Objective Measures of Individual Eating Styles across Different Food and Meal Types

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Introduction

Studying eating behaviour is important both in the fields of obesity and eating disorders [1,2]. However, while dietary habits receive a lot of attention [3], limited information exists on the behavioural patterns of individuals across meals at different times during the day or across meals with different food types. Does a person eat all their meals with a certain eating style? Is that style (partly) responsible for their weight and can we train the individual to normalize abnormal eating patterns? We believe that by using novel sensors and advanced data analysis we can answer these questions and integrate the generated knowledge into a novel, feedback-based guidance system.

It is often the case that the quantification of eating behaviour is excluded from studies dealing with obesity or eating disorders, as it is widely believed to be the direct effect of various cognitive "processes" or "traits" (e.g., [4]). An unfortunate side effect of this assumption is that the collection of self-reported, cognitive data is regarded sufficient to describe eating, which is therefore not actually studied (for an example see [5]). Nevertheless, it has been recently noted that the actual eating behaviour should be focused upon, in eating disorders and obesity [1,2].

In the past, the objective quantification of the eating behaviour has led to the identification of two distinct eating styles (linear and decelerated) in normal individuals, based on the progression of eating rate as a meal progresses. The use of cumulative intake curves (CICs) to model single meals (i.e., quadratic equations fitted on intake measurements across the meal), has since led to numerous reports of specific eating styles in normal [6] and patient groups [7]. In summary, both the decelerated and the linear eating styles can be identified in normal individuals [8], while patient populations are characterised by linear eating [7]. Additionally, there is some evidence that an individual's eating style is relatively stable under similar conditions [8], but it can be modified by training [9]. This principle has been successfully used in the treatment of eating disorders [10] and obesity [11]. Other parameters have also been shown to affect the eating behaviours in humans [6]. One such factor is the type of the consumed food, which has a pronounced effect on the eating characteristics [12]. To our knowledge, there is no information about the conservation of the relative eating style of an individual across different food items.

In order to describe the behavioural elements that result in the recorded CICs, we videotaped meals recorded with the Mandometer. That allows us to add information on the actual chewing during a meal, in tandem with the CIC. In addition to chewing, video recordings are coded for the occurrence of spoonfuls (i.e., food removal from the plate) and bites (i.e., food entering the mouth). Using this data we developed a semi-automatic procedure for the correction of the recorded Mandometer data series, using the coded bites as objective anchor points. The validity of our correctional technique was assessed by comparison with two separate manual corrections performed by trained researchers [13]. The introduction of this semi-automatic procedure enables faster, systematic analysis of food intake and chewing, and it is ideal for behavioural comparisons across meals and individuals. In this case, we tested the hypothesis that humans can be characterized by their individual eating styles, irrespectively of the type of meal (e.g., breakfast, lunch or dinner) or the type of food that is consumed.

The analysis of eating behaviour across meals and food types for an individual will allow the calculation of comprehensive personalised eating profiles. In the future, similar information might be used to relate individual eating styles with risk behaviours that lead to obesity or eating disorders and can potentially be normalized by the use of specialized personalised guidance systems. Steps in that direction have already been made, with the launch of SPLENDID [14], an ongoing EU-project, that will mainstream, automate and integrate our methodologies of analysing eating behaviour in order to identify and modify behavioural patterns in real life.

Subjects & Methods

Subjects and meals. Fourteen healthy, normal-weight, female volunteers (age: 25.1±3.3 years, BMI: 22.7±2.9 kg/m^2; group characteristics are presented as mean value ± standard deviation), with no history of eating disorders, were offered lunch and dinner at two different occasions in our facilities (semi-controlled environment). In both cases, they were served ordinary Swedish food consisting of a mix of vegetables with chicken bits (henceforth referred to as *vegetables with chicken*: 426kJ, 10.7g protein, 8.2g carbohydrates and 2.5g fat/100g). In another occasion, twelve healthy, normal-weight women (age: 22.8±2.5 years, BMI: 21.9±1.6 kg/m^2) were served two different lunch types. In one occasion *vegetables with chicken* was served. In the other, the served food was a curry rise and chicken mix (*Nasi Goreng*: 598kJ, 5.5g protein, 18g carbohydrates and 5.7g fat/100g). Note that the two food types differ in their component composition, but they were selected to have fairly similar component sizes. Finally, thirteen comparable (age: 23.3±2.12 years, BMI: 22.5±2.54 kg/m^2) women were served either *vegetables with chicken*, or a pasta dish with minced meat and sauce (*macaroni*: 754kJ, 6.3g protein, 17.8g carbohydrates, 9g fat/ 100g), i.e., two foods which differ both in the nutritional composition and the component texture. In all cases the experimental sessions took place around 12.00 h and 18.00h, for lunch and dinner respectively. The repeated sessions per individual were randomized, separated by at least a week. In every case, subjects were initially familiarized with the experimental procedure during training lunches that were not analysed. All the participants were asked to follow their usual eating schedule during the experimental days outside the test meals. Since comparisons across conditions for the whole behavioural spectrum were planned, data was analysed jointly for decelerated and linear eaters. Also, only women were included in the presented datasets for the sake of simplicity.

Apparatus. Weight-loss data during the meals were measured using the Mandometer® (Mikrodidakt, Lund, Sweden) [7], a weighing scale linked to portable computer. The device records the reduction of the weight of the food on a plate placed on the scale with 1Hz during a meal. The meals were videotaped using a digital video camera (Digitalcam, Samsung, South Korea), positioned approximately two meters away and aimed at the plate and the maxillary-mandibular area of the participant.

Data collection. The Mandometer® data and the meal videos were transferred to a PC for further analysis. The occurrences of bites and chews were manually time-stamped on the video feeds (custom Excel macro). The video-generated data-series were automatically synchronized with the weight-loss data and the intake data series were automatically corrected as previously described [12]. The corrected food intake data were used to calculate the cumulative meal characteristics, i.e., the total food intake, and the meal duration. The CIC, a quadratic equation: $y = kx^2 + lx$, where y = food intake, k = rate of deceleration, l = initial speed of eating and x=time, was also calculated from the intake data series (Figure 1). The combined video and weight-loss data series were used to calculate the number and weight of bites, the number of chews, bursts of chewing and the pauses between bursts (data not presented). Data points across the meals were averaged over thirds of the meal for easier comparison. Additional anthropometric measures (e.g., % body composition; TANITA BC-418 MA, Tanita Inc., IL, USA) and subjective measurements around each meal (e.g., hunger and fullness) and the acceptability and the taste of the food (e.g., overall taste, smell, saltiness, sweetness etc.) were also collected. However, since they are not the main focus of the methodology they are not presented in detail here.

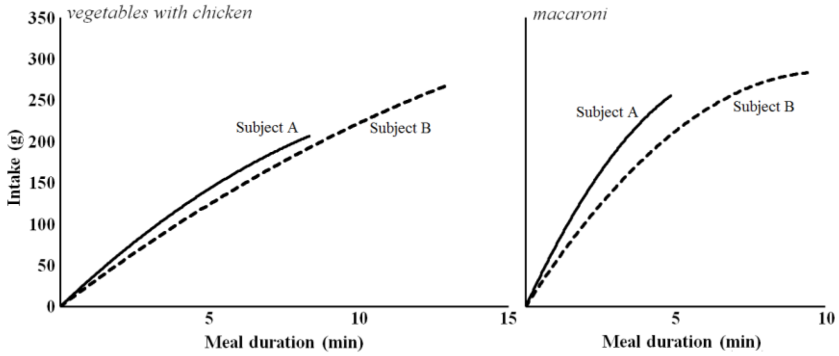

Figure 1. Data for two women being served different dishes for lunch. The presented eating curves have been fitted on weight-loss data collected by the Mandometer®.

Statistical analysis. All the statistical analyses were made using Sigmaplot 12.5 (Systat Software, CA, USA). Group differences were evaluated by using t-tests and analyses of variance, followed by post hoc tests, as needed. Correlations across conditions were performed in order to compare the relative similarities of the eating styles between different meals and food types.

Results

For sake of simplicity only results concerning the cumulative meal characteristics (i.e., total intake, meal duration, rate of deceleration and initial speed of eating) are presented here. This is the case for group comparisons, as well as measure correlations across conditions. The observed patterns mostly repeated (data not shown) when the detailed behavioural elements (e.g., chewing and bite rate progression over the meal etc.) were compared. Finally, group results are presented as means excluding measures of variability (for simplicity).

Group comparisons. Women ate about the same amount of food of *vegetables with chicken* at lunch and dinner (284 vs 275g respectively). The meals lasted about the same amount of time (9.5 vs 9.4min respectively). The eating styles across the meals (expressed through the CIC coefficients) were also not significantly different (coefficient k: -0.6 vs -0.7 and coefficient l: 35.5 vs 36.5 for lunch vs dinner, respectively). When women were served different foods with similar food itemization for lunch (*vegetables with chicken* vs *Nasi Goreng*), the participants ate similar amounts (282 vs 272g) in similar times (8.7 vs 9 min). The coefficients of the CIC were also similar (coefficient k: -0.7 vs -0.8 and coefficient l: 45.4 vs 42.4, respectively), showing that the different foods did not seriously affect the eating styles across the two food types. Finally, when women ate two very different foods for lunch (*vegetables with chicken* vs *macaroni*) they ate significantly different amounts (267 vs 312g, respectively, $p<0.01$). The *macaroni* dish was consumed faster (in 7.7 min vs 10.6 min for the *vegetables with chicken*) and the eating styles across the two food types were also significantly different (coefficient k: -0.8 vs -3.1 and coefficient l: 35.3 vs 63.2, for *vegetables with chicken* and *macaroni* respectively; $p<0.01$ in both cases). It is interesting to note that the subjects did not rate the foods differently in relation to their palatability ($p>0.1$).

Correlations. The total intake (r coefficient: 0.55, $p<0.01$), meal duration (r: 0.84, $p<0.01$), and the CIC characteristics (r: 0.4 and 0.39 for the coefficients k and l respectively, $p<0.05$ in both cases) correlated positively when women ate *vegetables with chicken*, either during lunch or at dinner, revealing that the relative eating styles of the subjects did not get affected by the type of the meal. When women consumed *vegetables with chicken* and *Nasi Goreng* for lunch, all the measures correlated strongly (data not shown) across the two food types, revealing that the relative eating styles across individuals remained unchanged. Finally, across the lunches with *vegetables with chicken* and *macaroni*, the eating styles remained relatively similar in all respects (see Table 1), even if the meal characteristics were significantly affected by the different food types (for an example see Figure 1).

Table 1. Correlations of measures across two lunches with different food types (*vegetables with chicken* and *macaroni*).

	Vegetables with chicken	*Macaroni*	Correlation coefficient r
Intake	267	312	0.78
Duration	10.6	7.7	0.94
Coefficient k	-0.8	-3.1	0.59
Coefficient l	35.3	63.2	0.83

Discussion

There is strong evidence that an individuals' eating style (i.e., linear eating) can be a risk of developing eating disorders or obesity [8, 10-12]. Here we present a methodology, based on objective measurement of eating behaviour in humans across different meals and food types, which can be a valuable tool for determining the baseline eating style of an individual. While the type of served food clearly affects a meal's characteristics (e.g., [12] and *vegetables with chicken* vs *macaroni*), individuals retain their relative personal eating style. Additionally, the timing of the meal doesn't seem to affect the eating style when similar food is served (*lunch* vs *dinner*). Similarly, individuals eat with matching styles when foods with comparable mechanical properties are served (*vegetables with chicken* vs *Nasi Goreng*).

The presented methodologies can be further developed to allow detailed measurements over longer periods of time and across a wider range of meal types. More importantly, modern technology can facilitate the collection of such measures in real-life settings in wider populations. With those aims in mind, our methodologies have already been deployed by SPLENDID [14], an ongoing EU-project. We aim to develop a Personalised Guidance System for training children and young adults to improve their eating (and physical activity) behaviour, using eating behaviour during meals as an indicator for detecting users at risk for developing obesity or eating disorders.

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References

1. DiLeone, R.J., Taylor, J.R., Picciotto, M.R. (2012). The drive to eat: comparisons and distinctions between mechanisms of food reward and drug addiction. *Nature neuroscience*, **15**, 1330-1335.

2. Walsh, B.T. (2011). The importance of eating behavior in eating disorders. *Physiology & behavior*, **104**, 525-529.

3. Burkert, N.T., Muckenhuber, J., Großschädl, F., Rásky, E., Freidl, W. (2014). Nutrition and Health–The Association between Eating Behavior and Various Health Parameters: A Matched Sample Study. *PloS one*, **9**, e88278.

4. Finlayson, G., Cecil, J., Higgs, S., Hill, A., Hetherington, M. (2012). Susceptibility to weight gain. Eating behaviour traits and physical activity as predictors of weight gain during the first year of university. *Appetite*, **58**, 1091-1098.

5. Korinth, A., Schiess, S., Westenhoefer, J. (2010). Eating behaviour and eating disorders in students of nutrition sciences. *Public health nutrition*, **13**, 32-37.

6. Westerterp-Plantenga, M.S. (2000). Eating behavior in humans, characterized by cumulative food intake curves—a review. *Neuroscience & Biobehavioral Reviews*, **24**, 239-248.

7. Ioakimidis, I., Zandian, M., Bergh, C., Södersten, P. (2009). A method for the control of eating rate: a potential intervention in eating disorders. *Behavior research methods*, **41**, 755-760.

8. Zandian, M., Ioakimidis, I., Bergh, C., Brodin, U., Södersten, P. (2009). Decelerated and linear eaters: effect of eating rate on food intake and satiety. *Physiology & Behavior*, **96**, 270-275.

9. Zandian, M., Ioakimidis, I., Bergh, C., Södersten, P. (2009). Linear eaters turned decelerated: Reduction of a risk for disordered eating? *Physiology & behavior*, **96**, 518-521.

10. Bergh, C., Callmar, M., Danemar, S., Hölcke, M., Isberg, S., Leon,… M., Södersten, P. (2013). Effective treatment of eating disorders: Results at multiple sites. *Behavioral neuroscience*, **127**, 878-889.

11. Ford, A.L., Bergh, C., Södersten, P., Sabin, M.A., Hollinghurst, S., Hunt, L.P., Shield, J. P. (2010). Treatment of childhood obesity by retraining eating behaviour: randomised controlled trial. *BMJ*, **340**, b5388.

12. Viskaal-van Dongen, M., Kok, F.J., de Graaf, C. (2011). Eating rate of commonly consumed foods promotes food and energy intake. *Appetite*, **56**, 25-31.

13. Ioakimidis, I., Zandian, M., Eriksson-Marklund, L., Bergh, C., Grigoriadis, A., Södersten, P. (2011). Description of chewing and food intake over the course of a meal. *Physiology & behavior*, **104**, 761-769.

14. http://splendid-program.eu. Accessed 27 March 2014.