Learning and Retention Time Effect on Memory for Sweet Taste in Children

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Abstract

This study investigated the effect of learning and retention time on memory for fruit purée varying in sweetness among 214 children aged 8-10 yrs. During a first session, all children received a snack including a target fruit purée. Half children tasted the snack without any mention to memory (incidental group), whereas the other children (intentional group) were explicitly asked to taste and remember it. During a second session, children of each learning group were divided in two groups, which were tested for memory after respectively one day and one week. Children were confronted with a series of samples consisting of the same target previously tasted and variants of it slightly modified in sweetness. Children performed also a hedonic and a perceptive test. Memory was better under incidental rather than intentional conditions. Recognition was based more on the correct rejection of the distractors rather than on the identification of the target. No clear evidence for a retention time effect on memory was found. The relationship between sweetness perception and memory is discussed.

Keywords: Incidental learning; Intentional learning; Retention time; Food memory; Children

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1. Introduction

Over the last decade, a remarkable amount of studies have been performed in an attempt to delineate the mechanisms involved in incidental learning and memory for food. If we consider the way we learn, store and retrieve sensory food input, it is fairly evident that we rarely pay attention to what we eat or drink, unless something differs from our expectations. Nevertheless, sensory information is unconsciously retained by the brain and remains "hidden" until the time when a new food is experienced (Köster, Prescott & Köster, 2004). At this moment, sensory memory becomes a determinant factor in food choice, since it enables the comparison of sensory information with stored information obtained in previous experiences with the same or a similar product, thus influencing food sensory and hedonic perception through expectations generation and cognitive associations expression. The resulting sensory image is added to memory and may in turn play a role in subsequent food experiences (Sulmont-Rossé, Issanchou, & Köster, 2003).

Food learning is almost never intentional or explicit and memory for food is also to a very large extent implicit (Morin-Audebrand et al., 2012). There are very few examples of explicit learning related to food, one of these is when subjects make an effort to remember the food sensory properties in sensory tests but this situation is pretty rare in everyday life. Indeed, when eating or drinking, it is extremely unusual to consciously decide "I have to remember this food" (Issanchou, Valentin, Sulmont, Degel, & Köster, 2002).

Since the nature of food memory is basically implicit, an implicit recognition paradigm was proposed and validated in order to investigate learning and memory for food in an ecologically valid way (Mojet & Köster, 2002). This paradigm includes two phases: (1) an acquisition phase and (2) a retrieval phase, which is carried out after a given retention interval. During the acquisition phase, participants are incidentally exposed to a target food (*i.e.* the only food to be remembered later) which is administrated in a natural eating situation. During the retrieval phase following the retention interval, participants are unexpectedly asked to recognize the target food among a series of samples slightly different in one or more sensory aspects (*i.e.* the distractors). This paradigm –

which differs from that used in almost all other (implicit and explicit) memory experiments in the literature – focuses on the recognition of minor changes of a target food provided in a real eating context. All other previous experiments have been directed to the identification of clearly different stimuli presented out of their natural context which must be later identified among other clearly distinct new stimuli.

Through the application of this paradigm, some food memory features have been delineated. First of all, a number of studies (Mojet & Köster, 2002, 2005; Köster et al., 2004; Morin–Audebrand, Laureati, Sulmont–Rossé, Issanchou, Köster & Mojet, 2009) have shown that memory for food occurs, but it is extremely product-dependent. For example, sweetness might be the crucial feature for the memorization of a custard dessert (Morin-Audebrand et al., 2009) but not for the recognition of an orange juice or a yoghurt, which are actually better remembered for their bitterness and sourness respectively (Köster et al., 2004). Furthermore, there is general agreement in the literature suggesting that memory for food is modulated by novelty (Morin-Audebrand et al., 2012). This means that, when a memory effect occurs, it is mainly based on consumers' ability to reject something not previously tasted (*i.e.* the distractors) rather than to identify a food already experienced (*i.e.* the target). Another common finding is that food memory seems to be independent from age; despite the recognised assumption that memory declines over the lifespan, it should be considered that this loss of memory ability is remarkable in explicit memory but not in implicit memory (that being the case of food memory), which is almost unaffected by age (Balota, Dolan, & Duchek, 2000). Accordingly, food studies carried out on differently aged consumers groups showed that adults (age 18-45) and elderly people (age > 60) have comparable memory indices (Møller, Wulff & Köster, 2004; Møller, Mojet & Köster, 2007; Laureati, Morin–Audebrand, Pagliarini, Sulmont–Rossé, Köster & Mojet, 2008; Sulmont-Rossé, Møller, Issanchou, & Köster, 2008).

Very few studies have attempted to compare incidental and intentional learning for sensory and food stimuli. Møller et al. (2004, 2007) compared incidental and intentional learning and memory in young and elderly subjects. They found that young adults remembered odors and flavors better under intentional than incidental learning conditions, whereas the elderly remembered these stimuli equally well under both conditions and as well as the young under the incidental condition.

There have been very few studies investigating the retention time effect on food memory, and the results of such studies are contradictory. Frijters (1977) explored the ability to discriminate odors within very short delay intervals (0, 5, 8 and 12 s) and did not find a retention time effect on subjects' performance. Barker and Weaver (1983) showed that through lengthening the time interval between the presentations of two explicitly learned stimuli, a decrease in the ability to remember odors occurred, whereas taste stimuli memory was less influenced by retention time. Cubero, Avancini de Almeida & O'Mahony (1995) and Avancini de Almeida, Cubero & O'Mahony (1999) showed that citrus flavored beverage discrimination was better when stimuli were experienced subsequently and that performance deteriorated as interstimulus interval increased. Similarly, Degel, Piper & Köster (2001) found that memory for unconsciously learned odors decreased with increased delay interval (from 60 min to 120 min). Contrasting results were obtained by Harker, Gunson, Brookfield & White (2002) who investigated the ability to detect differences in apple firmness when presented with fruit at 1 day and 1 min interstimulus delays. They reported that subjects encountered more difficulties in detecting texture differences after a 1 min interval as compared to a 1 day interval, but their results could be criticised on the basis of their testing procedure that demanded people to test apples at a very high rate in the one minute interval condition allowing no time for recovering from adaptation or even muscular fatigue.

Quite surprisingly, little research has been conducted on these topics despite their importance. Actually, when performing sensory testing, products are usually assessed subsequently with time intervals between tasting sessions as short as possible. These circumstances do not necessarily reflect real life conditions. In most cases, foods may only be tasted and compared days, weeks or months apart. The time interval depends on the specific foods and consumers involved in the study. Therefore, a more ecological approach to the consumers' food learning and memory investigation is important to be considered.

The aim of the present study was to investigate how the learning type (incidental *versus* intentional) and the retention interval length (one day *versus* one week) might influence food memory in children. Based on our knowledge and information, this topic has never been investigated so far.

Given that sweetness has a powerful hedonic appeal, especially among children and young people, sweet foods and beverages have been indicated as potential contributors to the obesity epidemic worldwide (Drewnoski, Mennella, Johnson & Bellisle, 2012). There is currently considerable research on the biological mechanisms that influence sweet taste preferences and drive the consumption of sweet tasting foods but very few studies were addressed to memory for sweet taste. Studying food memory may provide with an indication about the way in which incidental memory for food works and about sensory impressions' role in this memory. In addition, the study of sweet taste perception and memorization could provide food companies with strategic information on new low calories formulations development. This is especially important considering the growing and widespread children's obesity phenomenon.

2. Materials and Method

2.1. Subjects

Two-hundred-fourteen children (106 girls and 108 boys), aged between 8-10 years were recruited in two Milan schools. One school was tested for incidental learning and the other one for intentional learning of a food stimulus. The children were divided into two groups, which were tested for memory respectively after one day and one week after the learning phase. The two schools shared the same refectory and had the same lessons schedule. Children from the two schools were matched for gender (χ^2=0.02; p=0.89) and age (χ^2=0.74; p=0.69).

Parents were asked to read a short study explanation, to sign a consent form and to complete a questionnaire where they were to indicate whether their child had any food allergy or followed a specific diet. Parents also answered questions concerning their child's preference and consumption frequency for some foods, including those under study. All children involved in the study met the following criteria: healthy; not on a specific diet; not suffering from food allergies or from smell and taste disorders. Children did not receive any particular reward for participation, but an educational “taste lesson” at the end of the experiment.

2.2. Stimuli

A commercial apple fruit purée (Frutta Pura Mellin, SpA, Italy) was chosen for the study. The ingredients listed on the label were: apple and vitamin C. The experimental products, consisting of one target and two distractors (one less sweet and one sweeter than the target), were produced at the University of Milan sensory laboratory by adding different amounts of sucrose to 1000 g of fruit purée.

In order to obtain perceivable but subtle differences in sweetness intensity among the target and the distractors, the Just Noticeable Difference (JND) (*i.e.* the smallest difference perceived by 50% of the population) was calculated involving a separate group of 38 children. According to Köster et al. (2004), five fruit purée samples which differed for equal sugar concentration steps (C1, C2, C3, C4, C5) were produced. The middle concentration served as a reference (Ref=C3) and the other concentrations were used as comparison stimuli (C1, C2, C4, C5). The reference was compared to each of the other concentrations through a paired comparison test. Each pair contained at least one reference (Ref), the other sample was a comparison sample (C1, C2, C4, C5). The reference was also tested against itself. Each pair was presented twice: once with the reference presented in the first tasting position and once with the reference presented in the second tasting position. Thus, children received 10 fruit purées pairs. The pairs’ presentation order was systematically varied over children. For each pair, children were asked to state which of the two samples was the sweetest. Children were instructed to rinse their mouth with water before the test and after each pair.

In order to calculate the JND of the whole group, we determined the percentage of the times when each comparison stimulus was judged to be more intense in sweet taste than the reference. These percentages were turned into z-scores under the normal probability curve and plotted against the concentration of sugar added. The function of the best fitting straight line through these points was determined and the concentration values corresponding to z-values of –0.675 and +0.675 (z-values of 25% stronger and 75% stronger than the reference) were calculated from this function. The JND was found by taking half of the difference between these two concentration values. Although this method is slightly incorrect since the arithmetic mean was used instead of the geometrical mean between these two concentrations to determine the size of the JND's, it was considered that the difference was small enough to use it.

The distractors were respectively 1.5 JND lower (D-) and 1.5 JND higher (D+) in concentration than the target (T). The -1.5 JND distractor, the target and the +1.5 JND distractor were obtained by adding respectively 44 g, 87 g, and 130 g of sugar to 1000 g (1.5 JND=43 g/kg) of the base fruit purée, which reported on label a 96 g/kg concentration of carbohydrates naturally present in apples.

2.3. Procedure

2.3.1. Day 1: Learning Session

During the learning session (first day), children of both schools were offered a mid-morning snack consisting of a biscuit, a fruit juice portion and a target fruit purée portion. In order to guarantee an involuntary learning of food aspects, the incidental group of children was asked under a false pretense to eat the snack and to rate the liking degree of each food item. The false pretense was conceived just with the purpose of distracting children's attention from the real aim of the study, thus memory was never mentioned. Also the intentional learning group of children ate the snack and rated the liking degree of each food item but – accordingly with the explicit learning methods – they were asked to focus their attention on the features of food they would have consumed, since they would have been asked to perform a memory test later.

2.3.2. Day 2: Test Session

Children belonging to each learning group were divided in two groups, which were tested for memory after respectively one day and one week since the day of the learning phase. As previously mentioned, children belonging to the incidental group were unaware of the study aim and were unexpectedly asked to perform a memory test. All children were confronted with a series of fruit purée samples consisting of the target tasted during the learning session and each of the two corresponding distractors modified in sweetness. Children performed a memory test, a liking test, and a discrimination test. The memory test consisted in presenting a monadic series of 4 samples: 2 target samples and one sample of each of the 2 distractors. The ratio targets/distractors (1:1) was chosen to avoid unwanted learning effects due to overrepresentation of the target in the memory test. Children were asked to taste each sample and to answer the question: ‘‘Did you eat this sample yesterday/one week ago? Yes/No’’. They were not informed about the exact number of targets and distractors in the series, but they were told that some of the samples might be the same as the one previously tasted. Then, the children completed a liking test. They received three new samples in a monadic series (one target and the two distractors) and for each of them they were asked to rate how much they liked it on a seven-point hedonic-facial-vertical scale with the anchors ‘‘super bad’’ (bottom of the scale) and ‘‘super good’’ (upper part of the scale) (Pagliarini, Ratti, Balzaretti & Dragoni, 2003). Finally, a paired comparison test was conducted in order to check whether the children perceived the expected sweetness differences between the target and the distractors. Each child was given a tray consisting of three fruit purée pairs: one pair consisting of the less sweet distractor and the target (D- *vs* T), one consisting of the sweeter distractor and the target (D+ *vs* T) and one consisting of two identical samples of the target (T *vs* T). The pairs presentation was randomized over children and the test was performed so that, at the time of comparing the target *vs* a distractor, half of the children assessed first the distractor and then the target (D- *vs* T; D+ *vs* T), whereas the other half was to assess first the target and then the distractor (T *vs* D-; T *vs* D+). For each pair of fruit purée, children were asked to point out the sweeter sample.

2.4. Experimental Conditions

Sessions were performed in the classrooms, at 10 am mid-morning break in the presence of a teacher and an experimenter. The number of children in the classes ranged from 15 to 25. During the first session (learning session, day 1) children were invited to sit at their own table, thus ensuring real meal conditions as much as possible, and they were offered 100 mL of fruit juice, 80 g of fruit purée and 1 biscuit. During the test session (day 2), children received 20 g samples of fruit purée for each sample for the memory test and 15 g samples of fruit purée for each sample for the liking and discrimination tests.

Children were provided with a booklet for each test, and they were given a short explanation about the use of the scale and the instructions to complete the booklet before each test session. Children were instructed to rinse their mouth with water before the beginning of each session and after the tasting of each sample. Each experimenter had the instructions to read to the children for all the tests. In order to ensure consistency of the instructions provided, the interviewers were instructed to follow strictly the script.

The experimental samples were prepared the day before each session and stored at 4 °C. Samples were taken out from the cooling room 2 h before the session and served at room temperature in plastic cups covered with a plastic lid and coded with different three digit numbers in each test. Within each session, the design was balanced for order and carry-over effect (Macfie, Bratchell, Greenhoff & Vallis, 1989).

2.5. Data Analysis

Memory was tested by means of the Signal Detection Theory (SDT). According to the SDT, two factors underlie the participants' responses in a memory test: (1) the participants' ability to identify the target amongst distractors (memory strength) and (2) the participants' tilt toward one response or the other (response bias). Two parametric indices, namely the d' and c indices, are usually used to measure these two dimensions (Macmillan & Creelman, 2005). The index d' is commonly assessed by the proportion of ‘‘yes” responses to the targets (hits) corrected by the proportion of ‘‘yes” responses to the distractors (false alarms), whereas c is assessed by the average of ‘‘yes” responses relative to the average of ‘‘no” responses over all samples. To be computed, these parametric indices require a response frequencies normal transformation. However, the computation of these indices is questionable when the number of targets and distractors by participant is small (Snodgrass & Corwin, 1988) as in this case, since it was impossible to ask children to eat a too large number of samples. Therefore, according to Laureati et al. (2008), in the present study the proportion of “yes” answers to the target (YesT) and to the distractors (YesD) and the proportion of “no” answers to the target (NoT) and to the distractors (NoD) were determined and used to calculate memory indices based on the same principle as the d’ and the c, but non-parametric (*i.e.* the normal transformation is not required). For the targets, the ‘‘yes” responses correspond to the correct recognition, whereas for the distractors, the ‘‘no” responses correspond to the correct rejections.

As regarding the memory strength, a recognition index was computed: recognition index (P0) = YesT– YesD. This index is equivalent to the index P0 proposed by Snodgrass & Corwin (1988). The recognition index varies from -1 to +1. The more the recognition index is close to +1, the more the participant managed to recognize the target amongst the distractors. On the contrary, a recognition index equal to or lower than 0 reveals that the target incidental learning did not occur.

As regarding the response bias, a bias index was computed: bias index = 0.5*[(NoT + NoD) - (YesT + YesD)]. This bias index varies from -1 to +1. A positive bias index indicates a bias to respond ‘‘no’’, a zero bias index indicates no bias and a negative bias index indicates a bias to respond ‘‘yes’’. Student *t*-tests were used to assess whether memory indices were different from zero or not.

According to SDT, d' and C reflect two independent dimensions underlying participant's responses, thus we can state that a memory effect occurs if the proportion of ‘‘yes’’ responses for the target is higher than the proportion of ‘‘yes’’ responses for the distractors, even if the participants had a bias to answer ‘‘no’’ during the absolute memory test.

Analysis of variance (ANOVA) was performed considering type of *Learning* (2), *Retention time* (2), *Gender* (2), *Age* (3) and their two-way interactions as factors, and memory indices as dependent variables in the model. The paired comparison test results were analyzed through unilateral statistical test ($p=1/2$) according to the binomial distribution (ISO, 2005). For each pair, the correct answers number was calculated and compared with the minimum number of correct answers to affirm that there is a significant ($p<0.05$) difference between samples.

The hedonic test results were analyzed through ANOVA considering *Learning*, *Retention time*, *JNDs*, *Gender*, *Age* and their relevant two-way interactions as factors and hedonic values as dependent variable. Statistical analyses were performed using SAS/STAT statistical software package version 9.3.1. (SAS Institute Inc., Cary, USA).

3. Results

3.1. Discrimination Test

To check whether the children were able to perceive the differences between the target and the distractors, a paired comparison test was performed. For this test, a reduced number (n=65) of children was involved since not all children were available due to practical constraints. The number of correct answers for each pair and the minimum number at which a response becomes significantly ($p<0.05$) higher than expected on the basis of chance guessing was computed from the binomial distribution ($p=1/2$) and shown in Figure 1. Results showed that 49 out of 65 (75.4 %) of the children correctly perceived the D- distractor as less sweet than the target, whereas only 39 out of 65 (60.0%) of the children perceived the D+ distractor as sweeter than the target. This seems to suggest that the actual distance between the target and the D- distractor was 1.0 JND rather than 1.5 JND and that the actual distance between the target and the D+ distractor was even somewhat lower than 1.0 JND. This might explain the difference in correct response in the memory test to be reported below. Anyhow, considering that the minimum number to have a significant response is equal to 41 for $p<0.05$ (represented by a line in Figure 1), it can be stated that children identified the less sweet distractor more easily, whereas the answers for the sweeter distractor only tended to reach significance. The control pair target-target was not significant, suggesting that children correctly perceived the two target samples as equally sweet.

Results were also analyzed by learning and retention time in order to see whether children belonging to the incidental or intentional group or to the one day or one week group differed in their discrimination ability. It was found that the proportion of children who correctly judged the D- as less sweet and the D+ as sweeter than the target was comparable among groups (p-values always >0.05 based on a Chi-square analysis).

3.2. Memory Test: Learning and Time Retention Effect

Memory index P0 calculated by learning and by retention time is reported in Figure 2. As can be seen memory improved with increased retention time in the incidental condition, whereas under intentional learning conditions, memory declined with increased retention time. More specifically, under incidental learning conditions, children showed positive memory indices both after one day and after one week from the learning session, even if only after one week the index is significantly higher than zero ($M_{(P0)}=0.21$; $t_{(43)}=2.86$; $p<0.01$). In the case of the intentional group, no memory effects were found, whatever the retention time was.

ANOVA results highlighted a significant effect only for the main factor type of *Learning* ($F_{(1,199)}=3.61$; $p<0.05$) on children's ability (P0) to remember the stimulus previously experienced. According to the multiple range test, memory was better in incidental ($M_{(P0)}=0.16$) rather than intentional learning conditions ($M_{(P0)}=0.03$). No effect of *Age*, *Gender*, *Retention time* and of their two-way interactions on P0 has been found.

P0 memory index was also calculated by JNDs in order to establish whether children remembered better an increase or a decrease in sweetness. Thus, a memory index for each distractor was calculated for each child in both learning conditions and both retention times. Results showed no memory effect for both distractors under intentional learning conditions neither after a one day nor one week interval, whereas under incidental learning conditions the less sweet distractor was recognized but only after a one week interval ($M_{(P0)}=0.32$; $t_{(43)}=3.91$; $p<0.001$).

Bias index calculated by type of learning, retention time, gender or age was always positive and significantly ($p<0.05$) different from zero, suggesting the children's tendency to answer 'no' to the recognition question. No effect of learning condition, retention time, age, gender or their interaction was found on bias index, suggesting that children had the same tilt to answer to the recognition question whatever the type of learning and retention time were, and regardless of gender and age. This answer pattern is consistent with the data shown in Figure 3 where the proportion of correct answers for both the targets (hits) and the distractors (correct rejections) are reported. Data were averaged across retention time since ANOVA results highlighted no effect on memory for this variable. Chi-square results pointed out that, under both learning conditions, the correct rejections proportion was significantly higher than the hits proportion (χ^2=3.28, $p<0.01$ for incidental learning; χ^2=3.56, $p<0.001$ for intentional learning), suggesting that children identified something not previously experienced more easily than something already learned. Furthermore, results highlighted that the hits proportion was comparable between learning conditions, whereas the correct rejection proportion was significantly higher (χ^2=4.73, $p<0.05$) with incidental rather than intentional learning conditions.

3.3. Hedonic Test

Lsmeans hedonic scores by stimulus are reported in Figure 4. ANOVA results showed a significant effect for the main factor *JNDs* ($F_{(2, 615)}$=6.49; $p<0.01$). A tendency to prefer fruit purée with higher sucrose concentration is observed in Figure 4. More specifically, children gave significantly lower hedonic ratings to the less sweet distractor, as compared to the target and the sweeter distractor that were comparable in terms of liking. The *Age* ($F_{(2, 615)}$=6.22; $p<0.01$) and *Retention time* ($F_{(1, 615)}$=16.08; $p<0.01$) main factors were also significant. According to multiple comparison tests, 10 y.o. children gave significantly higher hedonic ratings than younger children. In addition, children gave lower liking ratings after one day as compared to one week interval. The other main factors and all their interactions were not significant.

4. Discussion

The present paper investigated a topic never considered so far: comparing children’s incidental and intentional learning and memory for sweetness in a real food product.

The main research output are: 1) children’s memory coming from a food stimulus involuntary learning is better than that originated by a voluntary learning effort of it; 2) the time elapsing in the interval between the food stimulus learning and the retrieval phase does not influence children’s memory.

Results obtained confirm previous studies which showed that children are able to incidentally learn and then memorize food stimuli (Laureati, Pagliarini, Mojet & Köster, 2011; Laureati et al. 2008).

Since no literature about the comparison between intentional and incidental children's food learning is available, our discussion is limited to research conducted on adults.

Møller et al. (2004) studied the voluntary (intentional) and involuntary (incidental) odor learning memory and found that odor memory was higher when stimuli were learned intentionally for the young, whereas the contrary was seen in the elderly, thus suggesting that intentional odor memory performance declines with age. Comparable results were obtained in a following study (Møller et al., 2007) aimed at comparing incidental and intentional learning in adults and elderly subjects using real food. It was found that the adults remembered novel flavors added in soups better under intentional than incidental learning condition, whereas the elderly remembered these stimuli equally well under both conditions. The results of the present study contrast with those obtained by Møller and colleagues, since the present authors found that children's memory was better under incidental than intentional learning conditions. This divergence might be explained at least in two ways. First, Møller and colleagues performed their studies in a laboratory context, which is somewhat different from the present study's conditions (*i.e.* taste stimulus added to a real food and evaluated in a natural eating context). Thus, it might well be that a formal condition, such as a laboratory test, might increase subjects' attention on the stimuli provided. Second, the age groups considered were different. As concerning this point, the present authors suspect that the discrepancy's cause is probably not the age-related differences but rather the other contextual factors. Indeed, there is evidence that food learning and memory under ecological conditions is comparable among children, adults and elderly people (Laureati et al., 2008).

The fact that involuntary food learning is more effective in generating memory should not be a surprising result if we consider that in everyday life we learn about food without any explicit effort. On the contrary, it is extremely rare that we pay attention to the food we eat or drink unless there is something unexpected. Another important consideration coming from this result is that explicit paradigms should be cautiously considered when applied for studying food learning and memory since they are probably not appropriate, being less ecologically valid than implicit experimental procedures.

A more detailed account of memory responses in terms of hits, misses, correct rejections and false alarms showed that children were not able to recognize the target previously tasted better than chance, since the percentage of hits under both incidental and intentional conditions was approximately 50%. The percentage of correct rejections was always higher than the percentage of hits, showing that under both conditions rejection of the distractors contributed more to memory performance than the target identification. However, the percentage of correct rejections was higher under incidental than intentional conditions and this might explain the better memory performance when children involuntarily learn food stimuli. This result is in agreement with Morin Audenbrand et al. (2012), who analyzed the results obtained in several experiments differing for experimental conditions, type of food and participants but sharing the same implicit paradigm used in the present experiment and found that – at least for incidentally learned sensory stimuli – memory is based on novelty or change detection (*i.e.* distractors) rather than on previously encountered stimuli recollection and recognition.

Considering the time retention effect on sensory memory, mixed results are present in the literature and none of them have been obtained involving children. In general, it is assumed that lengthening the time interval elapsing from the learning and the retrieval phase might have a negative effect on memory performance because of an increased possibility of fading and confusion of the stored bases resulting from the stimulations. In accordance with this assumption, odor recognition tests performed considering intervals between the stimuli initial and second presentation varying in terms of seconds (Engen, Kuisma & Eimas, 1973), minutes (Barker & Weaver, 1983), days (Rabin & Cain, 1984) or weeks (Engen & Ross, 1973), found that recognition performance generally deteriorated as the interval was longer. Taste stimuli are less influenced by time of retention (Barker & Weaver, 1983): this seems in agreement with our results. However, these studies are based on explicit or implicit paradigms which anyway considered simple sensory stimuli such as odors, and none of them were conducted on children, thus they are hardly comparable to the present one.

The memory storage systems for food sensory properties are not well understood. From vision and audition research (Baddeley, 1997), it would seem that the first memory stage is somewhat a wake of the sensations elicited by the food. This immediate memory would explain superior recognition skills at short retention time. Despite the contrasting opinions in literature, especially for olfactory memory, it has been suggested that, in the same way as for vision and audition, the sensations elicited by food would be expected to be held in a short term memory. Sometimes these would be transferred into a long term, more permanent memory (Baddeley, 1997). How long exactly the sensations elicited by a food are held in short term memory before being transferred to long term memory is not known. For auditory and visual stimuli, it seems to be a matter of seconds or minutes. For food sensations, it has never been investigated. In this context, we found no clear evidence of retention time effect on children's memory for sweetened fruit purée even though memory was better after one week than one day interval under incidental learning conditions. One hypothesis that might be forwarded to explain this result is that better memory for incidental learning after one week retention interval is due to a better food stimuli perception from children belonging to the incidental-one week group. However, this is not the case since results of the paired comparison test analyzed by learning and retention time showed no difference among children groups in their ability to discriminate the target from the distractors. Another point that should be considered is that different children were involved for incidental and intentional tests as well as for tests after one day and one week retention interval. However, this choice has been forced by the nature of the paradigm used. In this respect, care has been taken to balance each learning and retention time group for age and gender.

As concerning hedonic data, children liked more the fruit purées with a higher sugar concentration and clearly pointed out the less sweetened samples as the least pleasant, although pretty high liking ratings were observed for all the products evaluated (D-, T, and D+). This result is particularly significant in relation to the memory and discrimination tests findings. Indeed, when memory data were analyzed by distractor type, it was found that the less sweet distractor was better recognized. The less sweet distractor was also better discriminated from the target in terms of sweetness perception. This would suggest that children seem more aware of sugar subtraction than addition from a hedonic, perceptive, and a memory point of view.

The higher liking degree expressed by children for more sugary products is in accordance with literature data (Liem & de Graaf, 2004) and could be explained by the sour taste of the product chosen in the present experiment. This result is particularly interesting for food companies which are required more and more to optimize children's products by reducing the sugar and fats contents due to the growing and widespread phenomenon of children obesity. In this context, food developers should keep in mind that young consumers can perceive even the smallest differences in the sweetness of a given food product – especially in the case of a reduced amount of sugar. Children would also be able to learn and memorize involuntarily such variations in sweetness.

A possible explanation for the better discrimination of the D- distractor from a perceptive, hedonic, and memory point of view might be that in order to get the same discrimination, the sweetness difference between the D+ distractor and the target sample should have been larger than the difference between the D- distractor and the target sample. In the present experiment the sensory distance among the distractors and the target sample was equal. In other words, this would mean that the sugar amount added to the target (43 g) to obtain the D+ distractor would have exerted less influence on the perceived intensity than the sugar amount added to the D- distractor (43 g) to obtain the target sample. Nevertheless, although the effects found in the present experiment both for the hedonic and the perceptive tests seem to point into the same direction, it is unlikely that they explain all the difference observed for the couple D- *vs* Target and the couple D+ *vs* Target.

It should also be considered that the perceptive and hedonic tests results could in turn explain the outcome of a lower memory for the D+ distractor. A similar effect was found in Morin-Audebrand et al.'s (2009) paper where the authors highlighted that young adults were able to discriminate a 1.5

JND less sweet custard dessert from the target custard but not custards which were 1.5 JND and even 2.5 JND sweeter than the target. In Morin-Audebrand and colleagues' paper, a memory effect for taste occurred and depended more on the correct rejection of the distractors rather than on the identification of the target, as in the present case. Köster et al. (2004) also found the same type of insensitivity to added sugar and showed a distorted memory for sweet taste. In their experiment, an orange juice sample was varied in sweetness and bitterness and a yoghurt sample in sweetness and sourness. They used just noticeable differences to prepare distractors that varied from the target sample by -1.0, +1.0, +1.5 and +2 JNDs for each varied taste. They found that for both orange juice and yoghurt, varying sweetness had no effect on memory performance. Even the distractor that was 2 JNDs sweeter than the target sample was not recognized as different from the memory of the target. On the contrary, the distractors that differed in bitterness and sourness were clearly recognized as different from the memory of the target. They also assessed relative memory (asking subjects whether the experimental target and distractors were more, less or equally sweet/sour/bitter than the target eaten before) for the same foods and found that the memory for sweetness was distorted and that only addition of 2 JND sugar came to be marginally different from the target, whereas a deduction of – 1 JND caused a very clear and significant difference from the target. The same memory distortion for sweetness had earlier been found by Barker and Weaver (1983). Further research is needed to better understand the relationship between human taste perception and memory ability.

Finally, it should be borne in mind that the experiment results cannot be generalized due to the small number of children involved in the study. In this regard, in order to confirm our results, it is recommended to increase the number subjects and to extend the evaluation considering other food stimuli.

Acknowledgements

A special thanks to E.P. Köster for his helpful comments on an earlier draft of the manuscript and to Valentina Bergamaschi who offered an important contribution to the execution of the experiment.

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Figure caption

Fig.1 Results of the discrimination test: number of correct answers for each couple of stimuli: D- vs T, T vs T, D+ vs T (D- = distractor 1.5 JND less sweet than the target; T = Target; D+ = distractor 1.5 JND sweeter than the target). The line indicates the minimum number at which an answer becomes significant for $p<0.05$.

Fig.2 Results of the memory test: memory index by learning (incidental, intentional) and time of retention (day, week) and its significant difference from zero (** $p<0.01$; n.s. not significant).

Fig. 3 Proportion of correct answers for the target (hits) and the distractors (correct rejections) for incidental and intentional learning conditions.

Fig. 4 Results of the hedonic test: lsmeans hedonic ratings by JND. D-=distractor 1.5 JND less sweet than the target; T= Target; D+=distractor 1.5 JND sweeter than the target.

Figure 1

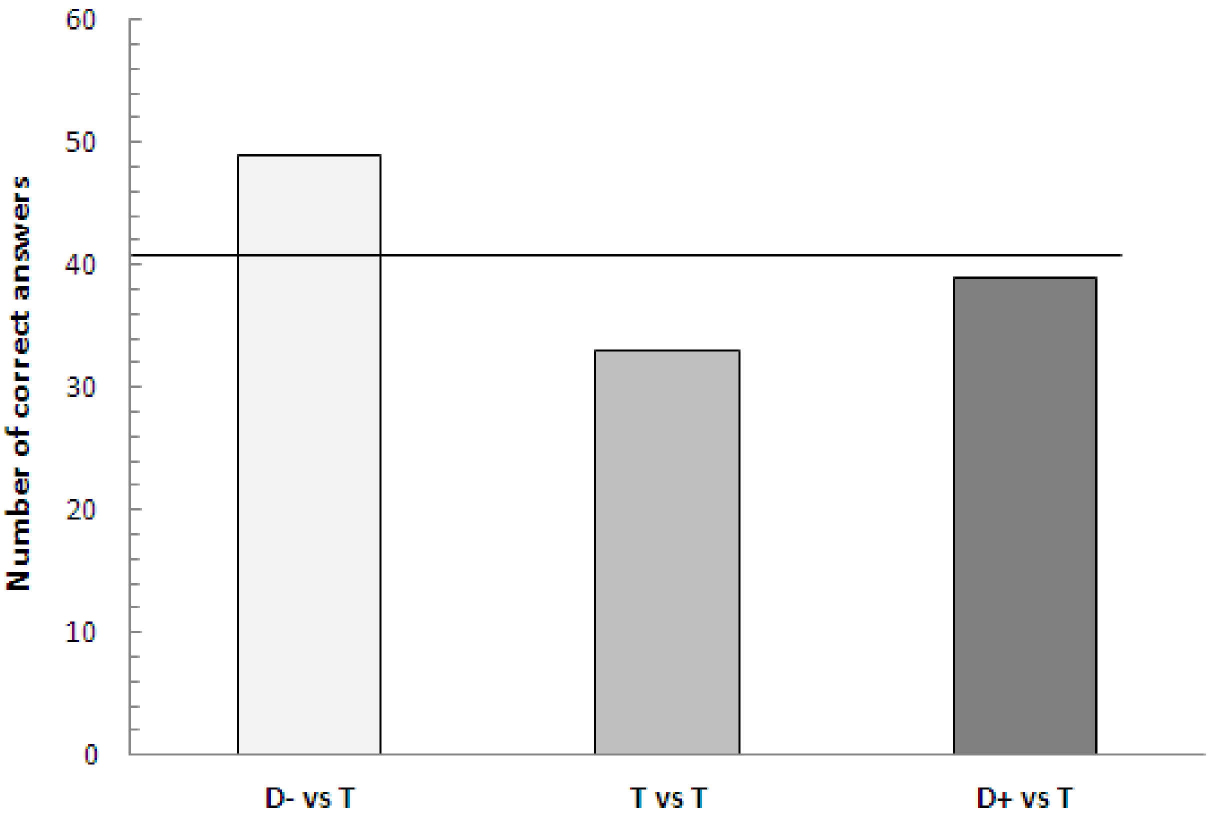

Figure 2

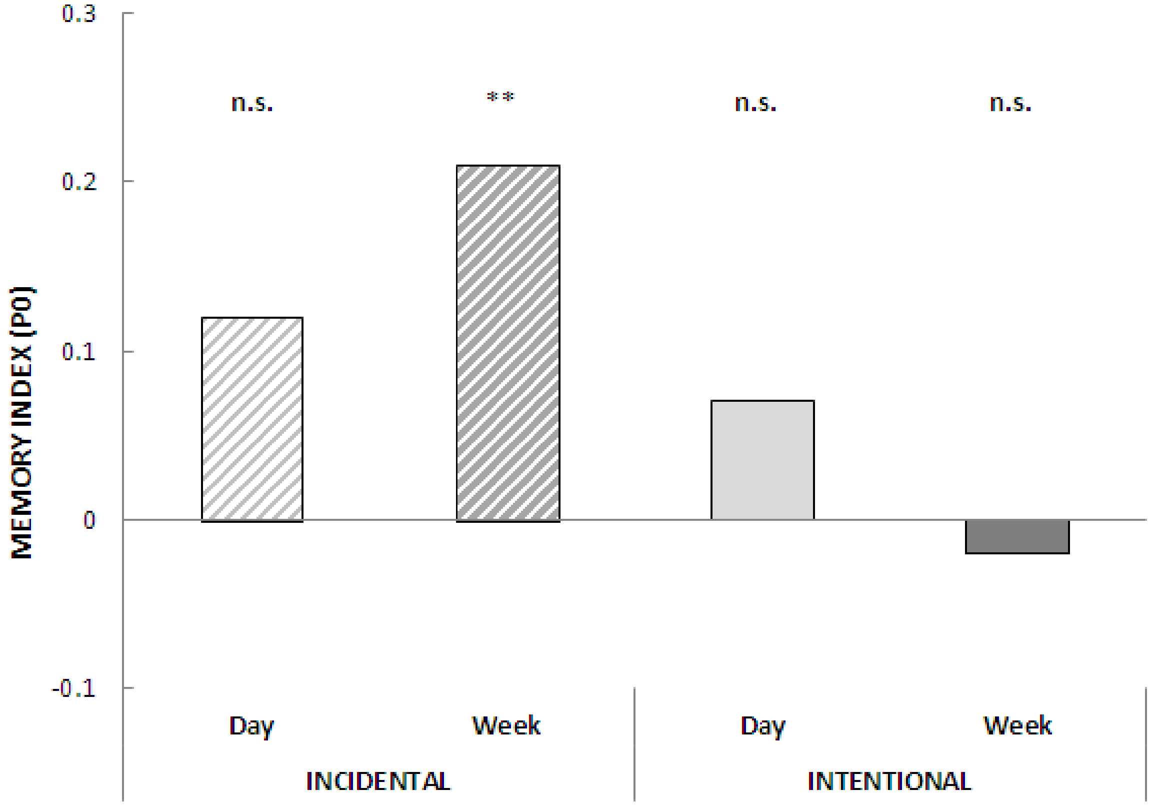
0.3
0.2
0.1
0
-0.1
MEMORY INDEX (P0)
n.s.
**
n.s.
n.s.
Day
Week
Day
Week
INCIDENTAL
INTENTIONAL

Figure 3

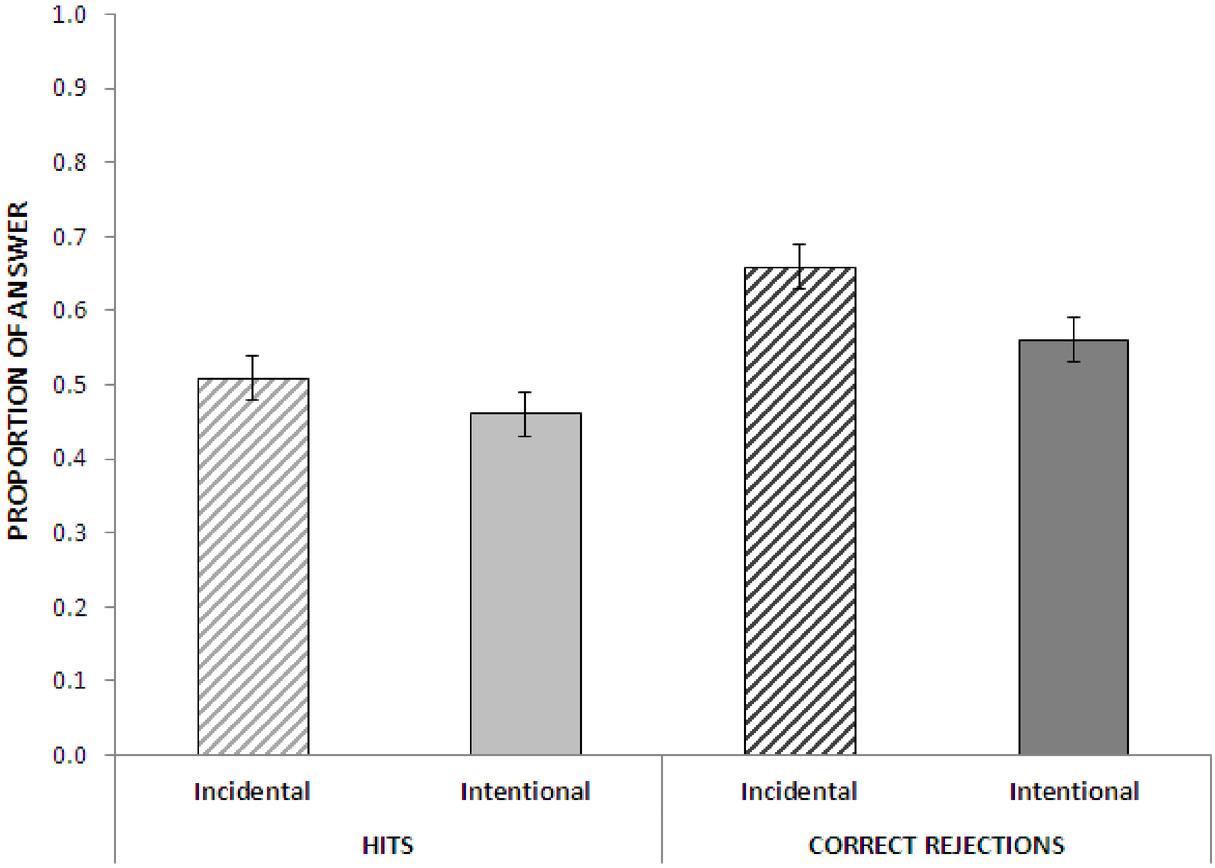
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PROPORTION OF ANSWER
Incidental
Intentional
Incidental
Intentional
HITS
CORRECT REJECTIONS

Figure 4