Feeling Hungry: Association of Dietary Patterns with Food Choices using Scene Perception

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Abstract: Studies on nutrition have historically concentrated on food-shortages and over-nutrition. The physiological states of feeling hungry or being satiated and its dynamics in food choices, dietary patterns, and nutritional behavior, have not been the focus of many studies. Currently, visual analytic using easy-to-use tooling offers applicability in a wide-range of disciplines. In this interdisciplinary pilot-study we tested a novel visual analytic software to assess dietary patterns and food choices for greater understanding of nutritional behavior when hungry and when satiated. We developed software toolchain and tested the hypotheses that there is no difference between visual search patterns of dishes *1*) when hungry and when satiated and *2*) in being vegetarian and non-vegetarian. Results indicate that food choices can be deviant from dietary patterns but correlate slightly with dish-gazing. Further, scene perception probably could vary between being hungry and satiated. Understanding the complicated relationship between scene perception and nutritional behavioral patterns and scaling up this pilot-study to a full-study using our introduced software approaches is indispensable.

1 INTRODUCTION

Hunger and forms of under-nutrition has been one of the nutritional research focus, investigating food and/or nutrient shortage and their impact on diseases and survival (Rubin, 2018; Berkemeyer, 2012). Scientific inquiry into over-nutrition has been extremely well-documented, with studies on obesity, metabolic syndrome, diabetes, cancers, and other diseases of civilization (Berkemeyer, 2009). Little though is known about food choice and food perception in the state of being hungry or satiated, a complex of physiological and behavioral processes. The attitude towards food, including food culture, and individual emotional relation to, perception of and preference of food, would co-determine food choice. Short-term food choices and long-term dietary patterns affect nutritional status, all which have bearing on etiology and therapy of nutrition-based diseases. (Breer et al., 2017; Payne et al., 2010; MacCormack and Lindquist, 2019).

The research field of visual analytic provides applications capturing gaze-data and visualizing the gazes as perception of the scene. In the field of nutrition the use of visual analytic is in its nascent stages. Thus, we combined these disciplines in this paper, opening up attractive opportunities to observe the visual search pattern on food, thereby finding application in nutritional research.

Next to the development of an easy-to-use toolchain for conducting and analyzing studies on scene perception of dishes for nutritional research, a pilot study was conducted. Our pilot study objective was to investigate scene perception with food gaze on dishes when hungry (before lunch) and the food gaze at satiety (after lunch), taking into account the prior knowledge of dietary patterns. The underlying assumption of our pilot-study was that *involuntary* gaze movements on food would be an index for spontaneous nutritional choices, with stated *priors* of nutritional patterns to augment our current understanding of nutritional behavior.

In the following sections we report our pilot study goals, the tooling developed for this pilot study, and state the hypotheses. In Methods we describe the setting, participants, development of the visual analytic tooling for assessing gaze-data to index scene perception and the data-analysis conducted. This is followed up by presentation of the Results and Discussion.

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2 GOALS FOR PILOT STUDY

In an interdisciplinary team comprising of nutritional, computer, and behavioral scientists, two goals were identified. Firstly, creating software for conducting surveys with eye-tracking at the site of food-consumption. Second goal was to test the analysis toolchain for first insights on before and after lunch scene perception. We thus set up our pilot study towards these two goals and for testing our developed software under realistic conditions.

2.1 Tooling

This application of scene perception in nutritional studies required data-collection directly at food-eating locations, e.g., canteens or food-courts. For our study, the university canteen, *Mensa*, setting was chosen due to nearness and easy feasibility of pilot-testing. We assumed that people would have limited time for lunch-break, as stipulated by employers, classically half-an-hour. Thus, the study's implementation goal was identified as a mobile hardware-software solution that would work without special equipment, such as chin-rests, and allow running each experiment at minimum time.

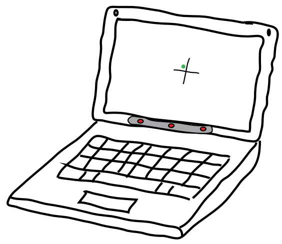
The second challenge, next to data-gathering, was data-storage for an interdisciplinary team. The concept of using multimedia container formats for storing survey-data (Schöning et al., 2017c,b), would allow first exploratory visual data analysis without any special tool. By improving our existing implementation, a more meaningful visualization was to be programmed, cf. Figure 4. The current approach and the future programming requirement would allow nutritional scientists to explore the data collected without additional requirement of special self-compilation or costly proprietary software, enabling newer dimensions in nutritional analytics.

2.2 Hypotheses

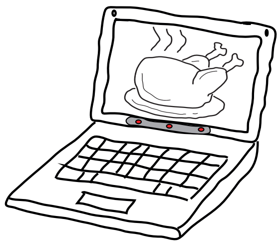
The prototyped survey tool enabled us to collect questionnaire-based information and gaze point on stimuli types such as photos, video footage, and animations.

For this pilot-study, the first null-hypothesis was defined as *1)* that there is no difference between visual search patterns of dishes when participants were hungry and when satiated. As the second hypothesis, we expected *2)* no difference between visual search patterns and a priori stated dietary pattern.

(a) Step I: answering a questionnaire (10*s*)



(b) Step II: recalibrate the low-cost eye tracking device (2*sec*)



(c) Step III: gazing on stimuli — different dishes (40*s*)

(d) Step V: having lunch Step V: gazing on stimuli again (40*sec*)

Figure 1: Steps of the study designed; not illustrated: Step IV have lunch.

3 METHODS

The study was conducted in January 2020 under the specifications of the declaration of Helsinki (World Medical Association, 2013). Informed consent was obtained prior to study participation. Ethical clearance was invalid for this pilot-study as no unique person-related, and identifiable data was gathered.

3.1 Setting

The pilot-study was based at a tertiary educational setting. Study participants included students, staff, or visitors of the tertiary educational institution. On the day of survey, four different main dishes and several side dishes were on offer at the canteen namely: **Dish 1**: organic spaghetti with organic soya bolognese, **Dish 2**: chicken schnitzel with peach and hollandaise sauce, **Dish 3**: gemstone pumpkin curry, **Dish 4**: beef sliced Esterhazy in vegetable sauce, **Dish 5**: side dishes i.e., potatoes, salad, soup, and noodles.

3.2 Study Design, Variables and Tooling

A cross-sectional study design was used for this exploratory study. For this early-stage feasibility study, a total of ten participants were recruited, which generated a medium volume of gaze-data. The recruitment ensued random selection of people visiting the canteen on the survey-day, given participant willingness to take part in the study and informed written study-consents were available. The inclusion of ten participant for a pilot feasibility was determined by the period of lunch-break, of about half an hour per person, over an entire lunch period of two hours between 12.00 noon and 14.00 p.m. on the day of data-collection and the use of a single computer based terminal equipped with visual analytic for data-gathering. Study participation, even so random stochastically determined, can not rule out study participation bias by those, who were inherently more interested in nutrition, compared to those, who were less interested in nutrition. The study was implemented by one study-personnel on the survey day, the software developed for this pilot study integrated a self-training sequence for those conducting the study allowing easy use and applicability.

Dietary patterns included non-vegetarian and vegetarian; non-vegetarian was defined as omnivore, healthy omnivore nutrition (Deutsche Gesellschaft für Ernährung e. V., 2020), and paleo-diet. Vegetarian was defined as ovo-lacto-vegetarian, ovo-vegetarian, lacto-vegetarian and vegan diets; raw-food, wholefood and flexitarian diets; and pesco-vegetarian diet. Dietary pattern was assumed to indicate long-term nutritional pattern and behavior. Food choices were defined by canteen menus that were chosen by the study participants on the survey-day. Food choices were assumed to indicate short-term nutritional behavior. There were five menus for choice on the study-day. Background data were collected on age, gender, and country of birth.

For the mobile hardware platform, a standard midclass laptop with a built-in, detachable low-cost eyetracking device was used. Estimating the computing power required for mobile software solution, it was determined that a low-cost laptop would not be able to simultaneously handle multi-threading, necessary for synchronous visualization of the stimuli, and datastorage of gaze data. We, hence, used a standard midclass laptop for the pilot study, laptop specifications were *Intel i5* CPU equipped with a *Tobii EyeX* eye tracker.

As seen in Figure 1, our software[1] covered the whole acquisition process of data, including humanmachine-interaction, e.g., for the questionnaire and for calibration of the eye tracking device. We provide this software as free, open-source software, which is capable of providing a timed graphical user interface for presenting the stimuli at a defined time and interoperable to different low-cost eye tracking device, in the programming language of C++. The software given as open-source for public research is also provided with an open-source free widget toolkit QT.

A simple calibration routine was implemented for the use of low-cost eye-tracking device along with the minimization of time spent for the study by each participant. As shown in Figure 1(b), the participant was therefore asked to fixate on a cross in the middle of the screen. The computer recognized a fixation over one second within an offset of 50 pixels, and the software re-calibrated the gaze tracking.

The study-design required that the stimuli presentation, as illustrated in Figure 1(c) would be flexible showing the day's dishes available at the canteen. The stimuli were not compiled with the software. Rather the stimuli, e.g., photos of dishes, were placed in a specified folder next to the executable built-in software. In this way, this pilot-study developed an easy, simple, and flexible solution for interchangeable stimuli. By naming convention, the order, as well as the duration of the stimulus, was set. For example, the photograph titled "dish1_3000.jpg" was shown for 3000*msec* followed by "dish2_1242.jpg" and so on. To avoid restarting the software repeatedly, a guided dialog was provided for the survey instructor, allowing back and forth movements with instruction repeats. Thus, the software applicability allowed easy, on-site training for people conducting the study, thereof saving time in study-specific schooling and training of personnel.

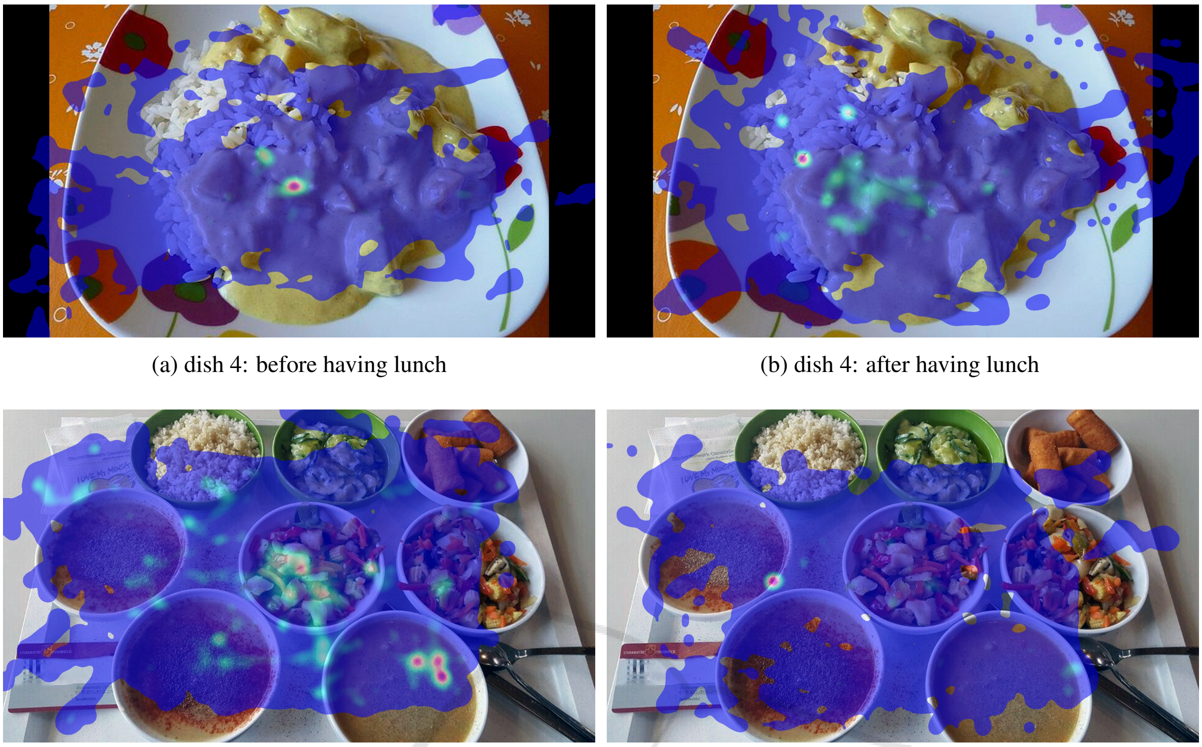
To regain participants after lunch we had a reward for the study participants built in to the study-design. Participants received a visualization of their gaze in the format compatible with standard multimedia players (Schöning et al., 2017a). This is described in detail in the following section.

3.3 Analysis

For scene perception analysis, the gaze trajectories on each dish were visualized for our investigation. Therefore static heat-maps, as shown in Figure 2, for each shown dish per participant, were generated by a simple Python script. Next to the five different dishes, cf. Subsection 3.1, a white screen was presented as well for zero-error correction calibration. For further analyses, the differences in the gaze patterns when hungry and when satiated were visualized.

According to the hypotheses *1)*, the resulting heatmaps were composed next to each other for visual inspection. In addition to the heat-maps per participant,

[1] The source code can be downloaded at https://www.hs-osnabrueck.de/prof-dr-julius-schoening/chira2020



(a) dish 4: before having lunch

(b) dish 4: after having lunch

(c) dish 5: before having lunch

(d) dish 5: after having lunch

Figure 2: Cumulated gaze patters off all participants on stimulus dish 4 and dish 5 , after having lunch the participants explore the outer areas of the stimulus.

cumulative heat-maps per dish for all participants was generated, cf. Figure 2. Finally *2)*, cumulative heat-maps over vegetarians and non-vegetarians were generated as well.

We compared the visual search pattern when hungry and when satiated as an assessment of nutritional behavior and compared it to participant's food choice of mid-day meal. Thereby, we visually examined, thereby testing, the possibility of using visual search pattern heat-maps for assessing nutritional behavior.

4 RESULTS

The overview of all study participants (cf. Appendix Table 1) shows that of the ten study participants, seven were non-vegetarian and three were vegetarians, thereof one vegan, one vegetarian, and one pescovegetarian. Age-range of the participants was 23-40 years. There were three women and seven men. Of the seven non-vegetarians, two were women and five men, and of the three vegetarians one was man and two were women.

Testing hypothesis *1)*, Figure 3 suggests that there was no significant difference between visual search patterns when hungry and when satiated using individual gaze-data. Visual inspection indicated that there could be gaze-deviation in cumulative gaze-patterns, i.e., when hungry and when satiated. However, this observation could also be due to, that the same photos were presented before and after lunch, which remains a study confounder.

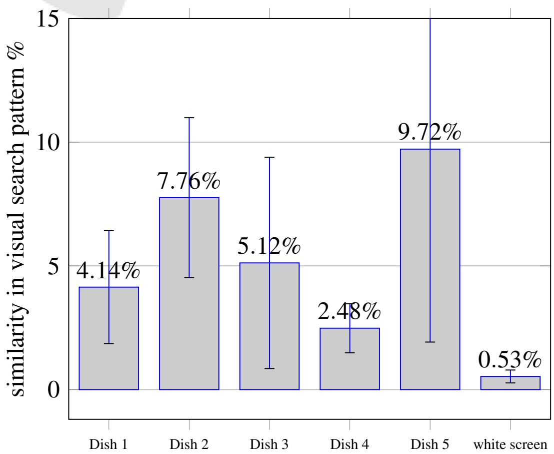


Figure 3: Similarity of visual search pattern when hungry and when satiated, accumulated over all participants.

Of the seven non-vegetarians, three gazed at dish 2, and two chose dish 2 (chicken schnitzel with peach and hollandaise sauce), one chose an undisclosed dish 5; two gazed at dish 4, and one chose it and the other chose dish 2. The seventh non-vegetarian was undecided and chose dish 1 (organic spaghetti with organic soy bolognase). Of the seven non-vegetarians, six were decided and one undecided at study-begin, and of the six only three chose what they gazed at. Of the three vegetarians, the vegan participant gazed and chose dish 3 (gemstone curry). One was undecided and chose an undisclosed dish 5. The third vegetarian (pescovegetarian) gazed, and chose dish 2. Of the three vegetarians, two chose different dishes than at onset; one food-choice was different from the dietary pattern, one remained undisclosed.

In total, only four (one vegetarian and three non-vegetarian) of the ten participants made food choices that coincided with what they gazed at. Two were undecided in food-choice from onset on (one vegetarian and one non-vegetarian). Of the remaining four participants (one vegetarian and three non-vegetarian), three food choices were different from what was gazed at, yet within the dietary pattern (non-vegetarian) and in one case food choice was different from the stated dietary pattern (vegetarian). We provide above-trend results for our hypothesis *2)*, which would require a full-scale study with large sample size.

5 DISCUSSION

Our pilot study indicates that individual visual search patterns were similar when hungry and when satiated, though cumulative visual search patterns suggest that participants could have gazed on food (central plate) when hungry and peripheral dish-area when satiated, which though remains confounded by the presentation of same before-after pictures. Initial analysis indicates that food choices tended to vary within dietary patterns, and at times food choices could be different from dietary patterns. The chance of greater undisclosed food choices was probably related to higher dietary pattern deviant choices, indicating nutritional behavior pattern to be more complex than the stated long-term dietary pattern or short-term food choice. Our pilot study further provides that the development of a low-cost tooling device can be used for nutritional studies with the development of more easy-to-use software for visual analytic.

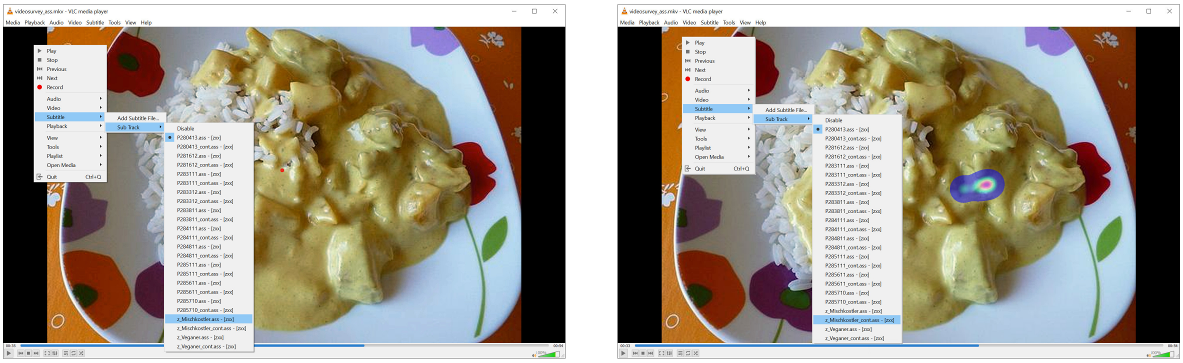
Exploring and analyzing the temporal behavior of the scene perception, the idea of using any multimedia player for exploratory analysis (Schöning et al., 2017a,c,b) was adopted and improved in our study. In this process we developed and improved the use of visual analytic to its stated purpose Thomas and Cook (2005), i.e., to derive insight from massive, dynamic, ambiguous, and often conflicting data, to detect the expected and discover the unexpected.

We further added transparent heat-map images as subtitle tracks instead of the use of the pure text-based universal subtitle format (USF), thereby we increased the meaning of gaze points per frame without leaking the ability to be played by the use of standard multimedia player such as the *VLC Player*. With our novel approach, refer Figure 4 (b) with the USF in Figure 4 (a), the information content was increased, because several gaze sampling points on the pixel were able to be visualized with colors. Despite these extensions, our approach still conformed to the multimedia container format and provided both instantaneous visualization with multimedia plays and the storage of all data in raw formats.

Our pilot study indicates that food choices and dietary pattern in frame of nutritional behavior pattern show variance. Very little is known about the decision-making process in food choices across the human life-span. Ogden and Roy-Stanley (2020) reported in children that food decision was automatic or considered or sanctioned. Greater autonomy in food decision-making does not automatically imply healthy food choices (Breer et al., 2017). Further, sanctioned behavior might also present a viable option in nutritional advice with diseases (Berkemeyer, 2009). MacCormack and Lindquist (2019) hypothesized that people experience hunger as emotions and misattribution process (Payne et al., 2010), to demonstrate that hunger (Rubin, 2018; Berkemeyer, 2012) shifts affective perceptions in negative but not in neutral or positive contexts. A role for intuitive eating to promote health has also emerged requiring further investigation (Rubin, 2018; Keirns and Hawkins, 2019).

A further application of our study results can be in the practice of how restaurants prepare food. Much of the processes are pre-defined and much of food preparation,such as, chopping, slicing, base sauce preparations are done in advance. Everything has its place and order in a professional kitchen to facilitate different people accessing same objects with these standardizations. Use of visual data analytic in scene perception in this practice-fields could help, for example, in training staff in simulations or real-life practice evaluations, which would be additional covariates in food choices. Food presentation has been shown to affect food choice (Ogden and Roy-Stanley, 2020).

Our limitations include the number of partici-



(a) universal subtitle format (USF) for visualization

(b) transparent image as sub station alpha overlays as subtitles for visualization

Figure 4: Gaze visualization with standard multimedia player; (a) former approach (Schöning et al., 2017a) and (b) our new approach providing a heatmap in each frame.

pants in our pilot study, which can be addressed in a full-study. Dichotomous grouping into vegetarians and non-vegetarians might be inadequate, requiring a third intermediate-grouping of semi-non-vegetarians including pescovegetarians and/or flexitarians. Further, our before-after study can be improved with assessment of food cultural and emotional factors, which co-determine food choices. Acquisition of healthy food-habits can be improved with reeducation, incorporating emotional association with food, which too remains an additional dimension application of the current pilot-study requiring future focus. Finally, even so participants were randomly recruited on the survey day we can not rule out participation bias by those, who are interested in nutrition, which remains a study-limitation. The use of cumulative heat-maps would require greater optimization, which can be conducted in future research in study-samples similar to and diverse from the current pilot samples, in order to generate long-term valid and reliable results.

This pilot-study indicates that by understanding scene perception and gaze-data, a greater understanding of nutritional patterns can be facilitated, including the future development of innovative nutritional therapy and innovative ways of preparing and serving food. Thus, a small unobtrusive bay leaf at the right place could probably instinctively help to make better food decisions, e.g., as a food-nudging intervention. Our pilot-study shows that such future goals can be the mainstay of innovative interdisciplinary research providing new, open, easy-to-use tools and exchange of different scientific approaches and perspectives.

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APPENDIX

Table 1: Overview of all study participants of the pilot-study.

ID	Age (years)	Gender	Brith Country	Mensa-Type	Nutritional Pattern	Food Gaze (when hungry)	Food choice (satiated)
P280413	31	Woman	Germany	Staff	NP-NV	Beef Sliced Esterhazy in Vegetable Sauce	Chicken schnitzel with peach and hollandaise sauce
P281612	30	Man	Netherlands	Staff	NP-NNV (Vegan)	Gemstone Pumpkin Curry	Gemstone Pumpkin Curry
P283111	23	Man	Germany	Student	NP-NV	Chicken schnitzel with peach and hollandaise sauce	A different dish
P283312	38	Man	Germany	Staff	NP-NV	Chicken schnitzel with peach and hollandaise sauce	Chicken schnitzel with peach and hollandaise sauce
P283811	25	Man	Germany	Student	NP-NV	Undecided	Organic spaghetti with organic soya bolognese
P284111	31	Woman	Germany	Student	NP-NNV (Vegetar-ian)	Undecided	A different dish
P284811	32	Woman	Germany	Student	NP-NV	Chicken schnitzel with peach and hollandaise sauce	Chicken schnitzel with peach and hollandaise sauce
P285111	32	Man	Germany	Student	NP-NNV (Vegetarian with fish)	Organic spaghetti with organic soy bolognese	Organic spaghetti with organic soy bolognese
P285611	40	Man	Germany	Staff	NP-NV	Chicken schnitzel with peach and hollandaise sauce	Chicken schnitzel with peach and hollandaise sauce
P285710	34	Man	Germany	Staff	NP-NV	Beef Sliced Esterhazy in Vegetable Sauce	Beef Sliced Esterhazy in Vegetable Sauce