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1 **IMPACT OF OLFATORY PRIMING ON FOOD INTAKE IN AN ALZHEIMER**  
2 **UNIT**

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10 *All authors have contributed to the work, agree with the presented findings. The work has not*  
11 *been published before nor is being considered for publication in another journal.*

12 **RUNNING TITLE**

13 Odor priming in an Alzheimer unit

14 **KEYWORDS**

15 Aged, 80 and over; Dementia; Alzheimer disease; Institutionalization; Priming; Nursing home;  
16 Odor; Malnutrition; Eating; Meals

17

18 **ABSTRACT**

19 Alzheimer's disease (AD) is often associated with feeding difficulties and changes in eating  
20 behavior with may lead to malnutrition. In French nursing homes, AD patients may live in  
21 special care units that better meet dementia residents' needs. However, meals are often  
22 delivered to AD patients by using meal trays coming from central kitchens. This led to the  
23 disappearance of cues that could help residents to foresee mealtimes, such as the smell of food  
24 odors. The aim of the present study was to assess the impact of odorizing the dining room of  
25 AD Units with a meat odor before lunch on subsequent food intake and eating behavior. Thirty-  
26 two residents (> 75 yo) from three AD Units were included in the study. They participated in  
27 two control lunches and two primed lunches, for which a meat odor was diffused in the dining  
28 room 15 minutes before the arrival of the meal tray (olfactory priming). Results of the first  
29 replication showed a significant effect of olfactory priming, with a 25% increase in meat and  
30 vegetable consumption compared to the control condition. Behavioral measurements also  
31 showed a significant increase of resident's interest toward the meal in the primed lunch.  
32 However, this effect was no longer observed when the priming session was replicated two  
33 weeks later with the same priming odor and the same menu. Despite further researches are  
34 needed to understand why this priming effect cannot be replicated, our experiment is one of the  
35 very first to investigate the effect of food odor priming on subsequent food intake in Alzheimer  
36 patients in a real life setting.

## 37 INTRODUCTION

38 Alzheimer's disease (AD) is often associated with feeding difficulties and changes in eating  
39 behavior which may cause a decrease in food intake [1-5]. Ikeda *et al.* [3] observed that 58% of  
40 AD patients showed at least one symptom among the following: swallowing difficulty (*e.g.*  
41 coughs or chokes when swallowing, takes a long time to swallow food or liquids), change in  
42 appetite (*e.g.* loss or increase of appetite), change in food preference (*e.g.* prefers sweet foods  
43 more than before), disorders of oral behavior (*e.g.* tends to overfill mouth, eats non-edible  
44 foodstuffs), feeding difficulties (*e.g.* eats with hands, takes a long time to eat). Distraction from  
45 eating, frequent table-leaving events and refusal to eat because of inability to recognize an  
46 object as food were other eating disorders frequently reported in AD patients living in long-  
47 term care facilities [6-8]. Finally, AD is often associated with poly medication which may  
48 contribute to decrease appetite (iatrogenic anorexia) [9, 10]. As a result, it is estimated that 30-  
49 40% of AD patients are malnourished [11, 12]. Malnutrition corresponds to a deficiency in  
50 nutritional intake, in terms of calories and/or nutrients and micronutrients. The many  
51 consequences include muscle wasting and impaired immune defenses. An elderly person with  
52 malnutrition is at risk of entering a vicious spiral: without prevention and without care,  
53 malnutrition leads to decreased mobility, an increased risk of falls or fractures, an increased  
54 vulnerability to systemic infections, which in turn contribute to loss of appetite and exacerbated  
55 malnutrition [13-15]. For AD patients, malnutrition increases the burden of cognitive and  
56 functional decline and worsen the patient's quality of life [11, 16, 17].

57 It has been previously demonstrated that exposing healthy adults to food odors may (i) increase  
58 appetite [18, 19], (ii) influence food choice [20-22] and (iii) increase food intake [23, 24].  
59 Regarding appetite, Ramaekers *et al.* [18] observed that exposure to food odors for 20 minutes  
60 increased appetite while exposure to non-food odors decreased appetite. Similarly, Zoon *et al.*  
61 [19] found that exposure to an odor signaling a specific taste (*e.g.* a beef odor) increase appetite

62 for taste-congruent food (*e.g.* beef croquette, cheese cubes and crisps). Regarding food choice,  
63 recent studies demonstrated that a non-attentively perceived pear odors increased the proportion  
64 of choices of a fruity dessert (*e.g.*, apple sauce) in adults, whereas a chocolate-croissant odor  
65 increased the proportion of choices of a fatty-sweet dessert (*e.g.* a waffle) [20, 22]. Regarding  
66 food intake, Fedoroff *et al.* [23] observed that food intake for pizza increase after exposure to  
67 the smell of pizza. However, all these studies were completed with middle-aged adult  
68 participants. To the best of knowledge, the impact of food odor on appetite and food intake in  
69 the elderly population, including elderly people with cognitive impairment, has not been yet  
70 studied.

71 In French nursing homes, AD patients may live in special care units ('Unités de Vie Protégées')  
72 that better meet dementia residents' needs, offering them a safe space adapted to their  
73 disabilities and preserved capacities. However, meals are seldom prepared within these units  
74 but rather delivered to AD patients by using meal trays coming from 'central kitchens'. This  
75 led to the disappearance of cues that could help residents to foresee mealtime, such as the sight  
76 of foods, the presence of a cooker or the smell of food odor. In fact, special care units are often  
77 overwhelmed by a disinfectant smell, even in the minutes before meals. In such a context, the  
78 present study aimed at assessing the impact of a food olfactory cue before lunch on subsequent  
79 eating behavior. Alzheimer disease can affect some forms of memory while leaving others  
80 relatively intact. One form of memory, explicit memory, is the ability to consciously and  
81 directly recall or recognize recently processed information. This type of memory is highly  
82 impaired in AD patients [25]. On the contrary, implicit memory recalls past experiences without  
83 thinking about them (unconscious recollection), which can affect thoughts and behaviors.  
84 Implicit memory is involved with the unconscious recognition of an object (*i.e.*, priming) and  
85 the correct completion of the steps in a task (*i.e.*, procedural memory). This kind of memory is  
86 assessed indirectly by measuring facilitation in performance (*i.e.*, decreased processing time or

87 increased accuracy) due to previous exposure to identical or related information. It has been  
88 consistently shown that procedural memory remains relatively preserved throughout the course  
89 of AD [26-28]. In other words, although AD patients have severe failures to consciously retrieve  
90 information from the past, these patients are usually able to access previous experiences through  
91 non-conscious memory processes.

92 The aim of the present experiment was to assess the impact of odorizing the dining room of  
93 Alzheimers' Units with a meat odor before lunch on subsequent food intake and eating behavior  
94 of the residents. We hypothesized that a non-attentional perceived food odor may trigger food-  
95 related mental representations, which in turn may stimulate appetite, willingness to eat and food  
96 intake through implicit processes (priming effect).

## 97 **MATERIAL AND METHOD**

98 AD patients (either diagnosed AD or displaying AD symptoms) living in a special care unit  
99 participated in a 'control' lunch and a 'primed' lunch, for which a meat odor was diffused in  
100 the dining room 15 minutes before the arrival of the meal tray (olfactory priming). Two  
101 measures were carried out for each participant: food intake measurement and behavioral  
102 assessment (*e.g.* willingness to eat, staying sitting at table). This procedure was replicated:  
103 participants completed a second control and primed lunch.

### 104 **Participants**

105 Three special care units (A, B, C) took part in our study. Altogether, 32 AD patients were  
106 recruited, 17 in establishment A, 9 in establishment B and 6 in establishment C (7 men and 25  
107 women; mean age: 86.8 years; age range: 75 to 98 years). Residents on a prescribed diet were  
108 not included, neither were residents with psychiatric disorders and those with an acute episode  
109 of disease at the time of the study. All the participants scored below 20 on the Mini Mental

110 State Examination (MMSE mean=7.7; range: 0 to 18) [29]. Four participants were at risk of  
111 malnutrition ( $35 > \text{albumin} \geq 40$  g/l) and 28 were malnourished ( $\text{albumin} \leq 35$  g/l). In  
112 accordance with current legislation, the protocol of the study was submitted to and approved  
113 by the ethics committee Comité de Protection des Personnes Est I (ANSM #2012-A01431-42).  
114 Residents were explained the study in simple terms, fitting with their level of understanding. If  
115 the elderly person did not manifest a refusal to participate in the study, the study was explained  
116 to his/her tutor who countersigned the consent form.

### 117 **Food products**

118 A menu composed of a starter (grated carrots), a main course (roast pork and green beans), a  
119 dairy product (cottage cheese) and a dessert (apple purée) was chosen by the dietician of the  
120 establishments to be neither disliked nor well-liked by the residents. The menu was strictly the  
121 same in the four lunches. Residents with dysphagia (n=7) were served with texture modified  
122 foods (grated carrots and pork were mixed to a pureed consistency; green beans were replaced  
123 by mashed potatoes).

### 124 **Olfactory priming**

125 The aroma “sauté de boeuf” (Scentys Fragrance©) was encapsulated and diffused in the dining  
126 room of the special care units using a large scent diffuser (Scentys4 #PSIA-J-000018 v.1.00,  
127 Scentys Fragrance©) and two small diffusers (Scentys Pocket, Scentys Fragrance©). An  
128 odourisation procedure was designed in order to: (1) obtain a homogeneous distribution of the  
129 odourant in the dining rooms; (2) obtain an intensity of the odour relatively stable during the  
130 priming phase; (3) obtain an odour intensity so that young adults would clearly notice the odour.  
131 The procedure adopted consisted in distributing in the room 90-s puffs every 30-s for the large  
132 diffuser and 30-s puffs every 30-s for the small diffusers. Odourisation started 15 min before the  
133 lunch (11h45) and ended just before serving the main course (around 12h15). Diffusers were

134 also turned on in the control condition with blank capsule to have the same background noise  
135 throughout all the lunches (diffusers make a slight purr).

## 136 **Procedure**

137 The residents took part in four lunches – two control and two primed lunches – at a rhythm of  
138 one lunch every two weeks. These meals took place at the same time, in the same room, using  
139 the same crockery and were served by the same service staff as the usual meals served in the  
140 establishments. Before the lunches, participants were free to come to the dining room and sat  
141 at their table when they want until 11:55. At this time, the service staff fetched residents who  
142 were not arrived. Lunches always started at noon. For the first helping, portion weights fitted  
143 to the weights recommended by the GEMRCN (2007) for meals served in French elderly  
144 institutions: 100 g for the grated carrots, 100 g for the meat, 150 g for the vegetables, 100 g for  
145 the cottage cheese and 100 g for the apple purée. A second helping was systematically proposed  
146 to participants who finished their plate (the weight of the second helping corresponded to one  
147 half of the weight of the first helping). Control and primed lunches were alternate; establishment  
148 A started with a control lunch; establishments B and C started with a primed lunch.

## 149 **Outcome measurements**

150 *Food intake.* Food intake was measured by weighing the plates before and after consumption  
151 (SOEHNLE scales, precision:  $\pm 1$ g). This was done for each participant and for each meal  
152 course.

153 *Behavior.* Six staff members of the hosting establishments rated participants' behavior during  
154 lunch by using an evaluation grid (Figure 1). In order to design this grid, a lunch (different from  
155 the lunches of the present study) was videotaped in a special care unit. Movies were analyzed  
156 by three experimenters (co-authors CSR, MG, SCG) to design the scales. A training session

157 gathering experimenters and staff members ensured consensual interpretation of the scales and  
158 homogeneous ratings. During the study, the staff members remained unaware of the  
159 presentation order of the conditions. They wore nose-clips before entering the special care unit  
160 until the end of the lunch to ensure blind evaluation. Each staff member rated the behavior of 3  
161 to 4 residents, the same throughout the study.

162 *Figure 1 about here*

163 *Olfactory capacities.* A non-verbal olfactory test was designed to assess participants' olfactory  
164 capacities. Participants completed 5 trials. Each trial comprised 3 vials, with only one vial  
165 containing an odorous compound among the three. Five different odorants were used – one per  
166 trial. The presentation order of the 5 trials and the presentation order of the 3 vials within each  
167 trial were randomized across participants. Odorants were chosen to be very unpleasant (Table  
168 1). Concentrations were adjusted to achieve rather high odor intensities, in order to ensure that  
169 above-threshold levels were reached. During the afternoon following the last lunch, face-to-  
170 face sessions were carried out between each participant and one experimenter. Experimenter  
171 wore nose-clips and was blind regarding the position of the odorous vials (vials were prepared  
172 and coded by another experimenter, who did not carry out the face-to-face sessions). For each  
173 trial, the experimenter was instructed to open the first vial, to put the vial under participant's  
174 nose for 5 seconds while asking him to smell it, to remove the vial, and to do so for the two  
175 other vials. Afterwards, the experimenter indicated in which of the three vials he thought the  
176 participant had perceived a smell. He based his answer taking into account both non-verbal  
177 reactions (e.g. facial mimics, breathing rhythm) and verbal reactions if any (e.g. onomatopoeia  
178 reflecting disgust).

179 *Table 1 about here*

## 180 **Data analysis**

181 The quantities consumed were converted into caloric intake according to the CIQUAL database,  
182 which gives the nutritional composition of nearly 3 000 foods available on the French market  
183 (version from 2012; <https://ciqual.anses.fr/>). Scale responses (“How does the participant react  
184 when the dish is put in front of him?” and “How does the participant react when eating the  
185 food?”) were converted into scores ranging from 0 (left anchor) to 6 (right anchor).

186 Categorical variables (*e.g.*, frequencies) were submitted to chi-square analysis by using the  
187 FREQ procedure of SAS software (SAS Institute INC., Cary, NC, USA). After checking for  
188 data normality, continuous variables (*e.g.*, caloric intake, scale score) were submitted to a three-  
189 way Analysis of Variance (ANOVA), with condition, repetition, participant as factors, and the  
190 interaction condition\*repetition. ANOVAs were performed using the General Linear Model  
191 (GLM) procedure of SAS software. Post-hoc analyses were computed for each significant  
192 factor using the LSMEANS option of the GLM procedure. Means (M) are associated with their  
193 standard errors computing in the LSMEANS analyses (SE). The threshold for significance was  
194 set at 5%.

195 Regarding the olfactory test, a score was computed for each participant by counting the number  
196 of odorous vials that were correctly found over the 5 trials (*i.e.* the number of correct answers).  
197 For a 1-out-of-3 test, the probability of having a correct answer at random is 1/3 and the  
198 probability of having a wrong answer at random is 2/3. When the test is replicated 5 times, the  
199 probability of observing  $k$  correct answers at random over the 5 trials is equal to  
200  $P = C_5^k (1/3)^k \times (2/3)^{5-k}$ . The probability of observing 1, 2, 3, 4 and 5 correct answers at random  
201 is respectively equal to 0.26, 0.27, 0.14, 0.037 and 0.004. Consequently, the probability of  
202 observing 4 to 5 correct answers at random is lower than 0.05 (the hypothesis  $H_0$  - all the  
203 answers were given at random – could be rejected for a *type I* error risk of 5%). In other words,

204 for an error risk of 5% we can conclude that participants who obtain a score equal to or higher  
205 than 4 have perceived at least one odor among the five trials.

## 206 **RESULTS**

207 *Food intake.* Table 2 depicts ANOVA results for the whole meal and for each dish (starter,  
208 meat, vegetable, dairy product, dessert). A significant repetition effect was observed for the  
209 starter, the meat and the vegetable, as well as a significant condition\*repetition interaction for  
210 the meat and an almost significant for vegetable. According to post-hoc analyses, participants  
211 consumed more meat and more vegetable in the primed session than in the control session  
212 during the first replication, but no significant difference was observed between the primed and  
213 the control session during the second replication (Figure 2). No significant interaction was  
214 observed on intake for the starter, the dairy product and the dessert (Table 2).

215 *Table 2 and Figure 2 about here*

216 *Eating behavior.* Most of the participants sat themselves down at the table before the lunch and  
217 no significant difference was observed between the meals (control 1: 81% of the participants  
218 sat themselves; primed 1: 71%; control 2: 65%, primed 2 : 85%;  $X^2=3.46$ ;  $p>0.05$ ). Regarding  
219 the percentage of participants paying attention to the meal tray before lunch, no significant  
220 difference was observed between the control and the primed meals during the first replication  
221 ( $X^2=0.35$ ;  $p>0.05$ ), neither during the second replication ( $X^2=0.16$ ;  $p>0.05$ ). However, more  
222 participants paid attention to the meal tray during the first primed lunch than during the two  
223 subsequent meals (primed 1 *versus* control 2:  $X^2=5.38$ ;  $p<0.01$ ; primed 1 *versus* primed 2:  
224  $X^2=4.26$ ;  $p<0.05$ ) (Figure 3).

225 *Figure 3 about here*

226 Regarding dish awareness, a significant condition\*repetition interaction was observed for the  
227 main dish ( $F=5.94$ ;  $p<0.01$ ). Participants paid more attention to the main dish during the first  
228 primed lunch ( $M=3.88$ ;  $SE=0.29$ ) than during the first control lunch ( $M=2.88$ ;  $SE=0.29$ ); no  
229 such difference was observed during the second replication. No significant effect was observed  
230 on the appetite score. Similarly, no difference was observed between the meals regarding the  
231 attention devoted by the participant to the service staff, whatever the dish.

232 *Olfactory capacities.* Figure 4 display the score distribution observed for the olfactory test.  
233 Eleven participants over 32 (34%) obtained a score equal or higher to 4 (*i.e.*, number of correct  
234 answers  $\geq 4$ ). When setting the threshold for significance at 5%, we can conclude that at least  
235 one answer was not given at random for these participants – in other words that they actually  
236 perceived at least one odor among the 5 trials. A significant correlation was observed between  
237 the olfactory score and the MMSE score ( $R^2=0.36$ ;  $p<0.05$ ). For the meat, the correlation  
238 between the olfactory score and the “priming” effect, namely the difference between the caloric  
239 intake of the first primed lunch *versus* the one of the first control lunch just failed to be  
240 significant (meat:  $R^2=-0.30$ ;  $p=0.10$ ). No correlation was observed for the other dishes.

241 *Figure 4 about here*

## 242 **DISCUSSION**

243 The aim of this present study was to assess the impact of an olfactory priming in AD patients  
244 before a lunch on their subsequent food intake, in special care units (‘Unité de Vie Protégée’).  
245 A specificity of Alzheimer disease is that, in this pathology, explicit memory is altered whereas  
246 implicit memory is relatively preserved [30]. Our main hypothesis was that a non-attentional  
247 perceived food odor will impact the implicit memory by activating food-related mental  
248 representations, which will stimulate appetite, willingness to eat and food intake. In fact, our

249 results highlighted that when the “sauté de boeuf” odor was diffused, participants pay more  
250 attention to the meal and increase their intake for the main dish compared to the control  
251 condition (non-odorized). Our results are in line with those of Guéguen and Petr [31] in a  
252 younger adult population. They have found that when a lavender aroma was diffused in a  
253 restaurant, this odor seemed to relax people which stay longer in the odorized area. However,  
254 this effect was no longer observed when the priming session was replicated two weeks later  
255 with the same priming odor and the same menu. Several hypotheses were considered to explain  
256 this intriguing result.

257 It could be argued that the priming effect may depend on the ability of AD participants to  
258 perceive the meat odor. To get rid of this possible limit as far as possible, the odorisation  
259 procedure was designed in order to obtain a quite strong odor intensity and a quite long exposure  
260 duration. Furthermore, an olfactory test was carried out afterwards to assess participants’  
261 olfactory capacities. Odor intensity was set up by the authors of the papers to range between  
262 medium and strong intensity, according to their expertise on odorisation procedure.  
263 Unfortunately, it was not possible to have a panel of healthy assessors coming into the dining  
264 room of the special care unit to assess odor intensity. The length of exposure duration (*i.e.*, 30  
265 minutes, between 11:45 and 12:15) was chosen because it may reflect an ecological situation –  
266 in France, it is not uncommon to smell cooking odor in a kitchen during the half-hour before a  
267 meal. On average, participants sat down at their table around 12:00, for both conditions (primed:  
268 11:99; control: 11:96;  $F=0.38$ ;  $p>0.05$ ) and both repetition (first: 11:97; second: 11:98;  $F=0.00$ ;  
269  $p>0.05$ ). However, from 11:30 to 12:00, almost all the residents were either sat down  
270 somewhere in the dining room or wandering in the large hallway that go through the dining  
271 room. Giving these conditions, it was not possible to have an exact measurement of odor  
272 exposure duration for each participant. Finally, the results of the olfactory test highlighted large  
273 inter-individual variability regarding the olfactory score, but no correlation was observed

274 between olfactory performance and the priming effect. However, as discussed further on, the  
275 olfactory test allowed to infer that ‘a participant was *able* to perceive odors’ when he obtained  
276 a score of 4 or 5 for an error risk of 5%, but it did not allow to infer that ‘a participant was *not*  
277 *able* to perceive odors’ when he obtained a score lower than 4 (*e.g.*, for participants who  
278 obtained 3 correct answers, the present test did not allow to decipher if the 3 correct answers  
279 were given at random or if the participant actually perceived an odor). As the odorisation  
280 procedure was strictly the same between the two priming sessions and as it is unlikely that  
281 participants’ olfactory capacities drastically changed between the two priming sessions, it is  
282 hardly plausible that changes in these parameters may explain the inconsistency between the  
283 results of the first and second priming repetition. However, future researches should definitively  
284 better control and assess these parameters. In particular, future experiments should better track  
285 the duration of odor exposure at an individual level. Furthermore, future researches should also  
286 consider individual factors such as dysphagia or severe malnutrition that often goes along with  
287 a severe decline in appetite, and thus may affect this impact of a priming odor on subsequent  
288 food intake.

289 Köster *et al.* [32] recently argued that in Humans, the role of implicit olfactory memory is to  
290 react immediately to unexpected odors rather than to notice well-known odors or in our  
291 everyday surroundings, olfaction being the guardian of vital functions such as breathing and  
292 food ingestion (“Misfit” Theory). Köster and Mojet [33] proposed that olfaction follows the  
293 rules “perception by exception”: odors stay in the “background” unless they are new or  
294 unexpected. In line with this theory, we can hypothesize that the perception of an unexpected  
295 meat odor activated related mental representations leading to an increase of meat intake during  
296 the first priming condition, but that the recurrence of the same odor in the same context failed  
297 to arouse olfactory memory during the second priming condition because of a habituation  
298 process. While the interval of two weeks seems to be long enough to prevent habituation, future

299 researches should consider extending this duration and assessing the impact of various odors  
300 over several priming sessions. Finally, it should be noted that to our knowledge, no other  
301 olfactory priming experiment had used a procedure involving multiple repetitions of priming.  
302 In cognitive psychology, priming is generally a “one shot” paradigm [34-37]. Beyond the  
303 specific paradigm used in the present study, future researches in cognitive psychology should  
304 investigate if a repeatable priming effect would be obtained or not from one session to another  
305 by considering various stimulus (and not only odor) and various population (and not only AD  
306 patients). This may lead to the development of a theoretical framework liable to account for the  
307 effect of learning and habituation effect through repeated priming events.

308 In the present experiment, the choice of a meat odor was done because it is often the odor of  
309 the main dish that predominates among the cooking odors in a real-life kitchen, but also because  
310 sustaining protein intake (and thus meat intake) is at key to prevent malnutrition. For young  
311 people, the selected odorant proved to be well-known and rather pleasant, but one could not  
312 rule out that this odor may have induced disgust among people who are disliking meat, and thus  
313 decrease meat consumption rather than increase it. Consequently, before providing clinical  
314 recommendations on the use of odor to promote food intake in a nursing home, future researches  
315 should carefully consider the impact of olfactory priming while taking into account individual  
316 food preference to avoid adverse effect.

317 Finally, the present experiment also provided interesting features regarding the ability of AD  
318 patients to perceive odors. As described in the literature, olfactory dysfunction is a widely  
319 admitted feature of Alzheimer’s with patients showing overt deficits in odor identification [38-  
320 40]. Smell loss can even precede cognitive symptoms by years [41, 42] and some authors have  
321 suggested the use olfactory identification tests for screening and follow-up [43-45]. However,  
322 identify an odor, that is to say find its name, is a reputedly difficult task (even for young people)  
323 and often requires the use of explicit memory that is known to be altered in Alzheimer disease

324 [46, 47]. The use of explicit identification tests may have led to an over-estimation of the  
325 olfactory decline in AD patients. In fact, odor identification performances does not only rely on  
326 the ability of the AD patient to detect an odor, but also on the ability of the AD patient to  
327 associate an odorous sensation with a verbal label [48]. Furthermore, using an identification  
328 task assumes that the name of the odor is known by the participant, namely that it was learnt  
329 during life course, which is far from being the case [46]. Finally, odor identification tasks are  
330 hardly utilizable with aphasic or almost aphasic patients, which was the case of several of our  
331 participants. If an identification task may be an interesting tool for screening Alzheimer disease  
332 at an early stage of the disease, it is not a suitable test for assessing the ability of AD patients  
333 to perceive odor at an advanced stage of the disease – which was the case of all our participants.

334 The two advantages of the olfactory test used in the present study were that it did not request  
335 any verbal answer from the AD patients and it did not represent any cognitive cost for the AD  
336 patients. Even a very simple 1-out-of-3 detection test is based on explicit memory capacities by  
337 requiring the participant to remember the smell of the 3 vials in order to decide in which one  
338 there was an odor. However, in the present test, the AD patients were just presented the 3 vials  
339 one after the other and no explicit memory capacities was solicited. The results showed that  
340 34% of the participants were able to perceive unpleasant odors. For the remaining participants  
341 (and in particular for the 37% participants for who 3 correct answers were observed), the present  
342 test did not allow to conclude if the correct answers were given at random or if the participant  
343 actually perceived an odor. The present test was a very first attempt to assess olfactory  
344 capacities in AD patients without requiring verbal answer or cognitive load from these patients,  
345 but it could of course be improved for future researches. Statistical power could be improved  
346 by increasing the number of trials. Reliability could be improved by videotaping the AD  
347 participants during the test and asking two independent observers to code the answers (instead  
348 of one in a face-to-face session in the present study). However, it may be difficult to standardize

349 the expected verbal and non-verbal reactions given the large inter-individual variability  
350 observed in the present test. For instance, one participant did not say a word during the test, but  
351 he systematically "sniffed" when he was presented an odorous vial. Another participant always  
352 said "It smell good" for all the vials (blank and odorous), but frown when he was presented an  
353 odorous vial. Some reactions were much more subtle (and even sometimes difficult to verbalize  
354 by the experimenter).

355 To conclude on the olfactory capacities, it can be assumed that Alzheimer's disease is  
356 accompanied by an increase in odor threshold. In fact, a meta-analysis conducted by Mesholam  
357 *et al.* [38] over 8 studies revealed significant higher odor threshold for AD patients compared  
358 to healthy control. However, AD patients may be still able to detect odors providing that their  
359 intensity is strong enough [49, 50]. In the present experiment, the use of a non-verbal olfactory  
360 test and quite intense odors showed that 34% of the AD participants perceived at least one odor  
361 among the 5 trials. Finally, the fact that an odor diffused in the diner room had a significant  
362 impact on food intake and behavior during the first priming session also suggests that AD  
363 patients remained somehow able to perceive the meat odor.

## 364 **CONCLUSION**

365 The present study revealed that diffusing a food odor just before a meal positively impact food  
366 intake and behavior in Alzheimer patients. However, when the experiment was replicated two  
367 weeks later in the same conditions, the effect faded away. Despite further researches are needed  
368 to understand why the priming effect cannot be replicated, this experiment is one of the very  
369 first to investigate the effect of food odor priming on subsequent food intake in Alzheimer  
370 patients in a real life setting.

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379 **CONFLICT OF INTEREST**

380 The authors have no conflict of interest to report.

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510

511

512

Table 1

513

Odorous compound used for the olfactory test

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Odorous compound	Supplier	Diluent	Concentration
Civet aroma	Cinquième Sens	Propylene glycol	200 ml/l
Goat aroma	Meilleur du Chef	-	Plain
Nuoc mam sauce	Vinawamng	-	Plain
Sulphur aroma	Cinquième Sens	Propylene glycol	200 ml/l
Petrol aroma	Cinquième Sens	-	Plain

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514

515

Table 2

516

Results of the ANOVA performed on caloric intake (ns: non significant).

Dishes	Condition	Repetition	Condition*repetition
Meal	F=0.01; ns	F=5.15; p<0.05	F=2.40; ns
Starter	F=0.00; ns	F=3.86; p=0.05	F=0.07; ns
Meat	F=0.97; ns	F=8.02; p<0.01	F=6.37; p<0.01
Vegetable	F=3.09; ns	F=3.41; p=0.06	F=3.54; p=0.06
Dairy product	F=0.03; ns	F=0.49; ns	F=0.10; ns
Dessert	F=1.61; ns	F=0.85; ns	F=0.05; ns

517

518 **Figure 1.** Evaluation grid to assess participants behavior during lunch

519

Before lunch, does the participant spontaneously sit down at the table?  
*Yes / No*

Does the participant pay attention to the meal tray upon arrival into the dining room?  
*Yes / No*

*The three following questions were rated for each dish (starter, main course, dairy product, dessert).*

Does the participant pay attention to the service staff?  
*Yes / No*

Dish awareness: does the participant pay attention to the dish when it is put in front of him?

*Few reactions*  *Many reactions*

Appetite: does the participant eat the food with appetite?

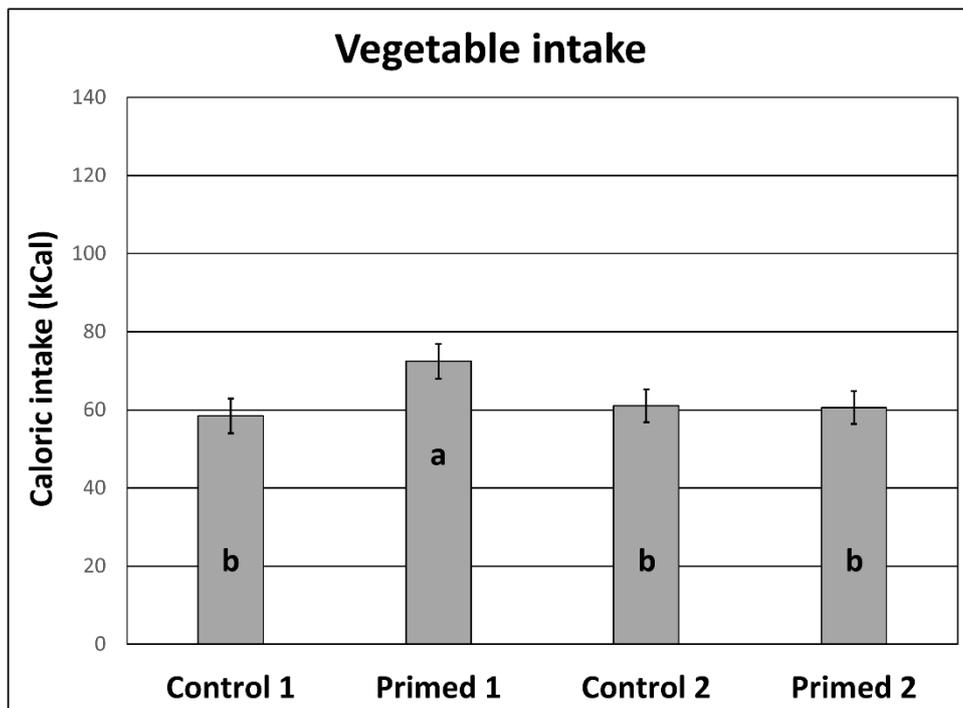
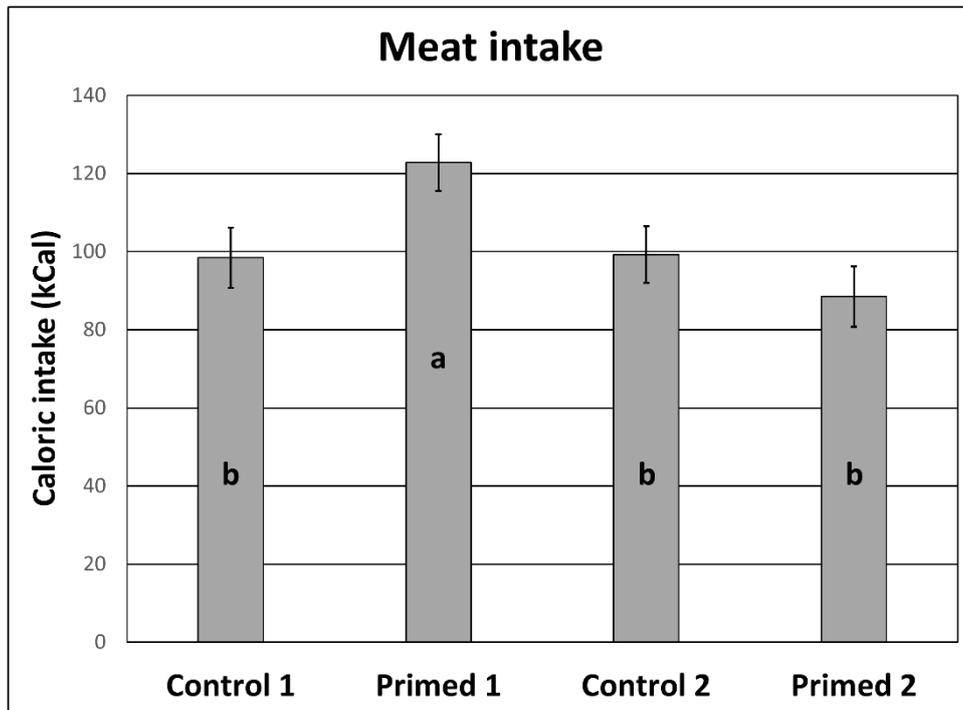
*Low appetite*  *Strong appetite*

520 **Figure 2.** Mean caloric intake ( $\pm$ SE) of meat (2.a) and vegetable (2.b) for each meal. Means  
521 with different letters (a, b) stand for significant differences ( $p < 0.05$ ; the p-values were obtained  
522 from post-hoc analyses). For each replication, the order of the control and primed meals were  
523 counterbalanced across the participants.

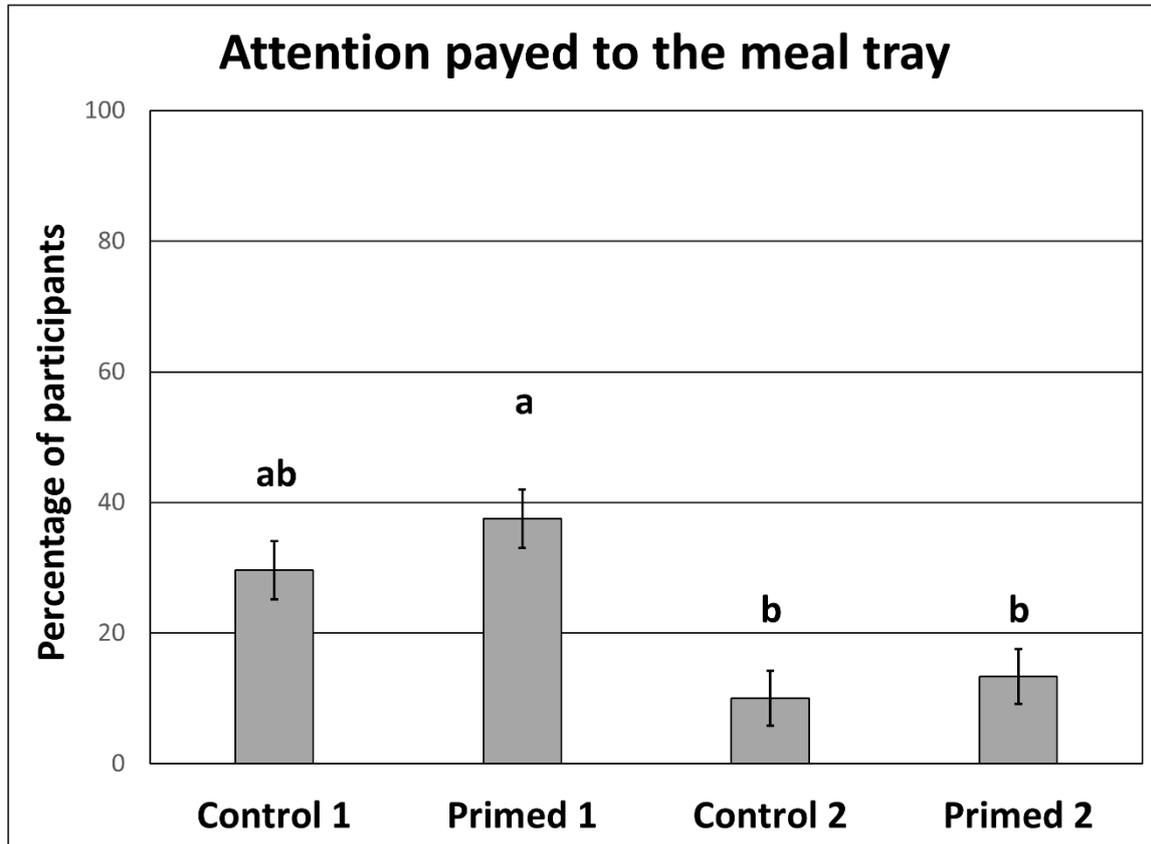
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527 **Figure 3.** Percentage of participants paying attention to the meal tray for each meal. The  
528 different letters (a, b) stand for significant differences ( $p < 0.05$ ; the p-values were obtained from  
529 chi-square analyses). For each replication, the order of the control and primed meals were  
530 counterbalanced across the participants.  
531



532 **Figure 4.** Distribution of the scores obtained at the olfactory non-verbal test.

533

