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1 The role of novelty detection in food memory

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12 **ABSTRACT**

13 Memory plays a central role in food choice. Recent studies focusing on food memory in  
14 everyday eating and drinking behaviour used a paradigm based on incidental learning of  
15 target foods and unexpected memory testing, demanding recognition of the target amongst  
16 distractors, which deviate slightly from the target. Results question the traditional view of  
17 memory as reactivation of previous experiences. Comparison of data from several  
18 experiments shows that in incidentally learned memory, distractors are rejected, while  
19 original targets are not recognised better than by chance guessing. Food memory is tuned at  
20 detecting novelty and change, rather than at recognizing a previously encountered food.

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22 **Keywords:** Incidental learning; Recognition; Signal detection theory; Memory function.

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2 25 **1. INTRODUCTION**  
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5 26 Eating, drinking and food choice are among the most frequent and most important human  
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7 27 behaviours. Although seemingly simple, they are in fact very complex behaviours in which  
8  
9 28 many physiological and psychological factors interact. Among these factors learning and  
10  
11 29 memory play a central role. Almost all food preferences, with the exception of an inborn  
12  
13 30 dislike for bitterness and an attraction to sweetness, are learned and a very substantial part of  
14  
15 31 this learning takes place at a very early age and in some cases even prenatally (Hausner et al.,  
16  
17 32 2010; Mennella et al., 2001; Schaal et al., 2002). The forms of learning involved are also  
18  
19 33 extremely diverse, varying from imprinting (Haller et al., 1999), flavour-nutrient conditioning  
20  
21 34 (Yeomans et al., 2008) and flavour-flavour conditioning (Stevenson et al., 1995) to imitation  
22  
23 35 (Birch, 1980), but these forms are almost never intentional or explicit and memory for food is  
24  
25 36 also to a very large extent implicit (for a review, see Köster and Mojet, 2007a, 2007b). Most  
26  
27 37 of us cannot describe the food we eat in any detail, but we are usually very keen in noticing  
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29 38 changes in its flavour or texture. Odour memory is more acute in detecting off-odours than  
30  
31 39 visual memory in detecting off-colours (Møller et al., 2009) and people may spend a long  
32  
33 40 time finding the 10 differences between two similar pictures in visual puzzles, but will usually  
34  
35 41 immediately notice the slightest differences in the odour, flavour and texture (mouthfeel) of  
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37 42 foods, although they can not describe them. Olfaction and touch are also the two senses that  
38  
39 43 are subject to complete adaptation. This means that the absolute sensitivity to a continuous  
40  
41 44 stimulus is completely lost, but that the sensitivity to new or stronger stimuli remains and may  
42  
43 45 even become more acute (Mojet et al., 2003). Thus, an incidentally learned implicit memory  
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45 46 that differs from verbal memory and memory for visual information seems to be functional in  
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47 47 eating and drinking behaviour. Strangely enough, the existence of an area of behaviour that  
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48 through its special characteristics seems to be the ideal terrain to study the functioning of  
49 incidental learning and implicit behaviour, has escaped the attention of most memory  
50 psychologists, who were either involved in verbal learning and memory or studied odour  
51 memory in the same way as verbal or object memory, devoting much attention to  
52 identification (Cain et al., 1998; Rabin and Cain, 1984). Nevertheless, over the last few years  
53 several groups of researchers have started to study the role of memory in eating and drinking  
54 in a different way. Presentation of some of their main results to other psychologists is the  
55 main object of this paper. In presenting it, two points should be made clear:

56 1) All authors (the same as the present authors) wanted to study the function of memory in a  
57 way that avoided experimental artefacts and guaranteed external ecological validity as much  
58 as possible. They were concerned with the reductionism of much laboratory research which  
59 threatens to be non representative of the functioning of the studied phenomena in real life. A  
60 new paradigm for incidental learning under normal eating circumstances was developed to  
61 this purpose.

62 2) The present paper deals only with one of the many forms of learning involved in food  
63 memory and is basically concerned with the question: “What sensory information is retained  
64 spontaneously in a normal eating situation and how is it retained?” The main concern is  
65 therefore to investigate the generality of the functioning of incidentally learned food memory  
66 throughout a number of different experimental settings, varying not only in using subjects of  
67 different age, gender and eating culture, but also in such experimental factors as the duration  
68 of the retention interval and the target/distractor ratio in the recognition tests. The invariance  
69 of certain memory features over such very diverse experimental circumstances is therefore  
70 considered to be the most important outcome of the paper. It not only shows the robustness of  
71 these features, but also questions the generality of certain methodological viewpoints in  
72 memory research.

73 A number of studies (Laureati et al., 2008; Mojet and Köster, 2002; Mojet and Köster, 2005;  
74 Møller et al., 2007; Sulmont-Rossé et al., 2008) investigated food memory with a new  
75 paradigm. In all of the experiments the subjects were invited to have a breakfast or a meal in  
76 the laboratory under a false pretence. Depending on the studies, the subjects were informed  
77 that they would be offered a meal to study their post-meal hunger feelings or that they would  
78 be offered a meal as a break between experiments that “took long or took place at awkward  
79 times” (e.g. before and after lunch time). After the meal which contained one or more “target”  
80 foods or drinks they returned to their own activities. No special attention was given to the  
81 hidden targets and memory was never mentioned. Only when the participants later came back  
82 for a second session, it became clear to them that they were to be tested on their memory for  
83 some of the food items they had eaten during that first meal. They received samples of the  
84 targets and distractors that had been made by varying the intensity of one of the sensory  
85 characteristics of the food (e.g. sweetness or viscosity) by small amounts or by varying the  
86 nature of the sensory characteristics of the food slightly (e.g. by adding a small amount of a  
87 new aroma component). Debriefing before the second session showed that none of the  
88 participants had guessed the true purpose of the experiment. In this way the artificiality of  
89 eating in a laboratory situation was circumvented and an unintentional learning situation was  
90 created that was comparable to a normal meal.

91 This paradigm differs from classic recognition experiments on olfactory and taste memory  
92 (Herz and Engen, 1996; Larsson, 1997) in several respects.

93 Firstly, in the learning phase of classic experiments clearly different stimuli are presented out  
94 of context and must later be recognised amongst other clearly distinct new stimuli. In the new  
95 memory paradigm, the targets are inconspicuous, since they are not presented out of context  
96 as individual items, but embedded in a natural meal setting.

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97 Secondly, the number of target foods used is below the number of stimuli used in classic  
98 recognition experiments. In odour recognition tests, this number varies from 10 to 48 (Engen  
99 and Ross, 1973; Lawless and Cain, 1975; Lehrner, 1993; Lyman and McDaniel, 1990;  
100 Murphy et al., 1991). To avoid satiety effects, in the present experiment at most 3 targets are  
101 learned, and recognition series contain maximally 12 samples.

102 Thirdly, the distractors differed only slightly from the target by a just-noticeable (perceptual  
103 discrimination in 50 % of the cases) intensity variation of one of their characteristics (e.g.  
104 sweetness, viscosity or crispiness) or by the addition of small amounts of a different  
105 ingredient (e.g. a tinge of some flavour) that left the overall sensory impression of the target  
106 intact. This was checked through preliminary experiments run with participants different from  
107 those who took part in the main study. Thus, all distractors still belonged to the same product  
108 space as the targets (e.g. all distractors of orange juice would still be identified as orange  
109 juice). As a result verbal memory by stimulus name could not play a role in the recognition  
110 test of the new paradigm, whereas in the classical recognition experiments with its very  
111 different distractors, it always mingles with the purely sensory based memory, even when  
112 uncommon odours or flavours are used for which people may create their own names. Finally,  
113 in the classic view, learning involves formation of mental representations of the learned items.  
114 Memory and recognition are based on storage and retrieval of these representations. The new  
115 paradigm makes no pre-conceived assumptions about memory. It simply observes peoples'  
116 reactions to slightly altered or the same foods as they have eaten previously in a meal without  
117 paying special attention to the food and without any intent to memorise it.

118 This paper presents a systematic and homogeneous analysis of the merged data from 6 studies  
119 (see table 1) with the new paradigm, in order to extract some 'general characteristics' of food  
120 memory. In all of these incidental learning studies, memory seemed to be based on correct

121 rejection of distractor samples rather than on correct recognition of the target. This suggests  
122 that participants use detection of novelty or change, rather than recollection and recognition of  
123 earlier experienced and encoded sensory stimulus patterns. In the experiments presented here,  
124 this hypothesis was tested in a variety of experimental conditions, to see whether it would  
125 keep up under different circumstances and to what extent it would be influenced by factors  
126 like gender, age and variation of experimental variables, such as the nature of the difference  
127 between targets and distractors and the signal probability in the memory tests. It is hoped that  
128 the overview of the results given here may contribute to the understanding of the actual  
129 functioning of memory in the lower senses and in incidentally learned behaviours and that it  
130 may stimulate research along the same lines in other sensory areas such as kinaesthesia,  
131 touch, audition and vision.

## 132 2. MATERIAL AND METHODS

### 133 2.1. Data sets

134 Table 1 summarizes the main characteristics of the six studies. All six studies investigated  
135 food memory by using the new paradigm described in the introduction.

#### 136 **Table 1 about here**

137 The data of 397 participants are included. In most studies, the men/women ratio was almost  
138 balanced. Age varied from 17 to 84. In studies S3, S4 and S5, participants were recruited  
139 among two discrete age groups. Different subjects were used in all experiments. Once they  
140 had taken part in the memory experiment they were never asked to participate in memory  
141 experiments again, unless only intentional learning and memory were involved. In all studies  
142 but S3, participants were led to believe that they took part in a study on hunger feelings. In



143 S3, during an interval in another long experiment participants were offered new soups as a  
144 snack and were casually asked their opinion about them. Since in all studies but S3,  
145 participants were led to believe that they took part in a study on hunger feelings, they were  
146 told to eat the complete amount served, under the pretence it had been standardized on energy  
147 content. In S3, participants were asked to eat the total amount of soup in order to be able to  
148 give their global appreciation of the soups after the lunch. Data from participants who did not  
149 eat the whole portion of each target food were excluded from the study. Depending on the  
150 study, participants were exposed to respectively 1 (S5), 2 (S3, S4) or even 3 (S1, S2) target  
151 foods. In S6, participants were exposed to two target custards in two different learning meals.  
152 In order to be able to separate the effect of episodic learning from everyday familiarity, the  
153 target stimuli always deviated somewhat from the regular market products.

#### 154 *Memory test*

155 After 8 hrs, 24 hrs or 1 week, depending on the study, participants came back for an  
156 unexpected test session. They received recognition series including targets (same as the foods  
157 in the learning phase) and distractors, prepared either by varying the concentration of one  
158 ingredient in the target (quantitative variation – S1, S2, S4, S5), or by adding a new flavour  
159 the target (qualitative variation – S3, S6). All distractors were selected in a preliminary  
160 experiment to be noticeably, but not too obviously, different from the target. In S1, S4 and S5,  
161 the Just Noticeable Difference (JND), *i.e.* the smallest difference perceived by 50% of the  
162 population, was estimated for each compound and for each food model (see Köster et al.,  
163 2004, for an exhaustive account of this procedure). The range of the difference between the  
164 targets and the distractors was -2 JND to +2 JND. In S2, the distribution of the targets and the  
165 descriptors in the sensory space was checked by a sensory panel trained in quantitative  
166 descriptive analysis (QDA). In S6 & S3, the perceptual distances between distractors and  
167 targets were checked and matched through similarity tests. Depending on the study,

168 recognition series included 4-12 samples with target/distractor ratios varying from 1:1 to 1:3.  
169 If several foods were involved, memory for each food was tested with a separate recognition  
170 series. Participants indicated whether each sample was the same as or different from the one  
171 consumed during the learning phase. In all studies but S3, participants also indicated their  
172 certainty about their decision (confidence rating). Finally, in all studies but S4, participants  
173 rated their liking for each target and distractor, using a separate set of newly coded stimuli.

## 174 2.2. Data analysis

175 Two indices, derived from Signal Detection Theory (Macmillan and Creelman, 2005), but  
176 adapted to the needs of experiments with low numbers of stimuli, a recognition index  
177 comparable to  $d'$  and a bias index similar to  $C$ , were used. Although the indices  $d'$  and  $C$ ,  
178 which require probit transformation of the response proportions, are most widely used, they  
179 are less apt for use with small sets of stimuli in which proportions of 0 and 1 occur frequently.  
180 Therefore an empirical logit transformation (Cox, 1970), was used to deal with extreme  
181 proportions:

$$182 \text{ Recognition index} = \log [(N_H+0.5)/(N_M+0.5)] - \log [(N_{FA}+0.5)/(N_{CR}+0.5)]$$

$$183 \text{ Bias index} = - \log [(N_H+N_{FA}+0.5)/(N_M+N_{CR}+0.5)]$$

184 with  $N_H$ ,  $N_M$ ,  $N_{FA}$  and  $N_{CR}$  respectively corresponding to the numbers of hits, misses, false  
185 alarms and correct rejections.

186 With regard to memory strength, a recognition index higher than zero means that participants  
187 answered more often “same” for the target samples than for the distractor samples, i.e. that a  
188 memory effect occurred. With regard to response bias, a bias higher than zero means that  
189 participants had a bias to answer “different” when uncertain about to which class of items  
190 stimuli belong. As stated by Signal Detection Theory and similarly to  $d'$  and  $C$ , these two

191 indices are independent: one could recognize the targets and, nevertheless has a bias to answer  
192 “different”.

193 These indices were calculated for each participant and for each of the 12 recognition series  
194 (each corresponding to a food in a given study). Confidence and liking ratings were converted  
195 into scores ranging from 0 (not sure/ disliked) to 10 (sure/liked).

196 Statistical analyses were conducted using the SAS/STAT® version 9.1 statistical software  
197 package (SAS Institute Inc., Cary, USA). All analyses were performed with the MIXED  
198 procedure of SAS. Post-hoc comparisons of means were computed for each significant factor  
199 by using the *lsmeans* option of the MIXED procedure. All results reported are significant at  
200 the  $P < 0.05$  level. Student statistics were used to assess whether indices were significantly  
201 different from zero. Confidence intervals derived from linear mixed models are reported.

### 202 3. RESULTS

#### 203 3.1. Food memory performance: an overview

##### 204 3.1.1. Recognition performance

205 Figure 1 depicts the average proportions of hits, misses, false alarms and correct rejections  
206 over all recognition series, resulting in a significantly higher than zero recognition index  
207 ( $M=0.59$ ,  $SE=0.05$ ,  $t_{782}=11.51$ ,  $p < 0.001$ ) and a positive bias index, ( $M=0.69$ ,  $SE=0.03$ ,  
208  $t_{782}=21.52$ ,  $p < 0.001$ ). Thus, incidental learning and memory effects occur when participants  
209 are confronted with a food, but as the figure shows, this memory effect depends more on  
210 distractor rejection than on target recognition. In fact, none of the 12 recognition series shows  
211 a proportion of hits significantly larger than would be obtained by chance guessing, whereas  
212 the proportion of correct rejections is always significantly better than chance guessing.

213 **FIGURE 1 about here**

214 The large number of observations allows reliable determination of hit and false alarm  
215 proportions for each position in the recognition series (Figure 2) and makes it possible to  
216 check whether target recognition increases over the recognition sequence. Both proportions  
217 increased, indicating that participants' bias to answer "different" decreases as they went along  
218 the series. However, the hit proportion never rose above 50% and false alarm proportions  
219 remained lower on all positions.

220 **FIGURE 2 about here**

### 221 *3.1.2. Confidence rating*

222 An analysis on confidence ratings with response category (hit, miss, false alarm and correct  
223 rejection) as a fixed factor and recognition series as random, revealed a significant effect of  
224 response category ( $F_{3,27}=19.34; p<.001$ ). A post-hoc comparison showed correct rejections to  
225 receive the highest ( $M=6.91; SE=0.43$ ) and hits and false alarms the lowest confidence scores,  
226 with misses intermediate and differing significantly from all 3 others (hit:  $M=5.01; SE=0.44$ ;  
227 false alarms:  $M=5.11; SE=0.44$ ; misses:  $M=5.71; SE=0.43$ ). Participants showed more  
228 confidence in their "different" than in their "same" responses, and much more in their correct  
229 rejections than in their hits.

### 230 *3.1.3. Liking rating*

231 An analysis on liking scores with response category (hit, miss, false alarm and correct  
232 rejection) as a fixed factor and recognition series as random revealed a significant effect of  
233 response category ( $F_{3,27}=4.19; p<.01$ ). Post-hoc comparison showed that correct rejections  
234 were associated with lower liking scores ( $M=3.88; SE=0.29$ ) than the three other response

235 categories (misses:  $M=4.58$ ;  $SE=0.30$ ; false alarms:  $M=4.68$ ;  $SE=0.30$ ; hits:  $M=4.93$ ;  
236  $SE=0.30$ ).

### 237 **3.2. Effect of participant-dependent factors on memory performance**

#### 238 **3.2.1. Effect of gender and age**

239 An analysis with gender as a fixed factor and recognition series as random, showed that  
240 gender had no effect on recognition ( $F_{1,11}=0.01$ ;  $p>.05$ ) but a significant effect on bias  
241 ( $F_{1,11}=13.36$ ;  $p<.01$ ). Women ( $M=0.80$ ;  $SE=0.09$ ;  $t_{11}=8.67$ ;  $p<.001$ ) had a significantly higher  
242 bias index than men ( $M=0.58$ ;  $SE=0.09$ ;  $t_{11}=6.18$ ;  $p<.001$ ).

243 The effect of age on memory performance was assessed in data from S3, S4 and S5 which  
244 included groups of less than 50 year old and of over 50 year old adults. Recognition and bias  
245 indices were analysed with age group as a fixed factor and recognition series as random.  
246 There was no effect of age on recognition ( $F_{1,4}=0.11$ ;  $p>.05$ ) or on bias ( $F_{1,4}=1.32$ ;  $p>.05$ ).

### 247 **3.3. Effect of experimental variables on memory performance**

248 A separate analysis was performed for each factor, since the levels of these factors were not  
249 systematically crossed between the recognition series.

#### 250 **3.3.1. Target/distractor ratio**

251 According to signal detection theory (Macmillan and Creelman, 2005), a target/distractor  
252 ratio of 1:1 is ideal, because other ratios, when known to or detected by the participants, may  
253 influence their response bias. In the present studies, the ratio is often unbalanced in favour of  
254 a higher number of (different) distractors. In classic recognition tests, participants are exposed  
255 to many different targets during learning, and receive each target once in the recognition

256 series. In the present paradigm, participants are exposed to only one target per food while  
257 learning. To reach a 1:1 target distractor ratio, it would be necessary to present this target as  
258 many times as there are distractors. This might lead to unwanted incidental learning effects,  
259 since only the target would appear repeatedly. Allowing other ratios reduces this risk. It was  
260 checked whether the unbalanced ratios had an impact on the responses, although participants  
261 were unaware of the signal probability and the short test series prevented implicit learning  
262 about the ratio. The ratio-effect was significant for recognition ( $F_{3,40}=12.86$ ;  $p<.001$ ), but not  
263 for bias ( $F_{3,40}=1.30$ ;  $p>.05$ ), indicating that there was no influence of the unbalanced ratios  
264 upon response behaviour.

### 265 *3.3.2. Nature of the difference between targets and distractors*

266 Analyses showed a significant effect of variation (quantitative–qualitative) on recognition  
267 ( $F_{1,43}=29.81$ ;  $p<.001$ ), but not on bias ( $F_{1,43}=0.04$ ;  $p>.05$ ). The over all significant recognition  
268 indices were higher for qualitative ( $M=1.25$ ;  $SE=0.13$ ;  $t_{43}=9.45$ ;  $p<.001$ ) than for quantitative  
269 variations ( $M=0.46$ ;  $SE=0.06$ ;  $t_{43}=7.96$ ;  $p<.001$ ). Obviously, new features stand out more  
270 clearly as novel than intensity variations.

## 271 **4. DISCUSSION**

272 Before discussing the main results of the experiments and their contribution to an  
273 understanding of the role and functioning of incidentally learned memory in eating and  
274 drinking behaviour and to memory theory in general, the effects of some of the variables that  
275 are supposed to influence memory performance will be considered shortly. Despite the fact  
276 that results may be biased because of the limited sample of studies (up to our knowledge, we  
277 gathered all the studies that used the paradigm proposed by Köster), the present paper is the

278 first to pool, in a global data set, the results of six independent studies on food memory based  
279 on the same innovative paradigm. Although this allows drawing reliable conclusions about  
280 the general food memory processes, discussions about the effect of the variables *age*,  
281 *target/distractor ratio* and *nature of the food variations* should be considered with caution as  
282 the level of these factors were not systematically crossed between the recognition series.

#### 283 **4.1. Gender differences**

284 In classic recognition experiments using well-known odours, women often show better odour  
285 memory than men (Lehrner, 1993). However, such a gender effect disappeared when verbal  
286 capacity was controlled for (Larsson et al., 2003; Monnery-Patris et al., 2009). As stated by  
287 Larsson et al. (2003), the finding that the observed female superiority in odour recognition  
288 disappeared when verbal proficiency was controlled for suggests that a gender difference in  
289 recognition memory is mediated by female superiority in verbal processing. With the  
290 incidental learning paradigm used here, this advantage is lost, since the basic flavour remains  
291 the same and therefore semantic information is not helpful. This is corroborated by Møller et  
292 al. (2004) who found no significant gender difference when using unidentifiable odours in  
293 classic recognition.

#### 294 **4.2. Age differences**

295 No significant effect of age on memory strength is observed. This result is in agreement with  
296 findings of studies on incidental learning and memory in other areas. In fact, there is a wealth  
297 of evidence that learning ability declines with age, but almost all of the studies that show such  
298 deterioration deal with explicit intentional learning and memory. All the recognition series  
299 included in our dataset were based on incidental learning, which is the kind of learning

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300 occurring in daily life. However, one of the studies, namely Møller et al. (2007), made a  
301 comparison between incidental and intentional learning in food memory. With intentional  
302 learning, the young showed better memory performance, whereas with incidental learning the  
303 elderly were as good as the young. Other studies have consistently shown that elderly people  
304 have a well preserved implicit learning ability (see Hoyer and Lincourt, 1998).

### 305 **4.3. Influences of experimental design**

#### 306 ***4.3.1. Signal probability or target/distractor ratio***

307 Signal probability, *i.e.* the ratio between targets and distractors, seems to have no impact on  
308 response bias. This might mean that novelty detection is a biologically based mechanism that  
309 overrules the more subtle mechanisms involved in signal detection decision theory. It remains  
310 open to discussion however, whether this is due to the fact that feelings of novelty seem to  
311 play a more important role than target detection. After all, participants were unaware of the  
312 signal probability and although they changed their response bias over time (fig. 2) this seemed  
313 unrelated to the target/distractor ratio. Experiments with varied signal probabilities using the  
314 same food stimuli should provide clarity.

#### 315 ***4.3.2. Nature of the food variation***

316 The finding that qualitative changes are more effective in being correctly rejected than  
317 quantitative changes might indicate that memory is tuned at detecting possibly dangerous  
318 changes. Conclusions should be drawn with caution, however. Although precautions were  
319 taken to have small and perceptually equivalent differences between targets and distractors, it  
320 is not certain that the differences were completely comparable over all studies.



321 **4.4. Nature of the learning processes involved**

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3 322 Incidental learning occurs during eating allowing participants to distinguish the eaten food  
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6 323 from new samples even if these are only slight variations of the initial food. On average,  
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8 324 participants do not better than chance guessing when confronted with the actual target stimuli,  
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10 325 and their memory performance depends mainly on the correct rejection of the stimuli they  
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12 326 have not had before. The fact that this result emerges from data collected in diverse  
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14 327 experiments with different experimental conditions, different types of food and participants  
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16 328 from different cultures strengthens the generality and validity of the results. Although this  
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18 329 phenomenon seems robust, one cannot conclude on the basis of this knowledge alone that  
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20 330 food memory is tuned at detecting novelty or change, rather than at recollection of previous  
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22 331 experiences. The low proportion of hits and the high proportion of correct rejections might be  
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24 332 due to response bias tuned to answer “different”. Here, the signal detection theory cannot  
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26 333 provide the answer. The idea, that novelty detection is indeed the predominant mechanism in  
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28 334 incidentally learned memory, is supported by the fact that participants are more certain about  
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30 335 their “different” responses (especially correct rejections) than about their “same” responses,  
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32 336 and by “same-different” reaction time experiments showing that in olfaction, making  
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34 337 difference decisions is much faster ( $\pm 200$ ms) than making same decisions (de Wijk, 1989),  
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36 338 whereas in vision same decisions are usually faster ( $\pm 50$ ms) than different decisions (Luce,  
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38 339 1986; Posner, 1986). Köster et al. (In preparation), confirmed these differences between  
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40 340 olfaction and vision, using a same-different paradigm with odour stimuli as different as  
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42 341 aniseed, soap, and curry. Results showed that the reaction times to “different” responses were  
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44 342 about 300 ms shorter than those to the “same” responses, whereas the same subjects  
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46 343 responded “same” 50 ms faster than “different” when visual presentations of the odour names  
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48 344 were used. All this, plus the fact that qualitative changes (introducing possibly dangerous new  
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345 aspects) were better detected than mere quantitative changes in already present features,  
346 corroborate the idea that “feelings of not knowing” play the decisive role in this type of  
347 memory. Thus, odour and flavour memory seem to have the characteristics of an efficient  
348 warning system that immediately reacts to novel information.

349 Neurophysiological evidence for a memory system based on novelty detection has recently  
350 been gathered. Two types of novelty detection, context novelty and feature or stimulus  
351 novelty, are described. The first refers to occurrence of an event out of context, the second  
352 one to occurrence of stimulus unfamiliarity (*i.e.*, with changed features as in the present  
353 distractors). These forms of novelty detection rely on different neural processes (Matsumoto  
354 et al., 2007). Daselaar et al. (2006a) showed that the medial temporal lobe can detect objective  
355 differences between old and new items that are not accessible to consciousness.

356 Furthermore, Daselaar et al. (2006b) found a triple dissociation in the medial temporal lobes,  
357 separating memory for past events into recollection, familiarity and novelty. According to  
358 them, the posterior half of the hippocampus deals with recollection, the posterior  
359 parahippocampal gyrus with familiarity, whereas novelty is associated with the anterior half  
360 of the hippocampus and with rhinal regions. Multiple regression analyses showed that  
361 recollection, familiarity and novelty made important and independent contributions to  
362 recognition memory performance.

363 All these authors stress that effective orienting towards novel stimuli is important for survival.  
364 This may be why novel stimuli with ‘emotional’ value, like odours or deviant specimens of  
365 familiar foods as used here, are efficient in capturing attention.

366 If novelty detection has survival value, it need not surprise that it seems to play a dominant  
367 role in the “near” senses (olfaction, taste and texture perception) that are involved in vital  
368 activities such as breathing and food ingestion. In these senses, potentially dangerous stimuli  
369 are already in contact with the body at the moment of detection, and only one type of

1 370 immediate reaction (fleeing for odour; spitting out for flavour) is needed to avoid serious  
2 371 harm by inhalation or ingestion. In these cases, there is no time and no need for identification.  
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4 372 For “far” senses (vision or audition) identification is useful, and more time to identify is  
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7 373 usually available. Different dangers may demand different reaction patterns (stepping aside,  
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9 374 fighting, submission, etc.).  
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11 375 Furthermore, rejection seems to be linked to the hedonic dimension of the food, suggesting  
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13 376 that liking acts as an indicator of food safety. At the same time liking seems not related to  
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15 377 target food recollection, since hit stimuli are not more liked than those that lead to false  
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17 378 alarms and misses. This is precisely what one would expect in a memory system with a  
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19 379 primary warning function that relies on danger detection and not on reviving earlier  
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21 380 experiences.  
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## 28 381 **5. CONCLUSION**

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31 382 In conclusion, incidental memory for food seems mainly involved in safeguarding our intake  
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33 383 and not in the recollection of previous experiences. This does not mean that recollection does  
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35 384 not play a role at all. It is used in conversations about previous eating experiences and  
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37 385 probably also in most food buying decisions, but in everyday eating and drinking behaviour  
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39 386 without such explicit attention, memory mechanisms like novelty and change detection  
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41 387 prevail. The fact that incidental learning in eating and drinking behaviour is probably the  
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43 388 oldest and even prenatal form of learning to be encountered in humans and that it is closely  
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45 389 linked to a vital survival function makes it a unique example for the study of the function of  
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47 390 non-verbal learning and memory.  
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486 Table 1

487 Overview of the studies included in the present paper.

N°	Study	Food	Nature of the variations between target and distractors	Participants			Recognition series		
				n <sup>1</sup>	Age <sup>2</sup>	M:W <sup>3</sup>	RI <sup>4</sup>	n <sup>5</sup>	T:D <sup>6</sup>
S1	Köster <i>et al.</i> , 2004	Orange juice Cream cheese Yoghurt	Sweetness, bitterness Sourness, bitterness Sweetness, sourness	41	17-35	1:1	24h	12 12 12	1:2 1:2 1:2
S2	Mojet & Köster, 2005	Multi-fruit juice Biscuits Yoghurt	Thickness Fattiness, crispiness Fattiness, thickness	76	19-60	4:5	8h	8 8 8	1:1 1:1 1:1
S3	Møller <i>et al.</i> , 2007	Grits soup Cheese cream soup	Flavour quality Flavour quality	38	21-34 54-75	2:1	24h	10 10	2:3 2:3
S4	Sulmont-Rossé <i>et al.</i> , 2008	Orange juice Dairy product	Sourness, flavour intensity Sweetness, flavour intensity	114	18-34 55-84	7:10	24h	12 12	1:1 1:1
S5	Laureati <i>et al.</i> , 2008	Custard	Sweetness, thickness, flavour quality	84	18-41 60-83	4:5	24h	12	1:3
S6	Morin-Audebrand <i>et al.</i> , 2006	Custard	Flavour quality	44	19-30	1:1	7d	4	1:1

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489 <sup>1</sup> n: number of participants; <sup>2</sup> Age: age range; <sup>3</sup> M:W: men/women ratio; <sup>4</sup> RI: retention interval expressed in  
 490 hours (*h*) or in days (*d*); <sup>5</sup> n: number of samples in the recognition test series; <sup>6</sup> T:D: target/distractor ratio in the  
 491 recognition test series

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1 494 Figure captions  
2  
3 495 Figure 1  
4  
5 496 Proportions of hits, misses, false alarms and correct rejections averaged over all studies  
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7 497 ( $n=397$  observations). Bars indicate 95% confidence intervals.  
8  
9  
10 498 Figure 2  
11  
12 499 Average proportions of hits and false alarms for each position in the recognition series.  
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15 500 Depending on the studies, recognition series included 4 to 12 positions in the recognition  
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17 501 series. Bars indicate 95% confidence intervals.  
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FIGURE 1

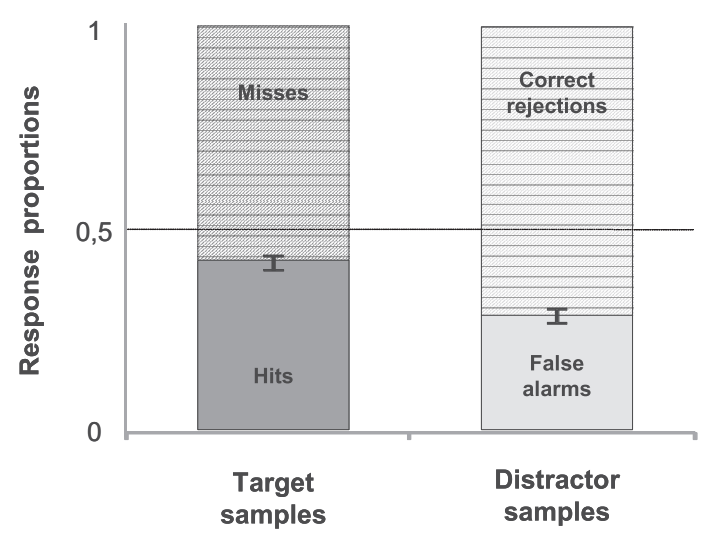




FIGURE 2

