In order to understand the relationship between choice and food category, and between choice and menu alternative, I have created a contingency table (Table 6). By examining the interaction between choice and food category, we

can see that participants were more likely to choose low-calorie starters/soups and tended to choose medium-calorie main courses and high-calorie desserts. When examining the relationship between choice and menu alternatives, we see that lower calorie foods were most often chosen by those who viewed the MTL-type menu, while higher calorie foods were more often chosen by those who viewed the black menu, and the menu with symbols was always ranked second in the ranking of menu alternatives.

Table 6: Contingency table between choice/ type of dish and choice/menu alternative

Contingency table (choice/type of dish)				**Contingency table (choice/menu alternative)**			
choice/type of dish	starter/soup	main course	dessert	**choice/menu alternative**	black	MTL	symbol
low kcal dish	22	21	19	low kcal dish	19	22	21
medium kcal dish	19	26	15	medium kcal dish	18	23	19
high kcal dish	19	13	26	high kcal dish	23	15	20

Examining the duration of fixations is important because there is a correlation between choice and fixation duration. Generally speaking, the product that one fixates on for a longer period of time is the one that one is most likely to eventually choose (CHOI et al. 2010). Therefore, I also examined the evolution of FD values for different menu alternatives. This correlation was observed for the MTL type menu, with most participants choosing the food to which they paid the longest visual attention and the fewest choosing the food to which they paid the least visual attention on average. This is not reflected at all in the case of the GDA type menu, while for the symbolic menu alternative, the correlation is only observed for most of the choices.

I also investigated the effect of menu alternatives on visual attention, using four eye-tracking parameters (FD, FC, DD and DC). Examination of each of these parameters revealed that participants paid the most visual attention to the GDA-type menu and the least to the symbolic menu alternative.

In the questionnaire, I also asked how useful participants found the inclusion of the energy value of each food on the menu and how much its presence influenced their decision. This also allowed me to examine the relationship between choice and self-reporting. In the case of the GDA-type menu alternative, there is no relationship between self-reporting and choice. Those who did not think that the kcal information was useful and had no impact on their decision chose in most cases foods with a low kcal value, while those

who thought that the information was useful and had an impact preferred foods with a higher kcal value. For the MTL-type menu alternative, self-reporting and choice were found to be consistent, i.e. those who thought that the presence of the kcal value was useful and influenced their choice mostly chose foods with a low kcal value, and vice versa. For the symbol menu alternative, the consistency was not observed, presumably because participants were not interested in the presence of the symbol or found it difficult to interpret and thus ignored it.

3.3.3 Nutri-Score labelling system

First, I retrieved the student data from the FaceReader software containing the results and for each product, I determined the max values of the basic emotions. Then I analysed the values using analysis of variance (ANOVA) to see which emotion had a significant difference. The results are shown in Table 7. The results clearly show that happy and surprised emotions only showed significant differences, so I only examined these emotions for the rest of the research.

Table 7: Analysis of variance (ANOVA) results for each emotion

Emotions	Neutral	Happy	Sad	Anger	Surprise	Fear	Disgust
Pr > F	0.625	**0.001***	0.985	0.923	**0.000***	0.644	0.989

*Bold and * indicate a significant effect at p<0.05.*

The interaction between the products and the two emotions was tested by repeated measures analysis of variance (RMANOVA). The results of the analysis of the interaction between the happy emotion and the products are illustrated in Figure 3. From the figure, it can be said that the Hungarian ESL fresh milk elicited the happy emotion the most.

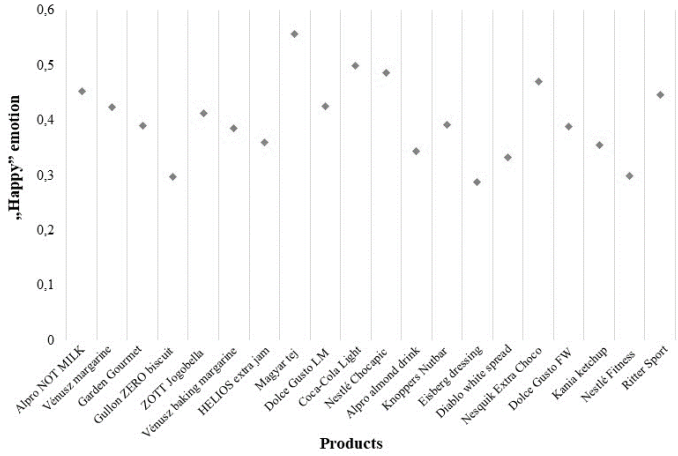

Figure 3: Representation of the interaction between happy emotion and products after RMANOVA analysis

The interaction between the feeling of surprise and the products was also found to be most surprising in the case of Magyar ESL fresh milk (Figure 4). Participants said that they were surprised that this product had the worst Nutri-Score E rating and that they should consider consuming it in the future.

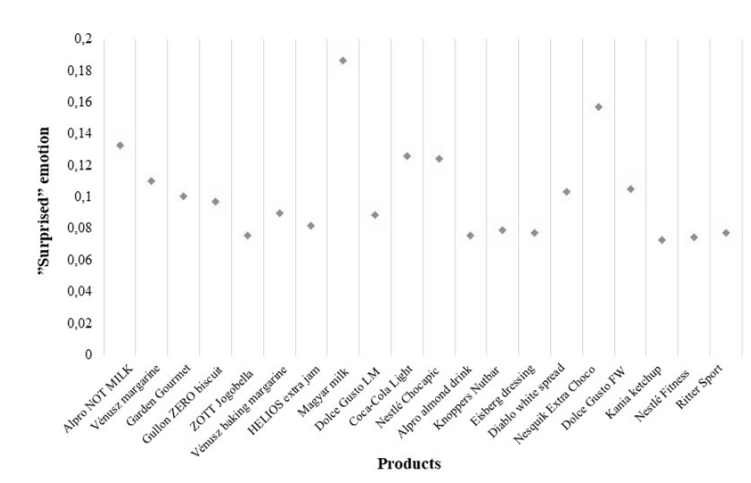

Figure 4: Representation of the interaction between surprised emotion and products after RMANOVA analysis

In addition, Coca-Cola Light carbonated soft drink, Nestlé Chocapic cereal and Nesquik Extra Choco Instant cocoa drink powder also elicited high emotional responses for both emotions. This may be due to participants laughing at the surprising things rather than showing their emotional state with a surprised expression.

The choice prediction was performed for the FD parameter using the random forest (RF) method. I called the FD data to the five Nutri-Score labels (A to E) and then determined whether participants correctly identified the label of each product or not. In the following, I only used data from participants who correctly identified the labelling. I then also determined how many Nutri-Score labels these participants had looked at before making their decision. Based on these results, I found that it was Alpro sugar-free almond drink that had the highest number of participants (46) who correctly judged its Nutri-Score labeling, of which 34 participants were able to immediately determine the correct labeling because they only looked at one Nutri-Score label. The table also shows that there were few products where participants found it so difficult to make a decision that they had to take all five Nutri-Score labels into account, but in the case of the Alpro NOT MILK oat drink, there were three participants who took everything into account. A similar finding can be made for the visual inspection of the four labels. The visual inspection of the three tokens did not show any significant difference from the visual inspection of the four and five tokens, however, Kania ketchup with basil and oregano had five participants thinking about it. Most of them looked at one or two nominations before making their decision. I think that those who hesitated between two labels found it difficult to tell the difference between the two closely related labels, so it would certainly be worth educating consumers and thinking about the label. Nesquik Extra Choco cocoa drink powder and Hungarian ESL fresh milk were both correctly labelled by only one person each, so it is not surprising that these two products elicited some emotion (happy or surprised) from participants. At the same level, few people correctly labelled Coca-Cola Light carbonated soft drink (six people) and Nestlé Chocapic cereal (four people) with the correct Nutri-Score. For these products, surprise as an emotion was strongly expressed by the participants, who got the classification of the products wrong in significant proportions.

4. CONCLUSION AND RECOMMENDATIONS

4.1 The effect of scent

The results from the study of the effect of strawberry scent highlight that strawberry scent did not have a significant effect on choice, but did affect the duration of first fixations (FFD). Furthermore, my results show that participants tend to choose the product to which they pay the most visual attention. Future studies, however, should seek to include other age groups and different scents to gain a more comprehensive understanding of the effects of scents on eye movement and choice. From an analytical point of view, further research should focus on the role of other types of scents (natural, artificial, etc.), the method of evaporation (thermal diffusion vs. cold diffusion) and the atmospheric concentration of scents as environmental factors affecting human perception.

4.2 The effect of music

The reduced visual attention to music reflects the fact that music helped participants to complete the choice more quickly and enhanced cognitive processes. This was supported by prediction models that showed increased accuracy with music. Ethnic music had a clear effect on eye movements and congruent food choice, but the four nations could not be clearly distinguished. The similar cultures (German-Hungarian and Italian-Spanish) showed no differences, but after combining them, clear differences were found. The music of geographically close countries should be treated together when consumers make food choice decisions. It would therefore be worthwhile in the future to carry out a study on this topic that looks at cultures that are very different from each other, such as comparing an Asian country with a European country. In this way, the influence of national music on food choices could be studied with greater precision.

4.3 The effect of visuality

4.3.1 The preference of different FoP labels

My results show that Hungarian consumers prefer informative FoP (front-of-pack) labels and do not have a positive attitude towards labels such as Nutri-Score, which provide limited information on the nutritional content of

products. In general, the Nutri-Score label has received less visual attention than the GDA (guideline daily amount) or MTL (multiple traffic light) labels, which is due to the fact that it contains less information and therefore information processing and decision making is faster. Another limiting factor is that the introduction of the Nutri-Score label in Hungary is still in its infancy, so it is less well known to participants and few information campaigns have been organised to raise awareness of the label. As an initial step of the measurement, it would have been worthwhile to inform the participants about the different FoP labels, but I decided not to do so, as the customers do not receive any additional information while standing in front of a shop shelf. In the future, it would be worthwhile to carry out the measurement with a larger sample and to group the respondents (e.g. label use by health-conscious shoppers and label use by non-health-conscious shoppers).

4.3.2 Menu alternatives

My aim in including different energy labels on menus was to explore which labels might be best suited to support a healthier lifestyle. Based on my results, I found that the most visual attention is paid to the top of the menu (regardless of the type of labelling), so it makes sense to include new information or foods in this area. In examining the interaction between choice and menu, I found that the use of colour in kcal labelling is sufficiently attention-grabbing that consumers may be more inclined to choose a food with a lower kcal label. The opposite effect was observed for monochrome labelling with only black colours, where participants preferred foods with higher kcal labelling. For desserts, however, it was the symbols that influenced participants to choose foods with lower kcal. These results show that there is no clear answer as to which labelling should be used in catering establishments, but it is clear that simple black labelling is not appropriate for consumers and I recommend avoiding it. This is further supported by the fact that this is the label that captured visual attention the longest, i.e. the label that took the longest time for participants to interpret. Overall, it can be concluded that the use of colours definitely supports consumers in their decision-making process, thus promoting healthier food choices. In the future, it would be worthwhile to investigate the impact of labelling in real restaurants, possibly in virtual reality, when the choice is at stake.

4.3.3 Nutri-Score labelling system

My primary objective in investigating the Nutri-Score labelling system was to explore the level of consumer awareness of the meaning of the FoP label in question. To do this, I set up a measurement in which participants were asked to decide which label belonged to which product. Based on my experience, consumers are still not familiar with the label, they cannot tell from the packaging which Nutri-Score label it is or could be. My suggestion would be that consumers should be educated by the food industry or by individual food manufacturers, because in the absence of this, consumers may misjudge a product's suitability for a healthier lifestyle.

5. NEW SCIENTIFIC RESULTS

T1. I was the first to investigate the effect of strawberry scent on food choice. My research found that for the food categories studied, the presence of strawberry scent may encourage consumers to choose strawberry flavoured products, as supported by the analysis of eye-tracking parameters DC (number of visits) and FFD (first fixation duration). For the chocolate and yoghurt product categories, the presence of strawberry scent increased the frequency of choice of strawberry flavoured products.

T2. I was the first to investigate how ethnically congruent music influences food choice when faced with a choice of food from different nations. I found that music reduces visual attention, making the choice task faster. The effect of music on visual parameters is detectable, but not generalizable. It was also found that for Hungarian consumers, Spanish music generates the highest visual attention and that the Hungarian music takes the least time for consumer decision-making, which may be due to the familiarity of Hungarian music. Furthermore, I also found that music from nations with the same culture has the same effect on consumers, so combining music and food from nations with similar cultures may be a good way to get closer to understanding the effect they have.

T3. I looked at which of the different front-of-pack nutrition labelling options is the most supportive to decision making. I found that the GDA (guideline daily amount) type of nutrition labelling was the most informative for the Hungarian consumers in the study, while the Nutri-Score labelling system was considered the least informative. Furthermore, in terms of product perception, I found that there was no difference between before and after the eye-camera measurement, i.e. the presence of the label did not change the perception of the products in terms of healthiness. The research was carried out both for the products in the study and for the different labels.

T4. I was the first to investigate how the energy labels on menus influence the decision making of Hungarian consumers and which labels are of sufficient help in achieving a healthier lifestyle. I found that the most ideal labelling for the research participants is to use both numbers and colours when labelling energy values. However, simple black numbers are not recommended as they take the longest to interpret. Furthermore, I found that the first third of the

menu is the area of greatest visual attention, so I conclude that it is in this area that new information or food on the menu should be presented.

T5. I was the first to use FaceReader software to see how familiar consumers are with the Nutri-Score nutrition labelling system. I found that for most products, consumers in the survey were unable to determine their Nutri-Score classification. I have found that Nutri-Score is more difficult for lay consumers to understand, so I recommend consumer education.

6. SCIENTIFIC PUBLICATIONS IN THE FILD OF THE DISSERTATION

Publication in scientific journals, in foreign languages:

Szakál, D., Fehér, O., Radványi, D., & Gere, A. (2022). Effect of Scents on Gazing Behavior and Choice. In: *Applied Sciences*, 12(14), 6899. https://doi.org/10.3390/app12146899 (Q2, IF=2.5)

Szakál, D., Cao, X., Fehér, O., and Gere, A. (2023): How do ethnically congruent music and meal drive food choices? In: *Current Research in Food Science,* 6(February). https://doi.org/10.1016/j.crfs.2023.100508. (D1, IF=6.2)

Szakál, D., Zulkarnain, A. H. B., Cao, X., & Gere, A. (2023): Odors change visual attention. A case study with stawberry odor and differently flavoured yoghurts. In: *Meat Technology* 64(2), 17-24. https://doi.org/10.18485/meattech.2023.64.2.3 (Q4)

Szakál, D., Fehér, O., Benke, E., Gere, A., & Radványi, D. (2024): Guideline Daily Amount (GDA) outperforms Nutri-Score in assessing healthiness. Case study with breakfast cereals. In: *Progress in Agricultural Engineering Sciences*, 20(1), 179-198. https://doi.org/10.1556/446.2024.00132 (Q3)

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