Food perception, lifestyle, nutritional and health status in the older people: typologies and factors associated with aging well

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ABSTRACT

The aging process is associated with physiological, sensory, psychological, and sociological changes likely to have an impact on food intake and the nutritional status. The present study aimed to explore the heterogeneity of the French older population (>65 years old) using a multidisciplinary approach. More specifically, the study aimed to highlight different typologies (i.e. clusters of individuals with similar characteristics) within the older population. We conducted face-to-face interviews and tests with 559 French older people, recruited from different categories of dependency (at home without help, at home with help, in nursing homes). Clustering analysis highlighted seven clusters. Clusters 1-3 contained 'young' older people (<80) with a good nutritional status; these clusters differed according to food preferences, the desire to have a healthy diet, or interest in food. Clusters 4-7 mainly contained 'old' older people (80+), with an increase in the nutritional risk from cluster 4 to cluster 7. Two of these clusters grouped healthy and active people with a good level of appetite, while the two other clusters were associated with a clear decline in nutritional status, with people suffering from eating difficulties or depression. The results raise the need to develop targeted interventions to tackle malnutrition and implement health promotion strategies among the seniors.

KEYWORDS: sensory, appetite, food preferences, depression, autonomy, nursing homes

1. INTRODUCTION

The aging process is associated with many physiological, sensory, psychological, and sociological changes likely to have an impact on food intake, and consequently on the nutritional status of the older people (Morley, 2001; Hays & Roberts, 2006; Elsner, 2002; Ahmed & Haboubi, 2010; de Boer, Ter Horst & Lorist, 2013; Sulmont-Rossé, 2020). The meta-analysis carried out by Leij-Halfwerk et al. (2019) on 196 studies showed that in the European older population, the prevalence of risk of malnutrition ranged from 28.0% to 8.5%, depending on the screening tool used to assess malnutrition. In the older population, malnutrition is the result of a deficiency in nutritional intake and leads to numerous negative consequences: it increases the incidence of falls, fractures, disease, and hospitalization; it causes or worsens a state of frailty and disability; and it affects the quality of life of older people (Nicolas, Andrieu, Nourhashémi, Rolland & Vellas, 2001; Margetts, Thompson, Elia & Jackson, 2003; Agarwal, Miller, Yaxley & Isenring, 2013; Rasheed & Woods, 2013). Malnutrition is not an inevitable side effect of aging, but it can be promoted by many age-related changes associated with this process (e.g., metabolic and hormonal changes, decline in sensory perception, oral health impairment) as well as with its trajectory (e.g., onset of frailty, disease, dependency).

Although it is widely acknowledged that the causes of malnutrition are extremely varied (Morley, 2001; Hickson, 2006, van der Pols-Vijlbrief, Wijnhoven, Schaap, Terwee & Visser, 2014) and could interact (Engelheart & Brummer, 2018), most studies have explored the factors associated with malnutrition from a discipline-specific point of view, such as the identification of a link between malnutrition status and chemosensory loss in the field of

sensory perception (Duffy, Backstrand & Ferris, 1995; Smoliner, Fischedick, Sieber & Wirth, 2013; Grinberg, Franco, Pinto-e-Silva & De Matos, 2020), oral health in the field of dental medicine (Cousson, Bessadet, Nicolas, Veyrune, Lesourd & Lassauzay, 2012; Saarela, Soini, Hiltunen, Muurinen, Suominen, & Pitkala, 2014; Bakker, Vissink, Spoorenberg, Jager-Wittenaar, Wynia & Visser, 2018), loneliness in the field of sociology (Ramic, Pranjic, Batic-Mujanovic, Karic, Alibasic & Alic, 2011; Vesnaver, Keller, Sutherland, Maitland & Loche, 2016; Eskelinen, Hartikainen & Nykänen, 2016), or depression in the field of psychology (Cabrera, Mesas, Garcia and de Andrade, 2007; Elstgeest, Winkens, Penninx, Brouwer & Visser, 2019). A few studies have considered a larger range of factors related to several disciplines, such as disease, depression, physical capacities, and chewing difficulties (Locher, Ritchie, Ronbinson, Roth, Smith West & Burgio, 2008; Vanderwee, Clays, Bocquaert, Gobert, Folens & Defloor, 2010; Landi et al., 2013; Donini et al., 2013; van Bokhorst-de van der Schueren, Lonterman-Monasch, de Vries, Danner, Kramer & Muller, 2013). In addition, studies have generally explored the factors associated with malnutrition by focusing on specific populations, such as older people in a retirement community (Pols-Vijlbrief, Wijnhovena, Schaapb, Terweeb & Visser, 2013), at home (Wong et al., 2019), in a hospital (Jacobsen, Brovold, Bergland & Bye, 2016) or in an institution (Landi et al., 2013; Meng & Dong, 2012).

Finally, it is striking that malnutrition risk in the older people has seldom been investigated with respect to variables related to food attitudes, preferences, and habits. In 2013, Pols-Vijlbrief et al. conducted a systematic literature review to provide an overview of potential determinants of protein-energy malnutrition in community-dwelling older adults. In total, 28 studies were included, from which 122 unique potential determinants were identified. Among these, only a few were related to food habits such as ‘number of meals a day’,

'snacking', and 'eating alone'. In the recent systematic literature review of O'Keeffe et al. (2019), thirty potentially modifiable determinants were identified from the 23 studies included in the review. However, only eight studies examined five determinants related to eating behavior: appetite/leaves food on plate, complaints about food taste, nutrient intake, modified texture diet, hunger and thirst. None were related to food preferences or food attitudes.

To fill the gap, the present study was an explorative study relying on a multidisciplinary approach. It explored the heterogeneity of the older population in France (>65 years old) using a large range of descriptors from various fields (geriatrics, psychology, sociology, sensory perception, eating behavior, food attitudes, food preferences) in relation to the nutritional status. More specifically, the study aimed to highlight different typologies (i.e. clusters of individuals with similar characteristics) and to identify factors associated with the risk of undernutrition which may vary from one typology to another. In order to include older people with different levels of autonomy, the volunteers were recruited from the following four living situations: living independently at home, living at home with non-food activity related assistance, living at home with food activity related assistance for at least three meals a week, and living in a nursing home.

2. MATERIALS AND METHODS

The data were collected as part of a program that aimed to study eating behavior and dependency (Aupalesens *project: Improving the pleasure of older people for better ageing and to fight against malnutrition*). This program was coordinated by the CHU of Dijon and

involved a multidisciplinary consortium of several public French research institutes and universities (sampling and statistics: ONIRIS; geriatrics and nutrition: CHU of Angers and Dijon; chemosensory perception and eating behavior: ESA and CSGA; food attitudes: LEMNA; psychology of aging: University of Tours; sociology of aging: University of Lille;).

2.1 Participants

In 2011, 559 older people (older than 65) were recruited in four French cites (Angers, Brest, Dijon, Nantes) among four categories of dependence: (1) living independently at home; (2) living at home with help unrelated to food activity (e.g., housekeeping; gardening; personal care); (3) living at home with help related to food activity for at least three meals a week (i.e., food purchasing; cooking; meals-on-wheels); and (4) living in a nursing home. Category 1 was intentionally over-represented in order to follow this sub-sample in a subsequent study. The recruitment criteria were as follows: older than 65 years old; no acute pathological episode at the time of the survey; no food allergies; not on a doctor-prescribed diet; no congenital anosmia or anosmia due to head injury; and scoring at least 21 on the Mini Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975). The MMSE screens for cognitive impairment where scores below 21 indicate moderate to severe cognitive impairment.

Recruitment was conducted through advertisements in local newspapers, flyers in local senior centers, and support from local organizations working with dependent older people (home-help services, meals-on-wheels services, nursing homes). The sampling plan was designed to ensure the representativeness of the samples in each category compared to French national statistics. Different sampling criteria were used depending on the living

situation: gender and marital status for older people living at home without help for food, gender only for older people living either at home with help for food or in nursing homes. Finally, in each city, recruitment was carried out in different areas characterized by differences in socio-economic levels (income level).

2.2 Procedure

Each participant underwent two face-to-face interviews of approximatively 60-90 minutes each. These two interviews took place on two different days, with a minimum of one day and a maximum of one week in between. During these sessions, extensive data were collected on the basis of questionnaires and tests. The work was conducted by six interviewers (all women) who had previously completed a one-day training session. All the interviewers had a Master Degree Level in dietetics or nutrition. Interviews took place either at a laboratory or at the individual's home (or nursing home), depending on the participant's mobility. All experimental protocols were approved by the French Ethics Committee for Research (CPP Est I, Dijon, #2010/42, AFSSAPS# 2010-A01079-30). In accordance with ethical rules, all participants (or their legal representative) gave their informed consent. The participants received financial compensation for their participation (20€).

2.3 Measurements

Participants completed questions, questionnaires and tests to assess their healthy nutritional, physical, psychological and social status as well as their eating behaviour and chemosensory perception. These were selected from the scientific literature or developed by experts from different scientific areas (co-authors of the paper) through several stages of

discussion. They are listed on Table 1. Fifteen questionnaires validated for an older population were selected from the scientific literature and six questionnaires were specifically designed for the present study (social life, eating difficulties, food consumption, change in food consumption, food preference, menu preference). A preliminary testing was carried out with 60 older respondents different from those included in the present study on already published questionnaires and self-developed questionnaires. This preliminary test showed that older people have difficulties to answer on Likert scales ('agree/disagree' scale), in particular for the items containing a negation. In French, it is difficult and counter-intuitive to answer 'I do not agree' to an item such 'I don't avoid food even though it may raise my cholesterol' or 'I don't believe that food should always be a source of pleasure'. Consequently, the scales of four already published questionnaires (Self-esteem, DEBQ, HTAQ, food authenticity) were adapted: Likert scales were replaced by a 4-point scale ('no', 'somewhat no', 'somewhat yes', 'yes').

Table 1 about here

Food consumption frequency and *change in food consumption*. A food frequency questionnaire was elaborated from published food frequency questionnaires (Cade et al., 2002). After preliminary tests, the list of items was shortened on the basis of discrimination and level of consumption in order to reduce the questionnaire burden and the choice was made to focus on protein foods (in relation to the issue of malnutrition) and on fruit and vegetables (the consumption of the latter is often severely affected by dental impairment; Tada & Muira, 2014). Respondents rated their consumption frequencies for the following items: red meat, white meat, poultry, deli products, ham, fish, dairy products, cooked

vegetables and raw fruit on a frequency scale ('never', 'rarely', 'at least once a month', 'at least once a week', 'several times a week', 'at least once a day'). In addition, respondents were asked to indicate for each food category whether they had decreased or increased their consumption frequency since they were 30-40 years old, and if so, why. Three scores were computed from these results: the number of modifications in consumption frequency because of health concerns, because of changing preferences, and because of changing appetite.

Food preferences. Food preferences were explored with 21 questions about food categories that had previously discriminated the main dietary patterns among the French adults (Kesse-Guyot et al., 2008). Each item consists of a 5-point scale with different proposals from left to right (e.g., 'Rare and tender roast beef: I love it' on the left and 'Rare and tender roast beef: it's disgusting!' on the right) (Maître, Amand, Cariou, Vigneau, Vanwymelbeke & Sulmont-Rossé, 2012).

Menu preferences. Respondents were presented with a restaurant-like menu card (Maître et al., 2012) and asked to tick the courses that they would choose for an ordinary lunch and an ordinary dinner during the week. A clustering analysis highlighted four clusters for each meal. For lunch, three clusters differed in the choice of the main meat dish: 'roast' for cluster 1 (26% of the respondents), 'fish' for cluster 2 (30%), and 'poultry' or 'meat with gravy' for cluster 3 (23%). The members of these clusters mainly chose 'vegetable' as a side, while those in cluster 4 (21%) mainly chose 'potatoes'. For dinner, cluster 1 (42% of respondents) chose a hearty dinner with fish or egg, cluster 2 (25%) chose ham, cluster 3 (16%) quiche and salad, while cluster 4 (17%) preferred a light dinner with soup. Respondents also reported

what dishes they used to eat for a regular weekday lunch or dinner at the age of 40. Two quantitative variables were computed for each respondent: the number of items chosen for lunch and dinner at present and when they were 40 years old.

2.4 Data analysis

Data were subjected to exploratory data analysis: a Clustering and a Disjoint Principal Component Analysis (CDPCA) (Vichi & Saporta, 2009). A preliminary analysis of the data (distribution of scores to keep the most discriminatory variables, correlation between the different items of a questionnaire) was conducted to select the active variables to be included in the CDPCA. For instance, the item *difficulties in eating* was highly correlated with the items *difficulties in cutting the food, putting in the mouth, chewing and swallowing.* Furthermore, these latter variables displayed a highly homogeneous distribution (e.g., participants were nearly unanimous in reporting no difficulty in cutting food (89%) or putting food in their mouth (95%); almost none (96%) of the participants reported having xerostomia). Consequently, only the item 'difficulties in eating' was included in the CDPCA. In the end, 56 active variables were included in the CDPCA (see Appendix). The variables *category of dependence*, *age*, *gender,* and *marital status* were not included in the clustering analysis but were used to characterize the clusters *a posteriori*.

The CDPCA procedure makes it possible to simultaneously group (i) variables in latent dimensions and (ii) older participants in clusters of individuals. Each latent dimension is a linear combination of variables (a variable cannot belong to several latent dimensions). The latent dimensions can be correlated. Each individual is associated with a score for each latent dimension.

The choice of partition size was the result of a compromise between model quality (i.e., maximization of the distance between clusters in the reduced space) and complexity (i.e., number of latent dimensions and number of clusters of individuals) (Figure 1). For the present analysis, 5 latent dimensions and 7 clusters of individuals were retained after inspecting several combinations (number of dimensions varying from 2 to 10 and number of clusters varying from 1 to 8).

Figure 1 about here

To characterize the clusters, individuals' scores for each latent dimension were analyzed using one-way Analyses of Variance (ANOVAs) with *cluster* as the fixed factor. However, to go further, the clusters of individuals were also characterized by the active variables (the ones that were included in the CDPCA and grouped in latent dimensions) and additional demographic variables (*category of dependency*, *age*, *gender,* and *marital status*). Quantitative and categorical variables were analyzed with one-way ANOVAs with *cluster* as the fixed factor. Dichotomous variables were analyzed with Chi-Squared tests. For the scores for each latent dimension and the quantitative variables, least-squares means were computed for each significant factor and subjected to multiple comparison analysis using the Fisher's least significant difference method.

Statistical analyses were conducted using the R library FactoMineR and STATGRAPHICS plus (5.1). One-factor analysis of variance (ANOVA) for the quantitative scores and χ^2 tests of independence for qualitative variables were performed using STATGRAPHICS plus (5.1). Least-squares means (LS-means) were computed for each factor and subjected to multiple

comparison analysis with the LSD method. A Bonferroni-Holm correction was conducted to account for multiple comparisons.

All results reported here were significant at a level of $p<0.05$ unless otherwise stated. Means (M) are given with their standard deviation (SD).

3. RESULTS

3.1 Characteristics of the study sample

The characteristics of the study sample across categories are presented in Table 2. The sample of older people living independently at home was 31% men, 43% people aged over 75, and 51% couples. This was quite similar to French national demographics: according to the 2014 census, the French older population is 42% men, 51% people aged over 75, and 56% couples (INSEE, 2014). For older people living at home with care support, the demographic breakdown is 27% men, 69% people aged over 75, and 35% couples (Soullier & Weber, 2011; Morel & Veber, 2011). Our sample of older adults at home (including independent at home, with non-food help, and with food help) was thus representative of the national population in terms of distributions of gender and partnership status; the maximum deviation between this sample and national statistics for these two characteristics was 7% and 10%, respectively. For the age distribution, however, there was more of a mismatch, with more people aged 75 and over in the survey samples compared to national statistics, in particular for the category “at home with food help” (95% aged over 75). Finally,

the sample of older adults in nursing homes was representative of the larger population in terms of both gender and age, with 25% men and 84% people aged 80 and over in the French nursing home population (Prévot, 2009; Lecroart, Froment, Marbot & Roy, 2013). From a socio-economic perspective, the sample was mainly composed of middle-class people (50% with a "fair" income; 69% completed primary or secondary school).

Table 2 about here.

3.2 Clustering analysis: identification of five latent dimensions

Five latent dimensions, with each a linear combination of active variables, were identified from the CDPCA analysis (Figure 2). Only the active variables with loadings higher than 0.1 are depicted in Figure 2. All mean values can be found in Table 3.

Figure 2 about here

The first dimension ('Being fit') combined several variables related to health and autonomy. This dimension was positively related to high functional (SPPB) and cognitive (MMSE) capacities, good nutritional status (MNA), good independent living skills (IADL), and a high frequency of outings and activities. It was negatively associated with the number of pathologies and the number of drugs with side-effects on taste or olfaction. This dimension was also linked to satisfaction for present meals, good salt perception, and low food selectivity. ***A second dimension ('Depressed & low food enjoyment')*** was positively associated with higher depression and loneliness scores and negatively with appetite, the importance of hedonic aspects of food choice (HTAQ questionnaire), and food authenticity (origin, identity, and naturalness scores). This dimension included also negatively odor

detection (ETOC test). ***A third dimension ('Eating difficulties')*** was quite specific and was only linked with two variables: eating with some difficulties (positive loading) and the score for 'I am looking for fat-free products' from the food preference questionnaire (negative loading). ***A fourth dimension ('Healthy eating')*** was positively associated with the importance of health in the food choice process (HTAQ questionnaire) and restrained eating behavior (DEBQ questionnaire), as well as with high consumption frequencies of fruit, vegetables, and fish. This dimension was also positively linked to late-life changes in food consumption because of health concerns and negatively with late-life changes in food consumption because of changing appetite. Looking at food preferences, this dimension included positively the score for 'I cannot do without fruit' and negatively the scores for 'I prefer cooking with butter rather than oil', 'I enjoy ready-to-eat dishes', and 'I have a weakness for pastries". With respect to selections from the lunch menu, this dimension was related to a greater frequency of fish and a lower frequency of potatoes and pastries. Finally, this dimension was negatively associated with the odor discrimination score. ***The fifth dimension ('Meat & deli products')*** mainly grouped variables related to the preference for and consumption of meat products. This dimension was positively associated with the scores for 'Rare and tender roast beef: I love it!', 'I always have a glass of wine or beer with my meal', and 'Sausage or rillettes make me happy', and negatively with the scores for 'I prefer fish over meat', and 'I rarely go without a dessert at the end of the meal". This dimension included also positively consumption frequencies for red meat and deli products, but negatively late-life changes in food consumption because of changing preferences. Finally, this dimension was positively associated with the self-esteem score and negatively with emotional eating (DEBQ questionnaire). Looking at the Pearson correlations above r=0.3

between these five dimensions, a positive correlation was observed between the dimensions 'Being fit' and 'Healthy eating' (r=0.45; p<0.001), while the dimension 'Depressed & low food enjoyment' was negatively correlated with 'Being fit' (r=-0.53; p<0.001) and 'Healthy eating' (r=-0.43; p<0.001).

3.3 Clustering analysis: identification of seven clusters of individuals

Seven clusters of individuals were identified from the CDPCA analysis. Figure 3 displays the score distribution of each cluster of individuals for the five latent dimensions (in boxplots while Table 3 provides the socio-demographic characteristics of each cluster (illustrative variables not included in the CDPCA). Table 4 presents the active variables associated with a significant *cluster* effect.

Figure 3, Table 3 and Table 4 about here

The ANOVA revealed that the illustrative variable *age* had a strong effect on cluster formation (F=51.2; p<0.001), with a cut-off around 80 years old. Clusters 1-3 mainly grouped respondents aged between 65 and 80, while clusters 4-7 mainly gathered respondents over 80. The ANOVA also revealed a significant association of cluster with all five dimensions ('Being fit', Depressed & low food enjoyment', 'Eating difficulties', Healthy eating', 'Meat & deli products'). Overall, clusters 1-3 scored higher on the 'Being fit' and 'Healthy eating' dimensions than clusters 4-7, and lower on the 'Depressed & low food enjoyment' dimension than clusters 5-7.

Characteristics of the youngest clusters, 1-3

Clusters 1, 2, and 3 were all characterized by healthy nutritional status: only 3%, 8%, and 5% of the respondents, respectively, were at risk of malnutrition, and none were malnourished. These individuals also had higher functional and cognitive capacities (SPPB and MMSE), independent living skills (IADL), and more social activities than those in clusters 4-7. People from clusters 1-3 mainly lived at home without help for food activities. ***Cluster 1*** (16% of the survey sample) had the highest MNA score, a higher score on the 'Meat & deli products' dimension, and higher score for the food preference item 'Rare and tender beef roast: I love it' than clusters 2 and 3. ***Cluster 3*** (20% of the survey sample; 80% women) had the highest score on the 'Healthy eating' dimension. This cluster had higher consumption frequencies for fish and demonstrated a preference for cooking with oil over butter compared to clusters 1 and 2. Respondents from cluster 3 were the ones who gave the most importance to health aspects in the food choice process and who had most changed their food habits because of health concerns, a finding that may have been related to the fact that they had a higher number of diseases than clusters 1 and 2. These individuals also had the highest restrained eating score across clusters. ***Cluster 2*** (21% of the survey sample; 86% women) displayed higher scores on the 'Depressed & low food enjoyment' dimension and the highest depression score (GDS) of the three 'young' clusters. Respondents from this cluster gave a lower liking score to their meals, they felt less connected and less in control of the food they ate, and they gave less importance to hedonic aspects of the food choice process than the two other clusters of younger respondents. They seemed to suffer from a slight decline in olfactory capacities, with lower odor detection and discrimination scores than clusters 1 and 3. Finally, they had the highest score for emotional eating of all the clusters.

Characteristics of the older clusters, 4-7

As shown in Figure 3, scores on the 'Being fit' dimension decreased from cluster 4 to cluster 7 while scores on the 'Depressed & low food enjoyment' dimension increased. The nutritional risk also increased from cluster 4 to cluster 7, with, respectively, 16%, 39%, 80%, and 86% of respondents at risk of malnutrition or malnourishment. Of these four clusters of older people, ***cluster 4*** (17% of the survey sample) displayed the highest functional capacities and independent living skills as well as the lowest number of diseases. This cluster demonstrated some similarities with the younger cluster 1 regarding meat consumption and preference. Among the older clusters, the respondents from cluster 4 considered more than those from clusters 5 to 7 that their diet was part of their identity. As for cluster 1, cluster 4 comprised almost as many women as men and the highest proportion of couples (37%) compared to the other older clusters. Finally, both clusters 1 and 4 displayed the highest self-esteem scores across clusters. Compared to cluster 4, clusters 5 and 7 scored lower on the 'Being fit' dimension. These clusters included 90% and 86% of older people requiring meal assistance, respectively. Both clusters 5 and 7 displayed lower meal satisfaction than cluster 4. However, individuals in ***Cluster 5*** (14% of the survey sample; 86% women) still reported a good appetite, somewhat comparable to the appetite score observed in cluster 4. Respondents of this cluster also scored higher on the dimension 'Healthy eating' than the three other older clusters. ***Cluster 7*** (7% of the survey sample) had the highest score on the dimension 'Depressed & low food enjoyment', as well as the highest depression score (GDS) and loneliness score of all groups. Respondents in this cluster reported low appetite. They were the most selective and gave less importance to health aspects of the food choice process than the other clusters. ***Cluster 6*** (6% of the survey sample) stands out from the

other clusters by grouping men and women suffering from eating difficulties. Unsurprisingly, this cluster displayed low appetite and the lowest meal satisfaction. Clusters 6 and 7 were both associated with the lowest importance given to hedonic aspects of food and the lowest scores for odor detection (ETOC).

4. DISCUSSION

Using an explorative and multidisciplinary approach, this study highlighted seven clusters of individuals in relation with the nutritional status within the French older population. Clusters 1-3 grouped 'young' older people with a good nutritional status. While cluster 1 included 'meat lovers', cluster 3 included women who valued 'healthy eating'. On the other hand, the participants in cluster 2 began to feel 'down' with less pleasure in eating. Clusters 4-7 were mainly composed of older people (80 years and older), with an increase in nutritional risk from cluster 4 to cluster 7. Cluster 4 included the most active and healthy participants among people aged 80 and over. As for cluster 2, cluster 5 included women who valued 'healthy eating'. Clusters 6 and 7 showed a marked decrease in nutritional status, with people suffering from eating difficulties in cluster 6 and people suffering from depression in cluster 7.

4.1 The issue of age and dependency

One strength of the present study was the recruitment of a large sample of older people from 'younger' to 'older' old age that included various living situations (at home *versus* nursing home; autonomous *versus* dependent). A striking result of the survey was the age cut-off around 80 years old between clusters 1-3 and clusters 4-7. It is interesting to note

that age was not included in the clustering analysis as an active variable, but was instead used as an illustrative variable to characterize the clusters of individuals. Our results revealed that older people included in the older clusters, 4-7, had lower functional capacities, lower cognitive performances, and lower nutritional status than older people in the younger clusters, 1-3. This finding is in accordance with the model of Ravaglia (2008), for which age over 80 was one of the nine predictors of frailty. However, the delegation of all or a part of food activities to a third party (called 'culinary dependence' by Cardon & Gojard, 2009) was also associated with a change in the relationship between an individual and his/her diet. Respondents from clusters 5 and 7, who comprised, respectively, 90% and 86% of older people receiving assistance for their meals (home helper for food purchasing or cooking, meals-on-wheels; catering service from nursing home) felt the lowest meal enjoyment, and a smaller degree of control and connection with their food than individuals in clusters 1-3 or even cluster 4, in which only 61% of individuals were culinarily dependent. In the present survey, the proportion of people that were malnourished or at risk of malnutrition was equal to 8% in people living at home without help, 16% in people living at home with help unrelated to food activities, and reached 46% in people living at home with help related to food activities and people living in a nursing home. Though the link has only been poorly studied, it is possible that culinary dependence increases the distance between an individual and his/her diet, which may have a negative impact on appetite and food intake. Indeed, Jyrkka, Enlund, Lavikainen, Sulkava & Hartikainen (2011) observed that living in an institution was linked to a decline in nutritional status over three years of follow-up. Similarly, Johansson, Sidenvall, Malmberg & Christensson (2009) observed that frequent use of a municipal home-help service increased the risk for malnutrition over four years of

follow-up. However, as malnutrition is known to have serious consequences on health (increased risk of falls and consequently of fractures; dysfunction of the immune system and consequently increased risk of infections and/or worsening of existing pathologies), malnutrition also increases the risk of dependency (Raynaud-Simon, Revel-Delhom & Hébuterne et al., 2011). However, it is noteworthy that cluster 5 displayed a somewhat better nutritional status than cluster 7, even though both of these groups were almost exclusively culinarily dependent. It thus seems that depression (cluster 7) penalizes the nutritional status of older people to a greater extent than does food dependency itself.

4.2 Identification of typologies among the older participants

The results of the present survey highlight an association between the nutritional status of older people and the triptych "physical fitness/psychological state/social life". Clusters 1 and 4, who displayed the best nutritional scores of their respective age groups (65-80 years old: clusters 1-3; >80 years old: clusters 4-7) also had the highest functional score (SPPB), the lowest number of pathologies, the lowest depression and loneliness scores, and the highest self-esteem score compared to clusters of similar age. This result adds to the substantial body of evidence demonstrating that having a healthy diet, practicing physical activity, and having a satisfactory social life are key factors in promoting mental well-being and healthy aging (Peel, McClure & Bartlett, 2005; Estaquio et al., 2008; Windle, Hughes, Linck, Russel & Woods, 2010; Rizzuto, Orsini, Qiu, Wang & Fratiglioni, 2012; Hammar & Östgren, 2013; Conklin, Forouhi, Surtees, Khaw, Wareham & Monsivais, 2014). Interestingly, clusters 1 and 4 also had the highest score on the 'Meat & deli products' dimension, which grouped variables related to the consumption and preference for meat products. This highlights the

importance for the older people of sustaining protein consumption, in old age in particular, to prevent muscle and immune system decline, in order to sustain functional capacities, and prevent the onset of disease (Bauer et al, 2013; Deutz et al, 2014). Conversely, the highest scores for the 'Healthy eating' dimension were found in cluster 3 (highest score overall) and cluster 5 (highest score among the older clusters). This dimension grouped variables related to healthy eating habits, including the consumption of fruit, vegetables, and fish, which are widely acknowledged to promote healthy aging (Van Duyn & Pivonka, 2000; Trichopoulou et al., 2005; Bamia et al., 2007; Estaquio et al., 2008; Hammar & Östgren, 2013). However, clusters 3 and 5 had a lower nutritional score (MNA), as well as a lower functional score and a higher number of diseases than clusters 1 and 4, respectively. Without making a causal link, it may be that, because these respondents had more medical conditions, they were more aware of their health. Interestingly, people from this cluster were also those who had most declared having changed their food habits because of health concerns.

The results of the present survey also highlighted two clusters (6 and 7) that clearly stood out from the others with respect to impaired nutritional status. Cluster 6 grouped older people who self-reported eating difficulties. It is well-known that aging can be associated with tooth loss (Muller, Naharro & Carlsson, 2007), decline in salivary flow (Vandenberghe-Descamps et al., 2016), swallowing disorders (Humbert & Robbins, 2008), and periodontal disease, as well as xerostomia (dry mouth) and oral candidiasis induced by several diseases or medications (Gonsalves, Wrightson & Henry, 2008; Razak, Richard, Thankachan, Hafiz, Kumar & Sameer, 2014). This decline in oral health makes the act of eating difficult and even painful; indeed, several studies have demonstrated a negative impact of oral disorders on food intake and nutritional status (see Tada & Muira, 2014; Kiesswetter et al., 2018 for a

review). In the present study, people with eating difficulties also reported low appetite and a low liking score for their meals. It is also worth noting that these people were distributed across the recruitment categories, with 86% living at home and 17% living at home without help. This reinforces the need for the design and implementation of preventive dentistry protocols for the older people as a key factor in promoting good nutritional status. Cluster 7, instead, grouped depressed older people, who felt alone and had lost interest in food (low appetite, low liking score for their meals, low importance of hedonic and health aspects in food choice process, high food selectivity). This result was consistent with those from previous publications, in which widely acknowledged risk factors for anorexia in the older people are depression (Hays & Roberts, 2006; Morley, 2012; De Boer, Ter Horst & Lorist, 2013; Landi et al., 2013) and loneliness (Holmén & Furukawa, 2002; Ramic, Pranjic, Batic-Mujanovic, Karic, Alibasic, Alic, 2011; Rizzuto, Orsini, Qiu, Wang & Fraticlioni, 2012; Conklin, Forouhi, Surtees, Khaw, Wareham, & Monsivais, 2014). The present results support a strong relationship between depression and several dimensions of eating behavior such as appetite, food preferences, food choices, and meal enjoyment. Among the younger clusters, cluster 2 displays a similar, though somewhat mitigated, profile as cluster 7. Respondents from this cluster scored higher on the depression scale and lower on variables related to food enjoyment (importance of hedonic aspects in food choice, meal satisfaction, food authenticity). These results point to the need for protocols at an early stage to stimulate appetite and food intake in older people showing signs of depression, in order to prevent the nutrition risks observed in cluster 7.

Increasing age has also been linked to a decline in chemosensory capacities (Methven, Allen, Withers, & Gosney, 2012); this was observed here in clusters 6 and 7, which had the lowest

scores for odor detection (ETOC test) of all clusters. Previous reports have implicated poor oral health in possibly amplifying age-related impairment in chemosensory performance (Griep, Mets & Massart, 1997; Lamy, Mojon, Kalykakis, Legrand & Butz-Jorgensen, 1999; Sulmont-Rossé et al., 2015, Braud, Descroix, Ungeheuer, Rougeot & Boucher, 2017). In the same vein, symptoms of and medications for depression go often hand in hand with a decline in the ability to perceive odor (Atanasova, Graux, Hage, Hommet, Camus & Belzung, 2008; Imoscopi, Inelmen, Sergi, Miotto & Manzato, 2012; Croy et al., 2014; Taalman, Wallace & Milev, 2017; Rochet, El-Hage, Richa, Kazour & Atanasova, 2018). With this in mind, it is interesting to note that cluster 2 displayed the highest depression score but also the lowest odor detection score among the younger clusters. Thus far, though, the evidence on the role of chemosensory decline in aging is mixed. Studies that describe a decline in chemosensory capacities with aging typically also report a large degree of inter-individual variability (Methven, Allen, Withers & Gosney, 2012; Sulmont, Maitre et al., 2015). Likewise, although a decrease in chemosensory capacities has been proposed to be a risk factor for anorexia and malnutrition in the older people (Rolls, 1999; Hays & Roberts, 2006), overall, evidence from the literature is far from conclusive (Duffy, Backstrand & Ferris, 1995; Griep et al., 1996; de Jong, Mulder, De Graaf, & van Staveren, 1999; Kremer, Holthuysen & Boesveldt, 2014; Fluitmanet al., 2019; Arikawa et al., 2020; Grinberg, de Mello Franco, Pinto-e-Silva, Matos, 2020). As an example, Griep et al. (1996) found significant link between olfactory perception and intake for energy but not for proteins in older women. De Jong et al. (1999) highlighted a decrease in chemosensory perception and lack of appetite in an older population, but no correlation was observed between chemosensory perception and food intake. However,

Gopinath et al. (2016) showed in a longitudinal study that olfactory impairment in older women at baseline could signal an increased risk of poorer diet quality 5 years later.

4.3 Limitations of the present study

The selection of questionnaires and the choice of assessment tools were strongly constrained by the necessity to create a survey that was 'not too long' and 'easy to understand' in order to prevent fatigue in frail and dependent older people. As much as possible, we selected questionnaires and tools that had been previously validated in the literature (e.g., SPPB, MMSE, DEBQ), but a few of them have to be adapted to meet the above-mentioned constraints. Other tools were specifically designed for the present study. Preliminary testing was conducted to test both changes in already existing questionnaires and newly developed questionnaires, but obviously, more researches are needed to further develop and validate questionnaires (*e.g.* test-retest assessment) suitable for old (and very old) people. Among others, two reservations could be made for the food frequency questionnaire. First, the items were mainly related to protein products such as meat or fish. In fact, a choice was made to restrict the list of foods to some key-foods regarding the malnutrition risk (and thus protein foods), in order to reduce the burden of this usually very long questionnaire. However, this may have biased the results by given too much weight to meat-related items. Furthermore, one can question whether older people were able to remember the food habits they have when they were 30-40 years old. No respondent complained about remembering difficulty. The 30-40 years period was chosen as it corresponds to a usually stable and active life stage. However, a test-retest would have reassured the reliability of the results. Finally, other choices of variables and tools were

possible. For instance, it might have been interesting to include a food neophobia scale in addition to the measurement of food selectivity (Ritchey, Frank, Hursti, Tuorila, 2003). We could have used the SNAC questionnaire (Simplified Nutritional Appetite Questionnaire) to measure appetite rather than a single question (Wilson et al., 2005), or the GOHAI (Geriatric Oral Health Assessment Index) to assess oral health (Atchison & Dolan, 1990). Despite these limits, our hope is that the present work paves the way for the inclusion of variables related to food habits, food preference, and food attitudes in studies looking at the determinants of malnutrition.

A second limitation of the present study is that the sample excluded older people suffering from cognitive impairment. In fact, this represents a major bottleneck in studies on older population: namely, the lack of questionnaires and tests validated for older people suffering from cognitive impairment. Future research must develop and improve tools or other ways to collect information from this population (e.g., observational tests, asking relatives). The fact of including older people living in nursing home could also be questioned. As they usually do not make food decision in terms of purchase and preparation, all the variables potentially related to these dimensions were not included in the present survey. However, considering the French context, a choice was made to explore the variability across dependent older people *among* and *between* various living situations (at home, nursing home). Interestingly, the cluster 4 who displayed the best nutritional score among the older clusters included 22% of the institutionalized participants. Conversely, the clusters who displayed the worst nutritional score included as many community-dwelling people with help for food as institutionalized people (cluster 7), or even more (cluster 6). These results highlight the variability between individuals living in nursing home, but also the nutritional

frailty of homebound people which is somehow comparable to the one observed in nursing home.

Regarding the statistical method, CDPCA was chosen as an explorative approach to reduce the dimensionality of the space generated by the variables measured in different disciplines (use of component or factor analysis to retrieve a limited number of latent dimensions) while summarizing the variability between the individuals (identification of mutually exclusive clusters of individuals). CDPCA does not impose restrictions on the number of variables that can be considered, which is usually required when dealing with problems of collinearity in regression models (Vanderwee et al., 2010; Donini et al., 2013; van Bokhorst-de van der Schueren et al., 2013). However, this analysis may end-up with latent dimensions that are not always easy to interpret. For instance, the "eating difficulty" dimension gathers an item related to the difficulty perceived when eating and an item on preference for fat-free products. This surprising combination may be due to the fact that eating fat-free products is not a priority for older people suffering from eating difficulties.

Finally, it should be kept in mind that the present work is a multi-disciplinary survey that does not allow the identification of causal relationships. In order to better understand the impact of variables such as culinary dependence, eating difficulties, depression, food attitudes, or food preferences on the etiology of malnutrition, longitudinal studies are needed. Nevertheless, cross-sectional studies are necessary to identify key variables that are associated with the nutritional status of the older people, that can then be included in the design of relevant and feasible longitudinal studies.

5. CONCLUSION

Although there is certainly room for debate on the selection of the variables included and the choice of tools to collect this information, the present study highlights comprehensive typologies in the population under study. This raises the need for developing *targeted* and *specific* interventions rather than *global* and *unique* solutions to tackle malnutrition and implementing health promotion strategies in our elders. In line with recent works, these researches should focus on the identification of modifiable determinants, but should also take into account food preferences and food attitudes alongside with nutritional, physiological, psychochological and sociological variables. In fact, the present study showed several possible relationships between malnutrition and variables related to food attitudes and preferences, which should be further explored. Finally, the identification of latent dimensions in the present study may be useful for efforts to design shorter questionnaires liable to assess eating behavior in older people using a wide range of disciplines.

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Data availability all data are available from the lead author (i.maitre@groupe-esa.com).

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Conceptualization	x	x	x	x	x	x	x	x	x	x	x	x	x
Data curation	x	x		x					x				x
Formal Analysis	x	x	x	x	x	x			x				x
Funding acquisition	x	x	x									x	
Investigation	x	x	x				x		x				x
Methodology	x	x	x	x	x	x	x	x	x	x	x	x	x
Project administration	x	x	x										
Resources	x	x	x	x	x		x		x	x			x
Software													
Supervision	x	x	x										x
Validation	x	x	x	x	x	x	x		x				x
Visualization	x	x							x				x
Writing – original draft	x	x											x
Writing – review & editing	x	x	x	x	x	x	x	x	x	x	x	x	x

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Figure 1 Number of latent dimensions and number of clusters of individuals

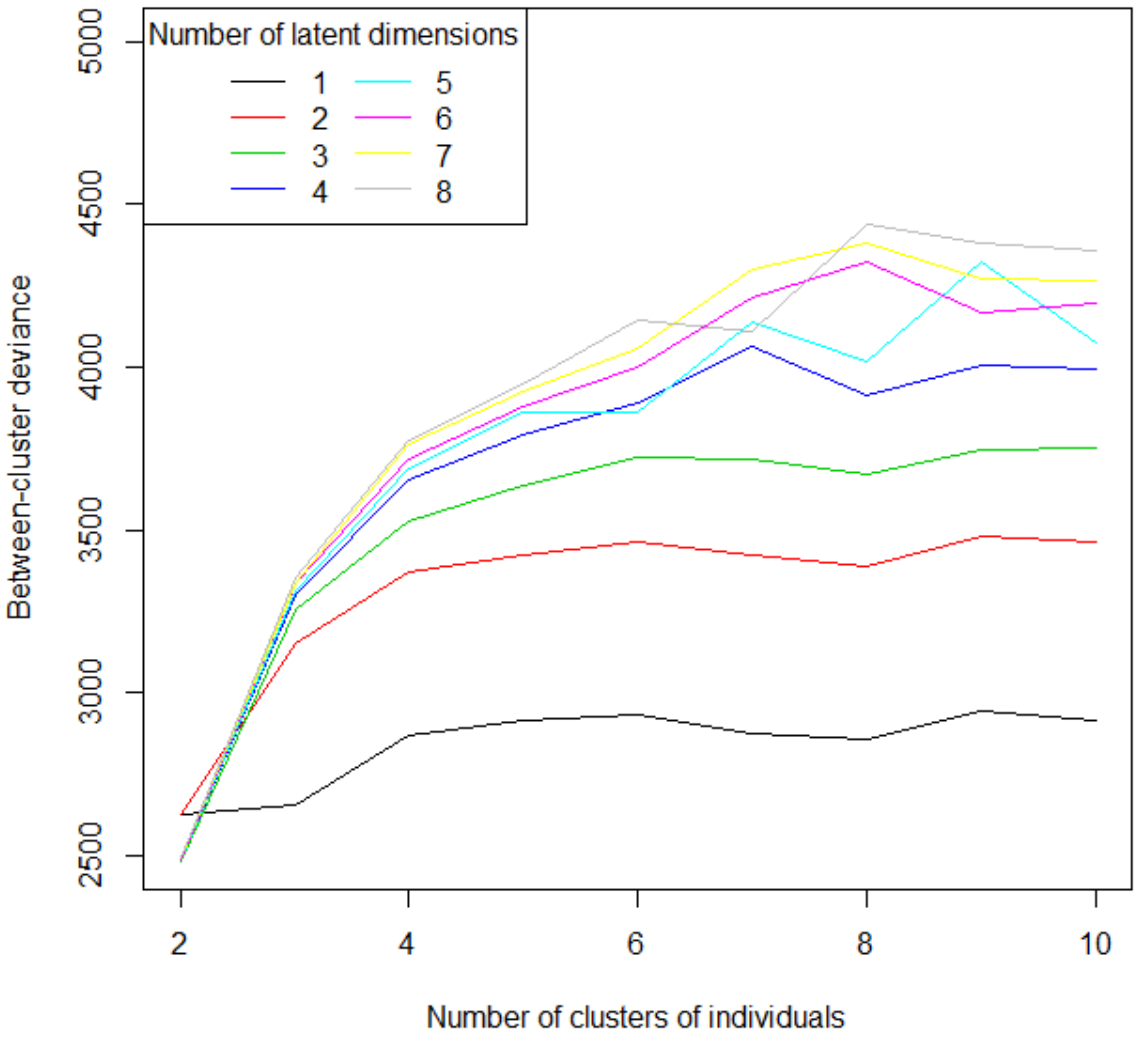
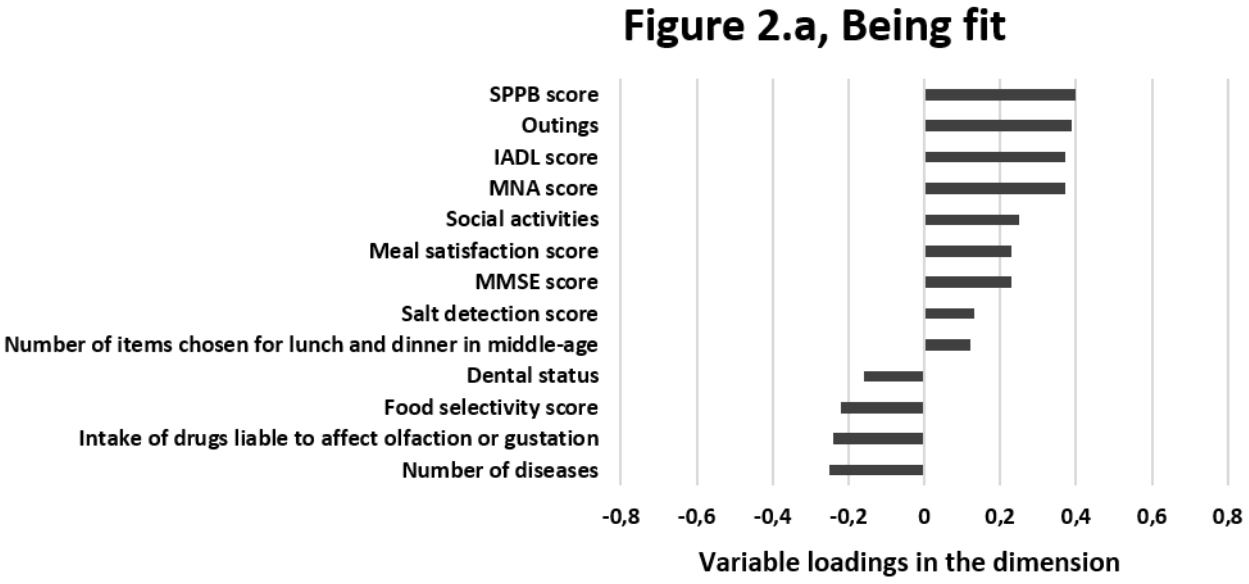


Figure 2. Latent dimensions

Figures 1.a to 1.e list the variables associated with each latent dimension; histograms depict the loading of each variable on the corresponding latent dimension (only the variables with a loading higher than 0.1 are represented).



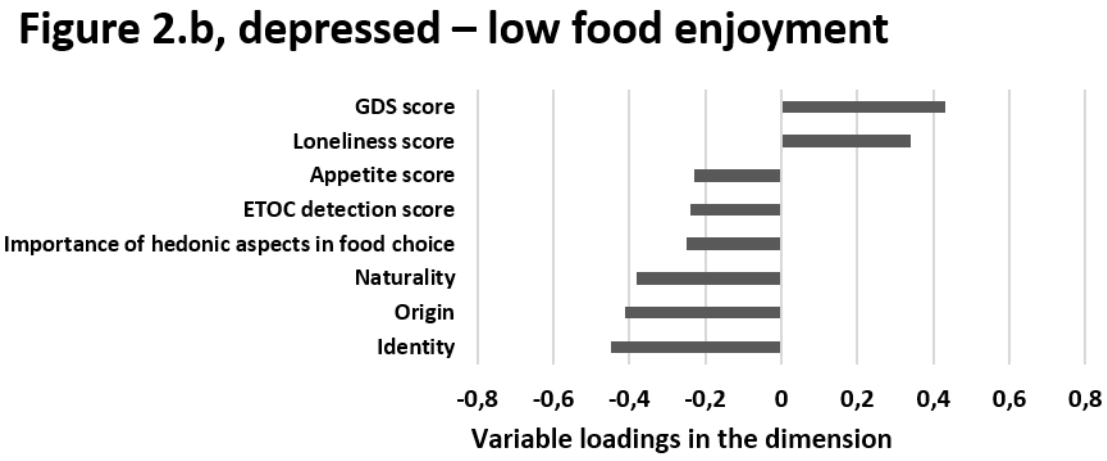


Figure 2.c, Healthy eating

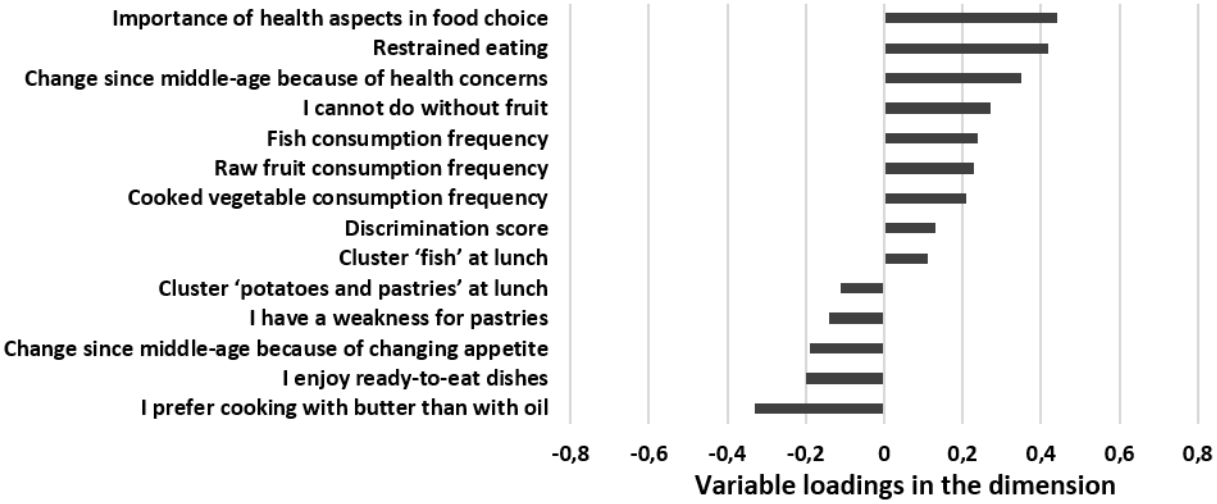


Figure 2.d, Meat & deli products

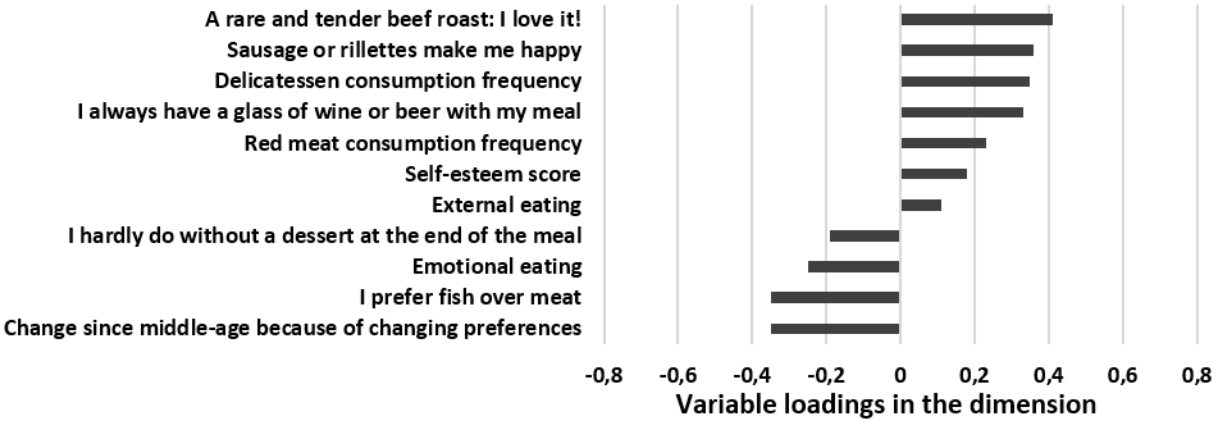


Figure 2.e, eating difficulties

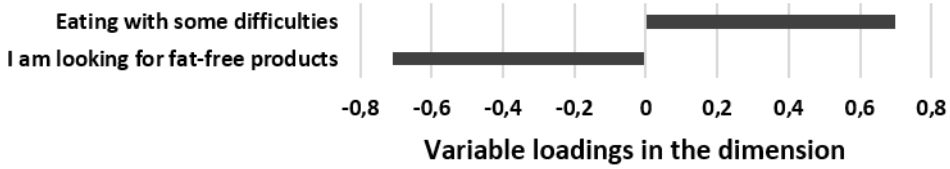


Figure 3.a to 3.e. Distribution of the scores of each cluster for the five latent dimensions
Distributions are represented by boxplots: the rectangle represents the second and third quartiles; the vertical line inside indicates the median value; the star indicates the mean; lower and upper quartiles are shown as horizontal lines on either side of the rectangle; dots indicate outliers (i.e., datapoints 1.5 times the interquartile range above the upper quartile and below the lower quartile). For each dimension, scores were subjected to a one-way ANOVA with *cluster* as the fixed factor (F-ratio and p-values are indicated below each plot). Means associated with the same letter are not significantly different according to post-hoc analysis (p>0.05).

Figure 3.f. Distribution of age across clusters
Means associated with the same letter are not significantly different according to post-hoc analysis (p>0.05).

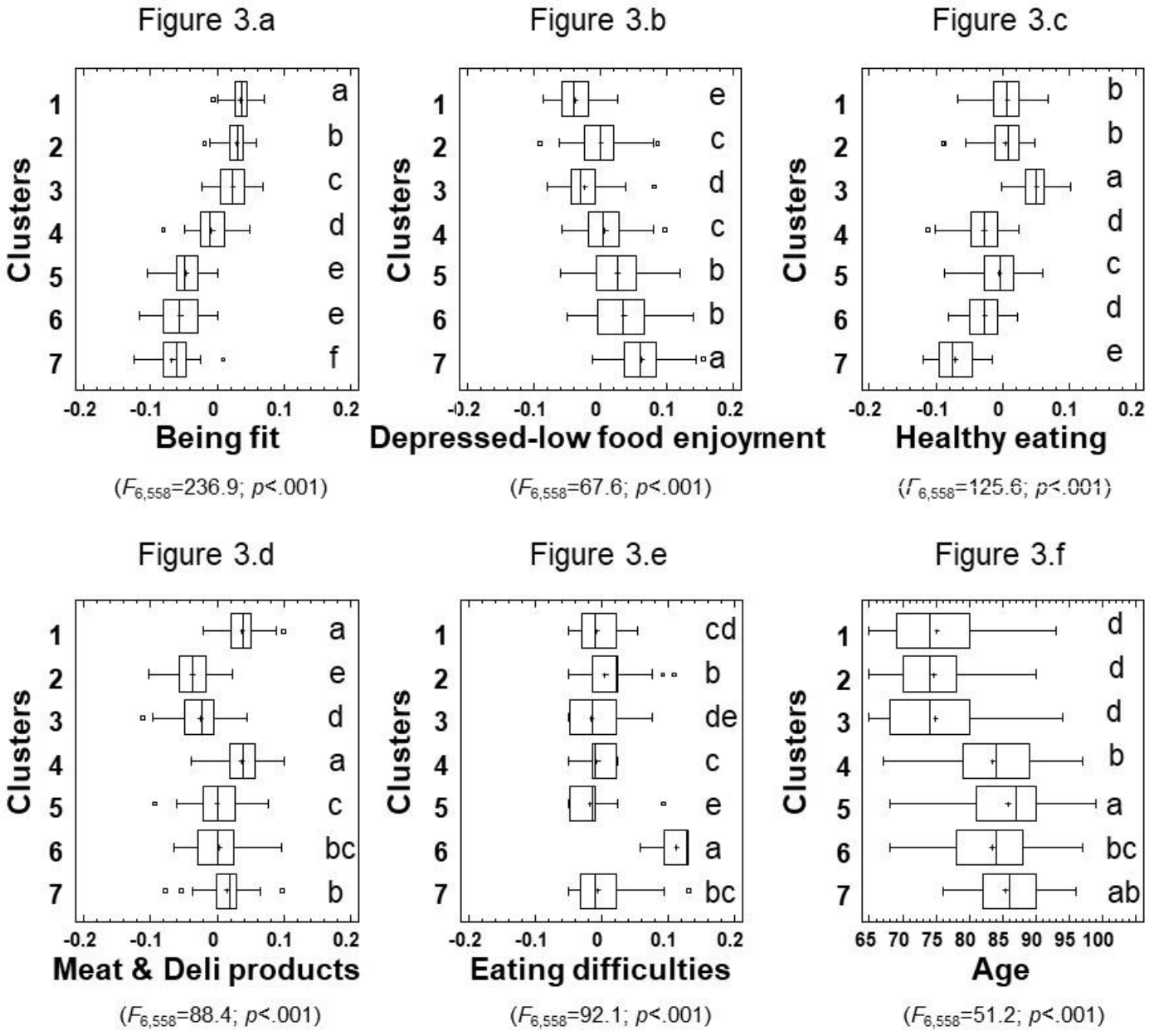


Table 1. Description of questionnaires and tests. Any adaptations made to the questionnaires already published are reported in the comments column otherwise the questionnaires where used without any change.

Outcome	Method	Description	Scoring	Comments
Socio-demographic		Age, gender, marital status marital status (single, couple, widowed), educational achievement (no degree, primary school degree, secondary school degree, university) and self-perception of financial resources (low, fair, good)		/
Nutritional, physical, psychological and social status				
Health	Self-report and medical prescription	Participants self-reported any acute or chronic health problems and provide their medical prescriptions. The responses and prescriptions were analyzed by a medical doctor to determine the number of pathologies, the number of drugs taken per day, and whether any of the drugs taken were liable to affect olfaction or gustation (yes/no)		/
Nutritional status	MNA Guigoz et al (2002)	18 items including anthropometric measurements and dietary and health characteristics	[0 – 30] The higher the score, the better nutritional status	/
Functional capacities	SPPB Guralnik et al (1994)	Gait speed, repeated chair stand and 3 standing balance tests	[0 - 12] The higher the score, the better functional performance	/
Cognitive capacities	MMSE Folstein et al (1975)	11 items assessing 5 cognitive function: orientation, registration, attention, recall, and language	[0 – 30] The higher the score, the better cognitive performance	/
Independent living skills	IADL Lawton & Brody (1996)	8 items assessing ability to perform daily tasks (*eg* cooking, housekeeping, budget)	[0 – 8] The higher the score, the better independent living skills	/
Self-esteem	Rosenberg (1965) Vallières & Vallerand (1990)	10 items assessing self-esteem (*eg* "On the whole, I am satisfied with myself"; "At times I think I am no good at all")	[0 – 10] The higher the score, the higher self-esteem	Participants answered on a 4-point scale (no, somewhat no, somewhat yes, yes) rather than on the original Likert scale

Depression	GDS Sheikh (1986); Bourque et al (1990); Mitchell et al (2010)	15 items assessing depression (*eg* "Are you basically satisfied with your life?"; "Do you often get bored?")	[0 – 15] The higher the score, the more depressed the person	/
Loneliness		1 item: "Do you feel isolated?"	[1 – 4] The higher the score, the more lonely the person	Participants answered on a 4-point scale ranging from 'not at all' to 'a lot'
Social life	Self-developed questionnaire	12 items on the frequency of in-person or phone contact (*eg* with relatives medical or social carers), activities (*eg* sports, art, volunteering for an association, caring for children) and outings (*eg* visiting family, shopping)	Social contact: [-3.0 - +1.8] Social activities: [-1.1 – +2.9] Outings: [-2.8 – +1.8] The higher the score, the more social contacts	Participants answered on a frequency scale (never, rarely, sometimes, often, everyday). For each dimension, a global score was obtained by combining items according to PLS-PL
Food habits, food preferences, and food attitudes				
Appetite		1 item: "Do you have a good appetite?"	[1 – 4] The higher the score, the greater appetite	Participants answered on a 4-point scale ranging from 'not at all' to 'a lot'
Meal satisfaction		1 item: "Do you like your meals at present"	[1 – 5] The higher the score, the more liked	Participants answered on a 5-point scale ranging from 'Not like at all' to 'like a lot'
Eating difficulties	Self-developed questionnaire	5 items: respondents indicate whether they experiment difficulty in eating, cutting their food, putting their food in mouth, chewing or swallowing	0: no difficulty 1: difficulty	Participants answered on a 4-point scales range (no, somewhat no, somewhat yes, yes). The answers were dichotomised.
Dental status		Respondents reported whether they were dentate with or without partial dentures, edentulous with partial or complete denture, or edentulous without denture.		
Xerostomia	Thomson et al (1999)	4 items assessing xerostomia (*eg* "My mouth feels dry when eating a meal", "I sip liquids to aid in swallowing food")	[0 – 20] The higher the score, the more severe xerostomia	/

Food selectivity	Maître et al (2013)	Participants tick the foods they disliked from a list of familiar foods	[0 – 71] The higher the score, the more selective the person	/
Food consumption	Self-developed questionnaire	Participants rated their consumption frequencies for 9 items	[1 – 6] for each food item The higher the score, the greater the consumption	See detailed description in the text
Change in food consumption	Self-developed questionnaire	Participants self-reported the reasons for changes in food consumption since adulthood	Changes because of health: [0 - 8] Changes because of preference: [0-8] Changes because of appetite: [0 - 8]	See detailed description in the text
Food preferences	Self-developed questionnaire	Participants rated their preference for 21 food items	[1 – 5] for each food item	See detailed description in the text
Menu preference	Self-developed questionnaire	Participants made a choice task to select food items for an ordinary lunch and an ordinary dinner.	Each respondent belongs to one of the four clusters observed from lunch and to one among of the four clusters observed for dinner	See detailed description in the text
Eating behaviour	DEBQ Van Strien et al (1986); Lluch et al (1996); Bailly et al, (2012)	11 items measuring 3 eating behaviours: emotional eating, restrained eating and external eating.	Emotional eating: [0 – 30] Restrained eating; [0 – 25] External eating: [0 – 25)	Participants answered on a 4-point scale (no, somewhat no, somewhat yes, yes) rather than on the original Likert scale
Eating attitudes	HTAQ Roininen et al (1999)	14 items measuring the importance of health and hedonic aspects of foods in the food choice process	Importance of health: [0 – 20] Importance of hedonic: [0 – 20]	Participants answered on a 4-point scale (no, somewhat no, somewhat yes, yes) rather than on the original Likert scale
Food authenticity	Camus (2004)	7 items to measure relationship with food: self-identity (“The foods I eat reflect my personality”), naturalness (“The foods I eat are natural”) and origin (“I know where the foods I eat come from”)	Self-identify: [-2.4 – +1.4] Naturalness: [-2.0 – +1.6] Origin: [-1.3 – +1.5]	Participants answered on a 4-point scale (no, somewhat no, somewhat yes, yes) rather than on the original Likert scale. For each dimension, a global score was obtained by combining items according to PLS-PL
Olfactory perception	ETOC Thomas-Danguin et al (2003); Sulmont-Rossé et al (2015)	Detection of 6 weak odors (1-out-of-4 forced-choice task)	[0 – 100] The higher the score, the better the performance	/

Olfactory perception	Discrimination test Sulmont-Rossé et al (2015)	Detection of an odd odor from two identical odors (duo-trio task)	[0 – 100] The higher the score, the better the performance	/
Olfactory perception	Monadic olfactory test Sulmont-Rossé et al (2015)	Detection of 12 medium-intensity odors (yes/no task) and categorization in food smell / non-food smell category	[0 – 100] The higher the score, the better the performance	/
Gustatory perception	Salt detection test Sulmont-Rossé et al (2015)	Detection of solutions containing 4 increasing concentration of NaCl among water solutions.	[0 – 100] The higher the score, the better the performance	/

MNA: Mini-Nutritional Assessment. SPPB: Short Physical Performance Battery. MMSE: Mini Mental State Examination. IADL: Lawton Instrumental Activities of Daily Living Scale. GDS: Geriatric Depression Scale. DEBQ: Dutch Eating Behaviour Questionnaire. HTAQ: Health and Taste Attitude Questionnaire. ETOC: Test of European Olfactory Capabilities. PLS-PM: Partial Least Squares Path Modeling.

Table 2. Characteristics of the survey sample according to dependence categories

	At home, without help	At home, non-food help	At home, food help	Nursing home	*p*-Value*
N	289	74	101	95	
Gender, % men	31%	27%	34%	28%	0.75
Age (yr) [a]	73.9 (0.3)	81.1 (0.7)	84.7 (0.6)	87.0 (0.7)	<0.001
65-75 yr	57%	16%	5%	4%	
≥75 yr	43%	84%	95%	96%	
Marital status					<0.001
Single	20%	22%	12%	22%	
Couple	51%	35%	25%	18%	
Widowed	29%	43%	63%	60%	
Education					<0.001
No	4%	11%	15%	17%	
Primary	25%	28%	41%	32%	
Secondary	43%	41%	31%	40%	
Graduate	28%	20%	12%	11%	
Income [d]					0.05
Low	19%	24%	33%	-	
Fair	53%	45%	46%	-	
Good	28%	31%	21%	-	

[a] Mean (standard deviation)

* *P*-value derived from either ANOVA or χ^2 test.

Table 3. Socio-demographic characteristics of the clusters

Clusters	1	2	3	4	5	6	7	Statistic
N	87	118	110	94	78	35	37	
Gender, % men	59 %	14 %	20 %	50 %	14 %	37 %	32 %	162.6***
Age mean (yr)	75.1[d]	74.5[d]	74.9[d]	83.5[c]	85.8[a]	83.4[bc]	79.1[ab]	51.2***
Standard Deviation	(7.0)	(5.5)	(6.8)	(7.1)	(6.3)	(7.3)	(5.1)	
65-80 yr [b]								
≥ 80 yr								
Dependence category								370.4***
At home, without help	80 %	89 %	74 %	21 %	6 %	17 %	5 %	
At home, non-food help	15 %	10 %	20 %	17 %	4 %	23 %	8 %	
At home, food help	5 %	1 %	5 %	39 %	39 %	46 %	43 %	
Nursing home	0 %	0 %	2 %	22 %	51 %	14 %	43 %	
Marital status								215.6***
Single	9%	26%	25%	15%	21%	20%	11%	
Couple	71%	36%	46%	37%	10%	20%	27%	
Widowed	20%	38%	29%	48%	69%	60%	62%	
Education								154.3***
No	6%	2%	5%	18%	17%	6%	16%	
Primary	15%	34%	25%	32%	37%	29%	35%	
Secondary	36%	44%	42%	38%	33%	57%	30%	
Graduate	43%	19%	26%	10%	13%	9%	19%	
Income [d]								402.4***
Low	15%	25%	20%	12%	19%	17%	27%	
Fair	46%	54%	52%	43%	17%	23%	30%	
Good	39%	21%	26%	23%	13%	14%	0%	

Statistic: F-ratio from an ANOVA (quantitative variable) or χ^2 test (qualitative variable). *p<0.05; **p<0.01; ***p<0.001. Means associated with the same letter are not significantly different according to post-hoc analysis (p>0.05).

[d] Income was asked only at home

Table 4. Active variables associated with a significant cluster effect and a loading >0.1

Clusters	1	2	3	4	5	6	7	Overall	Statistic
'Being fit' dimension									
MNA [0-30]	28.0 (1.7) a	26.6 (1.8) b	26.7 (1.8) b	25.9 (2.2) c	23.8 (2.2) d	21.2 (2.9) e	20.0 (3.8) f	25.6 (3.1)	99.6***
Number of diseases	1.7 (1.4) c	2.2 (1.7) c	3.1 (1.9) b	2.9 (1.7) b	4.5 (1.9) a	4.0 (1.7) a	4.6 (1.8) a	3.0 (2.0)	28.8***
SPPB [0-12]	11.2 (1.2) a	10.8 (1.6) ab	10.2 (2.4) b	8.6 (3.1) c	5.1 (3.2) d	5.2 (3.9) d	5.1 (3.4) d	8.8 (3.5)	78.6***
MMS [0-30]	28.0 (1.8) a	27.8 (2.1) a	27.8 (2.0) a	26.2 (2.7) b	25.9 (2.6) bc	26.1 (2.8) bc	25.2 (2.7) c	27.0 (2.5)	16.1***
IADL [0-8]	7.3 (1.1) b	7.8 (0.5) a	7.6 (0.9) ab	6.2 (1.7) c	4.8 (1.8) d	4.9 (2.3) d	4.5 (2.1) d	6.6 (1.9)	73.6***
Social activities [-1.1-2.9]	0.5 (1.0) a	0.3 (0.9) a	0.4 (1.0) a	-0.5 (0.8) b	-0.5 (0.8) b	-0.4 (0.9) b	-0.7 (1.0) b	0.0 (1.0)	24.8***
Outings [-2.8 – 1.8]	0.6 (0.5) a	0.5 (0.4) a	0.5 (0.5) a	-0.1 (0.8) b	-1.0 (0.9) c	-1.0 (1.0) c	-1.2 (1.0) c	0.0 (1.0)	93.9***
Food selectivity [0-71]	6.9 (6.2) e	5.9 (6.0) e	6.9 (6.9) e	9.3 (7.0) d	11.2 (7.4) cd	13.0 (8.7) bc	16.2 (8.9) a	8.7 (7.6)	16.2***
Meal satisfaction [1-5]	4.9 (0.3) a	4.6 (0.7) b	4.9 (0.4) a	4.6 (0.6) b	4.1 (1.1) c	3.4 (1.3) d	4.0(0.9) c	4.5 (0.8)	28.0***
No. of foods eaten during main meals at middle-age	10.9(1.9) a	11.1(2.3) a	11.0(2.1) a	9.58(2.6) b	10.1(2.3) b	10.0(2.6) b	9.1(3.4) b	10.5(2.4)	6.7***
Salt detection [0-100]	73 (15) a	70 (18) ab	69 (16) ab	67 (15) bc	62 (17) c	68 (16) abc	65 (18) bc	68 (17)	3.7***
Intake of drugs liable to affect olfaction/gustation (%)	23%	22%	55%	59%	81%	74%	81%	50%	118,4***
Bad dental status (%)	10%	16%	8%	20%	20%	12%	14%	25%	52.5***
'Depressed & low food enjoyment' dimension									
GDS [0-15]	1.4 (1.4) f	3.2 (2.6) d	2.4 (2.0) e	3.8 (2.3) cd	4.9 (3.0) b	4.4 (2.9) bc	7.8 (2.7) a	3.5 (2.8)	39.9***
Loneliness [1-4]	1.3 (0.6) d	1.6 (0.8) c	1.5 (0.8) c	1.6 (0.8) c	2.1 (1.1) ab	1.7 (1.0) bc	2.3 (1.2) a	1.7 (0.9)	10.0***
Appetite [1-4]	3.7 (0.5) a	3.5 (0.6) bc	3.5 (0.6) ab	3.3 (0.8) c	3.5 (0.7) bc	2.5 (1.0) d	2.4 (0.9) d	3.4 (0.8)	25.2***
Importance of hedonic in food choice [0-20]	17.9 (1.9) a	16.3 (2.8) b	17.4 (2.1) a	16.2 (3.3) b	16.1 (3.5) b	15.3 (2.9) bc	14.6 (3.5) c	16.5 (3.0)	9.7***
Self-identity [-2.4–1.4]	0.5 (0.7) a	-0.0 (0.9) b	0.4 (0.7) a	0.0 (1.0) b	-0.4 (1.0) c	-0.7 (1.2) c	-0.7 (1.1) c	0.0 (1.0)	16.5***
Naturalness [-2-1.6]	0.2 (0.9) ab	-0.2 (0.9) c	0.3 (0.9) a	0.0 (1.0) abc	-0.1 (1.0) bc	-0.2 (1.3) c	-0.4 (1.0) c	0.0 (1.0)	3.8**
Origin [-1.3–1.5]	0.6 (0.8) a	0.0 (0.9) c	0.4 (0.9) b	-0.2 (1.0) cd	-0.6 (0.9) e	-0.4 (0.9) de	-0.4 (1.1) de	0.0 (1.0)	19.1***
ETOC odor detection [0-100]	78 (21) a	70 (29) b	78 (22) a	58 (29) cd	64 (25) bc	52 (36) d	49 (29) d	67 (28)	11.9*** ***
'Eating difficulties' dimension									
Eating with some difficulty	1 %	3 %	1 %	0 %	1 %	100 %	8 %	8 %	439***
I am looking for fat-free products [1-5]	2.9 (1.4) bc	2.2 (1.5) d	3.3 (1.7) ab	2.7(1.4) c	3.4(1.5) a	2.0 (1.2) d	3.1 (1.4) abc	2.8 (1.6)	8.8***

< Table continued on next page >

Clusters	1	2	3	4	5	6	7	Overall	Statistic
'Healthy eating' dimension									
Consumption frequency for fish	2.0 (0.3) b	1.9 (0.5) bc	2.2 (0.5) a	1.9 (0.3) bc	2.0 (0.3) bc	1.8 (0.5) bc	1.8 (0.4) c	2.0 (0.4)	10.7 ***
Consumption frequency for cooked vegetables	2.9 (0.3) ab	2.9 (0.3) b	3.0 (0.1) a	2.9 (0.3) ab	3.0 (0.0) a	2.9 (0.3) bc	2.5 (0.7) c	2.9 (0.3)	16.1 ***
Consumption frequency for raw fruit	2.9 (0.3) a	2.9 (0.4) ab	3.0 (0.1) a	2.7 (0.6) c	2.9 (0.3) ab	2.7 (0.6) bc	2.3 (0.8) d	2.8 (0.5)	14.6 ***
Preferred menu for lunch: "Fish" (%)	22%	39%	56%	19%	18%	14%	11%	30%	132***
Preferred menu for lunch: "Potatoes & pastries" (%)	18%	9%	5%	34%	21%	43%	51%	21%	
Importance of health in food choice [0-20]	15.8 (2.7) b	15.2 (2.5) bc	17.7 (1.7) a	14.6 (2.9) c	15.6 (3.1) b	14.7 (3.6) bc	11.4 (3.6) d	15.5 (3.1)	28.8***
Changes since middle-age because of health [0–8]	1.6 (1.5) b	1.3 (1.2) b	2.8 (2.1) a	0.5 (1.0) c	0.7 (1.1) c	0.4 (1.2) c	0.7 (1.4) c	1.3 (1.6)	29.9***
Changes since middle-age because of appetite [0–8]	0.3(0.9) bc	0.1(0.5) c	0.2(0.6) c	0.6(1.1) b	0.2(0.6) c	0.6(1.3) b	1.2(2.01) a	0.4(1.0)	8.6***
I cannot do without fruit [1-5]	4.3 (1.2) a	4.4 (1.3) a	4.3 (1.3) a	3.4 (1.6) b	4.1 (1.4) a	3.5 (1.7) b	2.7 (1.7) c	4.0 (1.5)	11.7***
I prefer cooking with butter over oil [1-5]	2.7 (1.6) cd	2.6 (1.5) d	1.8 (1.3) e	3.6 (1.5) ab	2.9 (1.6) cd	3.2 (1.7) bc	4.1 (1.4) a	2.8 (1.6)	16.9 ***
I enjoy ready-to-eat dishes [1-5]	2.3 (1.4) bc	2.0 (1.3) cd	1.7 (1.1) d	2.5 (1.6) ab	2.8 (1.7) a	2.5 (1.5) abc	2.9 (1.6) a	2.3 (1.5)	7.0 ***
I have a weakness for pastries [1-5]	2.2 (1.5.) a	2.2 (1.4) a	1.8 (1.3) b	2.2 (1.5) a	2.6 (1.7) a	2.6 (1.7) a	2.5 (1.7) a	2.2 (1.5) a	3.0**
Restrained eating [0-25]	12.2 (4.0) bc	13.1 (4.0) b	18.0 (3.6) a	9.6 (3.7) ef	11.9 (4.2) cd	10.6 (4.9) de	8.4 (3.2) f	12.7 (4.9)	53.0***
Odor discrimination [0-100]	79 (24) a	65 (32) bc	79 (26) a	63 (35) c	72 (30) ab	67 (29) bc	64 (31) bc	71 (30)	4.8***
'Meat & deli products' dimension									
Self-esteem [0-40]	36.0 (3.4) a	30.8 (5.2) cd	32.9 (5.0) b	34.7 (4.2) a	32.1 (5.9) bc	32.3 (7.1) bc	29.1 (7.3) d	32.8 (5.6)	13.5***
Consumption frequency for red meat	2.0 (0.5) a	1.5 (0.6) d	1.6 (0.5) cd	1.8 (0.4) b	1.6 (0.6) cd	1.6 (0.6) cd	1.8 (0.6) bc	1.7 (0.5)	10.1 ***
Consumption frequency for deli meats	1.5 (0.6) bc	1.2 (0.4) de	1.1 (0.3) e	2.0 (0.6) a	1.5 (0.5) bc	1.3 (0.5) cd	1.6 (0.6) b	1.4 (0.6)	35.8 ***
Changes since middle-age because of preference [0-8)	0.8 (1.0) c	2.2 (1.6) a	1.8 (1.6) b	1.1 (1.4) c	1.1 (1.4) c	1.1 (1.4) c	0.9 (1.3) c	1.4 (1.5)	11.8 ***
Rare and tender beef roast: I love it! [1-5]	4.0 (1.1) a	2.3 (1.4) d	2.9 (1.5) c	3.5 (1.6) b	3.0 (1.6) c	2.8 (1.7) c	2.9 (1.7) c	3.1 (1.6)	13.0***
Sausage or rillettes make me happy [1-5]	3.7 (1.5) ab	2.5 (1.5) d	2.5 (1.5) d	3.9 (1.3) a	2.9 (1.6) cd	3.3 (1.7) bc	3.4 (1.7) abc	3.1 (1.6)	14.2 ***
I always have wine or beer with my meal [1-5]	4.0 (1.3) a	2.1 (1.4) d	2.0 (1.4) d	3.4 (1.7) b	2.0 (1.5) d	2.5 (1.7) cd	2.7 (1.9) c	2.6 (1.7)	24.2 ***
I can hardly go without a dessert [1-5]	2.9 (1.7) bc	3.8 (1.7) a	3.0 (19) bc	2.4 (1.7) d	3.4 (1.8) ab	2.7 (1.8) bcd	2.6 (1.9) cd	3.1 (1.8)	6.7 ***
I prefer fish over meat [1-5]	2.7 (1.2) b	3.5 (1.4) a	3.8 (1.2) a	2.9 (1.4) b	2.9 (1.4) b	3.0 (1.7) b	2.8 (1.8) b	3.2 (1.4)	7.6 ***
Emotional eating [0-30]	9.2 (4.2) cd	13.4 (5.4) a	12.1 (5.9) b	8.1 (3.1) d	9.7 (4.9) c	8.6 (2.6) cd	8.1 (2.6) de	10.4 (5.1)	17.6***
External eating [0-25]	11.8 (3.7) bc	13.2 (3.8) a	12.3 (4.3) ab	10.3 (3.4) d	11.0 (3.9) cd	11.0 (4.9) bcd	11.0 (3.9) bcd	11.7 (4.0)	6.0***

Mean (Standard Deviation). Statistic: F-ratio from an ANOVA (quantitative variable) or χ^2 test (qualitative variable). *p<0.05; **p<0.01; ***p<0.001. Means associated with the same letter are not significantly different according to post-hoc analysis (p>0.05).

APPENDIX. Active variables included in the CDPCA and their loadings in the five dimensions

Category	Variable	Type	Status	Dimension	Loading
Socio-demographic	Age	Quantitative	Illustrative	-	
	Gender	Qualitative	Illustrative	-	
	Marital status	Qualitative	Illustrative	-	
	Degree of education	Qualitative	Illustrative	-	
	Self-perception of financial resources	Quantitative	Illustrative	-	
Nutritional status	MNA score	Quantitative	Active	Being fit	0.37
Disease and drug intake	Number of diseases	Quantitative	Active	Being fit	-0.25
	Number of drugs per day	Quantitative	Not included		
	Intake of drugs liable to affect olfaction or gustation	Qualitative (0,1)	Active	Being fit	-0.24
Functional capacities	SPPB score	Quantitative	Active	Being fit	0.40
Cognitive capacities	MMSE score	Quantitative	Active	Being fit	0.23
Independent living skills	IADL score	Quantitative	Active	Being fit	0.37
Self-esteem	Self-esteem score	Quantitative	Active	Meat & deli products	0.18
Depression	GDS score	Quantitative	Active	Depressed & low food enjoyment	0.43
Loneliness	Loneliness score	Quantitative	Active	Depressed & low food enjoyment	0.34
Social life	Social contacts	Qualitative (0,1)	Active	Being fit	-0.06
	Social activities	Qualitative (0,1)	Active	Being fit	0.25
	Outings	Qualitative (0,1)	Active	Being fit	0.39
Appetite	Appetite score	Quantitative	Active	Depressed & low food enjoyment	-0.23
Meal satisfaction	Meal satisfaction score	Quantitative	Active	Being fit	0.23
Eating difficulties	Eating with some difficulties	Qualitative (0,1)	Active	Eating difficulties	0.70
	Difficulty in cutting food	Quantitative	Not included		
	Difficulty in putting the food in the mouth	Quantitative	Not included		
	Difficulty in chewing the food	Quantitative	Not included		
	Difficulty in swallowing the food	Quantitative	Not included		
Food selectivity	Food selectivity score	Quantitative	Active	Being fit	-0.22
Food	Red meat consumption	Quantitative	Active	Meat & deli	0.23

Category	Variable	Type	Status	Dimension	Loading
consumption	frequency			products	
	White meat consumption frequency	Quantitative	Not included		
	Poultry consumption frequency	Quantitative	Not included		
	Delicatessen consumption frequency	Quantitative	Active	Meat & deli products	0.35
	Ham consumption frequency	Quantitative	Not included		
	Fish consumption frequency	Quantitative	Active	Healthy eating	0.24
	Cooked vegetable consumption frequency	Quantitative	Active	Healthy eating	0.21
	Dairy products consumption frequency	Quantitative	Not included		
	Raw fruit consumption frequency	Quantitative	Active	Healthy eating	0.23
Change in food consumption	Change since middle-age because of health concerns	Quantitative	Active	Healthy eating	0.35
	Change since middle-age because of changing preferences	Quantitative	Active	Meat & deli products	-0.35
	Change since middle-age because of changing appetite	Quantitative	Active	Healthy eating	-0.19
Food preferences	A rare and tender beef roast: I love it!	Quantitative	Active	Meat & deli products	0.41
	I really enjoy fresh dairy products (yoghurt, cottage cheese…)	Quantitative	Not included		
	I always have a glass of wine or beer with my meal	Quantitative	Active	Meat & deli products	0.33
	I am fond of sweets (biscuits, candies…)	Quantitative	Not included		
	I like dishes with gravy	Quantitative	Not included		
	I consider myself as a meat lover, especially read meat	Quantitative	Not included		
	I cannot do without fruit	Quantitative	Active	Healthy eating	0.27
	I prefer cooking with butter than with oil	Quantitative	Active	Healthy eating	-0.33
	I always sweeten hot drinks or yoghurt with sugar, honey or jam	Quantitative	Not included		
	I eat a lot of soup	Quantitative	Not included		
	I have a weakness for pastries	Quantitative	Active	Healthy eating	-0.14
	I am a heavy consumer of bread	Quantitative	Not included		
	I am looking for fat-free products	Quantitative	Active	Eating difficulties	-0.71
	I enjoy ready-to-eat dishes	Quantitative	Active	Healthy eating	-0.20

Category	Variable	Type	Status	Dimension	Loading
	I like vegetables, especially when they are steamed	Quantitative	Not included		
	I prefer fish over meat	Quantitative	Active	Meat & deli products	-0.35
	I hardly do without a dessert at the end of the meal	Quantitative	Active	Meat & deli products	-0.19
	I almost always have potatoes, rice or pasta as side-dish	Quantitative	Not included		
	Sausage or rillettes make me happy	Quantitative	Active	Meat & deli products	0.36
	I enjoy exotic kitchen	Quantitative	Not included		
	I like eggs (fried, boiled, scrambled…)	Quantitative	Not included		
Menu preference	Cluster 'roast' at lunch	Qualitative (0,1)	Active	Meat & deli products	0.09
	Cluster 'fish' at lunch	Qualitative (0,1)	Active	Healthy eating	0.11
	Cluster 'poultry or meat with gravy' at lunch	Qualitative (0,1)	Active	Meat & deli products	-0.04
	Cluster 'potatoes and pastries' at lunch	Qualitative (0,1)	Active	Healthy eating	-0.11
	Cluster 'Copious' at dinner	Qualitative (0,1)	Active	Healthy eating	0.00
	Cluster 'Ham' at dinner	Qualitative (0,1)	Active	Eating difficulties	-0.05
	Cluster 'Light & soup' at dinner	Qualitative (0,1)	Active	Being fit	-0.02
	Cluster 'Quiche & salad' at dinner	Qualitative (0,1)	Active	Being fit	0.02
	Number of items chosen for lunch and dinner at present	Quantitative	Active	Being fit	0.08
	Number of items chosen for lunch and dinner in middle-age	Quantitative	Active	Being fit	0.12
Eating behaviour (DEBQ)	Emotional eating	Quantitative	Active	Meat & deli products	-0.25
	Restrained eating	Quantitative	Active	Healthy eating	0.42
	External eating	Quantitative	Active	Meat & deli products	0.11
Eating attitudes (HTAQ)	Importance of health aspects in food choice	Quantitative	Active	Healthy eating	0.44
	Importance of hedonic aspects in food choice	Quantitative	Active	Depressed & low food enjoyment	-0.25
Food authenticity	Origin	Quantitative	Active	Depressed & low food enjoyment	-0.41
	Self-Identity	Quantitative	Active	Depressed & low food enjoyment	-0.45
	Naturality	Quantitative	Active	Depressed & low food enjoyment	-0.38

Category	Variable	Type	Status	Dimension	Loading
Oral health	Dental status	Qualitative	Active	Being fit	-0.16
	Xerostomia score	Quantitative	Not included		
Olfactory perception	ETOC detection score	Quantitative	Active	Depressed & low food enjoyment	-0.24
	Discrimination score	Quantitative	Active	Healthy eating	0.13
	Monadic detection score	Quantitative	Not included		
	Categorization score	Quantitative	Not included		
Gustatory perception	Salt detection score	Quantitative	Active	Being fit	0.13