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Original Scientific Paper

Odors change visual attention. A case study with stawberry odor and differently flavoured yoghurts

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A R T I C L E I N F O

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A B S T R A C T

Eye-movements provide unique information on the understating of human behavior and food choices. Analysis of gazing behavior has been proven to be a successful tool to predict eye-movements or to analyze the effects of certain factors on purchase behavior, choice or opinions. In the current papers we introduce a case study on the analysis of gazing behavior, more precisely the analysis of time to first fixations and fixations durations, to understand the effects of scents/odors on eye-movements. The presented study was part of a larger set of studies and focuses on a four alternative forced choice task, that included four differently branded and flavored yoghurt products, while strawberry odor was/was not sprayed into the air. The analysis revealed that time to first fixations shortened when strawberry odor was present and the length first fixation increased for the strawberry flavored product when the odor was present. The results support the hypothesis that aroma compounds have significant effect on visual attention, however, they do not show significant effect on food choices, as these are driven by a myriad of other factors.

1. Introduction

Eye-tracking technology involves monitoring and recording an individual's eye movement and focus. It is most commonly used in psychology, market research, user experience design, and human-computer interaction. Eye-tracking can reveal important information about visual attention, gaze patterns, and user engagement (*Motoki et al.*, 2021). Eye-tracking technology could be used to study consumer preferences and behavior in the context of meat sciences. Researchers could gain insights into what aspects of presentation, branding, or labelling influence consumer decisions by tracking where individuals' eyes are drawn when presented with various meat products or packaging.

There have been many earlier uses of eye tracking in meat sciences, such as understanding consumer preferences and responses to different visual aspects of meat products. According to (*Ballco et al.,* 2019) research on consumer preferences on nutritional claims of yoghurt product on 100 participants, the presence of nutritional claims on yoghurts' front of pack increases consumer attention and visual attention (fixation count) increases the likelihood of purchase decisions. In addition, *Fraser et al.* (2021) conducted research on the relationship between the extent of visual attention and preference stability in a discrete choice exper-

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iment using eye-tracking to investigate country of origin information for meat on 100 participants and found that visual attention was positively related to preference instability. Researchers could gain insights into what visual cues or attributes influence consumer decisions by tracking where consumers' eyes are drawn when viewing meat products and/or packages.

Labelling and information display represent other applications of eye-tracking in meat sciences. Eye-tracking could be used to evaluate the effectiveness of meat product labels and information displays. As price is important to shoppers, a study conducted on 307 participants to investigate beef consumers' attention paid to price label information discovered that the use of an eye-tracking device was able to assist in improving consumer research by detecting a difference between what the participants said was important and what they focused on when shown packs of beef (*Lombard*, 2022).

Eye-tracking can also be used in food choices and sensory science because it is necessary to assess which factors of a dish affect the visual appeal and influence consumers' overall evaluation, as different dish cues are closely related to people's acceptance and consumption. A study conducted by *Zhou et al.* (2021) investigated 100 older people's evaluations of dishes by incorporating dish attributes: main course (meat and vegie meat), potatoes, vegetables, and dish label, where most older participants' first gaze settled on the main course area, and they had the longest total eye fixation time on the dish valued as the healthiest. This is associated with a study done by *Zhang et al.* (2021) where they investigated the 46 participants influenced by the container color of food (meat and vegetable dishes) on food choices and ratings in virtual reality (VR), and the results showed that container color influences food choices.

As a growing technology, virtual reality (VR) is an immersive technology that simulates a computer-generated environment, typically through the use of a head-mounted display (HMD). VR has found applications in a variety of industries, which may include the meat industry. VR could potentially be used in retail settings for virtual meat tastings or virtual meat counters. Customers could explore different cuts, textures, and cooking methods by creating realistic virtual representations of meat products, potentially improving their shopping experience. A conjoint analysis of eye-tracking and VR has great potential for various applications; however, their specific use in the meat industry may be limited or underutilised. A study of 124 participants was conducted to determine whether providing consumers with more detailed information about animal husbandry systems could influence their product choices at a virtual supermarket. The study discovered that the price of the product was the most important factor in the purchase decision (*Xu et al.,* 2023). However, as technology advances, these technologies may find novel and innovative applications within the meat production and consumption domains.

2. The role of vision and food choices

Consumer's food choices are driven by a complex set of elements, such as feelings, attitudes, and values (*Gere et al.,* 2017*; Mathiesen et al.,* 2022; *Pantoja & Borges*, 2021; *Szakál et al.,* 2023; *Takahashi et al.,* 2018). Vision is one of the crucial factors on construction of feeling. Although food is often linked with various senses, people rely on visual cues to determine essential characteristics of food. Previous research shows that the color or animation significantly influence attention, and the attention is the key factor of decision making (*Chen & Antonelli*, 2020; *Ye et al*., 2021). Bright and vibrant colors in fruits and vegetables are perceived as indicators of freshness and nutritional quality, making them more appealing to consumers (*Pathare et al.,* 2013). Similarly, food packaging and presentation can significantly influence consumer's perception of the food quality, and impact food selection (*Piqueras-Fiszman & Spence*, 2015).

The eye movement is associated with perception and cognitive processes (*Alemdag & Cagiltay*, 2018). Visual attention is linked to perceptual processing, and it affects what information is processed and remembered. The rational models of decision making, where attention is seen as a passive information gathering tool (*Orquin & Mueller Loose*, 2013). However, newer models, such as those derived from neuroscientific research, highlight the active role of attention in the construction of decisions (*Krajbich et al.,* 2010). Research on attention and eye movements has illuminated the cognitive processes before and during fixations, including the integration between attention and working memory. Evidence suggests that attention not only serves to enhance perception, it also limits and controls it (*Droll et al*., 2005). This modulation of perception by attention plays an integral role in decision-making, particularly in situations where an individual select from a variety of stimuli, such as in a grocery store. The enhanced perception provided by fixating on an item can result in a stronger influence on the decision making process (*Ye et al.,* 2021).

Furthermore, the control of visual attention can be influenced by both bottom-up and top-down processes (*Simonetti & Bigné*, 2022). Bottom-up control is driven by the physical characteristics of the stimuli, such as color or shape, which draw our attention. Conversely, top-down control is influenced by our cognitive expectations and perceptions (*Orquin & Mueller Loose*, 2013). For instance, an individual committed to environmental sustainability is likely to choose food products marked with the Rainforest Alliance logo, given that the price is comparable to other options. Besides, the role of working memory in decision making is also noteworthy. The findings on attention and working memory suggest that people often trade-off between fixations and working memory, potentially using fixations as an external memory space to lower working memory demands. For example, in a supermarket scenario, a consumer might remember the location of their favorite product on a shelf and ignore it until they need to make a direct comparison with another product (*Orquin & Mueller Loose*, 2013).

Vision is undoubtedly crucial in food selection, and it is important to note that other sense also impacts food choices. Previous study shows that the sense of smell can significantly influence the food selection, intake and evaluation (*Morquecho-Campos et al.*, 2020; *Proserpio et al.,* 2019). The aroma of a particular food can evoke emotional responses, memories, and physiological responses that can ultimately affect our food choices (*Herz,* 2016; *Köster & Mojet,* 2015; *Shepherd,* 2006). Studies have shown that pleasant aromas can increase the desire to eat, even when we are full (*Yeomans,* 2006). Conversely, unfavorable odors can render food unappetizing (*Parker et al.,* 2022). Additionally, olfaction can also contribute to the perception of flavor, as it combines with taste to form a multisensory experience, guiding us towards nutritious food and away from potentially harmful substances (*Small,* 2012). In conclusion, previous research show that food choices are significantly influenced by the sensory perceptions, particularly by vision. An additional question arises about the effect of fragrances on eye-movements and choice. The aim of the presented paper therefore is to analyze the effects of strawberry odor on food choices.

3. Materials and methods

Location and participants

The measurement was carried out in a quiet, well-lit room at the Buda Campus of the Hungarian University of Agriculture and Life Sciences. The com-

Table 1. Participant demographic datas for the control (odorless) and odor groups (%)

			Control	Odorless
Gender	male		19.4	22.6
	female		30.6	27.4
Place of living	male	capital city	11.3	14.5
		large city	3.2	1.6
		small town	3.2	1.6
		rural	1.6	4.8
	female	capital city	8.1	3.2
		large city	4.8	3.2
		small town	9.7	12.9
		rural	8.1	8.1
Education	male	graduate	3.2	1.6
		undergraduate	16.1	21.0
	female	graduate	8.1	6.5
		undergraduate	22.6	21.0
Visual aid	male	contact lenses	1.6	3.2
		glasses	4.8	6.5
	female	contact lenses	1.6	4.8
		glasses	8.1	3.2

puter was placed on a table in the middle of the room, above which an LED panel provided light (6500 K, 1600 lm). A pleasant strawberry scent was sprayed into the air using MAYAM elements essential oil and a Sencor SHF 920BL (Ricany, Czech Republic) vaporizer.

The participants were recruited at the Buda Campus. A total of 70 people took part in the survey. The participants were divided into two groups: one was the control group, where no strawberry scent was applied in the air, but the other group was. The mean age of the control group (odorless) was 22.85 years (SD = 6.55). The mean age of the odor group was 22.8 years (SD = 2.97). A total of 8 participants were excluded from the measurement due to low (<80%) eye-tracking quality. Detailed demographic data of the participants are shown in Table 1.

The most prevalent visual abnormalities were nearsightedness and farsightedness, and three participants squinted. Six subjects reported having suffered a partial loss of smell, and two participants reported having a partial loss of taste as a result of post-COVID symptoms at the end of the questionnaire. According to the subjects, these post-COVID symptoms have fully subsided, hence the measurement was unaffected.

Eye-tracker and software

According to the guidelines outlined in *Fiedler et al.* (2020), information regarding the eye-tracking process has been added. The measurement was performed using the Tobii Pro X2-60 (Tobii Pro AB, Danderyd, Sweden), a desktop type of eye-tracker. The images were presented to the participants via Tobii Pro Lab v.1.171 (Tobii Pro AB, Danderyd, Sweden) software. The eye-tracker illuminates the eye with a near-infrared pattern before taking high-resolution pictures of it. The 3D eye model algorithm is used by the image processing algorithms to determine the gaze point and location of the user's eyes by looking for distinctive characteristics and reflection patterns in their eyes. This kind of eye-tracker has the benefit of being compact, inconspicuous, and allowing some head movement during the measurement without disturbing the subject. The recommended viewing angle is 65°, and the optimal distance between the eye and the camera is 60 to 65 cm.

Process

The measurement was performed in two groups: control (odorless) and odor group. In both groups, 31 participants took part in the measurement. The control group was measured first, with no strawberry odor in the air. In the second round, the odor group was measured. The measurement procedure for the two groups was identical, the difference being the absence or presence of odor.

First, we asked participants to sit down in front of the computer and make themselves comfortable. They were then briefed on the measurement process and given some important information about the eye-tracker. The software of eye-tracker then performed a 9-point calibration, which, if successful, triggered a series of plots entered into the software.

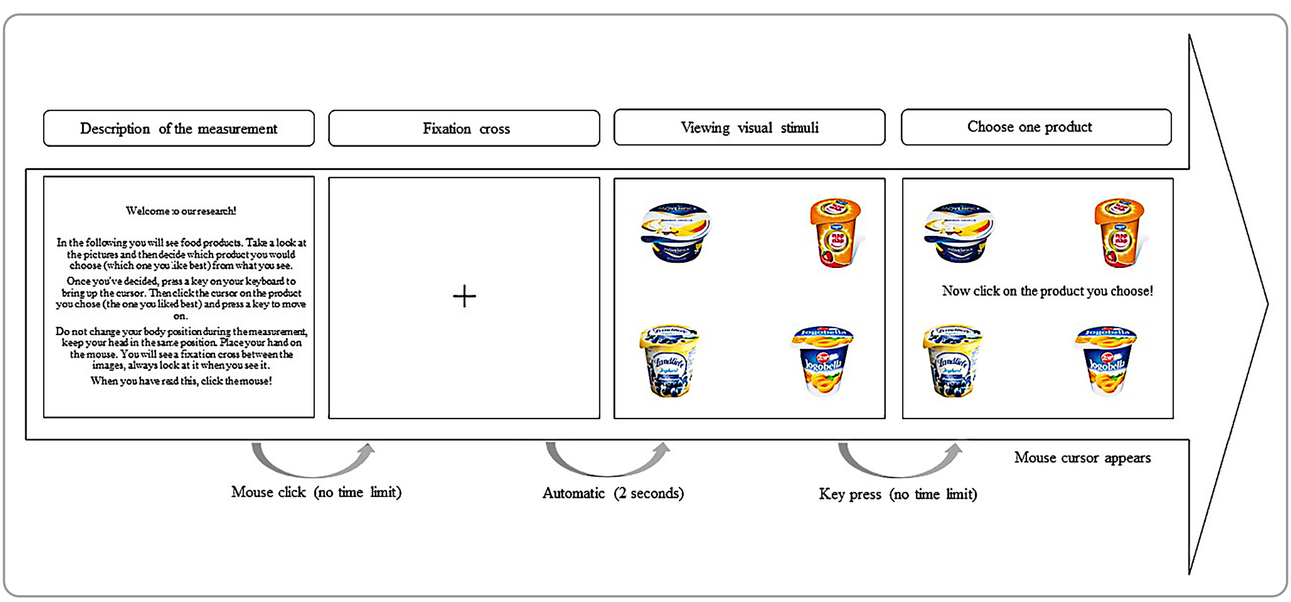

Figure 1. Detail of the timeline presented in the measurement

The first slide of the timeline contained an informative text describing what the participants should do during the measurement. After reading this, participants could jump to the next slide by pressing the left mouse button. At the beginning of the timeline, a trial slide was presented to the participants for practice. The trial slide included four limonades with different flavors (forest fruit, lemon, orange and peach). The trial slide contained products independent of the measurement and these were not included in the data analysis. After seeing the four products, participants were first asked to visualise them and then decide which one they would like to choose. Once they had made their decision, pressing a key on the keyboard brought up the mouse cursor so they could click on the product of their choice. After clicking with the mouse, they had to press a key again to move to the next slide. They had unlimited time to make a decision. A fixation cross appeared before each slide containing new products. The fixation cross was visible in the middle of the screen for 2 seconds. After this time, the software automatically moved on to the next slide. The measurement process is shown in Figure 1.

Visual stimuli

Participants had to choose one product from a total of four series of pictures. The first of the four image series was the trial slide, which was not included in the data analysis. The series of images included yoghurts in different configurations. The products included in the measurement are shown in Figure 2. The visual stimuli were presented on an LG W245VPF 24" Full HD LCD monitor with 1366 x 768 resolution. Areas of interest (AOIs) were defined per product presented, with the distance between AOIs maximized to avoid overlap.

Data analysis

During the data analysis, the following eye-tracking parameters were used:

- Time To First Fixation (TTFF, seconds passed between the introduction of a stimulus and the user focusing their attention on a substitute initially);
- First Fixation Duration (FFD, duration of the first focus on a substitute, in seconds).

The eye-tracking parameters were used as dependent (quantitative) variables, while qualitative variables were the presence of odor (odor vs. no odor) and the chosen products (Mm, De, La and Jb). Two-way multivariate analysis of variance (two-way MANOVA) was used to test the relationship between the two sets of variables.

Tobii Pro Lab v.1.171 (Tobii Pro AB, Danderyd, Sweden) was used to record the data. IBM SPSS STATISTICS (Version 25) (IBM, Armonk, New York, USA) was used for the analysis.

4. Results and discussion

Two-way MANOVA was conducted to determine whether strawberry flavour has an effect on product choice. There was a significant difference in test scores for choice: F(72.1103) = 6.433, p = 0.000; Wilk's lambda = 0.351; for odor: F(24.369) = 6.123, p = 0.000; Wilk's lambda = 0.715; and for the choice-odor interaction: F(72.1103) = 7.239, p = 0.000; Wilk's lambda = 0.315.

When looking at the eye-tracking parameters for each yoghurt product, there was a significant difference for the choice, odor and choice-odor interaction for the TTFF and FFD parameters for the strawberry flavored product.

Figure 3 shows the TTFF results for choice and the effect of scent. For choice, the time to first fixation was significantly reduced when strawberry

Figure 2. Products included in the measurement (name of products from left to right: Mövenpick Mango (Mm), Danone strawberry (De), Landliebe blueberry (Lá) and Jogobella peach (Jb))

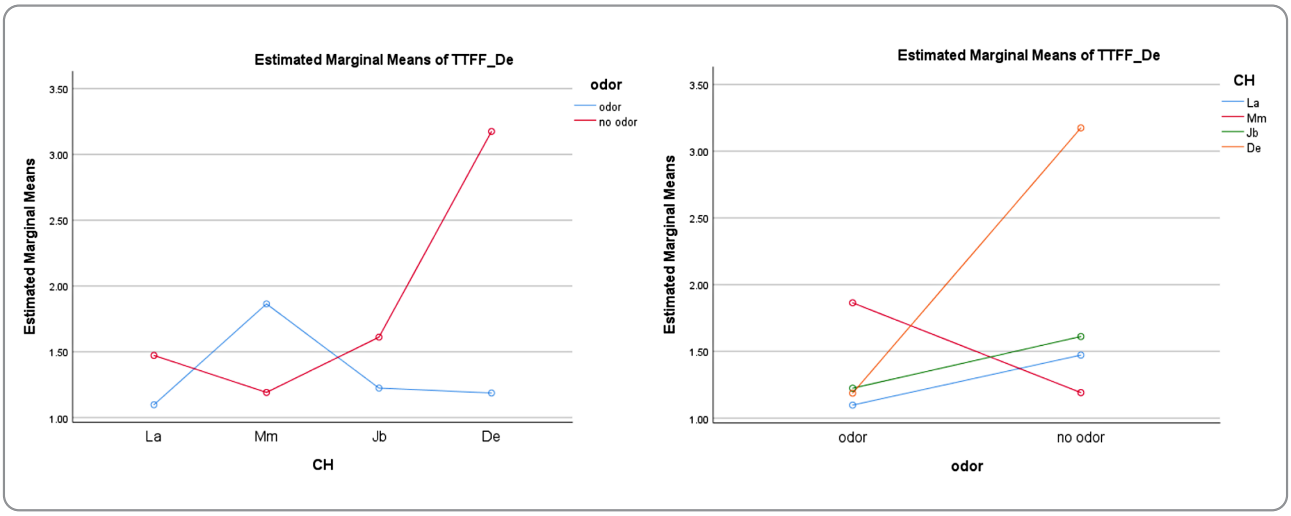

Figure 3. Time to first fixation (TTFF) results of the choice and between the odor and odorless conditions of four yoghurt product alternatives

Indicates: CH = choice, La = Landliebe blueberry, Mm = Mövenpick mango, Jb = Jogobella peach, De = Danone strawberry, TTFF = Time to First Fixation.

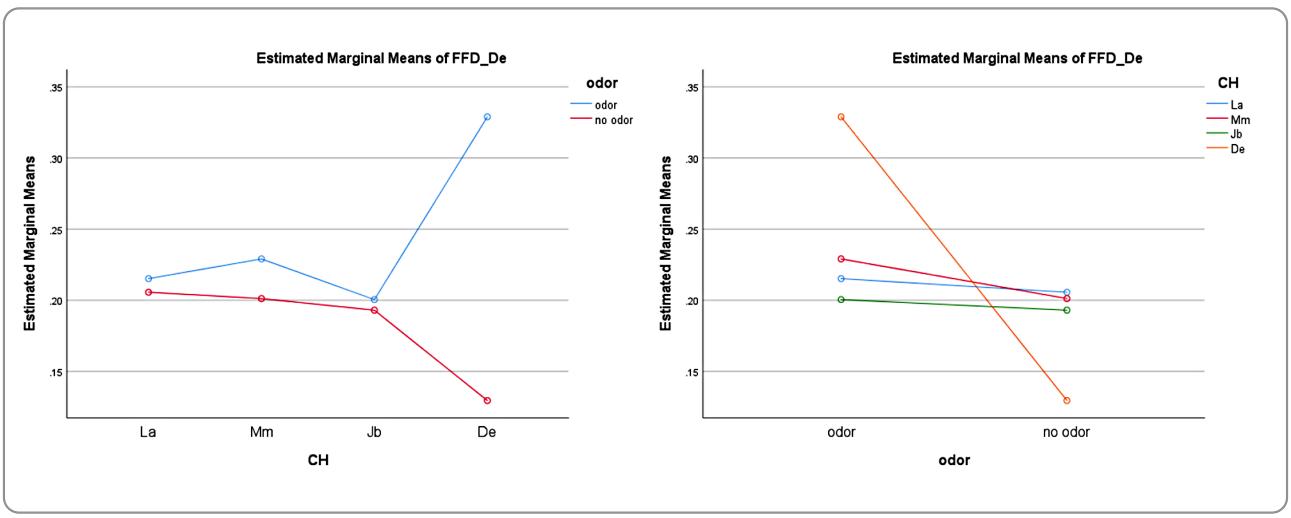

Figure 4. First fixation duration (FFD) results of the choice and between the odor and odorless conditions of four yoghurt product alternatives

Indicates: CH = choice, La = Landliebe blueberry, Mm = Mövenpick mango, Jb = Jogobella peach, De = Danone strawberry, FFD = First Fixation Duration.

odor was present. Thus, the participants perceived the strawberry flavored yoghurt (De) first. Regardless, the choice was based on preference, so it can be said that the choice was not influenced by the odor.

Figure 4 shows the results from the FFD eye — tracking parameter analysis. It can be clearly seen that the first fixation period by odor increased significantly for the strawberry flavored product, while the increase was minimal for the other products. Furthermore, it can be seen that more people chose the strawberry flavored product than the other flavors when exposed to fragrance.

5. Conclusion

The results demonstrated that time to first fixation and first fixation duration parameters are influenced by the presence of strawberry odor. Previous studies reported that first fixation duration might be influenced by odors (Seo & Hummel, 2009), however, recent studies demonstrated that this effect is dependent on the product being evaluatued (Szakál et al., 2022). Odors have been identified as being able to ’grab’ participants visual attention and to drive it to conguent images, however, the role of odors in final decisions is considered minor as there are multiple other factors influencing the final decision (Yang et al., 2023). A possible future direction would be to analyze differences between consumer groups (e.g. clusters), as a mind-set-based segmentation could reveal substantial differences among participants (Gere, 2023).

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