Highlights

- A novel approach, the Temporal Dominance of Behavior (TDB), has been proposed to summarize, visualise and interpret video observation data.
- The TDB approach provides a dynamic graphical synthesis of the subjects' eating behavior.
- Consumption dynamic is related to both dish and consumer characteristics.
- The analysis of bread consumption behavior highlights strong individual variations.
- Different consumer groups have been drafted.

Full title

The temporality of eating behavior as a discriminant tool to characterize consumers: Temporal Dominance of Behavior applied to bread consumption during a restaurant meal in France

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Abstract

Video observation is gaining popularity as a data collection technique to study eating behavior. Traditional approaches to data analysis of video observations are based on static counts reporting the number of times an action occurs, disregarding the dynamic aspects captured in the video. In this paper, we investigate French consumers' bread consumption patterns during a restaurant meal. We propose a novel approach, the Temporal Dominance of Behavior (TDB), to visualise the dynamic information contained in video material in terms of frequency, duration, sequence and simultaneity of actions based on standard data analysis principles from temporal methods such as Temporal Dominance of Sensations (TDS) and Temporal Check-All-That-Apply (T-CATA). TDB allows reporting hours of videos across several subjects in a single graphical output, providing an efficient summary overview suitable for results interpretation and communication.

Regarding bread consumption patterns during a restaurant meal in French consumers, three groups of consumers are drawn: the No-breaders (43%), the Bread-as-a-tool group (48%) and the Bread lovers (9%). Eating behavior varies in the consumed quantity of bread as well as in consumption dynamics throughout the meal, and it is related to both the type of dish that is consumed and to consumer characteristics. The Temporal Observation Curves approach provides a graphical synthesis of the dynamic information.

We discuss the added-value of the TDB method compared to single-point analysis, provide recommendations for future developments and suggest potential applications in the consumer and food domain.

Keywords: Video, Dynamic analysis, Consumers, TDS

1. Introduction

In the late 20th century, Meiselman (1992) already suggested the need for a sensory evaluation that resembled how people ate in the real world, because consumption behavior is different outside of the laboratory. In the recent years, different approaches have been proposed to study consumer behavior without disturbance, such as postmeal self-reports (Haugaard, Brockhoff, & Lähteenmäki, 2016), in which researchers photographed subjects' meals after they freely chose dishes at a commercial buffet, and then asked them some questions. Even if self-report data have been extensively useful (Lahne, 2018), they can be biased as subjects may not recall their behavior accurately, some actions being done unconsciously. Alternative approaches, such as observational methods, could then be considered. Consumer scientists and professionals look for intermediate ways between real-life and laboratory conditions to improve the ecological validity of experimental environments. The principle of a living lab is to collect consumer data in a real environment but keeping the control of contextual factors. To keep the realism of the consumption experience, technological equipment is used to record relevant data from users who have agreed to be observed (Giboreau, 2018). Meals could be audio and/or video recorded, then transcribed and coded in reference to the meal itself to gain insight on the experience of the participants.

Working in teaching restaurants at a culinary school provides a wonderful opportunity to control the meal without completely disrupting the meal context (Porcherot et al., 2015). The living lab technological system allows researchers to record video and evaluate the dynamics of food consumption together with the measurement of the liking of food at different moments in the meals. This is a complete approach which provides information on food appreciation concerning the kinetics of consumption (Allirot et al., 2014; Cliceri, 2018; Fernandez, Bensafi, Rouby, & Giboreau, 2013). Liking and actual consumption are not always correlated and emphasize the value of conducting multiple-level approaches and real-life situation studies (Iborra-Bernad, Saulais, Petit, & Giboreau, 2018).

Living lab experiments can be seen as an attempt to compromise with the limitations and advantages of laboratory and field experiments, as the control of contextual variables increases the internal validity of the study, while the situation is kept as ecological as possible (Galinanes Plaza, Delarue, & Saulais, 2019). "The Restaurant of the Future" in Wageningen, Netherlands (Hinton et al., 2013; Zeinstra, Koelen, Kok, & de Graaf, 2010), "The Grill Room" in Bournemouth, United Kingdom (Bell, Meiselman, Pierson, & Reeve, 1994; Meiselman, Johnson, Reeve, & Crouch,2000) and "The Living Lab" at the Research Centre of the Institute Paul Bocuse in Ecully, France (Porcherot et al., 2015, Dougkas, Vannereux, & Giboreau,. 2019) are examples of Living labs dedicated to food studies.

In the last 50 years, there has been limited interest in recording eating behavior by video, as demonstrated by ScienceDirect, which reports 303 publications since 1971 (search with keywords: eating/drinking behavior, video, camera). Among them, 162 also include the keyword meal, of which 61 concern the adult population (i.e. excluding particular consumer categories, such as child, children and elderly). Among those studies, 29 used video to induce emotions or contexts and only 32 recorded meal situations and analyzed the videos, focusing the attention on the effect of the context on consumption, perception, emotions (9), on validation of methodologies (7), on food choices (4) and other various topics. Only 4 out of 32 publications focused on consumption dynamics. Kissileff (Kissileff, Thornton, & Becker, 1982) modelled the dynamics of food intake in humans as a quadratic equation, defining three types of eaters: those who show a linear relationship between food intake and time, those who show an accelerated relationship (eating slowly in the beginning and fast at the end) and those who show a decelerated one. Two studies (Westerterp, Nicolson, Boots, & Mordant, 1988; Westerterp-Plantenga et al., 1990) analyzed the consumption dynamics in obese and normal subjects, assessing the influence of inter-individual variability. In both studies, the authors constructed cumulative contribution curves as a function of time and used quadratic equations to fit data and conformed Kissileff's model. Some years later, other scientists (Ioakimidis et al., 2012) described dietary intake in relation to the evolution of chewing sequences during meals, and

consumers were split into two groups: linear and decelerated eaters. They found that decelerated eaters took fewer and smaller bites for the last third of the meal. The chewing frequency was the same for all and constant during the meal. Allirot et al. (2012) showed good intra-individual repeatability of eating dynamics over three days. Finally, several studies showed the influence of contextual factors on the dynamics of eating or drinking patterns and consumer satisfaction (e.g. Rolls, Roe, Halverson, & Meengs, 2007, Cliceri et al., 2018). One reason for the limited occurrence of video observation studies, and especially of meal dynamics, may be that video material is very demanding to analyse and there exist no holistic approaches to model and visualise meal dynamics across time and subjects.

Noldus' Observer XT 12.0 Behavioral Analysis Software (Wageningen, the Netherlands) can be used to record and analyze the actions of the studied subjects, such as food intakes or social interactions during a meal. It is a standard tool to record the times, occurrences and durations of various behaviors of the subjects under study (Sun, 2018). However, those results are generally reported in terms of frequency of actions in table or bar chart format (e.g. El Khoury et al., 2015, Masson, Delarue, & Blumenthal, 2017), or in terms of nutritional characteristics of food intake over time (Allirot et al., 2014). To our knowledge, until now no approaches have been proposed to visualise video-recorded data by drafting a dynamic graph of consumer behavior over time in a meal situation and taking into account the diversity of consumer actions and food items. Video observation is a very interesting tool for studying consumer behavior, but it is necessary to find a graphic presentation that is easy and quick to interpret. In the last years, in the field of sensory analysis, several methods for evaluating sensory profiles over time have been developed such as Temporal Dominance of Sensations (TDS) (Pineau et al, 2009), Temporal Check-All-That-Apply (TCATA) (Castura, Antúnez, Giménez, & Ares, 2016), multi-attribute time-intensity (MATI) (Kuesten, Bi, & Feng, 2013) and Progressive profile (PP) (Esmerino et al, 2017). Among them the TDS method allows determining which sensory attribute predominates over time (Pineau & Schilch, 2015), with results presented as average dominance curves, showing the proportion of attributes

dominance against time. The method has also been extended to temporal measures of wanting, satiation and emotion (Schlich 2017). Inspired by TDS principles, the present publication explores a translation of temporal methods from sensory profiling to the domain of consumer behavior in video observations.

The French people have a dear relationship with bread. It is a highly traditional product, part of the national food identity and heritage, and it is no wonder that the French baguette is a symbol of Frenchmen (Ginon et al., 2009; Crucean et al., 2019). The average bread consumption in France is of about 120 g day per capita corresponding to 26% of carbohydrate, 22% of fiber and 25% of salt intake in French adults (Planetoscope, 2019; CREDOC 2016; Crucean et al., 2019). Bread is a steady component of breakfast, lunch and dinner in most French households, mostly in the form of the traditional French baguette, but also in various alternative shapes and recipes (whole grain, organic, gluten-free etc.). In France bread seldom constitutes the principal element of a meal (e.g. open sandwiches in the Scandinavian culture), but is rather available as an accompaniment to the foods consumed with cutlery in a plate. In this context, bread typically serves as a tool to for example push food on one's fork, wipe one's plate and cutlery clean before the next dish is served, or consume the sauce of a dish. A previous work on bread consumption by French consumers used video-recording to collect information on each piece of bread eaten during a meal. This was done thanks to the simultaneous use of VIC media player and Excel 2007 (respectively to watch and code behaviors) and allowed the creation of a grid analysis (Iborra-Bernad et al., 2018). However, no overall temporal behavior was reported through this approach.

As bread is generally consumed during the whole meal, it is interesting to assess bread-related behavior of consumers at the restaurant. To our knowledge, no previous research has investigated bread consumption patterns within the frame of a meal; there is therefore a need for exploratory research in this domain. Bread consumption during a meal could affect the hedonic appreciation of the whole meal or a particular plate, e.g. it could be consumed with a portion of food in a bite (van Eck & Stieger, 2020), but it surely has an impact on nutritional intake and satiety (Touyarou et al.,

2012). Consumer clusters are increasingly studied also based on differences in food attitudes to obtain useful information to characterize the different consumer segments. Understanding consumers' bread usage during a meal may provide useful insights to food product developers and to the hospitality sector for composing menus in canteens as well as in restaurants, e.g. improving the nutritional value of the meal and/or selecting the appropriate bread portion and composition.

Starting from those considerations, the main objective of the present paper was to propose a graphical way to present data from an observatory study, allowing to show the relationship between food intake and time as well as the diversity of behaviors due to various eaten foods. The proposed method draws inspiration from TDS curves to visualize which actions or events are dominant at any given moment over time in a set of consumers sharing a common situation. In particular, the proposed Temporal Dominance of Behavior (TDB) approach is used to assess the effect of dish characteristics on consumers' bread consumption behavior, and to study consumer profiles according to individual consumers' relationship with bread throughout the meal. The paper's ambition is to present a new concept that may be useful and inspiring to other researchers interested in video observation. We also discuss several avenues for future developments, hoping that the paper may inspire qualified statisticians to further develop the analytical approach and answer the challenges associated with observational data.

2. Materials and methods

2.1 Ethics

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and General Data Protection Regulation (GDPR), and they were approved by the Research Protocol Committee of Institut Paul Bocuse according to national ethics guidelines (Loi Jardé, n 2012-300, 12 March 2012). Written informed consent was obtained from all consumers before their participation in the study, including a video recording consent form.

2.2.Contextualized test

The test was performed at the Living Lab of the Institut Paul Bocuse Research Center. It is an experimental restaurant made up of a dining room and a kitchen entirely adjustable and equipped with a video recording system. This restaurant is open some periods of the year and while they book, clients are informed that they may take part in a research study involving to answer a questionnaire and/or being filmed during their meal.

2.3 Participants

A total of 133 French consumers participated in the study in Spring 2016 (4 weeks) at lunch time. They were clients of the Institut Paul Bocuse Experimental Restaurant. Subjects were not submitted to a screener when they booked. Upon arrival, volunteers signed a consent form agreeing to participate in a research study and being filmed during their meal. No reward was provided for participation, however, the experimental restaurant charges low fees with respect to the culinary quality and the quality of service provided.

The videos of 118 people were coded. The non-coded videos correspond to subjects who were either minors, foreigners, part of the Institut Paul Bocuse staff, who didn't consume bread at all during the meal (e.g. coeliac disease), or whose angle of filming did not allow to see precisely all gestures. Moreover, an additional 18 subjects were excluded because they shared their dishes with other subjects. In total 100 participants were included in the analysis.

2.4. Procedure

2.4.1. Self-administered questionnaires

Upon their arrival, clients had to answer a small questionnaire about their hunger level (9 points scale), their thirst level (9 points scale) and their current mood (CATA). A second questionnaire was distributed once the main dish and the bread basket and leftovers were removed from the table. It was constituted of three parts: the appreciation of the dishes, the bread and the wine (if applicable) (9

points scales), the bread consumption habits (moments of consumption, amount) and the socio-demographic characteristics of participants.

2.4.2. Videos

The Experimental restaurant was equipped with six cameras (SONY EVI-D70) fixed on the ceiling and distributed at different places of the room. Each camera is adjustable in a very precise way. Five cameras are placed above five different tables (table max capacity = 2-4 people), and the 6th camera shows the entire room. Every day, between 12 and 20 participants were filmed. Each recording started when the clients took place at the table and stopped when the 2nd questionnaire was distributed, i.e. after the main dish was consumed and before the dessert. Altogether, nearly 120 hours of videos were collected for the experiment.

2.5. Products

2.5.1. Meal

A typical, everyday French meal consists of a succession of two to four dishes. During the period of the test, the lunch menu at the experimental restaurant was composed of a fixed appetizer, a starter among three possible options, the main course among three possible options, and a dessert among three possible options (meal duration ≈ 1 hour). In Figure 1 the pictures of the different dishes are reported (as starters: a= quail egg, b= lamb's sweetbread, c= salmon; as main courses: d=bass, e= pork hock, f= poultry). The dishes varied in multiple visual, olfactive, textural, taste and flavour attributes with no systematic design. Some salient characteristics may be noted: the quail eggs, pig hock and poultry consisted of solid elements, the lamb's sweetbreads included a semi-solid puree, the salmon was rich in flavor and texture, and the bass featured a liquid sauce (Figure 1). Importantly, dishes were not selected individually but prepared in a balanced number and randomly assigned to the participants by the waiters, across and within tables. Participants were able to exchange a dish with their co-eaters before consumption, although this was rarely observed. Cases of

exchanging or sharing dishes after starting eating were not included in the data material (18 occurrences). Each plate was eaten by the same number of people (30-33).

Figure 1

2.5.2. Bread

The bread was a high-quality frozen bread from fine white flour. Each bread serving had the form of a small baguette and weighed 40 g (+/- 1.3 g). Its constant weight allowed to estimate precisely the amount of bread eaten from the video footage. Bread was available *ad libitum* from the guests' arrival at the table and until clearance of the table after the main course.

2.6. Coding of the videos

Each video was manually coded with The Observer XT software (Noldus, The Netherlands). It allows translating qualitative data (film) to quantified data (time, duration, frequency). During the coding one differentiates between so-called state events, which drag in time, and point events, which are brief and punctual. Point events can occur simultaneously to state events, but not simultaneously to one another. Different kinds of actions were coded as presented in Table 1: meal phases (waiting time, appetizer, starter and main dish, coded as state events) which highlight the frame for the meal structure, bread actions (point events, see below), and consumption (placing food, bread or drink in mouth, originally point events in nature but coded into last-item-in-mouth state events, see explanation below). Thus, the three consumption point events (food, bread or drink) are transformed into one state event (last item in mouth) varying in four modalities (eating food/eating bread/drinking/nothing). Sub-actions were defined after video recording, pre-watching a few videos and also based on a previous paper (Iborra et al., 2018). The manual coding for each subject took between 45 minutes and 1 hour, approximately 12 days of coding for 100 subjects.

The use of bread was made up of five sub-actions: no interaction with bread; bread-mouth action; bread-hand action; bread-plate action; bread-cutlery action). All videos were coded by the same

experimenter. Twelve videos (10% of total recordings) were coded a second time by a second experimenter for validation. The comparison was based on frequency/sequence of each action and state event, with a tolerance window of 10s. The agreement rate was 98.3 %.

Table 1

2.7. Data analysis

2.7.1. Temporal Dominance of Behavior (TDB) and bread actions for each dish

Presenting results in the form of videos is not practical; it is also inappropriate for representing multiple events across time and consumers. On the other hand, presenting temporal data in the form of frequency counts loses the sequential information of events; for example, do consumers typically eat bread before the food or together with the food? To give a visual overview of the behavior of all consumers during the meal, TDBs were designed inspired by the principles of graphical representations used in the TDS and T-CATA methods for dynamic sensory curves (Pineau & Schlich, 2015; Castura, Antúnez, Giménez, & Ares, 2016). The principle in TDS and T-CATA graphs is that each curve represents a sensory attribute, and displays how this attribute evolves in time between occurrence and non-occurrence episodes throughout a food or drink consumption event. The curve is reported for several subjects, where the higher the proportion of subjects who perceive the attribute, the higher the curve, potentially reaching significance level. The principle in TDB is that each curve symbolizes a behavior of interest (instead of a sensory attribute) and thus to visualize the proportion of subjects performing this behavior at any time during the meal. In this way, we can reveal dominant actions, i.e. the actions most typically performed by consumers during the different phases of the meal.

As the majority of actions during the meal are brief events, the probability that several subjects have performed the same action simultaneously is very low. For example, even if all consumers were to consume some bread before receiving the food, they would not all place the piece of bread in their mouth at the same time-point of the video footage (point event), preventing the accumulative

proportions required to visualise this action as dominant in the TDB graph. To overcome this issue, we coded the food intake data (drink, food and bread) as last-item-in-mouth state events and a TDS-like dataset was created (time discretization 1 second). That is to say that for example attribute "food" would remain active from the moment the subject places food in their mouth, until another item (bread or drink) enters the mouth, in the same way as in TDS curves a sensory attribute remains active until another one is selected. Thus, the signal we are modelling is similar to a TDS sequence, replacing the sensory attributes by the modalities of the state event, the products being the starters and main courses. Note that the TDB approach is closer to TDS than to TCATA, because the modalities of the state events are exclusive. Note also that a modality "nothing" is utilised.

To assess the effect of dish characteristics on what consumers eat at a specific moment, both for starter and main dish, the food intake data for each subject was considered in the following time range: from when the dish was put on the table until it was removed. Meal phase duration was left-standardised across subjects. Data were reported as the percentage of subjects that performed each action over time including the chance level (p_c=0.33) and the significance level (p_s=from 0.46 to 0.47 depending on the dish) (α=0.05) (Pineau, & Schilch, 2015). A TDB graph was built for each type of dish.

With a focus on starter dishes, each bread action was investigated in terms of percentage of subjects, the percentage of time occurrences and average duration. The percentage of subjects corresponded to the number of subjects that performed at least one time that bread action divided by the total number of subjects, reported in each hundred. The percentage of time occurrences was calculated by dividing the duration of that bread action by the total bread actions time, reported in each hundred. Finally, the average duration was calculated as the sum duration of that bread action divided by the number of times that it was performed. A two-way (type of action and dish type) ANOVA was performed on duration of each action. A multiple comparison analysis (Duncan's test) was also performed, when necessary.

All calculations were conducted in XLSTAT vers. 2010 (Addinsoft, France).

2.7.2. Consumer segmentation

To study the inter-individual differences in the use of bread during the meal, the subjects were segmented by Agglomerative hierarchical clustering analysis (AHC) according to two criteria: the amount of bread consumed and the frequency of different bread interactions (bread-hand, bread-cutlery, bread-plate and bread-mouth). A centring and reduction of the data was applied before clustering (XLSTAT vers. 2010). AHC was performed by choosing the Euclidean distance for dissimilarities and Ward's method as an agglomeration method. Entropy truncation was chosen as criteria to determinate cluster numbers.

2.7.3. Group characterisation

To characterize the different consumer groups in terms of socio-demographic, habitual and behavioral characteristics a Partial Least Squares Discriminant Analysis (PLS-DA) model was built. The model linked dependent variables for segment belonging (three binary variables with values 0/1) to the questionnaire data (hunger level from the first questionnaire, and socio-demographics and questions on consumer habits about bread, from the second questionnaire, respectively) and the observational variables during the meal (bread quantity and bread actions) as independent variables. All bread variables were log-transformed before analysis due to a high skewness in their distribution (skewness range before/after transformation: 1.1 to 2.6 / -0.3 to 1.1). A first model was run with all independent variables (i.e. 47 items), then was refined through variable selection based on a Jack-knife uncertainty test with a 95% confidence interval (Martens & Martens, 2000). Cross-validation with 20 random segments was used. The final model retains 12 independent variables and has a variance fit of 50% with two PLS factors. The models were run in Unscrambler X 10.4.1 (Camo Analytics, Norway).

2.7.4. Temporal Dominance of Behavior (TDB) of different groups

For each consumer group a TDB graph was reported, allowing to compare group-specific curves with the global TDB with all consumers. In this analysis, 4 different actions (nothing, eating, drinking, bread action) were considered, so the chance level was reduced (p_c=0.25) and the

significant level varied depending on the number of participants) (α=0.05). The evaluation time goes from when the breadbasket was put on the table until it was removed, i.e. after the main course. In this model, the total mealtime was not standardized as this did not bring any additional information. It should be noted that the experimental restaurant operates at specific hours: it welcomes all booked consumers at 12:30, serves all consumers relatively simultaneously, and closes after 90 minutes of service (including dessert and coffee, not part of the data presented here). Meal durations were therefore very similar across the different tables in this particular study.

3. Results

3.1. Characterization of the participants and consumption habits

The sample of filmed and coded subjects consists of 56% women and 44% men, aged 20 to 86 years with an average of 45 years +/- 13 years. Managers / liberal professions (37%) and employees (33%) are the most represented socio-professional categories, followed by retirees (13%). Their usual consumption of bread most often takes place during dinner (69%) and at breakfast (64%). Bread is reported to be mainly used to "taste the sauce" (84%) or as a support for another food (toast, sandwich, cheese) (73%).

3.2. Temporal Dominance of Behavior (TDB) and bread actions for each dish

In Figure 2 is reported the percentage of subjects (%) who performed a specific action (eating, drinking, bread interaction) over time, for each dish.

Figure 2

Similarly, for all dishes, i.e. both starters and main dishes, the first action was drinking.

More specifically, for starters (Fig 2: a) quail egg; b) lamb's sweetbreads; c) salmon) there was no particular difference among the dishes during eating. However, some differences appear at the end of consumption, where bread actions were dominant for the lamb's sweetbreads which included a semi-solid puree, and for the salmon which is rich in flavor and texture. Moreover, drinking was a

dominant action for salmon. No dominance of bread actions was observed for the quail eggs dish, which consisted of solid individual elements (Figure 1).

Looking at the three different main courses (Fig 2: d) bass; e) pork; f) poultry), differences among the dishes appear in the eating phase, in terms of duration of dominance (shorter eating dominance for the bass). In the final part, drinking was the dominant action for the three recipes, while bread actions were dominant only for short periods and only for one dish, the bass, which featured liquid sauce (Figure 1).

To deepen the contrasting differences of bread actions, consumer behaviors were analyzed in more details during consumption. Results for the starters are reported in Figure 3.

Figure 3

During starter consumption, the bread actions performed by almost all the consumers were “cutting” (>95%), followed by “piece of bread” (i.e. eating a piece of bread, >85%), ”with sauce” (i.e. eating bread with sauce) and “saucing” (i.e. absorbing sauce from the plate on a piece of bread) (Figure 3a). Those two final actions were performed by a different percentage of subjects depending on the type of starter, highest for lamb’s sweetbread, medium for salmon and lowest for quail egg.

The most performed bread actions, calculated as the time percentage of each action on the total time, were two bread-mouth actions, ”piece of bread” (45%), ”with sauce” (20-25%), followed by ”cutting” (15-20%), with no particular differences among the different starters (Figure 3b).

As expected, bread actions presented significant different durations, varying from 10 s for ”cutting” to 20-25 s for “piece of bread” (p=0.03). Analysis of variance showed that there was an effect of the dish only on the duration of 3 (one bread-plate and two bread-mouth actions) out of 14 bread-actions: “pushing” (p=0.03), “with sauce” (p= 0.023) and “with bread” (p=0.04). In particular, a significant longer duration of the actions ”with food” and ”with sauce” was found for salmon compared to quail egg and lamb, meanwhile “pushing” lasted more for quail egg than other plates.

3.3. Consumer segmentation

The quantity of consumed bread (from 10 to 180 g, mean 60±34.5 S.D), the number of bread-hand (from 3 to 56, mean 17.6±11.1 S.D), bread-cutlery (from 0 to 10, mean 1.1±1.8 S.D), bread-plate (from 0 to 42, mean 7.5±6.9 S.D) and bread-mouth (from 4 to 69, mean 22.5±12.9 S.D) actions all varied very much among consumers, allowing to split consumers into different groups with AHC. Three groups were formed, with a within-class variance of 36% and between-class variance of 64%. The first group was composed of 43 subjects (Centroid object characteristics: quantity of consumed bread= 38.1g, bread-hand actions= 10, bread-cutlery= 0.2; bread-plate= 3.5; bread-mouth= 13.3), the second group of 48 subjects (Centroid object characteristics: quantity of consumed bread= 69.8 g, bread-hand actions= 21.2, bread-cutlery= 1.9; bread-plate= 10.7; bread-mouth= 26.9) and the last one of only 9 subjects (Centroid object characteristics: quantity of consumed bread= 133.3 g, bread-hand actions= 40.8, bread-cutlery= 1.9; bread-plate= 13.9; bread-mouth= 40.8).

3.4. Group characterisation

In figure 4 the score plot of the PLS-DA model was reported, where the three groups from AHC were highlighted. This graph testifies of a rather clear distinction between the three groups with two latent factors (Y-explained variance 50%). Group 3 may be seen as an extreme subgroup of group 2, with the highest scores on factor 1 (characterising higher bread quantity and more bread actions, result not shown) and a reduced spread along with factor 2 (characterising socio-demographics and bread motives, not shown).

Figure 4

The group characterisation by PLS-DA approach revealed 12 significant variables in the differentiation of groups: the level of hunger before the restaurant meal, the five bread-related variables collected during the meal (bread quantity and bread-hand, bread-cutlery, bread-plate and bread-mouth actions), as well as consumption of wine during the meal; questionnaire variables on

stated bread consumption (never eats bread), stated motivations of bread consumption (to occupy waiting time, to sate hunger) and socio-demographic variables age and retired occupation (Figure 5).

Figure 5

Group 1 (43 %) may be called the "No-breaders": it was composed of individuals who stated rarely eating bread and who indeed consumed little bread during the restaurant meal (mean consumption: 40 g, i.e. one bread unit). They interacted little with bread altogether during the restaurant meal. These consumers also rarely ordered wine during the meal and tended to be younger. Consumers in Group 2 (48 %), the "Bread-as-a-tool" group, consumed a fair amount of bread during the restaurant meal (mean consumption: 70 g) and interacted with bread in particular with their plate and cutlery, allowing them to consume sauce and to "clean" the cutlery. These consumers most typically consumed wine with their meal; they were also typically older and had retired from their professional occupation. Last, Group 3 (9%) may be referred to as the "Bread-lovers": this group consumed the biggest amount of bread (mean consumption: 130 g) and their bread interactions were dominated with hand-bread and mouth-bread actions. They reported a higher level of hunger before the restaurant meal, which may explain their higher consumption. However, rather than a random occurrence, their high bread consumption seems to be a stable trait as this group also stated to typically use bread to sate hunger and to occupy waiting time during a meal. This group tended to be older than Group 1, yet still in professional activity.

3.5. Temporal Dominance of Behavior (TDB) of different groups

A typical French meal at the restaurant consists of an appetizer (A), followed by a starter (ST), a main course (MC) and a dessert (the latter is not inserted in the analysis as it is not consumed with bread). The duration of the meal was about 3600s and was divided into six different phases: 3 waiting times (W1-3) before each dish, and three eating phases (A, ST, and MC). In Figure 6 the

Temporal Dominance of Behavior (TDB) give a graphical representation of consumers' eating behavior during the meal, by reporting the percentage of subjects that performed each action over mealtime. The four main actions in focus were: no action, bread action, eating and drinking. Figure 6a reports results for all participants, while Figures 6b-c-d report results for the three consumer groups defined with AHC.

Figure 6

Looking at the global TDB (Figure 6a), during the first waiting period (W1), the dominant actions were *no action* from the beginning to the half of the time followed by *drinking*. During the appetizer phase (A), three actions were dominant: *drinking*, *eating* and *bread action* (only during the last part), and the most dominant one for a long time was *eating* with a consumer percentage varying from 40 to 60%. During the second waiting period (W2) both *drinking* and *bread action* were dominant, even if *drinking* was the most dominant action. During the starter consumption phase (S), the most dominant action was *eating*, for a long time, and only at the end of this phase two other actions were dominant, *bread action* and *drinking*. During the third waiting phase (W3), the most dominant action was *bread action* at the beginning followed by *drinking* for the biggest time. Finally, during the main course consumption phase (MC), *eating* was the most dominant action, with a very high consumer percentage, and only during the last minutes both *drinking* and *bread actions* were dominant with a comparable consumer percentage.

Looking at the consumer behavior of No-breaders (Group 1) reported in Figure 6b, it appears that bread action was never dominant during the mealtime, with an exception at the end of the starter phase. However, when No-breaders were waiting for a dish they preferred drinking than consuming bread.

For what concerns the Bread-as-a-tool group (Group 2), their behavior resembled that of No-breaders from the beginning to the W2 phase, during which bread action was never dominant. Meanwhile, during the end of the S phase, bread action became dominant and was also the most dominant action

for a short time. During the W3 phase, bread action was the most dominant action with a consumer percentage of 40-50%, then, drinking was the most dominant action, even if bread action was still above the significance threshold.

Consumer behavior of Bread lovers (Group 3) was completely different compared to the other two groups (Figure 6d). For those consumers, bread action was dominant not only during the waiting phases but also during the S and MC phases, for which eating was dominant only at the beginning. For those consumers, bread actions were performed during all the mealtime.

4. Discussion

4.1 Data acquisition and video data coding

The reported results were obtained at a living lab, in a restaurant with the booking done on the internet. No detailed information about the meal or the purpose of the study was known by the participants, who were coming to the restaurant to enjoy a meal with friends, colleagues and/or family and not to participate in a research study. This process guarantees natural eating conditions. However, it does not allow specific recruitment which led to the exclusion of about a quarter of the visitors (minors and subjects not consuming bread) who were filmed but not coded. Moreover, in a real consumption situation, customers act normally, so certain parameters varied greatly from one table to another or within the same table and could not be controlled, such as meal phases duration and waiting times, or the fact that subjects at the same table sometimes exchanged their dishes – leading to additional subject exclusions from the analysis. During a laboratory experiment, participants can be selected, several parameters can be controlled, but participants may tend to act differently from a natural eating condition, e.g. they may decrease their food/beverage intake if they believe that the amount of food they are eating during a study is being monitored (Robinson, 2014). Despite the advantages of having a natural situation, this condition caused data loss and a greater variability which requires greater sample sizes.

A limitation of the living lab is that some participants may remain aware of the cameras and refrain behaviours that may be considered socially inadequate (e.g. saucing their plate with a piece of bread). However, cameras may not be interfering more than public exposure to other clients and personnel in the restaurant. On the opposite, we expect people are better able to forget about the cameras and act naturally during a meal at the restaurant with friends or colleagues, than in an experimental lab. Further, a video for each consumer was recorded and coded. How to codify consumer behavior and report consumers' actions based on video observations is a big issue. Videos contain a very large amount of codable information and should be codified following the aim of the study. Several studies based on video observation have been interested in measuring eating behavior in terms of meal microstructure, relying either on manual count (or, more recently, on automatic detection) of bites, chews, and swallows (Fontana et al., 2015; Hossain, Ghosh, & Sazonov, 2020). Other studies have described a meal event at the microstructure level by adopting a qualitative approach to data analysis supported with numerical counts of particular events (see e.g. Liu et al., 2019). In the present application, the meal macrostructure is in focus with a particular interest on consumers' bread interactions during a meal. Consequently, the coding frame we developed shed light on all bread-related behaviors. One may imagine a similar study focusing on social and digital interactions during a restaurant meal, in which case a very different set of actions would be coded from the same footage (e.g. conversation events with fellow eaters and with waiters, and/or interactions with smart phones). A limitation of the manual coding method is the duration of video coding, because it takes between 45 minutes and 1 hour of coding per subject, approximately 12 days of coding for 100 subjects. One may hope that in the future artificial intelligence algorithms will be utilised in video coding software, to able to automatically recognise specific patterns in a video such as putting a piece of bread in the mouth or taking a sip of water.

As reported in material and methods, different kinds of actions were coded. Meal phases and last-item-in-mouth were coded as state events, whereas use of bread, food and beverage were coded as point events. However in the case of bread usage, that is the core of this paper, some actions were

quite long (for example, "cleaning the plate with the bread" or "playing with a piece of bread") and to consider them as a point events leads to some loss of information.

4.2 Temporal Dominance of Behavior (TDB)

Behavioral data are dynamic data, so after the coding, the quantitative data could be represented using dynamic methods. The TDB approach that we proposed makes it possible to summarize hours of video in a single graph. This visualisation gives an overview of consumer behavior during the meal or for a meal phase, reporting the sequence of these behaviors as dominant actions over time. This approach seems promising and could be of great help in observational studies of consumer behavior.

The videos of this study could for example also be used to study the consumption of drinks during the meal, the behavior of consumers towards wine, the consumption strategy of a dish (proteins first, vegetables first, or both together), but also the use of digital objects at the table (telephone, camera…), or the occupations of the subjects during the waiting phases. Of course, this list is not exhaustive and when this method is developed, it can be used to exploit observation data by researchers from many disciplines, whether in food science, social science or economical science.

Despite these prospects, some limitations came out. TDS curves are normally used to represent sensory descriptive data over periods of a few seconds whereas here, the data is behavioural and of the order of the hour. The probability that different consumers doing the same thing (e.g. taking a sip of water) would do this at the same time point is extremely low, and our preliminary analyses did not succeed in capturing cumulative behaviours of such brief actions. We addressed the issue by coding eating/drinking behavior as ‘last thing in mouth’. In this way, the curves of all consumers taking a sip of water in the period between two dishes may nicely cumulate; consequently, the duration of some actions could be strongly sur-estimated. If a subject consumes bread only once at the start of the waiting phase and does not consume anything until the arrival of the dish, he will be considered as eating bread during the whole waiting phase. Thus, our present coding highlights *what* consumers do in different parts of the meal rather than *for how long* they do it. One possible solution could be to

code the attribute "Nothing" as the last thing in the mouth either when there is a change in phase of the meal, or after a certain time without new food intake, similarly to a TCATA Fading approach (Ares et al., 2016).

A second issue is to decide if the standardization of data should be performed or not. To report consumer actions for different dishes, a time standardization was performed to align the meal phase times across consumers. This standardization may however be questionable, as it can be assumed that consumer behavior varies according to the actual phase duration. In particular, comparing the behavior of a consumer with low waiting time before the food arrives to the behavior of a consumer with longer waiting time may be biased, as the latter has more time to drink and interact with bread in the waiting phase. A standardisation per meal phase could in this case be recommended (Lesme et al, 2020). Further, to report the actions of different consumer groups over the whole meal, no time standardisation was applied. Yet standardisation could favour a more systematic comparison of frequencies and relative durations of actions during a particular meal phase. In this specific application, the absence of standardisation was acceptable as limited variation occurred in meal duration at the experimental lunch restaurant. Analysis at a lower level (per dish) may be more sensitive to standardisation. It is also possible that the segmentation led to a stronger coherence within each TDB. Further, one may consider decomposing single dishes into several periods, to better analyse dish-specific bread interactions at a micro-level. This approach may be especially interesting in combination with an experimental design, varying specific properties of the dishes systematically. Further methodological developments are needed to handle time standardisation for behavioral observation studies that stretch over time.

In summary, the concept we present here offers new opportunities, but also calls for further developments in line with the specificities of observational data. Among other, one may refine video coding strategies, highlight difference curves (Pineau et al 2009), optimise time standardization (Lenfant et al, 2009, Lesme et al, 2020), use data temporality in consumer segmentation (Cardot et

al, 2019), or explore other time-based statistical approaches (Kuesten, Bi, & Feng, 2013; Esmerino et al., 2017).

4.3 Bread behavior

The consumption of bread is a complex phenomenon and our study shows that it may vary according to individual preferences and characteristics, satiety level and type of dishes. In the French culture, bread is often consumed as an accompaniment to the food and its consumption will vary with the sensory characteristics, especially the textural characteristics, of the dish. Thus our study expectedly highlights that bread consumption increases with the fluidity of the dish, where the starter presenting sauce (lamb's sweetbread) led to more bread consumption than the starter including a puree (salmon) or the starter presenting solid elements only (quail egg). This may be an important aspect to consider in the food hospitality service for composing balanced menus. Our results also showed that the dish composition seems to affect both on the dominant actions over the meal and the type of bread actions. Experimental design on the ratio of liquid/semi-liquid components in the meal could be helpful to further study the role of culinary characteristics of the dish on bread consumption. Another opening for future research could be the characteristics of the bread itself: e.g. whether it is more or less soft, crunchy, high in the aroma as well as liking score.

Further, we drafted consumer profiles for three consumer groups, underlining relationships between consumer characteristics and their eating behavior during the meal. The clustering method identified that there are different consumer groups according to bread usage. The PLS-DA model revealed that besides the type of dish, individual habits and preferences strongly drive the motivation for bread consumption, the bread quantity consumed during a meal and the type of interactions with bread. While some consumers had little interest for bread (No-breaders, 43%), others used it primarily as an eating utensil (Bread-as-a-tool group, 48%) and others again substantially fed on it (Bread lovers, 9%). Looking at the bread-related behavior of each consumer group, the main differences laid during the waiting phases (W1-W2-W3), because, as expected, eating was often the most dominant action

whenever consumers were eating the appetizer, starter and main course. Future research may further investigate the role of individual characteristics and eating speed versus hunger level and dish composition on bread consumption. One may also segment consumers within products, to highlight food-specific behaviours. Moreover, in this study, the subjects' occupations during waiting times have not been coded (talking, using their phone, reading the menu, etc.). Future research may study the link between a subject's consumption of bread and their non-food-related behavior at the table (i.e. whether the subject speaks or listens during a conversation, whether he uses his phone, if he is playing with his cutlery or if he seems to be bored) and the social influence of co-eaters on eating behaviour.

5. Conclusion

This paper presents a novel approach to summarize, visualise and ease the interpretation of video observation data, the Temporal Dominance of Behavior (TDB). We applied the approach on video observations from 100 guests at a living lab restaurant, with a focus on bread consumption throughout a three-course lunch meal. The TDB approach provides a dynamic graphical synthesis of the subjects' eating behavior. By investigating not only the frequency of events but also their sequence, simultaneity and dominance, one may reach greater insights in consumer behavior. Future methodological developments are recommended to address the issues of treating punctual events and of time standardisation. The analysis of bread consumption behavior highlighted strong individual variations in terms of quantity as well as in terms of bread interactions during a meal, in part linked to textural differences in the different dishes. Three consumer groups differing in bread-related behavior throughout the meal were identified, profiled and characterized with the TDB approach. Future studies may further investigate the role of individual differences, dish composition and bread properties on bread consumption patterns during a meal.

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Table 1. Coding frame of the meal structure and behavioral actions of interest.

	Categories	Subcategories
State events		
Meal phases	*Waiting time*	
	Appetizer	
	Starter	Quail egg
		Lamb's sweetbreads
		Salmon
	Main course	Bass
		Pork hock
		Poultry
Last item in mouth	*Nothing*	
	Drink	
	Food	
	Bread	
Point events		
Bread interactions	*No bread interaction*	
	Bread-mouth action	Piece of bread (alone)
		(Piece of bread) With food
		(Piece of bread) With sauce
		Crumb
		Biting
	Bread-hand actions	Cutting
		Touching/Playing
		(Taking) from the (bread) basket
	Bread-plate actions	Saucing
		Pushing food
		Spreading
	Bread-cutlery actions	Cleaning the knife
		Cleaning the fork
		Jabbing with the fork

Italics indicate default setting upon start.

Figure captions

Figure 1. Pictures of the starters (a-b-c) and main courses (d-e-f)

a= quail egg; b= lamb's sweetbreads; c= salmon; d=bass; e= pig hock ; f= poultry

Figure 2. Temporal Dominance of Behavior (TDB) during starter (a-b-c) and main course (d-e-f) consumption

drinking; bread action; eating;
chance level (p_c); significance level (p_s)

Figure 3. Bread interactions during starter consumption for each starter

a= Percentage of participants (%) that performed each action; b= Percentage of occurrence of each bread action; c= Mean duration of single bread action (s) and standard error

3 Starters: = quail egg (31 subjects); = lamb's sweetbreads (32 subjects); = salmon (32 subjects)

For each bread interaction action, at different letters correspond significant different durations (Duncan's test $p<0.05$)

Figure 4. PLS-DA scores plot of the three consumer groups

Figure 5. Significant group characteristics for a) group 1, b) group 2, and c) group 3 from PLS-DA

Regression coefficients with confidence intervals crossing the 0 line are not significant for that specific group.

Figure 6. Temporal Dominance of Behavior during meal of all subjects (a) and for different subject groups according to bread interaction (b-c-d)

a= all subjects (100); b= group 1 (48 subjects), "No-breaders"; c= group 2 (43 subjects) "Bread-as-a-tool"; d= group 3 (9 subjects) "Bread lovers"

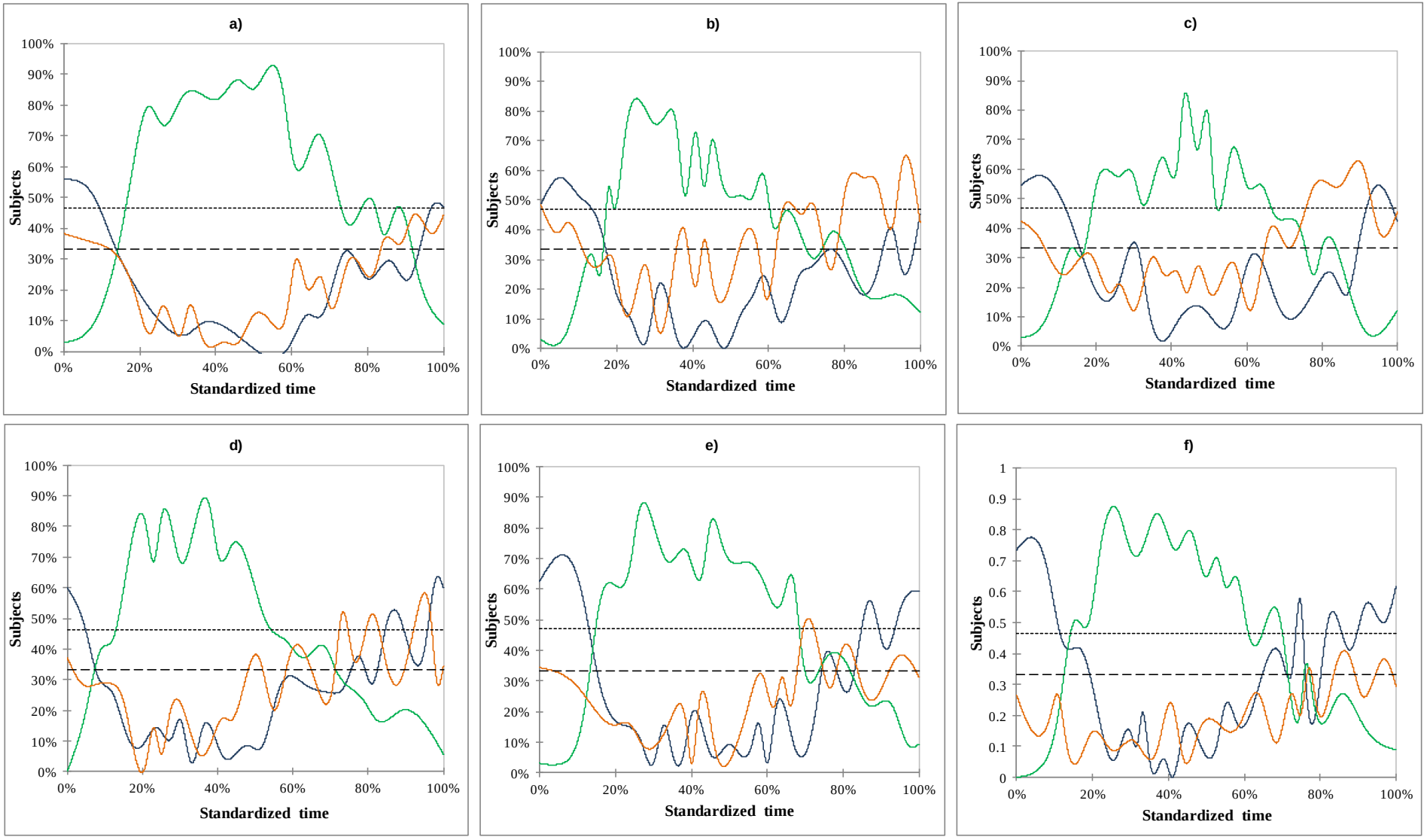
Different actions: no action; drinking; bread action; eating
chance level (p_c); significance level (p_s)

W1= First waiting time, before appetizer; W2= Second waiting time before starter; W3= Third waiting time before main course; AP=appetizer; S=starter; MC=main course

Figure 1

Click here to access/download;Figure;Figure 1.tif

Figure 2



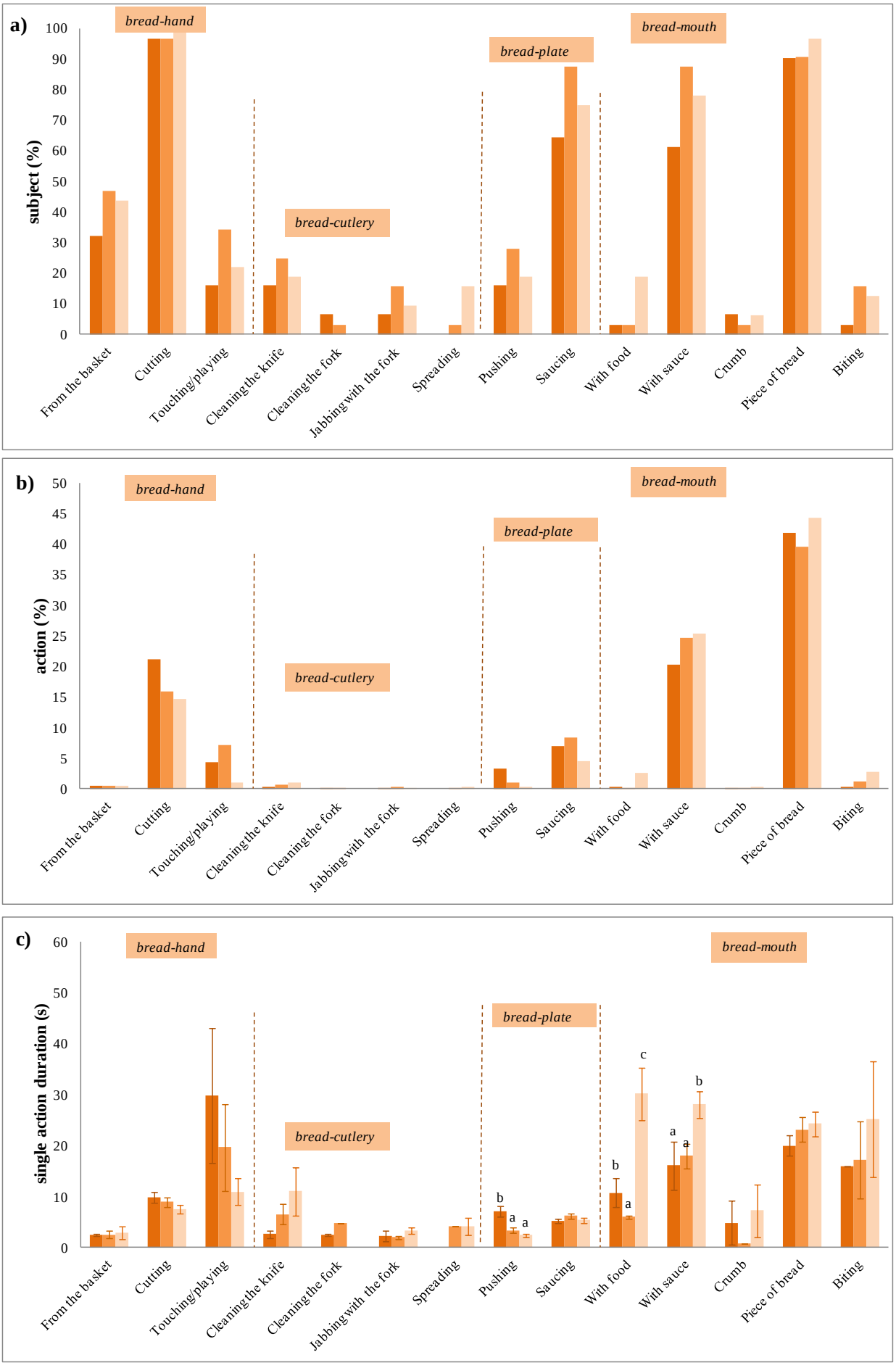


Figure 4

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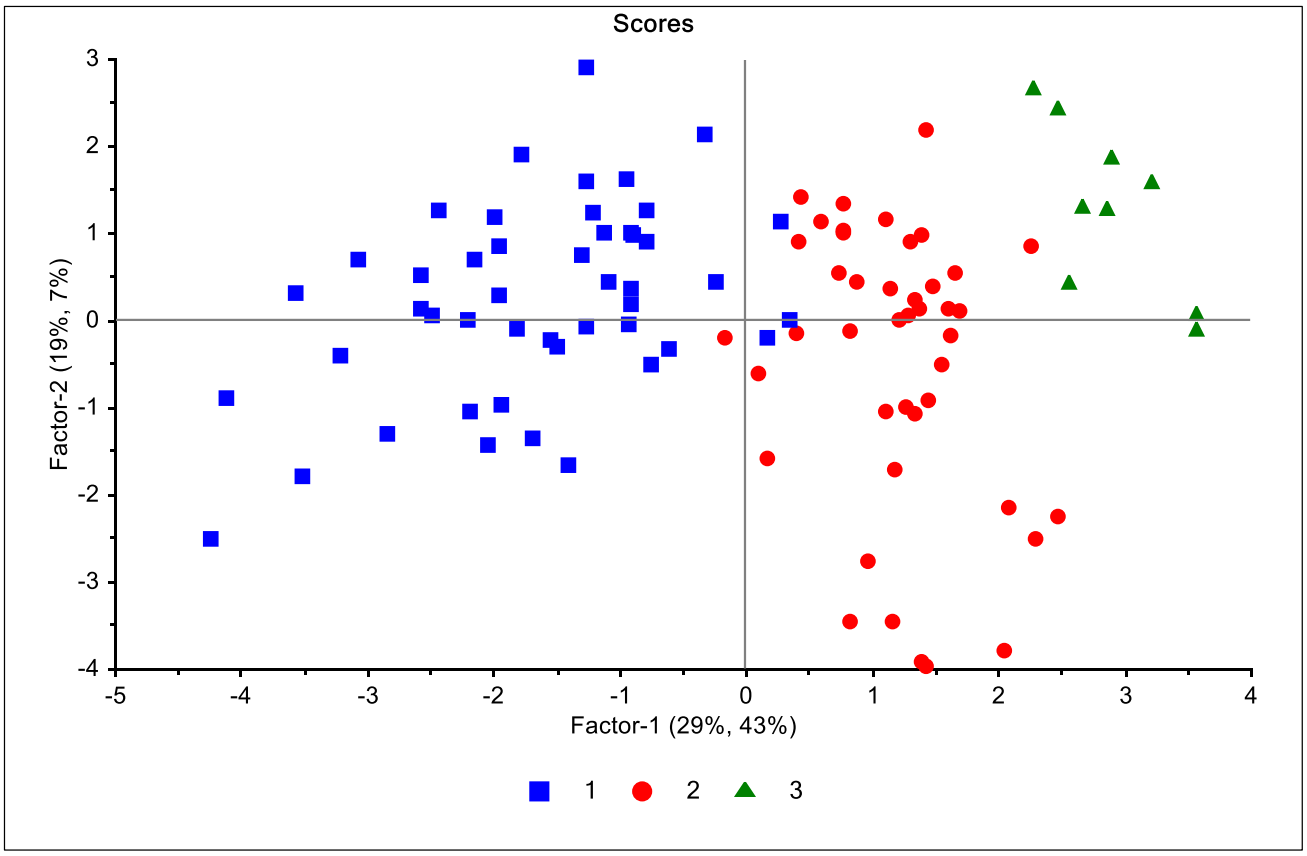

Figure 5

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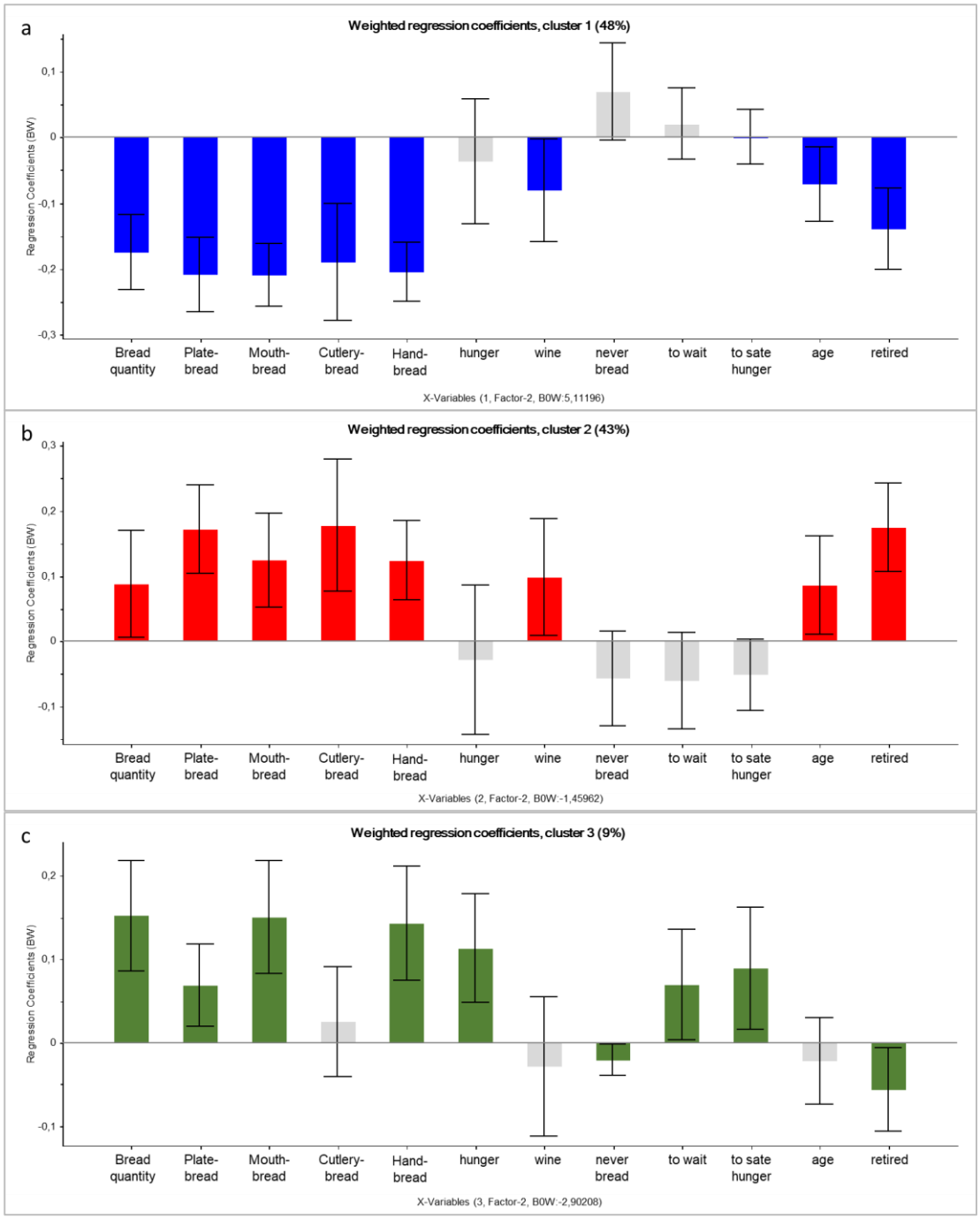

Figure 6

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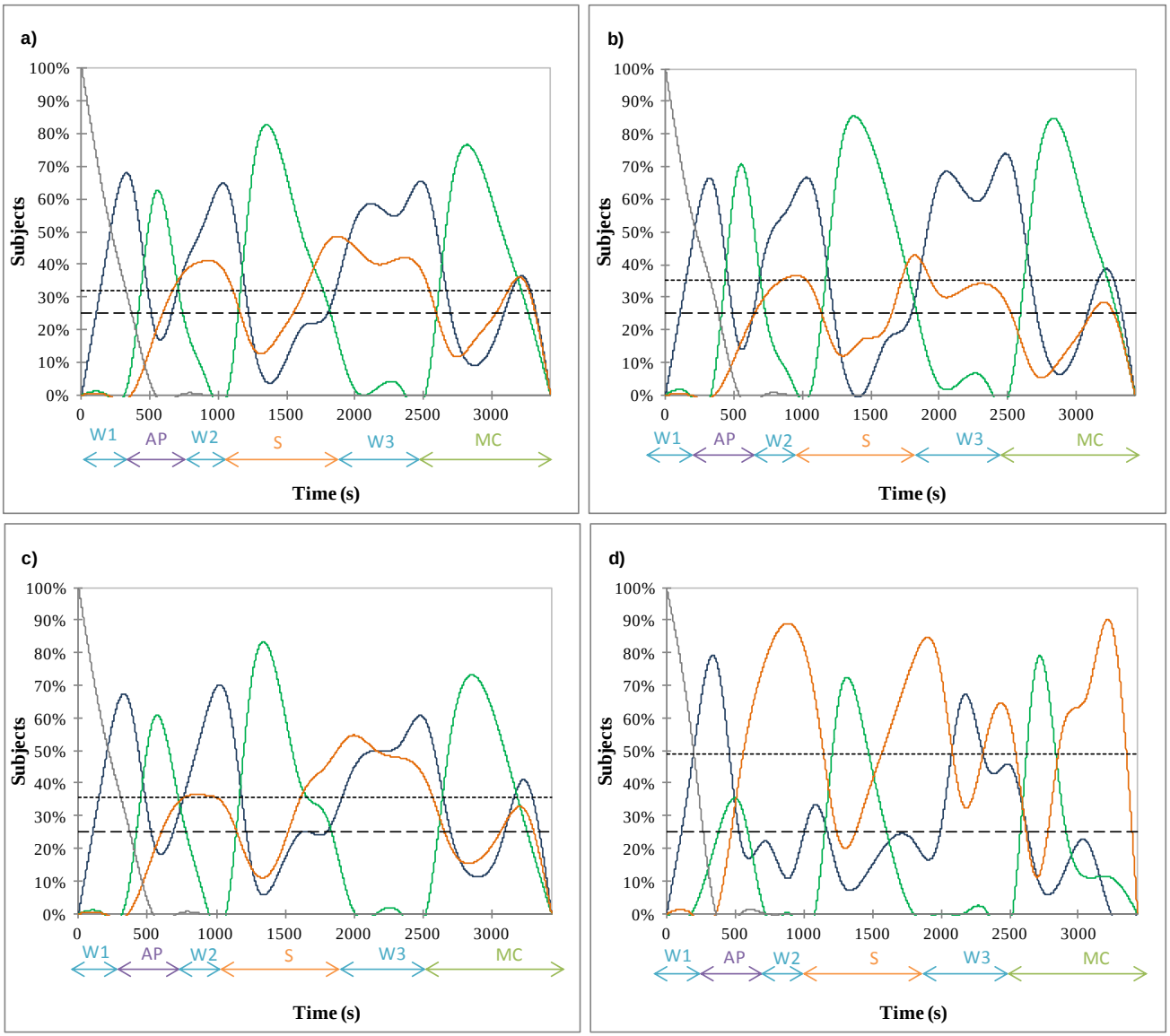


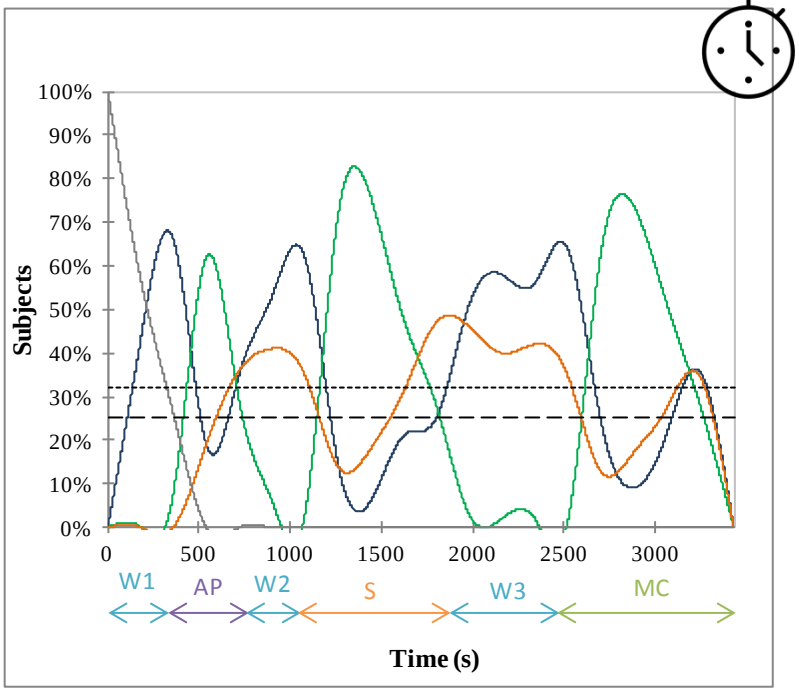
Graphical abstract

Dish characteristics

Consumer

- Socio-demographic characteristics
- Consumption habits
- Thirsty/ hungry/mood
- Food/drink appreciation

Temporal Dominance of Behavior (TDB)



drinking
eating
bread action

Dynamic bread behavior during a meal for different consumer clusters

Author declarations

The authors declare that they do not have any conflict of interest.

The authors declare that the study was conducted according to the guidelines laid down in the Declaration of Helsinki and General Data Protection Regulation (GDPR), and was approved by the Research Protocol Committee of Institut Paul Bocuse according to national ethics guidelines (Loi Jardé, n 2012-300, 12 March 2012).

Written informed consent was obtained from all consumers before their participation in the study, including a video recording consent form.