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Eye-tracking tests in consumer perception of food

1. Summary

Eye-tracking analyses provide an opportunity to record the eye movements of the participants, and then to evaluate the data obtained. The application of eye-tracking cameras is not yet typical in the food industry in Hungary, as opposed to the practice in Western Europe, where this technology is an important and commonly used tool of product development and marketing support. To the best of our knowledge, no eye-tracking analyses related to beets have been published so far in the domestic and international literature.

During the research, eye-tracking analyses were carried out in the Sensory Analysis Laboratory of the Faculty of Food Science of Szent István University, using a Tobii X2-60 eye-tracker and the Tobii Studio (version 3.0.5, Tobii Technology AB, Sweden) data processing software. The results draw attention to the fact that the decisions of the consumers interviewed were only slightly influenced by their knowledge of the treatment of the beets analyzed. On the other hand, extra information regarding the antioxidant content changed their decision regarding the selection. Eye-tracking analysis results showed that consumer decision can be monitored much more accurately than using traditional market research methods. The reason for this is that eye movement is very hard to control consciously, and so objective information can be obtained about consumer decision mechanisms which is practically impossible to get using subjective questionnaire methods based on self-declaration or focus group testing.

2. Introduction and literature overview

2.1. The eye-tracker

2.1.1. Eye-tracking analyses

Eye-tracking analyses are used to follow the movement of the human eye or, more accurately, to follow the gaze. The need to study eye movement arose at the beginning of the 20th century. It was observed in 1879 by Louis Emile Javal, a French ophthalmologist, that the eyes of his patients did not move smoothly over the text when reading, but stopped for longer times on certain words, while skimming the images of the other words quickly.

Visual stimuli entering the eye are detected by the retina, located at the back of the eyeball. The most sensitive part of the retina is the fovea centralis, surrounded by the parafovea belt and the perifovea outer region. Vision is sharpest in the area of the fovea, images are much fuzzier in the parafovea belt, and peripheral stimuli are completely lifeless, unrecognizable. The fovea sees only the central 2 degrees of the visual field, however, our eyes constantly jump from one point to another, that is why we perceive that our vision is sharp everywhere. The eyeball, and so the gaze is in constant motion, so none of the areas of the retina gets tired, and the environment can be scanned optimally **[2]**. Rapid eye movements are called saccades, and they are the fastest movements produced by the human body, lasting only 20 to 30 milliseconds, and there is no recording of visual information during this period. Fixations are the periods for which our eyes linger on a certain point, with an average length between 250 and 500 milliseconds, but there are also much longer and shorter fixations, and there are also large individual differences. If information processing has not been successful, the brain needs additional information, so the eyes return to the area that has already been fixed, and these backward eye movements are called regressions **[22]**.

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The most significant types of eye movements: saccades, smooth pursuit movements and tremors. Smooth pursuit movements make it possible to keep the retinal image of a moving object on the fovea, maintaining fixation and recording information continuously. Tremors are small, trembling eye movements, the function of which is to constantly move the place of sharp vision on the retina, avoiding the fatigue of the receptor cells involved in vision. These three eye movements form the basis for the „*eye-tracking*" method **[2]**.

The first instrument suitable for the tracking of eye movements was developed by Edmund Huey and, based on his research, he published a book in 1908 titled *„The Psychology and Pedagogy of Reading"*, which is the first publication on the topic of eye-tracking measurements. While eye-tracking was initially used only to record reading patterns, today the method is used in several areas, in the analysis of market research and the effects of marketing and advertising, as well as in information technology to assess the effectiveness of websites **[6]**.

2.1.2. Operation and types of eye-trackers

From a technical point of view, the operation of eye-trackers can be divided into two parts, the registration of the eye movement, and then its representation in a way that is understandable to the user.

Eye-tracker manufacturers usually use the *Pupil Centre Corneal Reflection* (PCCR) principle to record eye movements. The essence of the method is that the eye is illuminated by a light source, and the light reflected from the pupil and the cornea is recorded with the help of sensors. Based on the location of the reflection, a vector can be calculated, which gives the precise direction of the gaze. The eye and the spatial position of it, i.e., the exact location of the gaze is modeled from the data obtained using 3D image processing and physiological algorithms.

There are two ways for illuminating the pupil, the so-called bright- and dark-pupil methods. The gist of both methods is the creation of as great a contrast between the pupil and the cornea as possible. However, this is influenced by a number of environmental factors, therefore, it was necessary to develop both methods. In the case of the bright-pupil method, the pupil is perceived brighter than the cornea, while in the case of the dark-pupil method, it is the other way around. Use of the bright-pupil method is recommended in cases where the infrared light source is located close to the camera, and also in darker environments and when examining subjects with light eyes. The dark-pupil method is used when the infrared light source is located further away from the camera, or the measurement is performed in a room with normal brightness or at an outdoor location, and in the case of subjects with dark eyes. Usually, both systems are incorporated in their products by eye-tracker manufacturers, however, it differs whether the appropriate method has to be selected by the user, or the method most suitable for the given environment is determined by the control software.

There are two major types of the eye-trackers operating on the PCCR principle, the static or stationary, and the dynamic or portable eye-trackers. Static trackers are connected to a monitor, a television or another display device, and the information appearing on this is examined by the subject. Their advantage is that there is no direct contact between the subject and the eye-tracker, so it is easier for the subject to forget that their eye movements are being recorded, and they behave more naturally. However, a disadvantage is that, to ensure proper recording quality, subject can only move their heads slightly, within the mounting angle of the eye-tracker. Static eye-trackers are applied in research where visual stimuli to be analyzed can be displayed on a monitor easily (images or videos, for example). Because in static eye-tracker experiments all subjects must respond to the same stimuli, their eye movements are more easily compared, data analysis is much simpler and can be easily automated.

In research outside the laboratory, dynamic eye-trackers are used successfully, which have to be worn by subjects during the experiment as goggles. Since the subject of the experiment is in direct contact with the eye-tracker, it takes longer for them to get used to wearing it and to forget about it. The advantage of the device is that, with its use, the behavior of the person towards the product can be simulated more accurately, because with this method they come into direct contact with the product to be tested, the shelf layout in the store can be studied freely. However, its disadvantage is that, because of their different head movements, different visual materials are generated by the different participants, which makes data analysis significantly more complicated. Each recording has to be analyzed individually, and then conclusions have to be drawn based on the experience **[3]**.

2.1.3. Application areas of eye-tracking

For the efficient operation and development of education systems, it is important to gain as accurate information as possible about the thinking, learning, reading, information processing and problem solving strategies of students. The test method of eye-tracking is eminently suited for this task. Research procedures of this type allow for the performing of qualitative analyses, as well as quantitative measurements. With the application of this method, the lack of certain skills and the difficulties of students can be diagnosed sooner and more easily. By collecting the appropriate amount of data, parameters of the expected reading ability can be standardized at various ages.

During the research published by Steklács in 2014 **[22]**, the reading process of second grade students was examined (**Figure 1**). It was found, as expected, that the amount of time spent reading was very different for students with better or poorer reading skills.

Fixation distances of students with poorer reading skills were shorter, and regression was used more often, i.e., they glanced back to areas fixated previously more often. During the study, students lingered longer on certain words, which can be explained by the fact that these elements had not yet been included among the words more easily identifiable to them in their entirety. It was also observed that, during reading, the first and last fixations of the lines were generally longer **[22]**.

In addition to the above-mentioned reading process analysis, the examination of visual problem solving, music reading, playing of instruments and the process of solving word problems all prove that the method of eye-tracking holds great research and development potential in several areas from an education methodology point of view.

Beside the analysis of reading, eye-tracking measurements have been successfully applied for the inspection of food packagings and labels, as well as the evaluation of nutrition fact tables. Despite the fact that the graphical layout and the information content of product labels are different, the vast majority of consumers focuses on four areas, when asked about their willingness to purchase and the healthiness of the products. Consumers focus primarily on the image of the product, the brand, the list of ingredients and the nutrition information, while they spend significantly less time on information regarding the origin, the manufacturer, the weight and the expiration date, when examining a product label **[1]**.

It was found by Gofman et al. in 2009, that more attention is paid by consumers to graphical elements of product packagings than to the label or to text information **[9]**.

Food selection is a multi-complex process, influenced by several factors. These factors influencing the selection were classified by Köster into the following six groups: external and internal product characteristics, psychological and biological characteristics of the decision-maker, the decision-making situation, and socio-cultural factors **[14]**. Several international studies dealt with the psychological and economic factors that play significant roles in decision-making, however, the most important sensory aspect turned out to be the appearance of the food when making a selection **[24]**. In practice, the very sight of the food can trigger our desire to consume the food **[16]**.

Visual factors influencing food choice were further divided into groups by Wadhera et al.: visibility, color, selection, portion size, number, amount of liquids, shape and surface size. This was supported by the research of Piqueras-Fiszman and his coworkers, published in 2012, in which it was proven that pink-colored foods served on a white plate were found to be much tastier and sweeter by consumers than the same foods served on black plates. Consumer decision can also be influenced by the shape of foods: when college students were asked whether a rectangular or a round pizza was bigger in their opinion, 70% of the participants chose the rectangular pizza, even though the size of the pizzas was the same **[15]**.

Visual stimuli are basic constituents of the perception of food quality, and they influence consumer decisions greatly, because expectations and associations are mobilized by visual factors. Various studies have shown that several parameters describing eye movement are also related to the selection process, so the analysis of customers' eye movements can help to explore and understand consumer decision-making mechanisms.

Taking into account the results of several eye-tracking studies, it was determined that subjects usually fixated longer on the chosen product and they looked at it longer. The conclusion was also drawn during their research that the product will be chosen by the participants with a high probability which they fixated on first or, possibly, last **[18]**.

Eye-tracking measurements have also been used for the assessment of healthiness. When dishes made of fish were investigated, the research showed that consumers composed a list of the three dishes tested based on their perceived healthiness. Fish fillet was judged to be the healthiest by the participants, followed by fish burgers, while fried fish bites were thought to be the least healthy **[17]**.

In a study conducted recently, it was examined to what extent the number of images displayed at the same time influences the eye movement of consumers. When evaluating measurement results, it was determined that there was a significant correlation between the number of images and the number of fixations, as well as the eye movements between images, the more images were displayed, the more often consumers fixated. At the same time, there was very little correlation between the number of simultaneously displayed images and the time required for reaching a decision. It was also determined during the experiment that evaluation types have a very significant effect on all eye movement parameters. Consumers had to evaluate the food photos displayed on the monitor based on five different questions:

- which one is the healthiest;
- which one is the least healthy;
- rank product healthiness;
- evaluate product healthiness;
- which products are similar in terms of healthiness.

The shortest and fewest fixations before reaching a decision were observed in the first task, while the grouping task required the longest decision-making time **[25]**.

2.2. The significance of beet

All over the world, more and more importance is attached to vegetables. Increased consumption is encouraged in developed countries, in order to reduce excessive energy intake, and because of the minerals and fibers facilitating digestion. Great emphasis is also placed on increasing vegetable consumption in developing countries, in order to provide for the vitamin and mineral intake of the malnourished population with a one-sided diet. To this end, a number of applied marketing tools, aimed at increasing vegetable consumption, have been appearing, for example, carrot flowers that are currently being offered by a fast food restaurant (**Figure 2**).

Beet is a root vegetable with good nutrition physiological effects, because it can contribute to a healthy diet due to its high mineral content. Its high potassium content is coupled with a low sodium concentration, having a beneficial effect on the ion balance of the human body.

Csikkelné et al. **[5]** found that the macro- and microelement contents of the different parts of the beet plant differ significantly. Overall, it can be stated that the leaves have the highest mineral content, while the skin and the meat of the root contain significantly less. While the calcium content of the leaves is 156 mg/100 g raw material, it is 21 mg/100 g for the skin of the root and 10 mg/100 g for the meat of the root. Potassium, sodium and magnesium concentrations are also much higher in beet leaves than in the root. On the other hand, in terms of the phosphorus content it can be stated that the root skin (66 mg/100 g) and the root meat (49 mg/100 g) contain this macroelement in higher concentration than the leaves (37 mg/100 g). Of the microelements, it is also true for the iron, copper, manganese and zinc contents that these elements occur in the most significant amounts in the leaves.

Beet has strong antioxidant properties. The reason for this is that it contains significant amounts of phenolic compounds, including the water-soluble betalain pigments. The two main groups of betalains are the red betacyanins and the yellow betaxanthins. In beets, of the betacyanins, the betanin and isobetanin contents are the highest, while of the betaxanthin pigments, it is the amounts of vulgaxanthin I and II. Betacyanins prevent damaging processes due to the effects of free radicals triggering oxidative stress, they possess antibacterial and antiviral properties, inhibit the growth of cancer cells and participate in the prevention of cardiovascular diseases **[12]**.

In Hungary, mainly preserved pickles and juice ingredients are produced from beets by the processing industry, while less frequently beet concentrates or beet power is manufactured, to be used later as a coloring agent. From cylindrical beet roots sliced, while from spherical roots cubed products are prepared. Round varieties are preserved as baby beets. In several European countries, soups, stews and salad are prepared from tender beet leaves, but it is not typical in Hungary **[13]**.

Beets are also used as a source of natural food coloring, replacing the usually not preferred artificial coloring E123. Dried and concentrated beet juice are both used in several foods to increase the intensity of the red color. These products include ice creams, jams, desserts, tomato concentrates, juices and dairy products **[11]**. To the best of our knowledge, no eye-tracking analyses related to beets have been published so far in the domestic and international literature.

3. Materials and methods

Eye-tracking tests were performed in the Sensory Analysis Laboratory of the Faculty of Food Science of Szent István University, based on Gere's eye-tracking studies **[7]**. A Tobii X2-60 static eye-tracker (**Figure 3**) and the Tobii Studio (version 3.0.5, Tobii Technology AB, Sweden) data processing software were used to record and process the eye movement data of participants. Images providing the visual stimuli were displayed on a monitor with a 1280x1024 pixel resolution.

Participants of the eye-tracking study were recruited from the Buda Campus of Szent István University. At the beginning of the test, participants were seated in front of a monitor connected to the eye-tracker, so that their eyes were 60 to 65 cm from the monitor, they were asked to place their dominant hands on the mouse and not to change their position during the test, not to move their heads. A calibration was carried out before each test and, after a successful calibration, a text containing instructions related to the test appeared on the monitor, in which the process of the test was described in detail. Between the images, there was a black "+" sign, the so-called fixation cross, on the monitor, the purpose of which was to standardize the starting point of attention. This was followed by selection tasks. After reaching the decision, the participant clicked on the left mouse button to bring up the previously invisible mouse pointer on the display, and then they could click on the selected product (**Figure 4**).

First, participants had to choose between two beets cultivated in different technologies. Initially, only the images of the two beets were displayed, and they had to select the preferred beet, then information was given about which one was treated and which one was untreated, and, finally, they could see the amounts of antioxidants (anthocyanin, betacyanin and betaxanthin) that each beet contained. 57 people participated in the study and data recording was successful for everyone, so the results of each participant were included in the data analysis.

During the evaluation of the eye-tracking measurement results, work was based on the following definitions **[8]**:

1. Time to first fixation: the time elapsed between the appearance of the image and the first fixation of the gaze of the participant on a specific area of interest (AoI).
2. First fixation duration: the length of time for which the gaze of the participant lingers on the first fixation point.
3. Fixation duration: the average length of fixations on a given area of interest.

4. Fixation counts: the number of fixations for a specific product that shows how many times the given product was viewed by the participant.
5. Dwell duration: the average length of glimpses at different product images during gaze wandering between two fixations, when no information is absorbed.
6. Dwell count: the total number of visits for a given area of interest (AoI).

For the experiment, Cylindra beet varieties, treated with fertilizer (CAN) and untreated (control), produced at the Soroksár Experimental and Research Farm of the Faculty of Horticultural Science of Szent István University were used. Beets were cleaned of soil residues, washed thoroughly, peeled, cut into 2 mm thick slices with a kitchen slicer, and the samples obtained were kept in a refrigerator at -18 °C until carrying out the analytical test.

Before the laboratory tests, the frozen and sliced redbeet samples thawed to room temperature, then manually minced using a mixer. Minced samples pressed juice with the press cloth. Determination of the anthocyanin content was performed by a spectrophotometric measurement according to AOAC Official Method 2005.02. For the determination of the betacyanin and betaxanthin content, the spectrophotometric method developed by Stintzing et al. **[23]**, and by Castellar et al. **[4]** was used.

4. Results

4.1. Analysis of antioxidant content

The effect of excess nitrogen introduced into the soil with the fertilizer was that the size of cultivated beets increased, but this resulted in a decrease of nutritional values (**Table 1**). In untreated samples, the measured amount of anthocyanin, betacyanin and betaxanthin was roughly one and a half times higher than in beets treated with fertilizer. The latter two compounds play an important role in the formation of the color of beets, therefore, fertilizer treatment lessens the chances of the beets being used as colorant. **Figure 5** illustrates clearly that, according to our measurements, all three antioxidant compounds were found in the untreated beet sample in larger amounts than in the beet treated with fertilizer.

4.2. Eye-tracking tests

Before the eye-tracking tests, a measurement protocol was compiled. With the help of the Tobii Studio software, the complete process of measurement was put together, from the texts containing the instructions through the fixation crosses to the images to be examined. The entire flowchart of the eye-tracking test is shown in **Figure 6**. After a successful calibration, a text describing the test was shown to participants on the display and, after reading it through, they could move on by clicking on the mouse button. Then, the fixation cross was displayed on the monitor and, after 3 seconds, the program automatically progressed to the first image to be examined. A fixation cross was inserted between each selection task. Any given image was displayed twice in a row, the first was studied carefully by the consumer, the decision was made, and on the second image it was indicated by a click which product had been chosen. To facilitate the decision, gradually more and more information was given to the consumer.

First, the images of two beets were shown to participants, then the information regarding treatment was displayed, and, finally, the antioxidant content was also shown. At the end of the test, we thanked for the participation in the study.

4.2.1. Beet treatment methods

When introducing the untreated and treated beets, only the images of the two beets were shown to participants. Since they were just getting to know the products, almost all participants looked at these images, but there were 4 people, who did not look at the image of the untreated beet at all during the task. Consumers first fixated on the treated beet, and this first fixation lasted longer than in the case of the untreated beet. The first fixation on the treated beet occurred after 1.15 ms and lasted an average of 0.34, while fixation on the untreated product first happened after 1.35 ms, and the average length of the first fixation was 0.29 ms. Based on the total number and length of the fixations it can be stated that, after this, consumers fixated longer and more often on the treated sample, and their gaze returned to this product more often during the visits between two fixations. A visit is a gaze-shifting between two fixations, however, there is no information uptake during this time. Consumer eye movement data are summarized in **Table 2**.

During the first task, participants looked more closely at the image of the treated beet, they fixated on it more often, for a total number of 638, while only 386 times on the untreated beet. The number of fixations was much higher for both products than the number of visits, which means that during a single visit participants fixated on several points of the image of the beet. This is demonstrated by **Figure 7**, since the size of the spot marked red is larger and more intensive on the treated beet on the right. Of the 57 participants, 38 chose the treated beet and 19 the untreated one, as the preferred product.

The following figure already included the information regarding the fertilizer treatment of the beets (untreated, treated). When the picture appeared, participants first looked at the additional information, and paid less attention to the images of the beets, since they already knew these from the previous picture. First, after an average time of 1.57 ms, they read the treated label, and then, after 1.75 ms, the untreated label, and only fixated on the untreated (3.87 ms), and then on the treated product (4.67 ms) after this. **Figure 8** shows the areas consumers fixated on most often.

Based on the eye movements, only 3 participipnats fixated on the treated label, while 18 of them on the untreated label. These low values might be explained by the fact that the words were very short, and so most of the participants did not even have to fixate in order to absorb the information. Since new information can be processed very quickly, therefore, the lengths of the fixations on the labels were very short. In the case of the untreated label, the length of the first and of the average fixation were the same (0.18 ms), and the same can be said about the treated label, where the average fixation duration was 0.15 ms. The average fixation lengths of the product images were identical (0.29 ms). There were almost seven times as many fixations on the untreated label than on the treated label, with a more than sevenfold difference in total length. The number and length of the visits on the labels equals to the number and length of the fixations, which means that whenever they looked at the labels, fixation always occurred as well. When presenting the picture, some of the consumers did not even look at the images of the products before making a decision. During this task, of the 57 people interviewed, there was one person who did not look at the treated beet, and eight of them did not fixate on the image of the untreated sample. About the results of the selection it can be said that 25 people preferred the untreated beet, while 32 people preferred the treated product. It is noticeable that, as a result of the additional information, in this task more people chose the untreated product than before. Eye movement data of the participants are summarized in **Table 3**.

During the third sub-task, presenting treatment methods, the amounts of antioxidant compounds (anthocyanin, betacyanin and betaxanthin) were indicated next to the images of the beets. **Figure 9** clearly shows that participants already know the products, so they barely look at the images of the beets, they only play attention to the additional information. These inscriptions received the most fixations, and their share of visits was also higher than that of the product images. There were 694 fixations and 241 visits for the label belonging to the untreated product, while there were 419 fixations and 188 visits for the label of the treated beet, which shows that participants fixated with their gaze on several locations of the labels during a single visit, i.e., they read the information in the labels. On the other hand, there were only 192 fixations during 133 visits on the untreated product, and 107 fixations during 77 visits on the treated beet by the consumers. The total lengths of fixations and visits were roughly the same for both the products and the labels, also indicating that participants fixated on certain points of the images and the labels for the total length of the visit in almost each case to absorb the information. One of the reasons for this could be that there was more information in the labels than before, and consumers tried to compare these to each other, therefore, they fixated on the labels longer, and their gaze shifted between the two labels more often.

When the picture was displayed, the first fixation was on the label of the untreated beet (1.56 ms), then the antioxidant content information for the treated beet was examined by the consumers (3.35 ms). They fixated on the images of the treated (5.47 ms) and the untreated beet (5.68 ms) only later. In this case, there were more consumers who did not fixate on the products before picking one of them. 9 of the people interviewed did not fixate on the image of the untreated beet, while 21 of them did not look at the treated product before making a decision. Finally, 31 participants chose the untreated product, while 26 people chose the treated beet. Eye movement data of the consumers interviewed are summarized in **Table 4**.

Overall it can be stated that the decision of the consumers interviewed about preference was only slightly influenced by the treatment information, however, additional information regarding antioxidant content changed the decision of the majority of the participants.

5. Conclusions

During our eye-tracking measurements, we tried to find the answer whether consumer decision can be altered by supplying additional information about the products. Based on the selection results of the participants, it can be stated that additional information can indeed have a decision-altering significance. During the test, only the images of the treated and untreated beets could be seen by consumers at first, at this point most of them chose the bigger (treated) beet. In the following task, treatment data were also displayed, and it resulted in fewer people choosing the treated product. Finally, the antioxidant contents of the two beets were also displayed in the picture, changing the decision of most of the participants, i.e., in this task clearly more people selected the untreated product with higher anthocyanin, betacyanin and betaxanthin values.

Since participants of the eye-tracking study consisted almost exclusively of young adults recruited from the students of the university, research could be expanded to include more participants and different age groups. Also, it would be advisable to investigate other nutritional parameters, to see whether – and if so, to what extent – they influence consumer decision.

Eye-tracking measurement results showed that consumer decision can be monitored much more closely than by using traditional market research methods. The reason for this is that eye movement is very hard to control consciously, and so objective information can be obtained about the consumer decision mechanism which is almost impossible to secure by subjective, self-reporting questionnaire methods or focus group interviews.

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