The role of novelty detection in food memory

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ABSTRACT

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

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

1. INTRODUCTION

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

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

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

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

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

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

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

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

This paper presents a systematic and homogeneous analysis of the merged data from 6 studies (see table 1) with the new paradigm, in order to extract some 'general characteristics' of food memory. In all of these incidental learning studies, memory seemed to be based on correct rejection of distractor samples rather than on correct recognition of the target. This suggests that participants use detection of novelty or change, rather than recollection and recognition of earlier experienced and encoded sensory stimulus patterns. In the experiments presented here, this hypothesis was tested in a variety of experimental conditions, to see whether it would keep up under different circumstances and to what extent it would be influenced by factors like gender, age and variation of experimental variables, such as the nature of the difference between targets and distractors and the signal probability in the memory tests. It is hoped that the overview of the results given here may contribute to the understanding of the actual functioning of memory in the lower senses and in incidentally learned behaviours and that it may stimulate research along the same lines in other sensory areas such as kinaesthesia, touch, audition and vision.

2. MATERIAL AND METHODS

2.1. Data sets

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

Table 1 about here

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

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

Memory test

After 8 hrs, 24 hrs or 1 week, depending on the study, participants came back for an unexpected test session. They received recognition series including targets (same as the foods in the learning phase) and distractors, prepared either by varying the concentration of one ingredient in the target (quantitative variation – S1, S2, S4, S5), or by adding a new flavour the target (qualitative variation – S3, S6). All distractors were selected in a preliminary experiment to be noticeably, but not too obviously, different from the target. In S1, S4 and S5, the Just Noticeable Difference (JND), *i.e.* the smallest difference perceived by 50% of the population, was estimated for each compound and for each food model (see Köster et al., 2004, for an exhaustive account of this procedure). The range of the difference between the targets and the distractors was -2 JND to +2 JND. In S2, the distribution of the targets and the descriptors in the sensory space was checked by a sensory panel trained in quantitative descriptive analysis (QDA). In S6 & S3, the perceptual distances between distractors and targets were checked and matched through similarity tests. Depending on the study, recognition series included 4-12 samples with target/distractor ratios varying from 1:1 to 1:3. If several foods were involved, memory for each food was tested with a separate recognition series. Participants indicated whether each sample was the same as or different from the one consumed during the learning phase. In all studies but S3, participants also indicated their certainty about their decision (confidence rating). Finally, in all studies but S4, participants rated their liking for each target and distractor, using a separate set of newly coded stimuli.

2.2. Data analysis

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

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

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

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

With regard to memory strength, a recognition index higher than zero means that participants answered more often “same” for the target samples than for the distractor samples, i.e. that a memory effect occurred. With regard to response bias, a bias higher than zero means that participants had a bias to answer “different” when uncertain about to which class of items stimuli belong. As stated by Signal Detection Theory and similarly to d' and C, these two indices are independent: one could recognize the targets and, nevertheless has a bias to answer "different".

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

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

3. RESULTS

3.1. Food memory performance: an overview

3.1.1. Recognition performance

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

FIGURE 1 about here

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

FIGURE 2 about here

3.1.2. Confidence rating

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

3.1.3. Liking rating

An analysis on liking scores with response category (hit, miss, false alarm and correct rejection) as a fixed factor and recognition series as random revealed a significant effect of response category ($F_{3,27}$=4.19; p<.01). Post-hoc comparison showed that correct rejections were associated with lower liking scores (M=3.88; SE=0.29) than the three other response categories (misses: M=4.58; SE=0.30; false alarms: M=4.68; SE=0.30; hits: M=4.93; SE=0.30).

3.2. Effect of participant-dependent factors on memory performance

3.2.1. Effect of gender and age

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

The effect of age on memory performance was assessed in data from S3, S4 and S5 which included groups of less than 50 year old and of over 50 year old adults. Recognition and bias indices were analysed with age group as a fixed factor and recognition series as random. 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).

3.3. Effect of experimental variables on memory performance

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

3.3.1. Target/distractor ratio

According to signal detection theory (Macmillan and Creelman, 2005), a target/distractor ratio of 1:1 is ideal, because other ratios, when known to or detected by the participants, may influence their response bias. In the present studies, the ratio is often unbalanced in favour of a higher number of (different) distractors. In classic recognition tests, participants are exposed to many different targets during learning, and receive each target once in the recognition series. In the present paradigm, participants are exposed to only one target per food while learning. To reach a 1:1 target distractor ratio, it would be necessary to present this target as many times as there are distractors. This might lead to unwanted incidental learning effects, since only the target would appear repeatedly. Allowing other ratios reduces this risk. It was checked whether the unbalanced ratios had an impact on the responses, although participants were unaware of the signal probability and the short test series prevented implicit learning about the ratio. The ratio-effect was significant for recognition ($F_{3,40}$=12.86; p<.001), but not for bias ($F_{3,40}$=1.30; p>.05), indicating that there was no influence of the unbalanced ratios upon response behaviour.

3.3.2. Nature of the difference between targets and distractors

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

4. DISCUSSION

Before discussing the main results of the experiments and their contribution to an understanding of the role and functioning of incidentally learned memory in eating and drinking behaviour and to memory theory in general, the effects of some of the variables that are supposed to influence memory performance will be considered shortly. Despite the fact that results may be biased because of the limited sample of studies (up to our knowledge, we gathered all the studies that used the paradigm proposed by Köster), the present paper is the first to pool, in a global data set, the results of six independent studies on food memory based on the same innovative paradigm. Although this allows drawing reliable conclusions about the general food memory processes, discussions about the effect of the variables *age*, *target/distractor ratio* and *nature of the food variations* should be considered with caution as the level of these factors were not systematically crossed between the recognition series.

4.1. Gender differences

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

4.2. Age differences

No significant effect of age on memory strength is observed. This result is in agreement with findings of studies on incidental learning and memory in other areas. In fact, there is a wealth of evidence that learning ability declines with age, but almost all of the studies that show such deterioration deal with explicit intentional learning and memory. All the recognition series included in our dataset were based on incidental learning, which is the kind of learning occurring in daily life. However, one of the studies, namely Møller et al. (2007), made a comparison between incidental and intentional learning in food memory. With intentional learning, the young showed better memory performance, whereas with incidental learning the elderly were as good as the young. Other studies have consistently shown that elderly people have a well preserved implicit learning ability (see Hoyer and Lincourt, 1998).

4.3. Influences of experimental design

4.3.1. Signal probability or target/distractor ratio

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

4.3.2. Nature of the food variation

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

4.4. Nature of the learning processes involved

Incidental learning occurs during eating allowing participants to distinguish the eaten food from new samples even if these are only slight variations of the initial food. On average, participants do not better than chance guessing when confronted with the actual target stimuli, and their memory performance depends mainly on the correct rejection of the stimuli they have not had before. The fact that this result emerges from data collected in diverse experiments with different experimental conditions, different types of food and participants from different cultures strengthens the generality and validity of the results. Although this phenomenon seems robust, one cannot conclude on the basis of this knowledge alone that food memory is tuned at detecting novelty or change, rather than at recollection of previous experiences. The low proportion of hits and the high proportion of correct rejections might be due to response bias tuned to answer “different”. Here, the signal detection theory cannot provide the answer. The idea, that novelty detection is indeed the predominant mechanism in incidentally learned memory, is supported by the fact that participants are more certain about their “different” responses (especially correct rejections) than about their “same” responses, and by “same-different” reaction time experiments showing that in olfaction, making difference decisions is much faster (±200ms) than making same decisions (de Wijk, 1989), whereas in vision same decisions are usually faster (±50ms) than different decisions (Luce, 1986; Posner, 1986). Köster et al. (In preparation), confirmed these differences between olfaction and vision, using a same-different paradigm with odour stimuli as different as aniseed, soap, and curry. Results showed that the reaction times to “different” responses were about 300 ms shorter than those to the “same” responses, whereas the same subjects responded “same” 50 ms faster than “different” when visual presentations of the odour names were used. All this, plus the fact that qualitative changes (introducing possibly dangerous new aspects) were better detected than mere quantitative changes in already present features, corroborate the idea that "feelings of not knowing" play the decisive role in this type of memory. Thus, odour and flavour memory seem to have the characteristics of an efficient warning system that immediately reacts to novel information.

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

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

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

If novelty detection has survival value, it need not surprise that it seems to play a dominant role in the "near" senses (olfaction, taste and texture perception) that are involved in vital activities such as breathing and food ingestion. In these senses, potentially dangerous stimuli are already in contact with the body at the moment of detection, and only one type of immediate reaction (fleeing for odour; spitting out for flavour) is needed to avoid serious harm by inhalation or ingestion. In these cases, there is no time and no need for identification. For "far" senses (vision or audition) identification is useful, and more time to identify is usually available. Different dangers may demand different reaction patterns (stepping aside, fighting, submission, etc.).

Furthermore, rejection seems to be linked to the hedonic dimension of the food, suggesting that liking acts as an indicator of food safety. At the same time liking seems not related to target food recollection, since hit stimuli are not more liked than those that lead to false alarms and misses. This is precisely what one would expect in a memory system with a primary warning function that relies on danger detection and not on reviving earlier experiences.

5. CONCLUSION

In conclusion, incidental memory for food seems mainly involved in safeguarding our intake and not in the recollection of previous experiences. This does not mean that recollection does not play a role at all. It is used in conversations about previous eating experiences and probably also in most food buying decisions, but in everyday eating and drinking behaviour without such explicit attention, memory mechanisms like novelty and change detection prevail. The fact that incidental learning in eating and drinking behaviour is probably the oldest and even prenatal form of learning to be encountered in humans and that it is closely linked to a vital survival function makes it a unique example for the study of the function of non-verbal learning and memory.

REFERENCES

Birch, L.L. (1980). Effects of peer model's food choices and eating behaviors on preschooler's food preferences. Child Dev., 51, 489-496.

Cain, W.S., de Wijk, R., Lulejian, C., Schiet, F., See, L.C. (1998). Odor identification: Perceptual and semantic dimensions. Chem. Senses, 23, 309-326.

Cox, D.R. (1970). The analysis of binary data. London, Methuen.

Daselaar, S.M., Fleck, M.S., Cabeza, R. (2006). Triple dissociation in the medial temporal lobes: Recollection, familiarity, and novelty. J. Neurophysiol., 96, 1902-1911.

Daselaar, S.M., Fleck, M.S., Prince, S.E., Cabeza, R. (2006). The medial temporal lobe distinguishes old from new independently of consciousness. J. Neurosci., 26, 5835-5839.

de Wijk, R.A. (1989). Temporal factors in human olfactory perception. Unpublished Doctoral Thesis, Utrecht University.

Engen, T., Ross, B.M. (1973). Long-term memory of odors with and without verbal descriptions. J. Exp. Psychol., 100, 221-227.

Haller, R., Rummel, C., Henneberg, S., Pollmer, U., Köster, E.P. (1999). The influence of early experience with vanillin on food preference later in life. Chem. Senses, 24, 465-467.

Hausner, H., Nicklaus, S., Issanchou, S., Mølgaard, C., Møller, P. (2010). Breastfeeding facilitates acceptance of a novel dietary flavour compound. Clin. Nutr., 29, 141-148.

Herz, R.S., Engen, T. (1996). Odor memory: Review and analysis. Psychon. Bull. Rev., 3, 300-313.

Hoyer, W.J., Lincourt, A.E. (1998). Aging and the development of learning, in: M.A. Stadler, P.A. French (Eds.), *Handbook of implicit learning*. Sage Publications, London, pp. 445-470.

Köster, E.P., Mojet, J. (2007a). Boredom and the reasons why some new food products fail, in: H. MacFie (Ed.), *Consumer-led food product development*. Woodhead Publishing Limited, Cambridge, England, pp. 262-280.

Köster, E.P., Mojet, J. (2007b). Theories of food choice development, in: L. Frewer, H. van Trijp (Eds.), *Understanding consumers of food products*. Woodhead Publishing Limited, Cambridge, England, pp. 93-214.

Köster, E.P., van der Stelt, O., Nixdorf, R.R., Linschoten, M.R.I., Dijkman, N., de Wijk, R.A., Mojet, J. (In preparation). Olfactory imagination and odour processing: three same-different experiments.

Köster, M.A., Prescott, J., Köster, E.P. (2004). Incidental learning and memory for three basic tastes in food. Chem. Senses, 29, 441-453.

Larsson, M. (1997). Semantic factors in episodic recognition of common odors in early and late adulthood: a review. Chem. Senses, 22, 623-633.

Larsson, M., Lovden, M., Nilsson, L.-G. (2003). Sex differences in recollective experience for olfactory and verbal information. Acta Psychol., 112, 89-103.

Laureati, M., Morin-Audebrand, L., Pagliarini, E., Sulmont-Rossé, C., Köster, E.P., Mojet, J. (2008). Food memory and its relation with age and liking: An incidental learning experiment with children, young and elderly people. Appetite, 51, 273-282.

Lawless, H.T., Cain, W.S. (1975). Recognition memory for odors. Chem. Senses, 1, 331-337.

Lehrner, J.P. (1993). Gender differences in long-term odor recognition memory: verbal versus sensory influences and the consistency of label use. Chem. Senses, 18, 17-26.

Luce, R.D. (1986). Response times. New York, Oxford University Press.

Lyman, B.J., McDaniel, M.A. (1990). Memory for odors and odor names: Modalities of elaboration and imagery. J. Exp. Psychol.: Learn., Mem. & Cogn., 16, 656-664.

Macmillan, N.A., Creelman, C.D. (2005). Detection Theory: a user's guide, 2nd edition ed. New York, Cambridge University Press.

Matsumoto, M., Matsumoto, K., Tanaka, K. (2007). Effects of novelty on activity of lateral and medial prefrontal neurons. Neurosc. Res., 57, 268-276.

Mennella, J.A., Jagnow, C.P., Beauchamp, G.K. (2001). Prenatal and postnatal flavor learning by human infants. Pediatrics, 107, e88.

Mojet, J., Heidema, J., Christ-Hazelhof, E. (2003). Taste perception with age: Generic or specific losses in supra-threshold intensities of five taste qualities? Chem. Senses, 28, 397-413.

Mojet, J., Köster, E.P. (2002). Texture and flavour memory in foods: An incidental learning experiment. Appetite, 38, 110-117.

Mojet, J., Köster, E.P. (2005). Sensory memory and food texture. Food Qual Pref, 16, 251-266.

Møller, P., Mojet, J., Köster, E.P. (2007). Incidental and intentional flavor memory in young and older subjects. Chem. Senses, 32, 557-567.

Møller, P., Piper, D., Hartvig, D., Köster, E.P. (2009). Comparison of incidental and intentional learning of olfactory and visual stimuli. Chem. Senses, 34, A86-A86.

Møller, P., Wulff, C., Köster, E.P. (2004). Do age differences in odour memory depend on differences in verbal memory? Neuroreport, 15, 915-917.

Monnery-Patris, S., Rouby, C., Nicklaus, S., Issanchou, S. (2009). Development of olfactory ability in children: sensitivity and identification. Dev Psychobiol, 51, 268-276.

Morin-Audebrand, L., Sulmont-Rossé, C., Issanchou, S. (2006). Impact of hedonic appreciation on memory for custard dessert, in: XVII ECRO Congress, Granada, Spain, September, 4-8, 2006.

Murphy, C., Cain, W.S., Gilmore, M.M., Skinner, R.B. (1991). Sensory and semantic factors for recognition memory for odors and graphic stimuli: elderly versus young persons. Am. J. Psychol., 104, 161-192.

Posner, M.I. (1986). Chronometric explorations of mind, 2nd revised ed. Oxford, Oxford University Press.

Rabin, M.D., Cain, W.S. (1984). Odor recognition: familiarity, identifiability and encoding consistency. J. Exp. Psychol.: Learn., Mem. & Cogn., 10, 316-325.

Schaal, B., Soussignan, R., Marlier, L. (2002). Olfactory cognition at the start of life: The perinatal shaping of selective odor responsiveness, in: C. Rouby, B. Schaal, A. Holley, D. Dubois, R. Gervais (Eds.), *Olfaction, taste, and cognition*. The Press Syndicate of the University of Cambridge, Cambridge, UK, pp. 421-440.

Stevenson, R.J., Prescott, J., Boakes, R.A. (1995). The acquisition of taste properties by odors. Learn. & Motiv., 26, 433-455.

Sulmont-Rossé, C., Møller, P., Issanchou, S., E.P., K. (2008). Effect of age and food novelty on food memory. Chemosens. Percept., 1, 199-209.

Yeomans, M.R., Leitch, M., Gould, N.J., Mobini, S. (2008). Differential hedonic, sensory and behavioral changes associated with flavor-nutrient and flavor-flavor learning. Physiol. Behav., 93, 798-806.

Table 1

Overview of the studies included in the present paper.

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

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

Figure captions

Figure 1

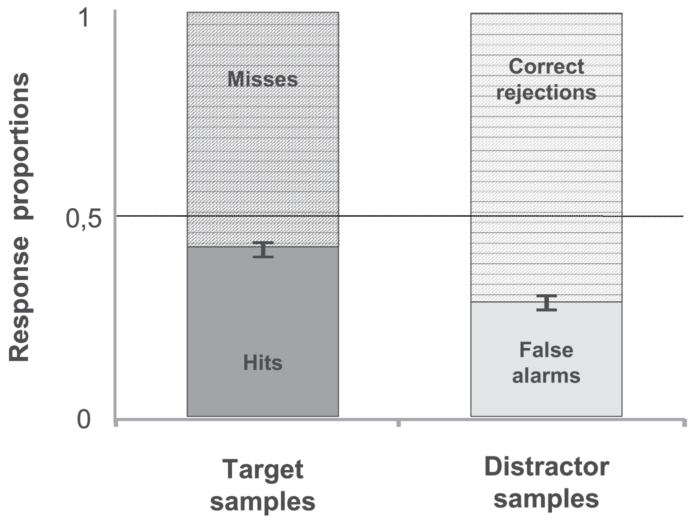
Proportions of hits, misses, false alarms and correct rejections averaged over all studies (*n*=397 observations). Bars indicate 95% confidence intervals.

Figure 2

Average proportions of hits and false alarms for each position in the recognition series. Depending on the studies, recognition series included 4 to 12 positions in the recognition series. Bars indicate 95% confidence intervals.

Figure

FIGURE 1



Figure

FIGURE 2