Shedding light on the effects of implied motion on adults’ food consumption

Demetrio Loddo (S2176599)

Department of Psychology, University of Twente

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1st supervisor: Dr. Funda Yildirim

2nd supervisor: Dr.ir. Juliet Haarman

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Abstract

This research aimed at exploring whether implied food motion is a visual cue that affects food consumption. It was hypothesised that implied food motion would positively influence food consumption and that the perceived freshness of non-processed food would mediate the relationship between implied food motion and non-processed food consumption. To test these hypotheses, 176 participants took part in a lab experiment using the Sensory Interactive Table (SIT; Haarman et al., 2020). The SIT was used to imply the motion of either processed food or non-processed food. Specifically, groups of four participants were assigned to one of two experimental conditions (healthy motion, unhealthy motion) or to the control condition (no implied motion). In the unhealthy motion condition, the SIT projected animations to imply the food motion of peanut M&Ms and TUC paprika crackers (processed foods). In the healthy motion condition, the SIT projected animations to imply the food motion of grapes and carrots (non-processed foods). In the control condition, no motion was implied for any of the foods. In each trial, groups of 4 participants sat down at the SIT and talked to each other while having the possibility of eating peanut M&Ms, TUC paprika crackers, grapes, carrots and hummus. Perceived food freshness was evaluated before the start of the trial and food consumption was measured after each trial. The results showed a positive influence of implied motion only on the consumption of processed food. This might have been because of the visual characteristics of the foods themselves which, together with implied motion effects, might have shaped the saliency and monitoring effects of food consumption. Finally, the perceived freshness of non-processed food was not found to be a significant mediator of the relationship between implied food motion and non-processed food consumption.

Introduction

Although taste plays a crucial role in regulating eating behaviour, typically the initial sensory experience with food occurs visually (Pereira & Van der Bilt, 2016). Research findings indicate that visual cues influence the perception and consumption of food. More specifically, food perception and intake can be influenced by colour, proximity, perceived and actual variety, number, shape, the surface area occupied, and size of food (Wadhera & Capaldi-Phillips, 2014). For example, Marchiori et al. (2012) observed that participants ate more cookies when these were cut into 16 pieces compared to 32 pieces. Additionally, the size of dinnerware often leads people to underestimate or overestimate the amount of food being served due to the Doelbeuf illusion. Specifically, when the ratio between the food and the plate's diameter is greater or equal to 0.67, people tend to perceive food and plate as one whole percept, thus, overestimating the food being eaten. When the same ratio is smaller or equal to 0.33, people tend to focus on the dissimilarities between food and plate and, consequently, underestimate the food on their plates (Van Ittersum & Wansink, 2012).

Biologically, the mere sight of food stimulates physiological responses which affect hunger and food intake. These responses include the release of saliva, gastrointestinal regulatory peptides and an increase in blood insulin levels (Skvortsova et al., 2021). Moreover, neuroscientific studies suggest that seeing food activates brain areas associated with expected reward and, consequently, motivation to obtain such a reward (Rolls, 2023). Overall, the aforementioned evidence suggests that manipulation of specific visual cues may be used to shape eating behaviour (Wadhera & Capaldi-Phillips, 2014).

Among the visual cues which can affect eating behaviour, implied motion has gained recent interest from researchers due to its evolutionary and cognitive salience. Implied motion refers to the innate ability to attribute motion to static objects (Shirai & Imura, 2016). Notably, the same brain regions involved in the identification of actual movement are activated by static images that imply motion (Kourtzi & Kanwisher, 2000). Examples of implied motion of food include pictures depicting orange juice being poured inside a glass or cereals moving towards a bowl (Figure 1).

Figure 1

Examples of implied food motion

Note. Image retrieved from Gvili et al. (2015)

Evolutionarily, the ability to discern animate beings such as prey and predators has been an essential survival mechanism for humans (Pratt et al., 2010). Consequently, humans might have developed a hard-wired sensitivity to cues of motion (Di Giorgio et al., 2017). Developmental research showed that infants as young as five months old shift their gaze, thus their visual attention, towards the direction of the implied motion of static figures (Shirai & Imura, 2016). This same effect is observed in adults as well (Gervais et al., 2010).

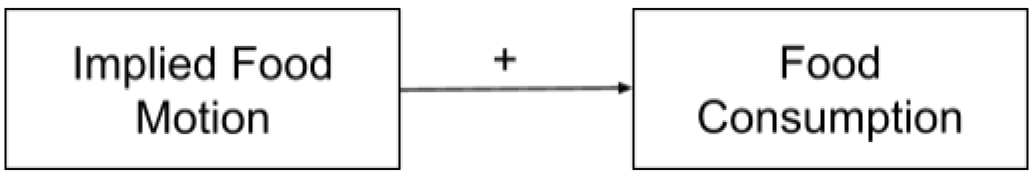
Additionally, implied motion may influence categorical decision-making. For instance, Gallagher et al. (2021), found that repeated exposure to images implying motion towards a certain direction bias decision-making in a subsequent categorisation task.

Similarly, with regard to eating behaviour, implied motion may direct attention and affect food choices (Gvili et al., 2015). For instance, Yu et al. (2022), conducted an eye-tracking study in which participants were asked to choose between four virtual orange juice packages. In the motion condition, one of the four packages implied motion by displaying orange juice jumping in the air whilst in the control condition the same package did not contain any cue of motion. The results showed that participants took more and longer gazes at the package with implied motion than the one without motion. Furthermore, the product implying motion was chosen significantly more than the package without motion. Other eye-tracking studies confirm the positive relationship between visual attention and choice likelihood (Peschel et al., 2019; Van Loo et al., 2021). In sum, implied motion seems to exert a positive influence on consumers' choices by enhancing visual attention to the product itself.

Despite this evidence, there are currently no empirical studies regarding the effects of implied motion on the final eating choice, namely, food consumption. Furthermore, implied food motion has mostly been studied through computerised experiments. Doing so reduces the ecological validity, the degree by which findings can be generalised to real-life settings, of the experiments (Andrade, 2018). As suggested by Gvili et al. (2017), it is necessary to conduct experiments about implied motion in a more realistic setting to investigate the robustness of the findings. Thus, this research aims to disentangle the possible effects of implied food motion on food consumption through a controlled experiment in a realistic environment. It is hypothesised that, in accordance with Yu et al. (2022), implying food motion will have a positive effect on food consumption (Figure 2).

Figure 2

Graphical representation of the first hypothesis (H_1): implied food motion has a positive effect on food consumption



Throughout the evolutionary history of humans, motion has been an indicator of freshness and a cue of life (Gvili et al., 2015). For example, moving animals are considered healthier than those that cannot. Compared to stagnant water, running water is fresher because it is less affected by bacterial and chemical contamination. Even in restaurants, seeing fish swimming in a tank improves the perception of freshness. Gvili et al. (2017) conducted an experiment in which participants had to rate the freshness of images of pretzels and cereals. One stimulus was shown in motion (e.g. being poured into a bowl) whilst the other was still (e.g. already inside a bowl). The results indicated that both pretzels and cereals in motion were rated as fresher than the same snacks shown motionless.

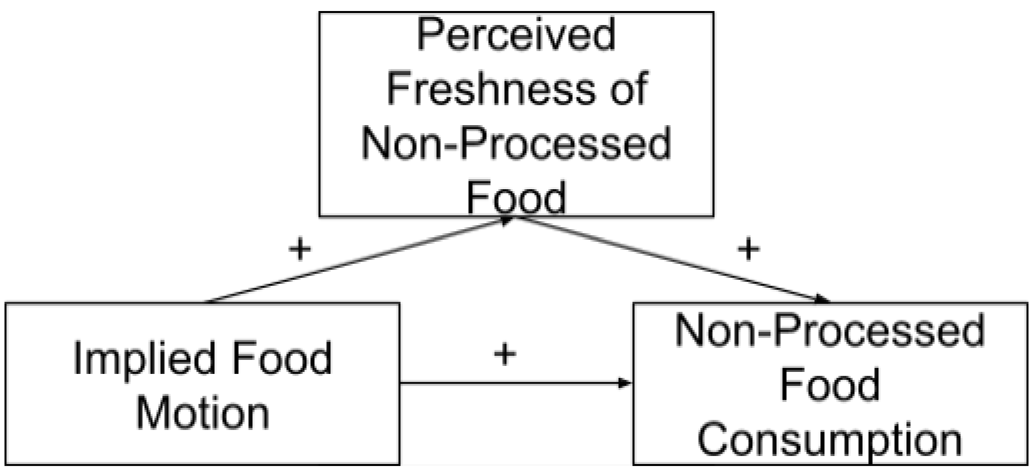
Additional neurophysiological evidence has confirmed the link between implied motion and freshness. Specifically, in an experiment by Li et al. (2021), participants were asked to rate on a Likert scale the perceived freshness of fruit, displayed as either static or implying motion, whilst recording their EEG signal. The event-related potentials (ERPs) showed significant differences between the two conditions in components from posterior electrodes recorded at 200-300 ms as well as components from frontocentral electrodes at 400-500ms. Cognitively, these differences in ERPs were interpreted to be representing, respectively, low-level visual perception of implied motion and subsequent high-level conceptual processing involved in rating the freshness of the food.

Furthermore, food freshness is considered to be one of the main criteria used by consumers to evaluate the quality of food notwithstanding age, gender or dieting status (Oakes, & Slotterback, 2002). This result is observed for different products including fish, beef, eggs, vegetables and fruits (Gvili et al., 2015). According to surveys conducted in the European Union, freshness has been identified as the most significant factor affecting food choices by consumers (Lennernas et al., 1997; Lappalainen et al., 1998). Moreover, Grebitus et al. (2013), set up an experimental auction in which participants bid to buy apples and wine whilst being informed about the distance of the cultivation of the two products. The results of the auction indicated that food freshness was a significant mediator of the relationship between the distance of cultivation and willingness to pay at the auction for apples but not wine. As a possible explanation of the differing results, the authors suggest that, while wine is a processed product, apples have a perishable nature. Therefore, the freshness factor appears more relevant for non-processed food such as apples than processed products.

In accordance with the aforementioned evidence, the second hypothesis investigated in this study regards a partial mediation of the perceived freshness of food in the relationship between implied food motion and food consumption (Figure 3). Specifically, it is expected that food will be evaluated as fresher whenever it is displayed implying motion. Thereafter, the perceived freshness will positively affect food consumption. However, taking into consideration Grebitus et al. (2013), this mediation is predicted to hold only for non-processed food. Particularly, in this research, processed foods are defined as “Foods that combine ingredients such as sweeteners, spices, oils, flavors, colors, and preservatives to improve safety and taste and/or add visual appeal" (e.g. crackers and carbonated drinks; Weaver et al., 2014) and non-processed foods are defined as "Single-ingredient foods with no or very slight modification that do not change inherent properties of the foods as found in its natural form" (e.g. fruit and vegetables; Crino et al. 2017).

Figure 3

Graphical representation of the second hypothesis (H_2): Perceived freshness of non-processed food will mediate the relationship between implied food motion and non-processed food consumption



Insights into this relationship will allow us to understand whether implied food motion may be a factor that can be used to nudge people to healthier choices. This knowledge is fundamental since an increased intake of foods high in fat, salt and sugar has been identified as one determinant of the three-fold increase in obesity and overweight compared to 40 years ago (WHO, 2021). Additionally, the manifold consequences of overconsumption of processed food impact individuals as well as, more generally, society and the environment. On the individual level, overconsumption of food can lead to medical conditions such as stroke and heart diseases

(Anand et al., 2015), diabetes (Sami et al., 2017), high blood pressure (Margerison et al., 2020), tooth decay (Sanz et al., 2013), as well as depression (Ljungberg et al., 2020). Furthermore, excessive food consumption has societal consequences such as reduced productivity, increased medical expenses, absenteeism, and consequently, increased welfare payments (Cornelsen, & Carreido, 2015). Lastly, an emphasis on producing more food without regard for sustainability has a significant adverse impact on the environment (Notarnicola et al., 2017). Among others, water depletion, terrestrial and marine eutrophication, climate change and freshwater ecotoxicity. Importantly, reducing by 25% food consumption and, consequently, the production of processed food such as pig meat, beef, dairy products (cheese, milk, butter) and poultry would reduce the aforementioned environmental effects (Notarnicola et al., 2017).

According to the aforementioned evolutionary, developmental, psychological, and neuroscientific evidence, implied motion appears to be an important factor involved in human cognition. Specifically, recent research has investigated the effects of implied motion on food perception. However, no research has been conducted to understand its effects on food consumption. Hence, this research aims at understanding the impact of implied food motion on food consumption. It is hypothesised that implied motion will increase food consumption of both processed and non-processed food. Furthermore, it is expected that perceived freshness of non-processed food will mediate the relationship between implied food motion and non-processed food consumption.

Methods

Participants

Participants in the experiment were recruited using convenience sampling. Specifically, pairs of friends were approached on the campus of the University of Twente. In order to participate in one trial of the experiment, one pair of friends was matched with one unfamiliar second pair of friends, thereafter, forming a group of four individuals. This was done to control for the effects of intra-group familiarity on food consumption. For instance, individuals often eat more when dining with friends compared to strangers in a phenomenon known as the social facilitation effect (for a full review see Herman, 2015). Hence, including a mixed group of familiar (i.e. a friend) and unfamiliar individuals (i.e. pair of strangers) was thought to mitigate the influence of social facilitation on food consumption.

176 participants were recruited for the experiment forming a total of 44 groups and 88 pairs. Of the 176 participants, 36 were excluded (18 pairs), resulting in a sample of 140 participants. The first six pairs of participants took part in the test run of each condition and, thus, were excluded from the final sample. Furthermore, 12 pairs of participants were excluded from the sample based on whether one or the other participant in the pair was allergic to one of the foods used in the experiment. The remaining sample consisted of 61 females, 78 males and 1 "prefer not to say" response aged between 18 and 42 years old (M = 22.9 years, *Median* = 22.0 *years,* SD = 4.4 years). Therefore, the final sample included 23 pairs of participants assigned to the control condition, 23 pairs of participants to the healthy motion condition and 24 pairs of participants to the unhealthy motion condition. A multiethnic sample was collected with participants coming from Australia, Azerbaijan, Brazil, Bulgaria, Curaçao, Denmark, Egypt, England, France, Germany, Greece, India, Indonesia, Iran, Ireland, Israel, Italy, Liberia, Luxembourg, Malaysia, Mexico, Nepal, Netherlands, Pakistan, Peru, Poland, Portugal, Romania, Saudi Arabia, Slovakia, South Africa, South Korea, Spain, Sri Lanka, Sudan, Sweden, Syria, Turkey, USA, Zambia. Participation in the study was voluntary, and participants had the opportunity to withdraw at any time.

Design

A between-subject design with two experimental conditions (*unhealthy motion*, and *healthy motion*) and one control condition (*no implied motion*) was used to test whether implied food motion had a positive effect on food consumption and if perceived freshness mediated the relationship between implied food motion and non-processed food consumption. Hence, the independent variable *implied food motion* was operationalised in three nominal categories namely, *unhealthy motion, healthy motion* and *no implied motion.* The unhealthy motion category represented the implied motion of processed foods, the healthy motion category constituted the implied motion of non-processed foods while the no implied motion was the category in which no implied motion was shown for any of the foods (see the Material section for more details). Specifically, the non-processed foods used in the experiment (carrots and grapes) were assigned to the category "healthy" considering their nutritious and low-caloric nature (high in vitamins and minerals) whilst the processed foods (peanut M&Ms and TUC paprika crackers) belonged to the category "unhealthy" due to their elevated sugar, salt and unsaturated fat levels (Crino et al. 2017). The dependent variable *food consumption* was operationalised with two continuous variables, namely, *food consumed in grams* and *number of bites*. The food consumed in grams was measured for each pair of participants and the number of bites was measured on an individual level. The mediator variable *perceived freshness* was measured on an interval level ranging from 1 = *not fresh at all* to 9 = *very fresh* for each participant. Particularly, the food consumed in grams, number of bites and perceived freshness were measured for each of the four foods used in the experiment. However, for the purpose of this study, the three aforementioned measurements of the two non-processed and of the two processed food items were averaged to create overall scores representing the same measurements for the non-processed food category and the processed food category.

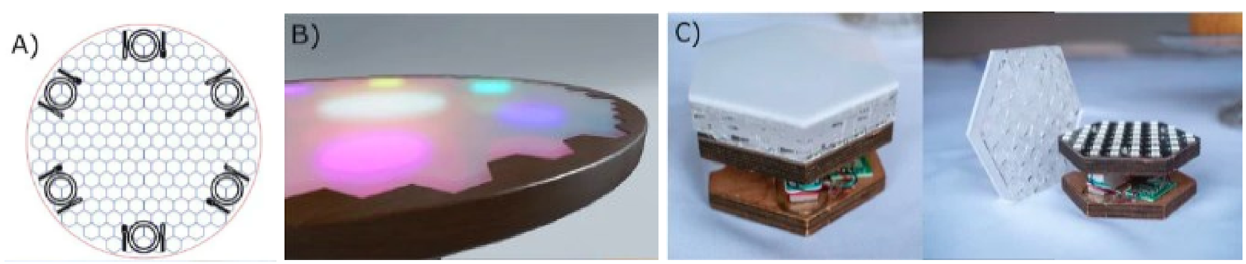
Materials

The food used in the experiment included peanut M&Ms, TUC paprika crackers, grapes, carrots, and Coop hummus. Grapes and carrots represented the non-processed food whilst TUC paprika crackers and peanut M&Ms belonged to the processed food category. These foods were selected to accommodate participants' personal preferences for either sweet or salty while controlling for the processed or non-processed nature of the foods. For example, participants could choose between two sweet options, namely peanut M&Ms and grapes, as well as decide whether to eat the processed or non-processed alternative. As suggested by the participants from the test phase "carrots are dull if eaten alone", hence, hummus was included as a dip to make the carrots more appetising. However, it was not considered as belonging to either of the two food categories used in the experiment. This is because, although hummus comes from a natural source, its caloric content (284 kcal) is in between that of the non-processed (grapes: 67 kcal; carrots: 41 kcal) and processed foods used in the experiment (crackers: 505 kcal; peanut M&Ms: 511 kcal). Furthermore, hummus was considered a dip that could be eaten together with foods from both categories, namely, carrots and crackers. Eight transparent glass bowls sized 20 cm x 10.5 cm were used to serve each of the four foods of interest whilst the hummus was served in two transparent glass bowls sized 10.5 cm x 4.5 cm. Specifically, each pair of participants was given four food bowls and one hummus bowl. The food was weighted using a digital kitchen scale (Soehnle Page Comfort 100), weighing up to 5kg and accurate to 1g. The peanut M&Ms, carrots and grapes were stored in a SMEG FAB30RRD5 fridge while the crackers were stored inside a plastic bag to reduce their desiccation.

The experiment was conducted using the Sensory Interactive Table (SIT) developed at the University of Twente (Haarman et al., 2020). SIT is a round dining table with a diameter of 1.45 meters which includes 199 controllable hexagon-shaped modules (Figure 4A) and a wooden frame (Figure 4B). Each of the modules has one load cell with a maximum loading weight of 5 kg and 42 RGB LED lights distanced 13mm apart from each other. The hexagonal modules are covered with, respectively, 15 mm thick plexiglass to diffuse the light from the LEDs and with a plastic layer to ensure waterproofing (Figure 4C). All the modules were covered with a synthetic tablecloth to have an extra protective layer. The processor Teensy 4.0 allowed the exchange of input and output between each module and the computer used to program animations through a micro USB cable. Therefore, in the context of this experiment, the SIT was used to program animations to imply the motion of either processed or non-processed food depending on the experimental condition participants were assigned.

Figure 4

Visualisation of the 199 hexagonal modules (A), wooden frame (B), and single hexagonal module (C)



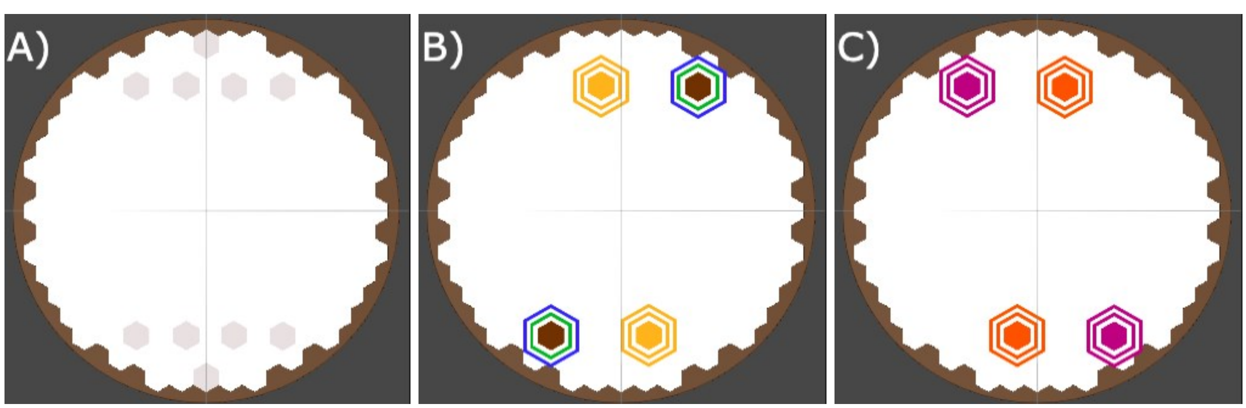
Note. Picture retrieved from Haarman et al. (2020)

The game engine Unity (version 2021.3.11f1) was used to program the LEDs present in the hexagonal modules. Specifically, two SIT animations were programmed to imply the motion of the food entailed by each of the two experimental conditions. These animations included three hexagonal-shaped lights. Two of the hexagonal-shaped lights, one having an apothem 2.5 cm longer than the other, encompassed the food bowls requiring the implied motion effect. The third and smallest hexagon lit the entire surface of the same food bowls rather than encompassing them. Both animations implied food motion in the following manner. Initially, all the hexagons were shown in the table, afterwards, each of the hexagons disappeared, starting from the larger one until the smallest one. Lastly, the hexagons reappeared starting from the smallest until the larger one. The time in between the (dis)appearance of each hexagon was one second. Thus, the total duration of the animation was six seconds but repeated in a loop from the beginning to the end of each experiment run. To watch the clips of the full animations for each condition see the link to the drive folder in Loddo (2023). This kind of pattern was designed to generate a greater sense of implied motion of food according to the classic gestalt principle of common fate. The common fate principle states that elements functioning or moving towards the same direction tend to be perceived as belonging together (Wagemans et al., 2012). For instance, the two hexagons encompassing each bowl function in the same way as the hexagon under the bowl itself (i.e. they all appear and disappear). Furthermore, all the hexagons moved away and towards the same bowl.

As mentioned before, the motion pattern was the same in the two animations implying food motion. However, this pattern was shown in different colours and positions on the SIT based on the conditions participants were assigned (see Figure 5). In the healthy motion condition, the animation showed the hexagon-shaped lights moving around the grapes and carrots. Thus, the colour of the hexagons around the carrot bowl was orange (hexadecimal value: FF6600) and the colour of the hexagons around the grapes bowl was purple (hexadecimal value: AB1F84). In the unhealthy motion condition, the animation entailed moving lights around the bowls containing TUC paprika crackers and peanut M&M's. Hence, the colour of the hexagons around the TUC paprika crackers bowl was dim yellow (hexadecimal value: F8B43C). Following the multicoloured appearance of the peanut M&Ms, the colour of the largest hexagon was blue (hexadecimal value: 114FF5), the colour of the middle hexagon was green (hexadecimal value: 44AB1F) and the colour of the smallest hexagon was brown (hexadecimal value: 6A350D). Matching the colour of the light with the food colours was thought to facilitate the association between the moving lights and the food itself. For instance, according to the classic gestalt principle of similarity, elements that share similar attributes, including colour, tend to be perceived as more related than dissimilar elements (Wagemans et al., 2012). A third animation was programmed for the control condition. This latter clip entailed constant white light under all the food bowls (hexadecimal value: FFFFFF) for the whole duration of the experiment. Figure 5 shows the initial state of the lights of the two experimental and control conditions.

Figure 5

Graphical representation of the initial state of the lights in the no implied motion (A), unhealthy motion (B), healthy motion (C) conditions



Note. The hexagons depicted in Figure 5 represent the position of the coloured lights shed by the

SIT. It is possible to see three hexagons (each having an apothem of 2.5 cm larger than the other) in the experimental conditions while only one hexagon in the control condition. Regarding the colours, Figure 5B shows the colours used for the crackers and peanut M&Ms while Figure 5C shows the colours used for the carrots and grapes. In the no implied motion condition (Figure 5A) the actual colour used in the experiment was white (hexadecimal value: FFFFFF). However, to make visible the position of the effect, the colour depicted in Figure 5A was altered to grey.

The experiment took place in the eHealth house located at the campus of the University of Twente. This environment was ideal to improve the ecological validity of the experiment. This is because the eHealth house offered a simulated living environment in which participants were able to enjoy their eating experience. For instance, the eHealth house includes a kitchen, dining area, living room, bedroom and bathroom (Figure 6). The SIT was placed in the dining area. The entire house was equipped with built-in cameras to record the participant's eating behaviour. However, the cameras used were situated in the kitchen area and, more specifically, recorded the SIT directly from above (see Figure 7A for the specific point of view). Moreover, a monitoring room was located above the house. In this room, it was possible to observe participants' behaviour through a computer displaying the camera recordings as well as through a one-way mirror revealing all the eHealth house areas. The CAE recording system was used to manage the camera recordings. Through this system, it was possible to control the camera's position and to review the recordings of each experiment trial. Particularly, the system had an annotation function to add comments to specific timestamps of the recording. While reviewing the recordings, this function was used to annotate the number of bites of each specific food per individual participant. The notes of each recording were formatted in the same way (i.e. "food name - part number") and summarised by the CAE system in a pdf file. Through a Python script, the latter pdf file was parsed to return the number of bites per participant of each specific food.

Figure 6

eHealth House kitchen (A), dining area (B), living room (C)

Note: images retrieved from Facilities & apparatuur | Technisch Medisch Centrum | Universiteit Twente

Finally, Google Forms was used to create and administer the consent form and debrief as well as the questionnaire for demographic information, perceived food freshness and participants' hunger levels. The consent form and debrief can be found respectively in Appendix A and Appendix B. The questionnaire included eight items. The demographic questions were "How old are you?", "What is your gender", and "What is your nationality?". The question about hunger asked participants to rate their hunger on a nine-point Likert scale ranging from 1 = *not hungry at all* to 9 = *very hungry*. The remaining four questions concerned the perceived freshness of the four foods. Specifically, the four questions were phrased as follows "On a scale from 1 (not fresh at all) to 9 (very fresh), please rate how fresh you perceive the … used in the experiment". In this format, the specific names of the four foods were substituted in place of the ellipsis. The answers were given on a nine-point Likert scale ranging from 1 = *not fresh at all* to 9 = *very fresh*. Moreover, the questionnaires' answers were automatically imported into a Google

Sheets file. In this latter file, the other two variables of interest, namely, food consumption in grams, and number of bites, were also recorded.

Procedure

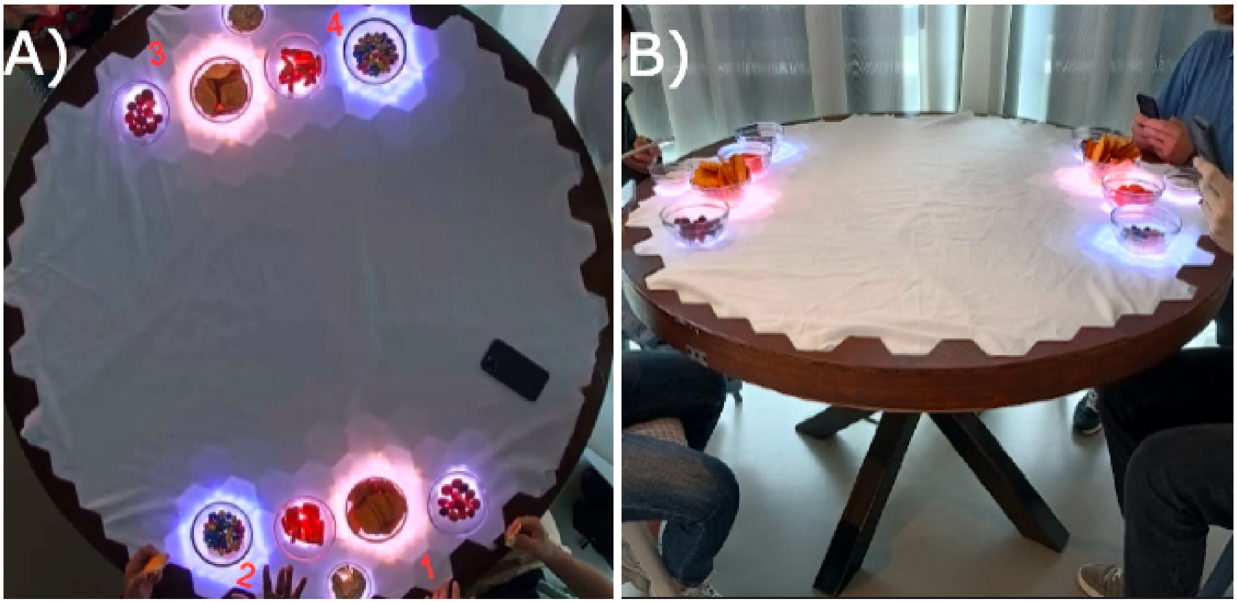
Before every trial of the experiment, five transparent bowls were filled respectively with hummus, carrots, grapes, crackers and M&Ms. The four bowls containing carrots, grapes, crackers and M&Ms were filled until reaching 100 grams. Specifically, each empty food bowl was placed on the scale and, thereafter, the weight on the scale was reset to 0. This was done to ensure that the weight of each food bowl would not affect the measurement of the food content. At this point, each of the four aforementioned foods was filled up to reach 100 grams. Doing so allowed each bowl to have the same content of food in every trial of the experiment. Differently, the hummus bowl was filled with 60 grams in order to replace, after every trial, its content more frequently. In fact, hummus tends to desiccate rather quickly after exposure to air. Furthermore, this amount was considered to be sufficient for the participants to dip their snacks. Once the snacks were weighed and placed in their respective bowls, they were covered with plastic foil and placed in the fridge to ensure correct and constant storage. After the preparation of the snacks, the researcher randomly determined, through the use of a random number generator, the condition to which the upcoming group of participants was assigned.

Subsequently, the recruiting process commenced. Pairs of friends were approached by the researcher nearby the experiment hall at the campus of the University of Twente. In order to seek their voluntary participation, participants were told a deceptive version of the purpose of the study. Specifically, the researcher explained that an experiment was being carried out to evaluate the newly developed Sensory Interactive Table (SIT) used for dining experiences. Furthermore, free snacks were offered as means to incentivise participation. Once the pairs of friends agreed to take part in the experiment, they were asked to wait up to 10 minutes at the eHealth house. In the meantime, the researcher looked for another pair of friends willing to take the experiment and, thereafter, grouped all the people together at the entrance of the eHealth house.

Upon entering the eHealth House, the participants were asked to take a tour of the house whilst the researcher set up the SIT animations and placed the pre-prepared food bowls in the correct position. The SIT animations were loaded on the table by first connecting the laptop with a micro-USB and, subsequently, playing the Unity file belonging to the pre-determined condition. For the entire duration of the experiment trial, the laptop was placed on a footstool under the SIT. With regards to the position of the bowls, these were placed in the same location for every trial of the experiment, regardless of the condition. Specifically, the food bowls were positioned respectively, from the left to right of the participants, in the following order: peanut M&Ms, carrots, TUC paprika crackers, and grapes. This order allowed each participant of the pair to be distanced equally from one non-processed food and one processed food option. Additionally, each participant was distanced equally to the one salty and one sweet option to accommodate individual taste preferences. For example, following the scheme in Figure 7A, the participant in position 1 was closest to the grapes (non-processed food; sweet option) and the TUC paprika crackers (processed food; salty option) whilst participant 2 was closest to carrots (non-processed food; salty option) and peanut M&Ms (processed food; sweet option). The same rationale applied to the participants in positions 3 and 4. Importantly, all the bowls were within arm's reach of the participants. Moreover, participants were seated next to their friends and, thus, it was hypothesised that participants would also feel comfortable reaching the furthest bowls. Lastly, the hummus bowl was placed in between the participant's chairs to be equally reachable from both participants.

Figure 7

Camera recording of an experiment trial (unhealthy motion)with labels representing participants' position (1 to 4)



Note. Figure 7A represents the position of the participants (1 to 4) with respect to the bowls' position in the unhealthy motion condition. From participants' left to right: M&Ms, carrots, TUC paprika crackers, grapes). Figure 7B shows another point of view of the table before the beginning of a trial.

Once the implied motion animations were running and the food bowls were placed on the SIT, the experiment trial started. Firstly, participants were asked to scan a QR code that redirected them to the link with the digital consent form and questionnaire. In this phase, freshness was described orally by the researcher as, in line with the definition by Gvili et al. (2015), "the closeness of a food product to its original state in terms of distance, time and processing" (p. 161). Subsequently, participants were reminded of the camera recording the SIT and explained a deceptive version of the task. Specifically, the participants were informed that the task was to get acquainted with the rest of the participants while the SIT would play animations. Additionally, the participants were told that the researcher would ask some questions about the experience at the end of the trial and that they could eat anything on the table. Each trial started as soon as the researcher left the room and started the video recording from the elevated monitoring room. Every trial lasted ten minutes. At the end of the ten minutes, the recording was stopped and participants were asked to stop eating. Afterwards, the researcher made sure the bowls from each pair were removed and grouped separately in two different spots in the kitchen. In the meantime, the participants were debriefed orally about the real aim of the experiment.

Once the participants left the eHealth house, their food consumption was measured. Specifically in chronological order, the food content was moved from the original bowl into an empty bowl, the original bowl was placed on the digital scale, the scale was set to 0 to take into account the weight of the original bowl and the food was placed back again in the original bowl. The weight shown on the scale was subtracted from the original 100 grams for the foods of interest and 60 grams for the dip. Finally, the food consumption was recorded on the Google Sheet file in which the results from the questionnaire were automatically imported. After each measurement, the content of the bowl was refilled to 100 grams and placed back in the fridge according to the aforementioned procedure.

At the end of the data collection phase, the video recordings of each trial were reviewed. This process entailed watching the recordings and annotating the specific food eaten by each participant through the CAE recording system. After annotating one video recording, the pdf containing the summary of the notes was downloaded. This pdf file was input to a Python script which returned the number of bites of each food per participant. The output given by the script was, subsequently, recorded on the Google Sheet data file. This process was repeated for all the video recordings.

Data analysis

Before conducting the main analysis, descriptive statistics concerning the means, standard deviation, minimum and maximum of food consumption and perceived freshness were analysed for each of the conditions (no implied motion, healthy motion and, unhealthy motion) and for both processed and non-processed food. Such descriptive statistics were then visualised through violin plots and scatterplots.

An Analysis of Variance (ANOVA) was conducted to test whether implied food motion increased food consumption (H_1)**.** Specifically, the ANOVA was used to determine if there were significant differences in the processed and non-processed food consumption means of the three different conditions. Moreover, post hoc analysis, using the Tukey HSD test, was conducted to determine which contrasts between the three conditions were significant. Lastly, Cohen's d was calculated to establish the effect size of the specific contrasts.

In order to test whether perceived freshness mediated the relationship between implied food motion and non-processed food consumption (H_2), three linear regressions between the three variables of the model were analysed. This ensured that the mediation model was viable, according to the three assumptions entailed by mediation analysis. Namely, there is a significant relationship between implied motion and food consumption, there is a significant relationship between implied motion and perceived freshness, and there is a significant relationship between perceived freshness and food consumption while taking into account the effects of implied motion. Thereafter, a Sobel test was conducted to determine the significance of the mediation model. Finally, all the parametric assumptions entailed by the aforementioned models were checked.

Results

Descriptive statistics

The means, standard deviations, maximums, and minimums of food consumption and freshness for the different food types and for each of the three conditions are reported. Specifically, Table 1 illustrates the descriptive statistics for the food consumption variable measured in grams. On average, processed food was consumed the most in the unhealthy motion condition whereas non-processed food was consumed the most in the healthy motion condition.

Table 1

Descriptive statistics of consumption variable measured in grams(IV) for each food type and condition

		Descriptive statistics			
Food type	Condition	Mean	SD	Min	Max
Processed Food	No implied motion	14.4	14.4	7.5	55.0
Processed Food	Unhealthy food motion	26.4	22.0	0	66.5
Processed Food	Healthy food motions	17.2	12.5	0	40.0
Non-Processed Food	No implied motion	31.9	24.2	0	91.0
Non-Processed Food	Unhealthy food motion	41.9	18.3	0	72.5
Non-processed Food	Healthy food motion	46.4	22.3	0	93.5

Note. All the numbers in Table 1 refer to food consumption measured in grams.

Moreover, Table 2 shows the descriptive statistics for the freshness variable measured on a nine-point Likert scale ranging from 1 = *not fresh at all* to 9 = *very fresh*. The results show that, on average, processed food was evaluated as the freshest in the no implied motion condition while non-processed food was rated the best in the healthy motion condition. Welch two-sample t-tests were conducted to understand whether the freshness scores of the processed and non-processed food differed from each other. In the no implied motion condition, there was no significant effect in the freshness scores, $t(90) = 1.5$, $p = .14$, although processed food was judged fresher ($M = 7.20$, $SD = 1.50$) than non-processed food ($M = 6.72$, $SD = 1.56$). Regarding the unhealthy motion condition, there was no significant effect in the freshness scores, $t(88) = -1.1$, $p = .27$, despite non-processed food being judged fresher ($M = 6.10$, $SD = 2.03$) than processed food ($M = 6.50$, $SD = 1.54$). With regard to the healthy motion condition, there was no significant effect in the freshness scores, $t(87) = .03$, $p = .97$. For instance, the processed food was judged similarly fresh ($M = 6.76$, $SD = 1.67$) compared to the non-processed food ($M = 6.77$, $SD = 1.40$).

Table 2

Descriptive statistics of the perceived freshness variable (mediator) for each food type and condition

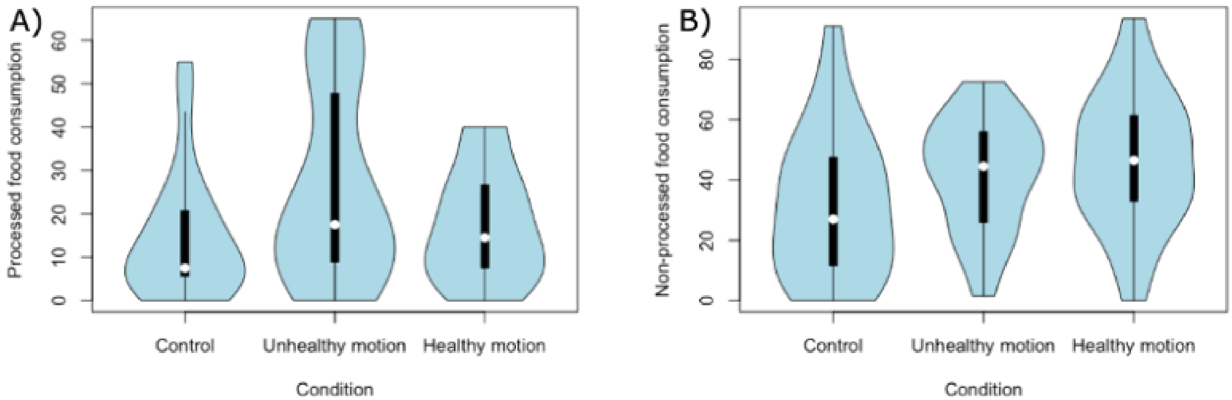
		Descriptive statistics			
Food type	Condition	Mean	SD	Min	Max
Processed Food	No implied motion	7.20	1.50	4.50	9.00
Processed Food	Unhealthy food motion	6.10	2.03	1.00	9.00
Processed Food	Healthy food motion	6.77	1.67	1.00	9.00
Non-Processed Food	No implied motion	6.72	1.56	2.50	9.00
Non-Processed Food	Unhealthy food motion	6.50	1.54	3.00	9.00
Non-processed Food	Healthy food motion	6.76	1.40	4.00	9.00

Note. All the numbers in Table 2 refer to the perceived freshness measured on a scale from 1 = *not fresh at all* to 9 = *very fresh.*

The violin plots of the processed and non-processed food consumption for each of the three conditions can be found, respectively, in Figure 8A and Figure 8B. In Figure 8A, it is noticeable that participants in the unhealthy motion condition consumed more processed food ($Median_{unhealthy}$ = 17.5) than those in the healthy motion and no implied motion groups ($Median_{healthy}$ = 14.5; $Median_{no\ motion}$= 7.5). In Figure 8B, it is possible to observe that participants had a greater median consumption of non-processed food in the healthy motion condition ($Median_{healthy}$ = 46.5) compared to the other two conditions ($Median_{unhealthy}$ = 44.5; $Median_{no\ motion}$ = 27).

Figure 8

Violin plots of the score distribution of processed food consumption (A) and non-processed food consumption (B) for each of the three conditions

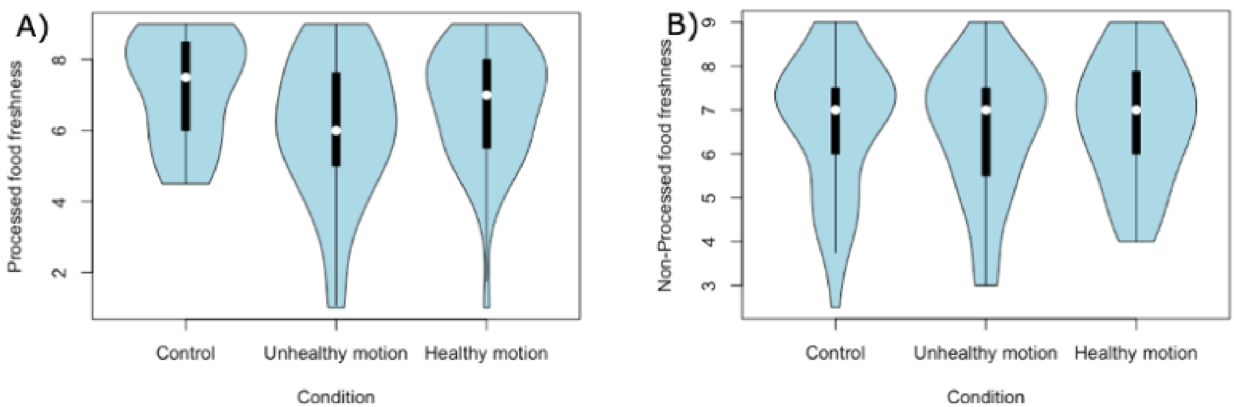


Note. The x-axis represents the condition (control, unhealthy motion and healthy motion). The y-axis in Figure 8A depicts the processed food consumption measured in grams (*min* = 0 to *max* = 65) and the y-axis in Figure 8B shows the non-processed food consumption measured in grams (*min* = 0 to *max* = 93.5). The white dot in each violin plot represents the median consumption score for the specific condition. The black lines represent the Inter Quartile Range (IQR) of each distribution.

Figure 9A shows that the median scores for *freshness* of processed food were highest in the no motion condition ($Median_{no\ motion}$ = 7.5) followed by, respectively, *healthy motion and processed motion* conditions ($Median_{unhealthy}$= 7.0*;* $Median_{healthy}$= 6.0). From Figure 9B, it is possible to observe that the median of the *freshness* scores for the non-processed food is the same regardless of the condition participants were assigned ($Median_{no\ motion}$ = 7.0; $Median_{unhealthy}$= 7.0; $Median_{healthy}$ = 7.0).

Figure 9

Violin plots of the score distribution of the perceived freshness of processed food (A) and the perceived freshness of non-processed food (B) for each of the three conditions.

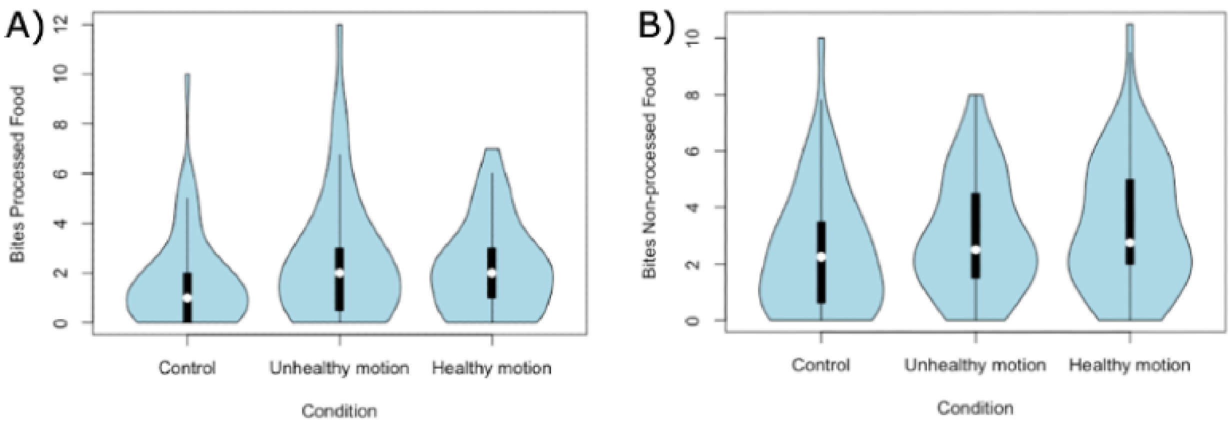


Note. The x-axis represents the condition (control, unhealthy motion and healthy motion). The y-axis in Figure 9A depicts the perceived freshness of processed food (1 = *not fresh at all* to 9 = *very fresh*) and the y-axis in Figure 9B shows the perceived freshness of non-processed food (1 = *not fresh at all* to 9 = *very fresh*). The white dot in each violin plot represents the median perceived freshness score for the specific condition. The black lines represent the Inter Quartile Range (IQR) of each distribution.

On the individual level, the distribution of the number of bites is depicted in Figure 10. With regards to processed food, Figure 10A illustrates that the median number of bites of processed food was the highest in the healthy motion and unhealthy motion conditions ($Median_{unhealthy}$= 2.0; $Median_{healthy}$ = 2.0) followed by the no implied motion condition ($Median_{no\ motion}$ = 2.0). With regards to the non-processed food, Figure 10B depicts that the median number of bites of non-processed food was the highest in the unhealthy motion condition ($Median_{unhealthy}$= 2.75) followed by, respectively, the healthy motion condition ($Median_{healthy}$ = 2.5) and the no implied motion condition ($Median_{no\ motion}$ = 2.25).

Figure 10

Violin plots of the score distribution of the number of bites of processed food (A) and the number of bites of non-processed food (B) for each of the three conditions.

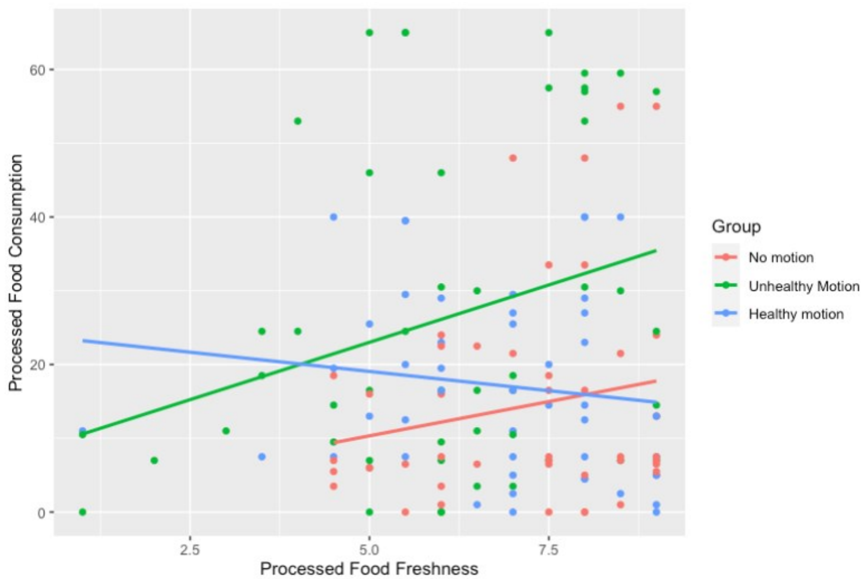


Note. The x-axis represents the condition (control, unhealthy motion and healthy motion). The y-axis in Figure 10A depicts the number of bites of processed food (*min* = 0 to *max* = 12) and the y-axis in Figure 10B shows the number of bites of non-processed food (*min* = 0 to *max* = 10.5). The white dot in each violin plot represents the median number of bites for the specific condition. The black lines represent the Inter Quartile Range (IQR) of each distribution.

Figure 11 illustrates the relationship between perceived freshness scores of processed food (x-axis) and processed food consumption (y-axis) for each condition. It is possible to observe that as the freshness scores increase the processed food consumption increases as well in the no implied motion and processed motion but not for the healthy motion. For instance, the slope of the regression line is positive in the processed motion and no motion whereas it is negative in the healthy motion. Specifically, in the no implied motion condition, the linear regression revealed that the perceived freshness of processed food was not a significant predictor of processed food consumption, $b = 1.86$, $t(44) = 1.31$, $p = .20$, $R^2 = .01$. In the unhealthy motion condition, the linear regression revealed that the perceived freshness of processed food was a significant predictor of processed food consumption, $b = 3.11$, $t(46) = 2.02$, $p = .048$, $R^2 = .06$. In the healthy motion condition, the linear regression revealed that the perceived freshness of processed food was not a significant predictor of processed food consumption, $b = -1.04$, $t(44) = -0.94$, $p = .35$, $R^2 = -.002$.

Figure 11

Scatterplot of the perceived freshness of processed food (x-axis) and processed food consumption (y-axis) for the three conditions

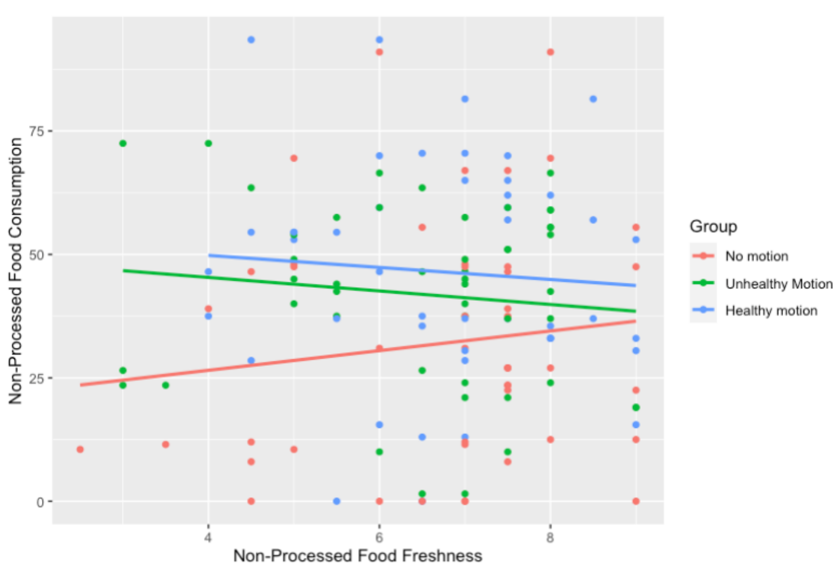


Note. The x-axis represents the perceived freshness of processed food measured on a scale ranging from 1 = *not fresh at all* to 9 = *very fresh* and the y-axis illustrates the processed food consumption measured in grams (*min* = 0 to *max* = 65). The different lines represent the regression lines between the perceived freshness of processed food and processed food consumption in each of the three conditions.

Figure 12 depicts the relationship between non-processed food freshness scores (x-axis) and non-processed food consumption (y-axis) for each condition. It is possible to notice that as the freshness scores increase the non-processed food consumption decreases in the healthy motion and unhealthy motion but increases in the no implied motion condition. For instance, the slope of the regression line is negative in the unhealthy motion and healthy motion whereas it is positive in the no implied motion condition. Specifically, in the no implied motion condition, the linear regression revealed that the perceived freshness of processed food was not a significant predictor of processed food consumption, *b*= 2.00*, t*(44) = .86, *p* = .40, R^2 = -.006. In the unhealthy motion condition, the linear regression revealed that the perceived freshness of processed food was a significant predictor of processed food consumption, *b*= -1.37*, t*(46) = -.78, *p* = .044, R^2 = -.008. In the healthy motion condition, the linear regression revealed that the perceived freshness of processed food was not a significant predictor of processed food consumption, *b*= -1.22*, t*(44) = -0.51, *p* = .61, R^2 = -.02.

Figure 12

Scatterplot of perceived freshness (x-axis) and non-processed food consumption (y-axis) for the three conditions



Note. The x-axis represents the perceived freshness of non-processed food measured on a scale ranging from 1 = *not fresh at all* to 9 = *very fresh* and the y-axis illustrates the non-processed food consumption measured in grams (*min* = 0 to *max* = 93.5). The different lines represent the regression lines between the processed food freshness and processed food consumption for each of the conditions.

Main analysis

Considering the first hypothesis namely, *implied food motion* has a positive effect on *food consumption*, a one-way ANOVA showed significant differences in the mean food consumption between the three groups for the processed food $F(2, 67) = 2.9$, $p = .046$, but no significant differences for the non-processed food $F(2, 67) = 2.63$, $p = .08$.

With regard to the non-processed food, posthoc comparisons using the Tukey HSD test showed that the differences between the mean consumption between the unhealthy motion and no implied motion conditions were not significant (*CI* [-5.37, 25.3], $p_{adjusted} = .27$). The mean non-processed food consumption between the healthy motion and no implied motion was not significantly different (*CI* [-1.02, 30.0], $p_{adjusted} = .07$). Nevertheless, Cohen's d analysis indicated a moderate effect size ($d = 0.43$) for the difference in mean non-processed food consumption between the healthy motion and no implied motion conditions. Furthermore, the mean non-processed food consumption between unhealthy motion and healthy motion was not significant (*CI* [-10.8, 19.9], $p_{adjusted} = .76$).

Concerning the consumption of processed food, the Tukey HSD test revealed significant differences between the mean consumption in the unhealthy motion and no implied motion (*CI* [0.08, 24.0], $p_{adjusted} = .048$). Cohen's d analysis indicated a moderate effect size ($d = 0.63$) for the difference in mean processed food consumption between the unhealthy motion and no implied motion conditions. The mean processed food consumption between the healthy and *no implied motion* was not significantly different (*CI* [-9.25 14.86], $p_{adjusted} = 0.84$). The mean processed food consumption between unhealthy motion and healthy motion was also not significant (*CI* [-21.1, 2.75], $p_{adjusted} = 0.16$). However, Cohen's d revealed a moderate effect size in the mean processed food *consumption* between unhealthy motion and healthy motion condition ($d = 0.63$).

On the individual level, when measuring food consumption by the number of bites, no significant differences between implied motion and food consumption were observed. Specifically, a one-way ANOVA showed no significant differences in the mean *number of bites* between the three groups for both processed food $F(2, 137) = 1.81$, $p = 0.17$, and non-processed food $F(2, 137) = 2.045$, $p = 0.13$.

The second hypothesis, namely, *perceived freshness of non-processed food* will mediate the relationship between *implied food motion* and *non-processed food consumption*, was analysed by ensuring that the three assumptions entailed by mediation analysis were respected. Specifically, since the focus of the second hypothesis was on non-processed food the variable implied food motion was considered only when the implied motion effect was applied to non-processed food (healthy motion condition). The first assumption, namely, the association between healthy motion and non-processed food consumption was previously reported to not be significant. The second assumption, namely, the relationship between the healthy motion and perceived freshness was also not significant as revealed by the linear regression, $b = .04$, $t(44) = .13$, $p = .90$, $R^2 = -.02$. The third assumption, namely, the significance of the relationship between perceived freshness and non-processed food consumption while taking into account the healthy motion condition was not met as revealed by the multiple linear regression, $b = .96$, $t(43) = .30$, $p = .76$, $R^2 = .04$. Finally, the Sobel test for the mediation model between healthy motion (IV), perceived freshness(mediator), and non-processed food consumption (DV), was not significant, $z = .10$, $p = .92$.

Importantly, the normality assumption was not respected for the ANOVA and linear models including the processed food consumption variable. However, a power analysis was conducted to determine whether the sample size used for the models was valid. To reiterate, the final sample size consisted of 140 participants divided into 70 pairs (23 pairs in the no implied motion group, 24 pairs in the unhealthy motion group, and 23 pairs in the healthy motion group). All the power analyses were conducted using the conventional medium effect size ($d = 0.5$), the conventional significance level ($\alpha = .05$) and the conventional statistical power ($1\text{-}\beta = .80$) as indicated by Sullivan and Feinn (2012). With regard to the ANOVA, the power analysis revealed that the sample size required to achieve the aforementioned statistics was 13 pairs of participants in each group ($n = 13$). Hence, the sample size used for the ANOVA was valid considering that the used sample included at least 23 pairs of participants in each group and resulted in a statistical power of $1\text{-}\beta = .96$. With regard to the linear models, the power analysis revealed that the sample size required to achieve the aforementioned conventional statistics was 52 participants ($n = 52$). Hence, the sample size used for the linear models was valid considering that the used sample included 140 participants and resulted in a statistical power of $1\text{-}\beta = .99$. Thus, the normality assumption was deemed partly respected following the high statistical power given by the analysed sample for both the ANOVA and linear regression models. Finally, all the parametric assumptions for the remaining models described in this section were verified and met.

Exploratory Findings

Exploratory analysis was conducted following the close-to-significant p-value observed when comparing the mean non-processed food consumption of the three groups ($F(2, 67) = 2.63$, $p = .08$). More specifically, a moderate effect size was observed for the mean non-processed food consumption between healthy motion and no implied motion condition ($d = 0.43$). With regards to processed food consumption, although posthoc analysis revealed a non-significant difference in the mean processed food consumption between unhealthy motion and healthy motion condition (CI [-21.1, 2.75], $p_{adjusted}$ = .16), Cohen's d revealed a moderate effect size (*d* = .63).

Consequently, the relationship between implied motion and food consumption was analysed by conducting a one-way ANOVA for each of the foods used in the experiment. The mean grapes consumption was significantly different between the three groups ($F(2, 67) = 5.0$, $p = 0.009$). The Tukey HSD test revealed significant differences in the mean grapes consumption only when comparing the unhealthy motion to the no implied motion (CI [5.5, 47.2], $p_{adjusted}$ = 0.009). The mean carrots consumption was not significantly different between the three groups ($F(2, 67) = 2.2$, $p = 0.12$). The three groups also did not differ in their mean TUC paprika crackers consumption ($F(2, 67) = .57$, $p = .57$). Lastly, the mean peanut M&M's consumption was significantly different between the three groups ($F(2, 67) = 6.12$, $p = 0.004$). Specifically, the posthoc results of the Tukey HSD test showed significant differences in peanut M&M's consumption when comparing the unhealthy motion group to the control motion group (CI [3.55, 34.5], $p_{adjusted}$ = .01) and when comparing the healthy motion group to the unhealthy motion group (CI [-35.4 -4.46], $p_{adjusted}$ = 0.008).

Following the observations given by the scatterplot in Figure 11, further analysis was conducted to understand whether *perceived freshness of processed food* might mediate the relationship between *implied food motion* and *processed food consumption*. The first assumption, namely, the association between unhealthy motion and processed food consumption was verified and met as described in the main analysis. Regarding the second assumption, namely, the relationship between the unhealthy motion and perceived freshness was significant as revealed by the linear regression, $b = -1.10$, $t(44) = -2.85$, $p = .007$, $R^2 = .13$. The third assumption, namely, the significance of the relationship between perceived freshness and processed food consumption while taking into account the unhealthy motion condition was met as revealed by the multiple linear regression, $b = 4.95$, $t(43) = 2.46$, $p = .02$, $R^2 = .17$. Finally, the Sobel test for the mediation model between unhealthy motion (IV), perceived freshness(mediator), and processed food consumption (DV), was not significant, $z = -1.86$, $p = .06$.

Finally, a multiple linear regression was conducted to take into consideration *hunger* as a moderator of the relationship between implied motion and food consumption. With regard to processed food consumption, hunger was not a significant moderator neither of the relationships between unhealthy motion and processed food consumption ($b = 1.25$, $t(64) = 0.54$, $p = 0.59$, $R^2 = .16$) nor of the relationship between healthy motion and processed food consumption ($b = -1.33$, $t(64) = -.56$, $p = 0.57$, $R^2 = .16$). Furthermore, hunger was not a significant predictor of processed food consumption ($b = 2.73$, $t(64) = 1.5$, $p = .13$, $R^2 = .16$). Similarly, with regard to non-processed food consumption, hunger was not a significant moderator of either the relationship between unhealthy motion and processed food consumption $b = -2.34$, $t(64) = -.79$, $p = .43$, $R^2 = .14$) or the relationship between healthy motion and processed food consumption ($b = -1.03$, $t(64) = -0.34$, $p = .74$, $R^2 = .14$). However, in this latter model, hunger was a significant predictor of non-processed food consumption ($b = 5.96$, $t(64) = 2.18$, $p = .03$, $R^2 = .14$)

Discussion

The current research aimed to understand whether implied food motion increases food consumption (H_1). Additionally, it was hypothesised that the perceived freshness of foods would mediate the relationship between implied food motion and non-processed food consumption (H_2). Regarding the first hypothesis, the results showed a positive relationship between implied motion and processed food consumption but no significant relationship between implied motion and non-processed food consumption. Moreover, food freshness was not found to be a mediating factor in the relationship between implied motion and non-processed food consumption. In fact, none of the assumptions entailed by mediation analysis were met.

With regard to the first hypothesis, the results observed are in line with Yu et al. (2022). In their eye-tracking study, it was found that displaying implied motion on packages increased visual attention and, consequently, led to a greater choice of the product implying motion. Importantly, the two products used in this study were processed foods, namely, milk and orange juice. Similarly, in the current study wherein product choice was measured in the form of food consumption, implied motion increased food consumption of processed food. Nevertheless, implied motion did not significantly increase the consumption of non-processed food.

An explanation of the differing effects of implied motion on food consumption of processed and non-processed food might be given by the two opposite effects that increased visibility of food has on consumption. On the one hand, according to the salience effect, increased visibility makes the food more salient, thereafter, increasing food consumption (Wansink, 2004). On the other hand, increased visibility induces monitoring of food consumed and, thereby, reduces consumption (i.e. monitoring effects). As previously suggested, the motion animation might have increased visual attention to either, depending on the condition, processed or non-processed food. This, in turn, may have triggered monitoring or salience effects based on the visual characteristics of the individual foods.

For instance, Deng and Srinivasan (2013) observed that the dominance of either the monitoring or the salience effect depends on the size and colourfulness of foods. In their experiment, the researchers found that consumption of small and colourful food (Froot Loops and M&Ms) increased whenever it was served in a transparent package compared to an opaque one. Furthermore, the consumption of visually plain food (baby carrots) was the same regardless of whether the food was served in a transparent or opaque package. Therefore, it was hypothesised that the visibility of food affected consumption based on the size and colourfulness of the food. Specifically, regarding the size, small food reduces the monitoring effect compared to large food since small food units are perceived by individuals as a less harmful threat to their self-control (also see Trope, & Fishbach, 2000). Moreover, colourful food is regarded as more visually attractive compared to plain food, thus, enhancing the saliency effect.

Considering the enhanced visibility resulting from the motion effects along with the size and colourfulness of the food, the present findings support the mechanisms suggested by Deng and Srinivasan (2013). For instance, M&Ms might have been consumed significantly more in the unhealthy motion condition since the visibility of their small and colourful nature was enhanced by the implied motion effect. This might have led to an increased saliency effect and decreased monitoring effects. With regard to TUC crackers, given their large and plain nature, enhancing their visibility might have increased the monitoring effect, whilst, reducing the saliency effect. In support of this net effect, the consumption of TUC crackers did not significantly differ between any of the three conditions. Additionally, implying the motion of the grapes and carrots might have enhanced the visibility of their visually plain nature which, in turn, reduced saliency effects and resulted in analogous food consumption between the conditions. Furthermore, the effect of their size on the monitoring effect might not be relevant due to the low motivation to monitor low-caloric food such as vegetables and fruit. Notably, the two foods in common with Deng and Srinivasan (2013), namely, M&Ms and carrots, held the same consumption patterns when manipulating visibility.

Moreover, although hunger is a physiological and psychological factor nudging food consumption, the exploratory analysis revealed that hunger did not moderate the relationship between implied motion and food consumption. This result might be due to the social modelling effect that the four participants had on each other. For instance, Goldman et al. (1991) found that participants conformed with the amount of food consumed by a confederate even after 24 hours of food deprivation. Herman et al. (2003) suggested that individuals conform to others' intake to avoid appearing as an excessive eater. Hence, social pressure might have counteracted physiological pressures for food consumption.

Concerning the second hypothesis, perceived freshness was not found to be an explaining variable of the relationship between implied motion and non-processed food consumption. Specifically, there was no correlation between implied motion and perceived freshness of non-processed food. This non-significant effect was also observed in the study by Mulier et al. (2021) in which participants had to rate 26 food pictures that, depending on the condition, depicted the food as either static or in motion. Considering that Mulier et al. (2021) found contrasting results compared to Gvili et al. (2015) and Gvili et al. (2017) using different food pictures, the effects of implied motion on freshness may be stimuli-dependent. Nevertheless in the current study, differently than the aforementioned research, freshness was evaluated by looking at physical food rather than digital pictures. Hence, it is possible that the actual freshness of the non-processed food influenced the judgments of freshness. For instance, the daily decision to buy fresh grapes and carrots depended on whether left-over remained from the day before. Therefore, some groups ate left-over grapes or carrots which could have lost some of their freshness, ultimately, affecting participants' judgments.

Additionally, the relationship between perceived freshness and non-processed food consumption was not significant. This might be due to the characteristics of the sample used in the research. Specifically, the majority of the participants were students from the University of Twente. Several studies report that university students tend to consume fruit and vegetables that fall below the portion size recommended by the WHO (El Ansari et al., 2009; Lee, & Loke, 2005; Škėmienė et al, 2009). Thus, although freshness is considered one of the most important factors affecting the choice of vegetables and fruits (Oakes, & Slotterback, 2002), the perception of freshness might have not driven the willingness to consume non-processed food due to student's eating habits.

Strength and Limitations

On the individual level, implied motion was not significantly correlated to either processed or non-processed food consumption. In other words, individual participants assigned to the three conditions did not differ in the number of bites eaten for each food category. This ran contrary to the significant effect observed when analysing the processed food consumption on a group level, namely, the consumption for each pair of participants. This could have been due to mistakes in the coding of the recordings. Specifically, in certain experiment trials, participants may have taken multiple units of food at once. However, the point of view of the camera did not allow the researcher to note such details, thus, making the coding of the number of bites flawed. Moreover, participants might have eaten food outside the recording time. For instance, participants could grab food in the time elapsed since the experimenter left the participants alone and started the recording and between the time elapsed since the experimenter left the recording room and stopped the experiment.

Another limitation of the study concerns the small explained variance observed in the linear regression. For instance, only four per cent of the variance in non-processed food consumption was explained by implied motion and perceived freshness. This is because in the current research only three variables, namely, implied motion, freshness, and hunger were included in the analysis. However, food consumption is influenced by several visual cues including colour, shape, proximity, visibility, size of the food and portion size (Wadhera and Capaldi-Phillips, 2013) and by environmental factors such as atmospheric conditions, social influences, eating efforts and distractions (Wansink, 2004).

Lastly, the questionnaire used in the study was not validated. For instance, freshness was measured with only one item per each food. Moreover, excluding allergies, the specific dietary preferences were not assessed. This might have compromised the consumption of processed food since M&Ms and TUC crackers were products that could not be eaten by vegan participants.

Importantly, this was the first experimental study analysing the influences of implied motion on food consumption. In previous research, implied motion of food has often been depicted in static pictures or packages, and consequently, did not allow for an investigation into food consumption. In the current research, it was possible to recreate implied motion on real food using the Sensory Interactive Table (SIT) developed at the University of Twente. Specifically, the motion effects were designed according to the classical gestalt principles of similarity and common fate. Notwithstanding its limitation, the experimental setup was designed to control the influence of the positioning of the food bowls, of the participant's proximity to the food, of the social facilitation effect and of the participants' individual taste preferences on food consumption. Furthermore, conducting the experiment in the eHealth House provided a realistic environment where participants could enjoy the eating experience, ultimately, enhancing the ecological validity of the experiment. Finally, the recruited sample included 39 different nationalities. This allowed for a reduction of the sampling bias, thus, ensuring that the results are not generalised based on a specific cultural group.

Future Research and Practical Implications

Recommendations for future research can be drawn from the implications of this research as well as its limitations. Firstly, to assess the reliability of the findings it is necessary to replicate the current study by correcting for its limitations. Specifically, future research should include a wider range of age groups. For instance, the ERA-EU project recommends including a broad range of age groups when studying food consumption to consider the diverse eating patterns observed within each group (van Rossum et al., 2022). Importantly, using a larger sample might allow to normalise the distribution of processed food consumption. Furthermore, it is advised to improve the coding of the consumption per participant in order to measure accurately the effects of implied motion on the food consumption of each participant. In this way, it would also be possible to analyse individual participants' intake to understand whether within-group consumption was shaped by social phenomena such as social modelling (Goldman et al., 1991). Lastly, it is important to assess food freshness with validated scales such as the one developed by Péneau et al. (2007).

Secondly, in a follow-up study, it might be helpful to choose the foods used in the experiment based on several visual cues found to be affecting food consumption. Considering the similarity between the current findings and those of Deng and Srinivasan (2013), it is suggested to further investigate size and colourfulness as visual cues in relation to implied motion. Specifically, implying motion on colourful food might enhance food consumption due to increased saliency effects whereas implying motion on plain food might reduce food consumption due to decreased saliency effects. Additionally, implying motion on large foods might increase monitoring effects while implying motion on small foods might decrease monitoring effects. Saliency and monitoring effects might be assessed, respectively, using validated questionnaires such as the Food Choice Questionnaire (Fotopoulos, 2009) and the tempest self-regulation questionnaire for eating (De Vet et al., 2014). Ultimately, choosing the experimental foods based on these visual cues might allow the development of a more comprehensive model explaining the effects of implied motion on food consumption.

Finally, practical implications can be warranted following the aforementioned findings. Marketers might try to shed pulsating light to imply the motion of processed food and nudge people into particular food choices. For example, pulsating light might be applied to particular products found on supermarket shelves. In all-you-can-eat buffets, implied motion effects could be useful to shape food choices towards the least expensive foods. Lastly, depicting implied motion on processed food packages might increase sales of particular products.

Conclusion

Overall, this research expanded the present knowledge about the effects of implied motion on eating behaviour. Particularly, this study was the first to investigate the effects of implied motion on food consumption. On the one hand, it showed that implied motion might increase processed food consumption. On the other hand, implied motion did not have any effect on non-processed consumption. This might be due to the physical characteristics of the food used in the experiment. Specifically, size and colourfulness are hypothesised to mediate the effects of implied motion on food consumption. Moreover, differently than previous research, implied motion did not influence the evaluation of freshness of non-processed foods. This might be due to differences in the stimuli used in the contrasting research. For instance, previous research has used food pictures whereas the current research used real non-processed food which is susceptible to decay within hours from the first usage. Furthermore, non-processed food freshness was not found to be a driver of non-processed food consumption. This could have been due to the general eating habits of the sample of university students.

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Appendix A

Consent Form

Dear participant,

You are asked to participate in a study conducted by Demetrio Loddo from the BMS Faculty at the University of Twente. This study is part of a bachelor's thesis. I thank you for taking the time to participate in the study! Please read the information below about the details of the study.

Purpose

The purpose of this research is to develop a better understanding of how the newly developed Sensory Interactive Table (SIT) influences a social experience. Your help is needed to improve the design and functionality of the table before commercial use.

Procedure

As a participant in this study, you will be asked to answer some questions before beginning to experience the Sensory Interactive Table. Afterwards, get to know the people in front of you and feel free to eat any snack. In the meantime the SIT might show some animation through its LED lights. The experience lasts 10 minutes. When this is finished, you will be asked some short questions about the experience and, thereafter, you will have completed your participation.

Confidentiality

All information obtained in connection with this study that can be identified with you will remain confidential. No individual identities will be used in reports or publications arising from the research. All data will be stored separately from names or other direct identifications of participants. Anonymous raw data may be made publicly available to other researchers. Research information will be kept in locked files at all times. Only research personnel will have access to the files. Research material may be retained for up to 10 years before being deleted.

Recording

For the entire duration of the experiment, the table will be video recorded. However, the camera is set up to record only what is happening on the table and, hence, the recording will not include any personally identifiable information. Moreover, the recording is safely stored in the UT cloud system until the end of the experiment. After the end of the experiment, all recordings will be deleted.

Risks or Discomforts

I foresee no risk with participating in this study.

Participant Rights

Your participation is voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without any consequences of any kind or loss of benefits to which you are otherwise entitled. To withdraw from participation at a later time, please inform the researcher via email within 30 days of your participation.

Identification of Investigators

If you have questions about your rights as a research participant, wish to obtain information, or discuss any concerns about this study with someone other than the researcher, please contact the Secretary of the Ethics Committee, ethicscommittee-bms@utwente.nl

For further information about this study, contact me at d.loddo@student.utwente.nl.

Do you confirm NOT being allergic to Sulfur Dioxide/Sulfites, Wheat, Peanuts, Milk, Soy, Lactose, Eggs, Sesame, Almond, Hazelnut, and Nuts contained in the food being used in the study?

- ☐ Yes, I confirm NOT being allergic to the aforementioned allergens
- ☐ No, I AM allergic to the aforementioned allergens

Your consent indicates that:

- You understand that any information you give may be used in future reports, articles, publications or presentations by the researcher/s, but that your data will not be identifiable.
- You understand that anonymized data will be kept according to University guidelines for up to 10 years after the end of the study.
- You understand that your participation is voluntary and that you am free to withdraw your participation, without explanation, until 30 days after participation

I consent to participate in the aforementioned study to evaluate my experience with the Sensory Interactive Table

- ☐ Yes
- ☐ No

Appendix B - Debrief

Dear participant, thank you again for participating in our study. Below you will find the information on the study.

Study objective

Even though taste plays a crucial role in controlling our food consumption, typically our initial sensory experience with food occurs visually. For instance, simply seeing food can increase our craving for it and stimulate the brain regions and neural pathways linked to pleasure. In the years, researchers have proposed a variety of visual cues influencing food perception and consumption. Amongst those, food motion has been found to be a factor that leads to better ratings of food taste, freshness, healthiness, and purchase intention. However, to current knowledge, no empirical research has been conducted about the impact of food motion on food consumption. Therefore, the aim of this research is to explore whether displaying food in motion can increase food consumption. Doing so will possibly allow to shape consumers' snacking behaviour towards healthier food choices and, consequently, reduce the consumption of unhealthy snacks that, when eaten on a regular basis, could lead to chronic health problems.

How did it work?

As a participant in this study, you were randomly assigned to either the experimental or control condition. If you saw the lights under the foods moving then you were assigned to one of the experimental condition. One condition was the "healthy motion" condition in which the grapes and bell pepper bowls were animated. The other condition was the "unhealthy motion" condition in which the M&Ms and TUC paprika crackers were animated. Otherwise, you participated as control.

After the experiment, you were asked some questions about the perceived freshness, healthiness and tastiness of the food in front of you. During the experiment, the Sensory Interactive Table(SIT) recorded how many grams of food you consumed. For this reason, you were asked to not move the bowls from their place.

Why is this important?

By participating in this study, you contributed to broadening the knowledge about how visual cues influence food consumption. This is of great importance to designing a variety of products, policies, and interventions that aim to help individuals to achieve a healthier diet. Doing so will allow reducing the burden of the costs governments spend to support those with chronic diseases caused by (partially) an unhealthy diet.

Withdrawing Policy

If you decide that you want to withdraw from this research, please contact us (researchers) within 30 days and quote your participation number to allow us to locate your data and withdraw it.

Furthermore, please contact us if you should have any queries or concerns. If you feel unable to raise these concerns with me, then you may speak in confidence to my supervisor (see contacts below.

If you have questions about your rights as a research participant, wish to obtain information, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee, ethicscommittee-bms@utwente.nl

Thank you for your participation.

Demetrio Loddo(d.loddo@student.utwente.nl)