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## How protein containing foods are represented in memory? A categorization study

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31 **Keywords**

32 Categorization, representation, flexibility, protein containing food

33

## 34 1 Introduction

35 In Western cultures, animal products, in particular meat, play a major role in protein provision  
36 (Fiddes, 1991; Jallinoja et al., 2016); although, the negative effects of intensive livestock farming  
37 on the environment, especially on carbon dioxide (CO<sub>2</sub>) emission and loss of biodiversity, are  
38 well established. The production of plant protein sources - such as legumes, seeds, nuts, and  
39 cereals - is linked to a smaller CO<sub>2</sub> emission than food products from animal origin (Carlsson-  
40 Kanyama & González, 2009; Godfray et al., 2010; Virtanen et al., 2011). To cover the upcoming  
41 protein demand in a sustainable way, a shift from animal-based food items to plant-based ones  
42 would thus be necessary. However, the way to implement this shift remains an unsolved  
43 problem, as meat still plays a central role in the representations of meal structure in most  
44 Western cultures (Melendrez-Ruiz, Chambaron, et al., 2019; Tziva et al., 2020).

45 Previous surveys suggest that the main barriers for plant-based food consumption are a lack of  
46 knowledge and a negative image of these food items (de Boer et al., 2017; de Boer & Aiking,  
47 2019; de Gavelle et al., 2019; Graça et al., 2019; Melendrez-Ruiz, Buatois, et al., 2019; Vainio et  
48 al., 2016). Health information or emotional messages might not be powerful enough for  
49 consumers to go beyond these barriers. Despite an awareness of the situation and a behavioral  
50 intention to reduce meat consumption (Harguess et al., 2020) several studies highlighted the  
51 existence of an attitude-behavior gap whereby consumers' in-store behavior does not align with  
52 their attitude (Hoek, Luning, et al., 2011). To facilitate the transition toward plant-based food,  
53 we need to understand the representations that people have of protein containing food from  
54 plant and animal origin, as food representations guide food practices and *vice versa* (Urdapilleta  
55 et al., 2005). One way of exploring these representations is to look at the way individuals  
56 categorize food stimuli. In this paper, we will focus on the structure and properties of protein  
57 containing food categories. Our assumption is that food items that belong to nearby categories  
58 or to categories sharing properties will be more easily exchangeable than items considered as  
59 belonging to different, more distant categories (Hoek, van Boekel, et al., 2011). The rationale  
60 behind this assumption is that one of the main use of categories is to infer properties from the  
61 known items of a category to new items. So, if a new item is recognized as belonging to a certain  
62 food category, the properties of the category will be extended to this new item.

63 Research on food category structures and properties is rather scarce. In the 80's, Rozin & Fallon,  
64 (1980) were among the first to be interested in food categorization. They tried to understand  
65 how humans differentiate between edible and non-edible items. They designed a questionnaire  
66 to capture the essential characteristics of distaste, danger, and disgust food categories among  
67 American college students. Their results showed that items in the disgust category were in  
68 majority from animal origin: arthropods, mammals, other invertebrates, parts of edible animals

69 (e.g., liver, kidney, tongue), and non-mammal vertebrates. Non animal items (plant and mineral  
70 origin) were much less frequent in the disgust category. They were rejected simply because they  
71 are not considered food in the American culture (e.g., grass or sand). Overall, it seems that there  
72 are some clear psychological distinctions among foods that share similar nutritional or sensory  
73 properties and these distinctions are linked to the origin of the foods.

74 Since this seminal work of Rozin and Fallon, to our knowledge, very few studies have  
75 investigated how adults categorize food items. Ross & Murphy (1999) examined the different  
76 types of categories people have about foods. They gave participants a list of basic food items and  
77 asked them to generate some categories for each of these foods. They obtained three main kinds  
78 of categories based on either taxonomic (common properties) or script (same role in an event)  
79 relation. About 50% of the responses corresponded to the type of foods (e.g., breads, dairy foods,  
80 fruits), about 40% to the situations in which the food could be eaten (e.g., breakfast foods, snack)  
81 and about 10% were linked to the food macronutrients (e.g., proteins, carbohydrates). Using a  
82 multiple card task, Blake et al. (2007) also observed three kinds of food categorization: personal-  
83 experience-based (food I like vs. food I dislike), context based (winter vs. summer food) and  
84 food-based. The latter included three subdimensions: Food group (fruit and vegetable vs. meat),  
85 nutrient composition (starch vs. protein), and physical characteristics (sweet vs. salty foods).  
86 These taxonomic or script-based food categories seem to be already acquired by the age of 2 to 3  
87 years (Nguyen & Murphy, 2003). Children above 4 or 5 years-old are able to generalize the  
88 psychological and biological properties of food items within a type of food: If an apple is good for  
89 health, a pear is also good for health; as they both belong to the fruit category (Nguyen, 2007;  
90 Thibaut et al., 2020).

91 Although food categorization seems to be generally performed at the level of food items, it can  
92 also occur at other scales. For example, Aschemann-Witzel et al. (2019) examined how people  
93 categorize food ingredients using a projective mapping technique. The underlying dimensions  
94 that emerged were: 1) kind of ingredients, 2) specific function of ingredients (e.g., flavoring,  
95 feeling), 3) healthiness and 4) familiarity. Recent work in neuroscience highlighted other  
96 important dimensions of food categorization. Among those dimensions the most studied one is  
97 food energy density: the energy content of visually presented foods modulates brain activation  
98 during food/nonfood categorization (Killgore et al., 2003). Food transformation attracted also a  
99 lot of research. EEG studies suggest that natural foods (e.g., apples, tomatoes, carrots) are  
100 processed differently from transformed foods (e.g., pasta, cakes, pizza) just like natural objects  
101 are processed differently from artefacts (Coricelli et al., 2019; Warrington & Shallice, 1984).  
102 Experimental data indicate that the former are more frequently described with sensory or  
103 internal biological (e.g., sweet, bitter) properties whereas the latter are more frequently

104 associated with functional (e.g., suitable for breakfast) properties (Rumiati & Foroni, 2016)  
105 which does make sense since artefacts are intentionally made to serve a given purpose, whereas  
106 natural objects exist without human intervention and intention (Lafraire et al., 2020). Along the  
107 same line, Pergola et al. (2017) report a strong association of natural food (e.g., apple) with  
108 sensory primes and a stronger association between transformed food (e.g., lasagna) and  
109 functional primes.

110 In this article we will focus on the origin (animal vs. plant) and processing degree (unprocessed  
111 vs. transformed food) dimensions. If the first dimension is mainly dichotomous -- in natural  
112 foods, proteins are of plant or animal origin -- the distinction between natural and processed  
113 food is not as clear cut, which was also noted for the distinction between natural objects and  
114 artefacts (Gelman, 1988). In the case of food, the processing dimension is probably better  
115 represented as a continuum going from totally natural (e.g., fresh fruit) to highly processed (fruit  
116 compote with preservative, added aroma, and texture agent). In contrast to natural food,  
117 processed foods have very fuzzy boundaries and do not possess an "inner essence" based on  
118 DNA to distinguish them from one another; like for example an apple is different from an orange.

119 The aim of this article was to better understand the role of origin and process in protein  
120 containing food representation. We carried out two experiments using categorization tasks of  
121 protein containing food pictures. The first experiment used a forced categorization paradigm  
122 and the second experiment a free categorization paradigm. Our first hypothesis (H1, experiment  
123 1) was that the importance of origin would depend on the degree of processing of food. Because  
124 the boundaries between natural food are sharper than the boundaries between processed foods,  
125 we expected origin to be more salient in natural foods than in processed foods. Our second  
126 hypothesis (H2, experiment 1) was that the effect of origin would also depend on the structural  
127 similarity between the foods. Based on the observation that objects belonging to the same  
128 category tend to be more similar in shape than objects belonging to different categories (Gerlach  
129 et al., 2015), we expected the effect of origin to be less important for food structurally similar  
130 than for food structurally dissimilar. Our third hypothesis (H3, experiment 2) was that the origin  
131 and process dimensions were highly activable in memory and thus spontaneously used in a free  
132 categorization paradigm. Our fourth hypothesis (H4, experiment 2) was that, based on previous  
133 work on artefact and natural categories, unprocessed foods would be associated with sensory or  
134 inner biological properties and highly processed foods with functional properties.

## 135 **2 Material**

136 To explore protein containing food representations, we used 64 pictures of different foods  
137 including meat, legumes, and cereals. While this selection is not representative of all available  
138 protein containing foods, it constitutes a workable sample which has the advantage to be  
139 manageable and wide enough to test our hypothesis. These pictures were organized in six  
140 categories (Figure 1) with three levels of processing on the continuum from natural to highly  
141 processed foods (unprocessed, slightly processed, highly processed), and two different origins  
142 (animal vs. plant). We labeled these six categories as follows: 1) unprocessed meat (UA), 2)  
143 legumes and cereals (UV), 3) processed meat (PA1, steak and sausages), 4) processed legumes  
144 and cereals (PV1, patties and sausages), 5) ready-to-eat dishes with meat (PA2, pasta and  
145 couscous box) and 6) ready-to-eat dishes without meat (PV2, veggie pasta and couscous box).  
146 Each category was represented by either eight (processed categories) or sixteen (unprocessed)  
147 pictures to ensure the generalizability of results. Overall, the number of processed and  
148 unprocessed food pictures or animal-based and plant-based food pictures was balanced.

149 The pictures were chosen to cover a large range of protein containing food. Different types of  
150 meat were presented for the unprocessed meat group, (beef, chicken, ...) with different cuts  
151 (slice, steak, filet, ...). For unprocessed plant foods, different types of legumes and cereals were  
152 presented (lentils, beans, quinoa...) in different packaging. For processed foods, we additionally  
153 manipulated the similarity between items from animal and plant origin (i.e., Similar: chopped  
154 beef steak vs. soy steak; pasta with meat vs. pasta without meat. Dissimilar: chopped beef steak  
155 vs. plant sausage; pasta with meat vs. couscous without meat). This was done to evaluate the  
156 impact of the structural similarity between animal- and plant-based processed foods in the  
157 categorization process. Pasta and couscous boxes were chosen as ready-to-eat dishes because  
158 they exist with and without meat. A series of pre-tests was carried out to make sure that the food  
159 pictures were easily identifiable either visually because the packaging was transparent or via the  
160 labels and images on the packaging. All the protein containing food pictures were presented to  
161 participants either on a computer screen (1366 pixels × 768 pixels, Experiment 1) or in the form  
162 of plastic cards (65 mm×65 mm; 307 pixels × 307 pixels, Experiment 2).

## 163 **3 Experiment 1: Effect of origin and process dimensions in a forced** 164 **extraction task**

165 Experiment 1 was designed to evaluate the relative importance of origin and processing degree  
166 in food categorization (H1 & H2). A forced extraction task was used. Triplets of pictures

167 combining protein containing food of different origin or processing degree were presented to  
168 the participants who had to indicate the odd one. The extraction task is classically used in the  
169 study of categorization processes to determine which critical dimensions are extracted as being  
170 defining of contrasting categories. The rationale behind this task is that categorization is  
171 grounded in the dimensions that distinguish categories: as a result of experience with stimuli  
172 belonging to different categories, the cognitive system discovers the dimensions that  
173 discriminate best between the categories for a given individual based on his/her representation  
174 system.

## 175 **3.1 Material and method**

### 176 **3.1.1 Participants**

177 In total 82 volunteers participated in the study; 26 males and 56 females aged from 18 to 28-  
178 year-old (mean age:  $21.54 \pm 2.16$  years). All were students from the University of Burgundy.

### 179 **3.1.2 Materials**

180 The 64 protein containing food pictures presented in Section 2 (Figure 1) were used in this  
181 study to create two equal sets of 32 pictures (Set A and Set B). Both sets included unprocessed  
182 and processed food; however, they differed in terms of processed food items. Set A contained  
183 slightly processed food from Categories 3 (processed meat) and 4 (processed legumes and  
184 cereals) and Set B highly processed food from Categories 5 (ready-to-eat dishes with meat) and  
185 6 (ready-to-eat dishes without meat). For both sets, the unprocessed food pictures came from  
186 Categories 1 (unprocessed meat) and 2 (legumes and cereals).

187 The triplets within each set were obtained by crossing the origin and process dimensions so that  
188 each triplet consisted of at least one animal-based (A) and one plant-based (V) as well as at least  
189 one processed (P) and one unprocessed (U) protein containing food picture. Crossing all  
190 possible picture categories (PA, PV, UA, UV) led to four triplet conditions: Cond. 1: PA-PV-UA;  
191 Cond. 2: PA PV-UV; Cond. 3: UA-UV-PA and Cond. 4: UA-UV-PV. In Condition 1 and 2, half of the  
192 triplets contained similar PA-PV pictures (e.g. chopped beef steak vs. soy steak) while the other  
193 half contained dissimilar PA-PV pictures (e.g., chopped beef steak vs. plant sausage).

### 194 **3.1.3 Procedure**

195 Firstly, participants completed a consent form in which the task was explained, and an  
196 information sheet to obtain general information (sex, age, level, field of study). The participants  
197 received the following instructions: "You will see three food pictures on the screen at the same  
198 time and you will have to decide which one, according to your opinion, is the odd one. There is



199 no right or wrong answer, we are interested in your personal opinion. As we will measure the  
 200 time you need to make your decision, click on the button below the picture as soon as you have  
 201 made your choice. You don't have to give any justification, so answer intuitively and without  
 202 reflection.”

203 The three pictures in a triplet were simultaneously presented in the center of a computer screen.  
 204 Half of the participants saw the triplets from Set A first, while the other half saw the triplets from  
 205 Set B first. Each participant had to evaluate successively the 32 triplets of each set with a 30  
 206 second break between the sets. The food pictures were presented to the participants, via E-  
 207 Prime (Version: 3.0.3.80, Studio Version: 3.0.3.82, Psychology Software Tools, Sharpsburg, PA,  
 208 USA).

### 209 **3.1.4 Data analysis**

210 Two dependent variables were used to test our hypotheses: Frequency of occurrence of the  
 211 underlying dimensions (origin and process) and reaction time (RT). As the results obtained for  
 212 the two variables converged, for simplicity sake, we present only the results for the frequency of  
 213 occurrence. The RT results are presented in additional material (1).

214 Data were first coded by determining the dimension participants used to select the odd item in  
 215 each triplet as shown Table 1. For example, in Condition 1 (PA-PV-UA), if PV was chosen to be  
 216 the odd one, the underlying categorization dimension would be ‘origin’ as the other pictures (PA  
 217 and UA) represent a protein containing food from animal origin. If UA was chosen by the  
 218 participant the underlying dimension was ‘process’, since it is the only unprocessed food item in  
 219 this triplet. The term ‘other’ was used to code cases in which PA was chosen neither on the basis  
 220 of the origin nor process dimension.

221 Table 1. Coding scheme for each condition and triplet.

	<b>Conditions</b>	<b>Underlying dimensions</b>
<b>Condition 1</b>	<u>PA</u> PV UA	Other
	PA <u>PV</u> UA	Origin
	PA PV <u>UA</u>	Process
<b>Condition 2</b>	<u>PA</u> PV UV	Origin
	PA <u>PV</u> UV	Other
	PA PV <u>UV</u>	Process
<b>Condition 3</b>	<u>UA</u> UV PA	Other
	UA <u>UV</u> PA	Origin
	UA UV <u>PA</u>	Process
<b>Condition 4</b>	<u>UA</u> UV PV	Origin

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UA	<u>UV</u>	PV	Other
UA	UV	<u>PV</u>	Process

---

222

223 The triplets in Conditions 1 and 2 were additionally coded to reflect the structural similarity  
 224 between the two processed protein containing foods (PA and PV). The triplets containing  
 225 similar PA-PV pictures (e.g. chopped beef steak vs. soy steak) were coded with the word  
 226 “similar” and the triplets containing dissimilar PA-PV pictures (e.g. chopped beef steak vs. plant  
 227 sausage) were coded with the word “dissimilar”.

228 Chi<sup>2</sup> tests were carried out at three levels ranging from the most general to the most specific to  
 229 evaluate: 1) the effect of type of set, 2) the effect of triplet condition, and 3) the effect of  
 230 structural similarity.

### 231 **3.2 Results**

232 A total of 5248 responses was collected. A chi-square test indicated that the dimensions “origin”,  
 233 “process” and “other” were not used equally ( $X^2 = 21.19$ ;  $p < 0.001$ ). Overall, the dimension  
 234 “origin” was the most frequently used (57.1%), followed by the dimension “process” (32.9%).  
 235 The dimension “other” was used only in 10.0% of the cases.

#### 236 ***3.2.1 Interaction between dimensions and degree of processing (H1)***

237 To check whether the dimension used by the participants to perform the task depends on the  
 238 degree of processing, we compared the results obtained for Set A including slightly processed  
 239 food with those obtained for Set B including highly processed food. We expected the frequency  
 240 of origin to be higher for Set A than for Set B. Figure 2 represents the frequency of occurrence of  
 241 the origin, process, and other dimensions as a function of the set of protein containing food  
 242 pictures. For each set, a total of 2624 responses was collected. A Chi<sup>2</sup> test shows a significant  
 243 difference between the two sets, with participants being more likely to categorize food pictures  
 244 according to origin when presented with Set A and according to process when presented with  
 245 Set B ( $X^2 = 934.76$ ,  $p < 0.001$ ). No difference was observed for the other dimension.

246 To verify if the interaction between dimension and degree of processing is modulated by the  
 247 composition of the triplets (cf Table 1), we analyzed the data separately for each condition  
 248 within each set. Figure 3 shows the frequency of occurrence of the origin, process, and other  
 249 dimensions in each condition for the two sets of protein containing food pictures. For Set A, the  
 250 triplet condition influenced globally the response of participants ( $X^2 = 930.66$ ,  $p < 0.001$ ). Origin  
 251 was significantly more frequent than process, whatever the condition ( $p < 0.001$ ). This  
 252 superiority of origin over process was significantly higher in Condition 1 and 3 (two animal

253 items) than in Condition 2 and 4 (two plant items). In Condition 4 (unprocessed animal vs.  
254 processed and unprocessed plant items), the other dimension was significantly higher than in all  
255 other conditions of Set A. For Set B, the choice of participants also changed according to the  
256 condition ( $X^2 = 693.63$ ,  $p < 0.001$ ). Origin was always significantly more frequent than process  
257 when the triplet included two unprocessed pictures (Condition 3 and 4). Inversely, process was  
258 significantly more frequent than origin when the triplets included two processed items  
259 (Condition 1 and 2).

### 260 **3.2.2 Effect of similarity (H2)**

261 Figure 4 shows the frequency of occurrence of the origin, process, and other dimensions for  
262 similar and dissimilar pictures in each condition and each set of food items. Globally, the main  
263 effect of set remained significant: The origin dimension was more frequent for Set A ( $p < 0.001$ ),  
264 whereas for Set B, it was the process dimension ( $p < 0.001$ ). Additionally, a significant effect of  
265 similarity was observed in Condition 1 for Set A ( $X^2 = 48.93$ ,  $p < 0.001$ ) and in condition 1 and 2  
266 for Set B ( $X^2 = 8.02$ ,  $p < 0.05$  and  $X^2 = 18.17$ ,  $p < 0.001$ ): the frequency of occurrence of process  
267 was higher for similar pictures and the frequency of origin for dissimilar pictures.

### 268 **3.3 Discussion**

269 This experiment suggests that the level of processing of food items has an influence on their  
270 categorization. This influence is modulated by the composition of the triplets. However, no effect  
271 of structural similarity between pictures was observed.

272 When the triplet included two **unprocessed food items**, only a few participants used the  
273 process dimension. Origin in this case was very salient, which suggests that unprocessed plant-  
274 based food and unprocessed meat are clearly two distinct food categories. To validate this  
275 interpretation, we asked an additional group of participants to rate the perceived similarity  
276 between all possible pairs of unprocessed plant-based foods and unprocessed meats in our set  
277 on a seven-point scale, going from 1 not at all similar to 7 very similar (Additional material 2). As  
278 expected, the average similarity score was very low (mean=1,39; SD=0,86). Such taxonomic food  
279 categories have been previously reported in the literature (Ross & Murphy, 1999) and seem to  
280 be well anchored in food classification system. Furthermore, they seem to be independent of  
281 context (Blake et al., 2007). Additionally, the unprocessed foods used in this study were close to  
282 natural types of categories (e.g., animal vs. plant) which are known to have sharp and objective  
283 boundaries compared to artefacts which tend to have more flexible boundaries (Lafraire et al.,  
284 2020).

285 Likewise, participants were more likely to categorize **slightly processed food** items according  
286 to origin, rather than to process. This effect was somewhat modulated by the composition of the  
287 triplets: The predominance of the origin dimension was somewhat reduced when the triplets  
288 included two plant items as opposed to two meat items. This result suggests that participants  
289 perceived a higher similarity between unprocessed and slightly processed items from animal  
290 origin than between legumes or cereals and slightly processed plant-based food. Accordingly,  
291 the perceived similarity between unprocessed and slightly processed meats (mean=4,75;  
292 SD=1,74) was significantly higher than that between unprocessed and slightly processed plant-  
293 based food (mean=2,60; SD=1,63). In agreement with this interpretation, participants took less  
294 time to indicate origin as response for the triplets including two meat items than for the triplets  
295 including two plant items. The origin dimension is thus more salient for the animal food items  
296 used in our study than for plant-based ones. This can be due to the appearance of the slightly  
297 processed plant foods which were evaluated as more similar to slightly processed animal foods  
298 (mean=2,98; SD=1,65) than to unprocessed plant foods. Thus, it seems that perceptual based  
299 information such as the form or the color of a food might play an important role in adult food  
300 categorization as was already reported by Hoek, Luning, et al. (2011) for meat and meat  
301 substitute items. Previous work suggested that the mode of presentation of food affects also  
302 children food behavior by helping them identifying the food items. For example, children judged  
303 a sliced fruit more edible than an unprocessed one (Lafraire et al., 2020). It might also be due to  
304 the fact that slightly processed meat items share more inner properties with the unprocessed  
305 item from which they originate than do slightly processed plant items.

306 In regard to the **highly processed food**, participants were more likely to use the process  
307 dimension than the origin dimension, independently of the number of animal or plant-based  
308 items in the triplet. In agreement with this observation, participants answered faster when they  
309 used the process dimension for highly processed food than the origin dimension (see additional  
310 material 1). This suggests that the process dimension is more salient in highly processed food  
311 than in slightly processed food. This difference in saliency may be due to a difference in  
312 similarity as the perceived similarity between highly processed items (mean=4,39; SD=1,95)  
313 was significantly higher than that between slightly processed items (mean=3,39; SD=1,66). Both  
314 the high similarity between highly processed items and the saliency of the process dimension  
315 might be linked to perceived energy density, as previous work showed that the energy density of  
316 food is one of the main underlying factors in the differentiation of raw and processed food items.  
317 (Froni et al., 2016; Froni & Rumiati, 2017; Greenwald et al., 1998). Participants in our  
318 experiment may have considered that pasta and couscous meal boxes have a higher energy  
319 density than unprocessed or slightly processed food. Another plausible explanation is that  
320 participants relied on other properties conferred by the process, such as distance from edibility

321 (i.e., work still required to bring the food item into an edible state; Foroni et al., 2013). Couscous  
322 and pasta boxes are complete dishes, while unprocessed or slightly processed foods should be  
323 combined with another food item to constitute a dish. Hence, the saliency of the process  
324 dimension when two ready-to-eat items were in a triplet might be driven by inference on the  
325 function attributed to highly processed food or actions they require in order to be prepared.  
326 Previous work showed that adults tend to make inferences about function when confronted with  
327 processed food whereas for unprocessed foods they tend to infer biological properties (Pergola  
328 et al., 2017). Lafraire et al. (2020) talk about “functional affordance” in resonance with Gibson,  
329 (1966) perceptual affordance, as a possible mechanism behind this effect: Highly process food  
330 items are readily perceived as being easily eatable, independently of their animal or plant origin.

## 331 **4 Experiment 2. Free sorting task and property generation**

332 The objective of Experiment 2 was to determine whether the origin and process dimensions  
333 were used spontaneously by adults when asked to categorize food items (H3) and to explore the  
334 properties attached to unprocessed, slightly and highly processed foods. Based on the results of  
335 Experiment 1, we expected a decrease of the weight of the origin dimension in the categorization  
336 process and an increase of the number of shared properties as a function of the degree of  
337 processing of the foods. More precisely, we expected unprocessed animal and plant-based food  
338 items to form very distinct categories with only a few shared properties and highly processed  
339 foods to form a single category with many shared properties regardless of their origin. We also  
340 expected unprocessed food items to be associated with sensory or inner biological properties  
341 and highly processed foods with functional properties (H4).

### 342 **4.1 Material and method**

#### 343 **4.1.1 Participants**

344 Forty participants were recruited from the Campus of the University of Burgundy, including 22  
345 women and 18 men. They were aged from 20 to 27 years (mean age:  $20.33 \pm 1.72$  years) and  
346 were mostly students from different fields (biology, human science, geoscience and agriculture).

#### 347 **4.1.2 Materials**

348 All 64 protein containing food pictures presented in Figure 1 were used in this experiment. In  
349 order to check the generalization of our results the 64 pictures were separated in two sets (Set 1  
350 and Set 2) and the same task carried out with each set. Half of the pictures of each category were  
351 randomly attributed to Set 1 and the other half to Set 2 under the constraint that 1) for PA1 and

352 PV1: two steaks and two sausages pictures and 2) for PA2 and PV2: two couscous and two pasta  
353 pictures were selected for Set 1 and Set 2. The pictures were presented to the participants in the  
354 form of plastic-coated color cards (65 mm×65 mm) identified by a random 3-digit code on the  
355 verso.

### 356 **4.1.3 Procedure**

357 The experiment was conducted individually. First, participants completed an informed consent  
358 form and a demographic form (sex, age, field of study). The sets of cards were shuffled between  
359 each participant to ensure randomness before being presented simultaneously to the participant  
360 on a white table. Then, the sorting instructions were given to participants, indicating that they  
361 could use any criteria they wanted to sort the pictures, with the exception that they should not  
362 make hedonic categories (according to their personal preferences: “I like” vs. “I do not like”). We  
363 deliberately chose to focus on non-hedonic dimensions because we were interested in accessing  
364 stable collective representations stored in semantic memory rather than *ad hoc* individual  
365 representations. There was no time limit. They were free to make as many groups as they  
366 wanted and to include as many pictures in the groups as they wanted. After participants had  
367 formed their groups, they were asked to indicate the properties that would make it possible to  
368 define these groups. They were also told that there was no time limit for answering these  
369 questions. Participants could give as many properties for each group as they wished, and no  
370 restrictive instruction was given. Half of the participants did the sorting task with Set 1 and the  
371 other half with Set 2.

### 372 **4.1.4 Data analysis**

#### 373 **Sorting data**

374 Sorting data obtained for the two sets of protein containing food pictures were analyzed  
375 separately. For each set, data were encoded in a rectangular matrix where the rows represented  
376 the pictures and the columns the participants. The groups of pictures formed by each participant  
377 were indicated in these matrices by arbitrary numbers: “1” for all pictures placed in the first  
378 group, “2” for all pictures placed in the second group and so on. The matrices were analyzed  
379 with Distatis (Abdi et al., 2007). DISTATIS is a generalization of multidimensional scaling (MDS)  
380 that takes into account individual data, by performing the calculation directly on individual  
381 distance matrices. It starts by transforming the individual sorting data into cross-product  
382 matrices as in classical MDS and evaluating the similarity between these matrices using RV  
383 coefficients. Then, it computes a compromise matrix which is the best aggregate of the individual  
384 cross-product matrices and analyses it with a Principal Component Analysis giving rise to a  
385 similarity map of the stimuli (here the Distatis positioning map). Two stimuli close together on

386 this map were often sorted together. As in classical MDS the meaning of the map dimensions is  
387 inferred from the characteristics of the stimuli the most correlated with these dimensions.

388 A bootstrap resampling technic with replacement was used to build confidence ellipses around  
389 the protein containing food pictures. Then, a hierarchical cluster analysis (HAC) using the Ward  
390 criteria and Euclidean distances was applied to the picture coordinates in the Distatis spaces.  
391 The clusters obtained for the two sets of pictures were compared to assess the stability of the  
392 data. All statistical analyses were performed using R (Version 3.5.2) for Windows with the  
393 DistatisR package (Beaton, Chin Fatt, Abdi, version 1.0.1).

#### 394 Properties

395 The terms generated for the two sets of protein containing food pictures were merged. They  
396 were lemmatized and then grouped according to their meaning. During this process, only terms  
397 corresponding to properties were kept (e.g., denominations of food items such as chicken legs  
398 were deleted). This preprocessing was carried out independently by two researchers. Once the  
399 two researchers agreed on the groupings, the frequencies of occurrence of the properties were  
400 calculated for the six protein containing food picture categories (unprocessed meat, legumes and  
401 cereals, processed meat, processed legumes and cereals, ready-to-eat dishes with meat, ready-  
402 to-eat dishes without meat). Properties used by only one of participant were not taken into  
403 account in the analyses.

404 Two analyzes were performed on the frequencies of occurrence of the properties. Firstly, for  
405 each of the six categories, a word cloud has been created. The properties best defining the  
406 categories were identified using a hypergeometrical law to compute their probability of  
407 characterizing a category with an alpha level of 5% (Lebart, Morineau, Piron, 1995). Second, a  
408 correspondence analysis (CA) was performed to visualize the distances between the six  
409 categories. Data processing and statistical analyses were performed with the statistical software  
410 SPAD®, V8.2 (Coheris, France)

## 411 **4.2 Results**

### 412 ***4.2.1 Accessibility of the origin and process dimensions in a free categorization task (H3)***

413 Figure 5 and 6 show the projections of Set 1 and Set 2 food pictures onto the first three Distatis  
414 dimensions. For both sets, the first three dimensions of Distatis explained more than 75% of the  
415 variance (85% for Set 1 and 76% for Set 2). For both sets, the first dimension (69% and 65% of  
416 variance) opposed the meat items (UA and PA1) to the legumes and cereals (UV) and ready-to-  
417 eat dishes (PV2 and PA2). The second dimension (11% and 7% of variance) opposed the  
418 legumes and cereals (UV) to the ready-to-eat dishes with and without meat (PV2 and PA2). The

419 small size of the confidence ellipses indicated a good reliability of the data reflecting a high  
420 consensus among participants for both sets. The third dimension (5% and 4 % of variance)  
421 opposed processed legumes and cereals (PV1) to other items. The HCA carried out on the  
422 projections of the food pictures onto the first three Distatis dimensions revealed a segmentation  
423 in four clusters for both sets. These clusters are identified on the Distatis maps (Figure 5 and 6).  
424 Cluster 1 included all meat items regardless of process. For both sets, this cluster projected on  
425 the negative side of the first Distatis dimension. Although the confidence intervals of the items of  
426 this cluster were small and overlapping, we can note that processed meats (PA1) were slightly  
427 different from unprocessed meats (UA). Cluster 2 consisted of legumes and cereals. Again, the  
428 confidence ellipses were rather small and overlapping within the cluster. Cluster 3 included all  
429 the ready-to-eat dishes: pasta, couscous, with and without meat. The confidence ellipses for  
430 ready-to-eat dishes with (PA2) and without meat (PV2) intersected with a small overlapping,  
431 which suggests that the presence or absence of animal protein was not a discriminating  
432 dimension for these food items. Both cluster 2 and 3 projected on the positive side of the first  
433 dimension in opposition to cluster 1. However, they were separated on the second dimension.  
434 Cluster 4 consisted of processed legumes and cereals. It was opposed to the three other clusters  
435 on the third dimension indicating that the food items included in cluster 4 were often set apart.  
436 An analysis of the raw data confirmed this observation as 13 and 12 out of the 20 participants  
437 (Set 1 and Set 2) formed a separate group with these processed legumes and cereals (PV1).

#### 438 **4.2.2 Effect of the type of categories on their associated properties (H4)**

439 Fifty-nine properties emerged after preprocessing. As was already reported by Gaillard &  
440 Urdapilleta (2011) for the same type of task, these 59 properties included biological (e.g., animal  
441 or plant origin), nutritional contents (e.g., protein, starch, fiber, fat), functional (e.g., processed  
442 vs. unprocessed, need cooking, need to be reheated, meat substitute), evaluative (e.g., not-  
443 environment friendly, barbaric, no additive, healthy, time consuming, expensive), sensory (e.g.,  
444 taste, texture). The type of properties depended on the type of foods. Some properties were  
445 preferentially associated with some food categories. For example, biological categories were  
446 more frequently used for unprocessed foods than for ready-to-eat dishes which were more  
447 frequently associated with functional and evaluative properties.

448 To have a closer look at the properties associated with the six food categories, we created a  
449 word cloud for each category. Figure 7 presents the six property clouds for each of the  
450 categories. These clouds show that the unprocessed and slightly processed meat categories (UA  
451 and PA1) were characterized by the same properties such as *meat, protein, animal origin, animal,*  
452 *animal protein, not environment friendly.* For slightly processed meat (PA1), the property  
453 *processed* was additionally displayed. By contrast, the unprocessed and slightly processed plant



454 categories (UV and PV1) were associated with very different properties. While the category  
455 “legumes and cereals” (UV) was characterized with properties such as *healthy, vegetal, fiber,*  
456 *unprocessed, starchy food, need cooking, protein, no meat,* the category “processed legumes and  
457 cereals” (PV1) was mainly represented by *meat substitute* and in second position by *for*  
458 *vegetarian, no meat* and *vegetal*. Finally, the two ready-to-eat categories (PA2 and PV2) were  
459 characterized by the same properties whatever their origin (plant or animal). Their associated  
460 properties were *fast, ready to eat dish, bad for health, additive, unreliable, practical, need to be*  
461 *reheated, “malbouffe” (junk food).*

462 A CA was performed on the food categories by properties table to visualize the distances  
463 between the categories. Figure 8 presents the first two dimensions of the CA map (79,12% of the  
464 variance). The first dimension (40.82 %) opposed unprocessed food categories (UA and UV) to  
465 highly processed one (PA2 and PV2). The second dimension (38.30 %) opposed the meat-based  
466 categories to the plant-based categories. Globally, when these two dimensions were crossed,  
467 three groups emerged. The first group was composed by highly processed items (PA2 and PV2)  
468 which were very close to each other and did not share any properties with the other groups: The  
469 properties that differentiated them from the other groups were either positive (*easy, practical,*  
470 *fast, ready to eat dish*) or negative (*bad for health, less healthy, malbouffe, additive, fatty acid,*  
471 *unreliable, less quality, tasteless*). At the opposite side, UV et PV1 categories, which were  
472 described by different properties on the word cloud, presented here on the CA map, common  
473 characteristics around healthy and vegetal properties. These common properties opposed these  
474 two categories to UA and PV2 categories which were described by properties related to non-  
475 ethics and taste. What is the more noticeable is that plant and animal-based categories (UA-PA1  
476 and UV-PV1) shared common properties such as nutritional (*protein, less fat, no additive,*  
477 *balanced*) and practical (*need cooking, not complete dish, unprocessed*) that let us think that these  
478 categories could be somewhat flexible.

### 479 **4.2.3 Discussion**

480 The first objective of Experiment 2 was to determine whether the origin and process dimensions  
481 are used spontaneously by adults when asked to categorize food items. The second objective of  
482 this experiment was to explore the properties attached to unprocessed, slightly, and highly  
483 processed food items from animal and plant origin. We expected unprocessed animal and plant  
484 food items to form very distinct categories with only a few shared properties and highly  
485 processed foods to form a single category with many shared properties regardless of their  
486 animal vs. plant origin. The results of the sorting task showed that participants based their  
487 sorting on these two dimensions but the role and preponderance of each of these dimensions  
488 depends on the type of food items.

489 For meat items, the process dimension does not seem to play an important role: slightly  
490 processed meat items (chop steaks and sausages) were frequently grouped with unprocessed  
491 meat items such as beef steaks or chicken filets and shared many properties. Both were clearly  
492 identified based on their animal origin (*meat or animal origin*) and shared biological (*protein*),  
493 functional (*need-cooking*), moral (*not-environment friendly, animal abuse, or barbaric*), and  
494 evaluative (*quality, health*) properties. Among all properties associated with these items, the  
495 most frequent one was animal origin as if this property transcended all other properties. The  
496 existence of a clear meat category separated from plant-based foods was also reported in other  
497 studies (Blake et al., 2007; Hoek, van Boekel, et al., 2011; Ross & Murphy, 1999). Only a few  
498 participants mentioned the process dimension (*processed vs. unprocessed*). The saliency of the  
499 animal-meat connection has been thoroughly discussed in the literature (see Benningstad &  
500 Kunst, 2020 for a recent review) in connection with what is called the “meat paradox”  
501 (Loughnan et al., 2010). Although they enjoy eating meat, meat eaters tend to dislike the idea of  
502 killing animals. To avoid the state of cognitive dissonance (i.e., discrepancy between what people  
503 think and what they do, Festinger, 1962) created by this paradox, people tend to dissociate meat  
504 items from their animal origin; especially people with meat-intensive diets. Yet, in the present  
505 results, as in Hoek, van Boekel, et al. (2011) the meat or animal origin was central for the  
506 categorization of protein containing food pictures yielding either positive evaluative properties  
507 linked to nutritional values or health or negative ones linked to animal welfare. This suggests the  
508 existence of an awareness of the animal origin of unprocessed or slightly processed meats  
509 among our participants. This awareness could be due to the fact that the present experiment  
510 was performed in France where cuisine plays a major role and people tend to be more aware of  
511 their food than in other industrial countries where food is less associated with pleasure. Some  
512 authors report that much of the time individuals are able to cope with contradictions arising  
513 from their eating behavior inhibiting thoughts creating the state of cognitive dissonance  
514 (Rothgerber, 2020). Meat eaters would, thus, inhibit thoughts linked to animal welfare and  
515 enhance thoughts linked to meat positive evaluations (e.g., *healthy, protein, quality, taste*). On the  
516 contrary, vegetarians promote the belief system that killing animals for food is unethical  
517 associating meat products with properties such as *animal abuse* or *barbaric*.

518 For plant items, the process dimension is more salient than for meat-based items. Although, raw  
519 and slightly processed plant-based items share numerous properties (*healthy, no-meat, plant*  
520 *origin, for vegetarian, environment friendly*) attesting that participants were aware of a common  
521 origin these items were rarely grouped together in the sorting task. Contrary to unprocessed  
522 meat items, unprocessed plant items were not associated with their origin in the first instance  
523 but with an evaluative property: *healthy*. The plant origin comes later, along with other  
524 biological properties linked to nutritional content: *protein, fiber, starchy food*. The saliency of the

525 "healthy/unhealthy" dimension was previously reported in Furst et al. (2000) study on food  
526 classification. Using deep interview these authors highlight the link between this dimension and  
527 nutrients such as "fatty foods", "things with cholesterol, "sweets/sugared/sweetened things",  
528 "starches", and "low salt/full of salt". Interestingly, our results show that the notion of health  
529 was strongly associated with plant food items. This might be attributed to the recent  
530 government dietary recommendations. Indeed, these recommendations have been the subject of  
531 numerous communications (e.g. Iriti & Varoni, 2017; Rebello et al., 2014; Rio, 2017).

532 Slightly processed plant-based items were classified as a category in itself and were clearly  
533 identified based on their function: *meat-substitute*. Contrary to a previous study by Hoek, Luning,  
534 et al. (2011), our participants did not regroup slightly processed meat and plant items despite  
535 the visual similarities between them. In our study, slightly processed plant-based items shared  
536 more properties with unprocessed plant items than with slightly processed meat. Our  
537 participants associated meat substitutes clearly with veganism (*for vegetarians*). The separation  
538 between meat and meat-like food is anchored in consumers early taxonomic learning that meat  
539 constitute a basic food category distinct from plants. According to Hoek, van Boekel, et al.  
540 (2011) "*the fact that consumers roughly divide foods into animal and plant-based foods, and learn*  
541 *repetitively from early age on about meat as a basic food category, make it a difficult starting point*  
542 *for new meat substitutes to be regarded as an alternative for meat on the plate* (p. 378)". In  
543 agreement with this statement, a recent study on the acceptance of meat substitutes (Lemken et  
544 al., 2019) showed that a cluster of consumers consider buying processed legume products only if  
545 these products are not marketed as an alternative to meat. Another cluster preferred to directly  
546 substitute meat with specific legumes rather than having highly processed products. Such a  
547 strong negative attitude towards meat substitutes might explain why perceptual similarity was  
548 not enough, in our study, for consumers to group processed meat and meat substitutes; as it was  
549 done by participants in the Hoek et al (2011) study. In the latter, food items were presented  
550 unpackaged, thus, minimizing top-down effects. Our choice of presenting packaged food items is  
551 closer to the conditions in which food purchase decisions are made and so, our results may  
552 predict better how protein containing food are categorized in real life situation. Although the  
553 main function of processed plant-based item was identified as *meat-substitute*, these items were  
554 not grouped with meat items. In line with this observation, a recent study (Elzerman et al., 2021)  
555 showed that globally meat products were perceived as more appropriate than their vegetarian  
556 equivalents in many situations. However, a vegetarian hamburger was judged as more  
557 appropriated than the normal hamburger for the situation "when I want to eat a healthy meal".  
558 The evaluation of appropriateness was nevertheless affected by frequency of consumption of  
559 meat substitute with higher appropriateness ratings for the more frequent meat-substitute

560 users. Further work on categorization of meat substitute should take this variable into  
561 consideration.

562 For ready-to-eat dishes the process dimension clearly overshadows the origin dimension. All  
563 ready-to-eat items have been grouped together even after having been isolated from  
564 unprocessed items to limit anchoring effects. In agreement, a recent dietary survey with 74470  
565 participants (Julia et al., 2018) showed that ultra-processed foods are associated with  
566 unbalanced nutritional intake. Our study also highlights that ready-to-eat dishes are clearly  
567 associated to negative health properties, but they are also highly associated to functional  
568 properties such as practicality. Our results are in the line with those of Aviles et al. (2020) which  
569 showed that convenience, liking, and health and price considerations were the most relevant  
570 aspects determining the consumption of ready-to-eat animal-based meals for Spanish and  
571 Argentine consumers. It might be possible that ready-to eat dishes, whatever their origin, and  
572 their associated functional properties are so anchored that they erase the origin dimension. For  
573 plant and animal ready-to-eat dishes, functional properties take the upper hand.

574 To sum up, Experiment 2 showed that food items used in this study are categorized in four  
575 stable categories relatively distinct. Some of the properties attached to these categories are  
576 shared by several categories and others are specific to a given category. For example, the ready-  
577 to-eat category is isolated from other categories in that it does not share properties with other  
578 categories. On the contrary, the plant and animal categories share some biological (e.g., *protein*,  
579 *balanced*, *essential*) or functional properties (e.g., *need cooking*, *unprocessed*, *not complete dish*),  
580 creating some flexibility among those categories. Unexpectedly, despite visual similarities the  
581 slightly processed meat and slightly processed plant items constitute very different categories  
582 without shared properties.

583 In our study, we used two types of categorization tasks, a forced and a free task. These two tasks  
584 are complementary and were used as a way of testing the internal validity of our results. The  
585 fact that the same dimensions (origin and process) emerged from these two tasks highlights the  
586 importance of these dimensions in the categorization process of protein containing food. One  
587 limitation of our study is that in the free sorting task we asked participants to avoid using  
588 hedonic criteria. This choice was driven by the fact that we were interested in accessing stable  
589 collective representations stored in semantic memory and not *ad hoc* individual representations.  
590 However, it is possible that this instruction led to less spontaneous responses since participants  
591 might have made a cognitive effort to avoid using hedonic criteria. Another limitation is linked to  
592 the fact that the food items we selected in this study are not representative of all protein  
593 containing food and further work would be needed to validate the generalization of our results

594 to a wider set of food items including fish, egg... Additional dimensions beside origin and process  
595 might emerged from such a wider set.

## 596 **5 Conclusion**

597 Our assumption was that items from categories sharing properties might be more  
598 interchangeable. In our results we saw that plant-based and animal-based ready-to-eat dishes  
599 share a large number of properties and thus could be a potential way of decreasing meat  
600 consumption by substituting one by the other. Properties attached to this category of food are  
601 mainly evaluative properties with both positive and negative valence. Due in part to their  
602 positive functional properties (*practical, easy, fast,...*) the consumption of ready-to-eat dishes  
603 including plant-based variants increased these last years. For example, a recent study by France  
604 Agrimer shows an 18% increase in the quantity of ready-to-eat dishes purchased by French  
605 households between 2008 and 2017 (France Agrimer, 2019). A solution to mitigate the negative  
606 image of this type of food could be to improve their nutritional properties. Launching such  
607 improved ready-to eat dishes on the market, along with nudging or labeling strategies, might  
608 gradually lead consumers to decrease their animal-based food consumption through perceptual  
609 learning. Eventually, this learning could generalize to other types of food. A remaining question  
610 is: Would it be possible to increase the flexibility of protein containing food category structure?  
611 A recent study, based on nudge theory, encouraged meat substitutes sales by placing them in  
612 pair with sensory similar meat products rather than in a separate vegetarian section  
613 (Vandenbroele et al., 2019). Such an approach could lead to an increase of the number of shared  
614 properties between meat products and their vegetarian counterparts. However, further work is  
615 needed to validate this approach and evaluate whether it has a long-term effect on category  
616 flexibility.

617

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Figure 1. Protein containing food pictures used in the two experiments.

Figure 2. Number of times a dimension was used by participants to perform the forced extraction task as a function of degree of processing (Set A: slightly processed item, Set B: highly processed item).

Figure 3. Number of times a dimension was used by participants to perform the forced extraction task as a function of condition (*i.e.*, composition of the triplets: PA-PV-UA, PA-PV-UV, UA-UV-PA, UA-UV-PV) and degree of processing (Set A: slightly processed item, Set B: highly processed item). PA: processed animal item; PV: processed plant item; UA: unprocessed animal item; UV: unprocessed plant item.

Figure 4. Number of times a dimension was used by participants to perform the forced extraction task as a function of condition (*i.e.*, composition of the triplets: PA-PV-UA, PA-PV-UV), similarity (similar and dissimilar) and degree of processing (Set A: slightly processed item, Set B: highly processed item). PA: processed animal item; PV: processed plant item; UA: unprocessed animal item; UV: unprocessed plant item.

Figure 5. DistatisR positioning maps (Dimension 1 and 2) of items with confidence ellipses (95%), Set 1 (left) and Set 2 (right). The point size is proportional to the contribution to the axes. Each picture is labelled with letters and number after underscore. The letters correspond to UA - unprocessed meat, UV - legumes and cereals, PA1 - processed meat (steak and sausages), PV1 - processed legumes and cereals (patties and sausages), PA2 - ready-to-eat dishes with meat (pasta and couscous box) and PV2 - ready-to-eat dishes without meat (pasta and couscous box). The number identify the picture (see figure 1 for correspondence).

Figure 6. DistatisR positioning maps (Dimension 1 and 3) of items with confidence ellipses (95%), Set 1 (left) and Set 2 (right). The point size is proportional to the contribution to the axes. Each picture is labelled with letters and number after underscore. The letters correspond to UA - unprocessed meat, UV - legumes and cereals, PA1 - processed meat (steak and sausages), PV1 - processed legumes and cereals (patties and sausages), PA2 - ready-to-eat dishes with meat (pasta and couscous box) and PV2 - ready-to-eat dishes without meat (pasta and couscous box). The number identify the picture (see figure 1 for correspondence).

Figure 7. Property clouds for each category. Categories with animal-based items on the left and categories with plant-based items on the right. UA - unprocessed meat, UV - legumes and cereals, PA1 - processed meat (steak and sausages), PV1 - processed legumes and cereals (patties and sausages), PA2 - ready-to-eat dishes with meat (pasta and couscous box) and PV2 - ready-to-eat dishes without meat (pasta and couscous box).

Figure 8. CA map of property generation. Categories with animal items are in red and categories with plant items are in green. The dotted lines connect the categories with the same degree of process. UA - unprocessed meat, UV - legumes and cereals, PA1 - processed meat (steak and sausages), PV1 - processed legumes and cereals (patties and sausages), PA2 - ready-to-eat dishes with meat (pasta and couscous box) and PV2 - ready-to-eat dishes without meat (pasta and couscous box).

**Category 1: UA**  
Unprocessed Meat



**Category 2: UV**  
Legumes & Cereals



**Category 3: PA1**  
Processed Meat  
(steaks & sausages)



**Category 4: PV1**  
Processed legumes & Cereals  
(patties & sausages)



**Category 5: PA2**  
Ready-to-eat dishes with meat  
(pasta-couscous box)



**Category 6: PV2**  
Ready-to-eat dishes without meat  
(pasta-couscous box)

















