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Research report

Selecting food. The contribution of memory, liking, and action ☆

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ABSTRACT

The goal of the present experiment was twofold: identifying similarities and differences between flavour memory and visual memory mechanisms and investigating whether kinematics could serve as an implicit measure for food selection. To test flavour and visual memory an 'implicit' paradigm to represent real-life situations in a controlled lab setting was implemented. A target, i.e., a piece of cake shaped like either an orange or a tangerine, covered with either orange- or a tangerine-flavoured icing, was provided to participants on Day 1. On Day 2, without prior notice, participants were requested to recognize the target amongst a set of distractors, characterized by various flavours (orange vs. tangerine) and/or sizes (orange-like vs. tangerine-like). Similarly, targets and distractors consisting of 2D figures varying in shape and size were used to assess visual memory. Reach-to-grasp kinematics towards the targets were recorded and analysed by means of digitalization techniques. Correlations between kinematic parameters, memory and liking for each food item were also calculated. Results concerned with memory recollection indices provided evidence of different key mechanisms which could be based either on novelty of flavour memory or visual memory, respectively. To a moderate extent, kinematics may serve as an implicit index of food selection processes.

Introduction

All living beings experience the necessity to elaborate and to organize sensory information in order to create a coherent representation of the external world. This representation, stored in one's memory, is then used to adaptively solve common environmental problems, such as programming and executing actions. It is, therefore, evident that perceptual, cognitive and motor processes are tightly linked to each other and all contribute to the explanation of complex daily behaviours. As an example, when eating a piece of cake, sensory features (mainly visual and chemosensory) firstly and crucially contribute to trigger the formation of a specific 'cake-experience' memory. Then, in conjunction with sensory specifications, broadly-tuned information concerning motivation – in the form of food preference and motoric aspects necessary to act upon the selected food – are also stored.

The aim of the present study was twofold. In the first instance, the link between sensory and cognitive information of food items was addressed. Specifically, we compared the mechanisms underlying visual memory and flavour memory. In the second instance, the experiment aimed at investigating whether hand kinematics, representing the motor component involved in complex daily behaviours, could serve as an implicit index to evaluate food selection. For the sake of clarity, the state of the art concerning the central issues of the present work, namely food, visual memory and motor-mediated food selection processes will be separately overviewed.

Although memory is involved in most every-day-life activities, we are not always aware that we are relying on it. Consider the example of buying a food item at a supermarket: when seeing the packaging and then eating the food, it is rare that one consciously decides to memorize either the food item or the visual appearance of the packaging (Issanchou, Valentin, Sulmont, Degel, & Köster, 2002). It is more likely that one acquires knowledge regarding both the food and the visual characteristics of the packaging without any particular attentional or learning effort. This information is stored implicitly and ready-to-use when

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appropriate (Castelhano & Henderson, 2005; Mojet & Köster, 2005). In this perspective, it might be assumed that food choice (and intake) is modulated to a certain extent by the food expectations based on previous experience. The same reasoning may also be applied to the visual domain. Indeed, as natural products of scene perception, visual items are able to produce visual representations that lead to the formation of expectations (Bressler, 2004).

In order to investigate flavour memory, an innovative implicit memory paradigm has been developed (Mojet & Köster, 2002) and recently used in a number of studies (Köster, Prescott, & Köster, 2004; Laureati et al., 2008; Mojet & Köster, 2005; Morin-Audebrand et al., 2009, 2012; Møller, Mojet, & Köster, 2007; Sulmont-Rossé, Møller, Issanchou, & Köster, 2008). Without any reference to memory, participants were presented with food targets during an ecologically valid situation (e.g., a meal). After a variable retention interval (from hours to a week) and without prior notice, participants were requested to recognize previously eaten targets amidst distractors, consisting of slightly varied versions of the targets formerly presented. Using this kind of recognition paradigm provided a number of advantages. First, the paradigm gives the possibility to study flavour memory within a natural context. Presenting food targets within a meal prevented participants from paying too much attention to food sensory properties, mimicking what usually happens in real-life situations. Second, distractors used later in the test were similar to the target in their basic features, while being just-noticeably different in some sensory aspects (Morin-Audebrand et al., 2012). They therefore belonged to the same product type as the target and in this way the possible influence of verbal memory in recognising them was excluded. Although the mechanisms underlying implicit flavour memory are still largely unexplored, knowledge regarding implicit visual memory is well documented. Research conducted in the mid-1990s described the features of the memory trace determined by a visual object. Evidence of long lasting (e.g. a month) and highly detailed representations of novel bi-dimensional shapes – uninfluenced by attention – was found (DeSchepper & Treisman, 1996). Similarly, complex 3D scene representations – closer to real-life experience – seemed to produce analogous evidence (Castelhano & Henderson, 2005). It was then suggested that implicit memory traces may reflect the same stored material as explicit memory traces, but could be retrieved by following different routes (Treisman & DeSchepper, 1996). This issue takes part in the classic debate on dual-process memory judgements supporting the existence of two mechanisms either based on recognition or familiarity (Rotello, Macmillan, & Reeder, 2004; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996). Within the familiarity domain, a series of findings explained in the framework of the signal detection theory (SDT) supported the idea that implicit memory relies on the 'feeling of knowing' (Kelley & Jacoby, 1996). That is, participants were better able to recognize whether the presented object was the target instead of one of the distractors. Expressed in SDT terms, participants obtained a higher number of hits (saying 'yes' when the target was present) when compared to the number of correct rejections (saying 'no' when the target is absent).

In this respect, evidence from flavour memory studies has shown a reversed pattern of results (Morin-Audebrand et al., 2012). In incidentally learned food memories, distractors are most of the times correctly rejected while targets are poorly recognised (i.e. not better than chance guessing). In other words, participant's answers are better explained in terms of 'feeling of not knowing' rather than in terms of 'feeling of knowing'. Taken together, these results seem to suggest that flavour memory judgments are based on a novelty detection mechanism rather than guided by detailed representations of the target, as proposed for visual memory judgments (Morin-Audebrand et al., 2012; Rotello et al., 2004). However, to the best of our knowledge, no direct comparison between flavour memory and visual memory has been previously reported.

Assessing food-related behaviours from an integrated perspective calls for an involvement of the motor aspects characterizing the actions necessary to interact with food items. Previously-published research has shown that the "activation of the motivational systems initiates a cascade of sensory and motor processes, enhanced perceptual processing, and preparation for actions that have evolved to assist in selecting appropriate survival behaviours" (Bradley, 2009). Along these lines, a number of studies have focused on the oral movements performed when the food is already into the mouth, providing compelling evidence of their effect on sensory food perception (de Wijk, Engelen, & Prinz, 2003; de Wijk, Wulfert, & Prinz, 2006). Nevertheless, to analyse the cascade of motor processes activated by an appetitive attitude, it is worth considering a different approach. In this respect, the selection-for-action theory seems an appropriate theoretical framework (Allport, 1987). Allport (1987), considering the problem from a sensorimotor point of view, suggested that specific attentional mechanisms select the motor program needed to accurately act upon a particular object (i.e. the target) and simultaneously maintain at a lower threshold the motor programs for irrelevant objects (i.e. the distractors) which are present within the same reaching space. The classical example of the bowl of fruit might help to clarify this issue. When a bowl contains many different fruits, we can see and reach all of them. But only one fruit that motivates us – namely, our target – will guide our action. This means that the specific kinematic pattern to successfully grab the target will be pushed into operation (for review see Castiello, 1999).

Only recently research has provided evidence of specific chemosensory influence on the kinematics of visually-guided reach-to-grasp movement towards food targets (Castiello, Zucco, Parma, Ansuini, & Tirindelli, 2006; Parma, Ghirardello, Tirindelli, & Castiello, 2011; Tubaldi, Ansuini, Tirindelli, & Castiello, 2008). Specifically, facilitation effects were evident on hand kinematics when 'size' congruent odours or flavours preceded the presentation of the visual object to be grasped. Conversely, interference effects emerged on hand choreography when 'size' incongruent odours or flavours preceded the presentation of the visual to-be-grasped object. It is worth noting that both the facilitation and the interference effects reported in the above mentioned experiments were not voluntarily produced by the participants, who were not aware of the differences in their hand movements between conditions.

Given that the reach-to-grasp movement cannot be explicitly controlled in its parameterisation, it can be considered a movement implicitly reflecting appetitive intentions. To our knowledge, no previous studies have investigated whether the reach-to-grasp movement could serve as an implicit index of food selection. If this is the case, kinematic parameters would be correlated to the implicit flavour memory index and, possibly, to liking ratings. This would provide a new and reliable implicit index aimed at ascertaining consumer's attitudes towards food selection, while avoiding the risk of consumers' consciously-induced bias.

In summary, the aims of the present study concern the analysis of an example of food appetitive behaviour, considering both the sensory–cognitive relationships and the motor-mediated food selection process. Specifically the main questions become the following. What are the similarities and the differences between flavour memory and visual memory in the specific context of the features taken into consideration here? Is novelty a key concept in differentiating food recognition and visual recognition? Does food liking modulate flavour memory recognition? Does flavour memory recognition influence the motor control of the hand? Does food liking affect the motor control of the hand? Can kinematics serve as an implicit index in the food selection process? In the effort of answering these questions, we exposed participants to a food (e.g., piece of cake) and a visual target (e.g., a bi-dimensional figure) on Day 1. Two days later (on Day 2), without prior notice, participants were requested to recognize both the food and the visual target amongst a set of distractors. Food distractors might differ from the target in flavour (orange vs. tangerine) and/or size (orange-like vs. tangerine-like). Visual distractors might vary from the target in terms of shape and/or size. Memory recollection indices were calculated in order to determine whether food and visual memory are based on different novelty/familiarity feelings. Reach-to-grasp kinematics towards the pieces of cake were recorded and analysed in order to be correlated with memory and the liking ratings.

Materials and methods

Participants

Forty-eight participants (24 women, 24 men; age range = 19–40 yrs) that were either Dutch ($N = 44$) or English ($N = 4$) speakers were recruited. Three participants were not included in the final analyses because they did not show up for the second experimental session. All the participants included in the sample ($N = 45$) reported normal or corrected-to-normal vision, had normal smell and taste ability, had no history of smell or taste dysfunctions, were not smokers, were right-handed and had no history of repetitive-strain injuries. Participants were required to stop eating, chewing gums and drinking anything but water at least 1 one hour before each experimental session started. All were naïve as to the purpose of the experiment (food and visual memory recollection as well as kinematic measurements) and gave their informed written consent to participate. The experimental session lasted approximately 1 h on Day 1 and 1 h on Day 2. The experimental procedures were in accordance with the Declaration of Helsinki and approved by the local Review Board.

Stimuli

To test flavour memory abilities, a commercially-available unflavoured cake (Madeira cake, C1000) was chosen as the basis for both the target and the distractors. Cakes were cut in a shape reminding of a tangerine [cylinders of $4 * 4 * 4$ cm; 4 cm is the average diameter of tangerines (*Citrus reticulata*)] or in a shape reminding of an orange [cylinders of $6 * 6 * 6$ cm); 6 cm is considered the average diameter for sweet oranges (*Citrus sinensis*)]. The flavour (0.01% of Tangerine 051927 A FP and 0.02% Orange 051915 T, Firmenich) was provided by means of a white icing (1 kg powder sugar, 200 ml cold water) covering the whole piece of cake. A preliminary triangle experiment ($N = 20$) was conducted to check if people could accurately distinguish between the tangerine- and orange-flavoured pieces of cake (Accuracy rate = 70%). Size and flavour were varied across the stimuli determining four experimental conditions: (i) tangerine-like cake size covered by tangerine-flavoured icing (TT); (ii) tangerine-like cake size covered by orange-flavoured icing (TO); (iii) Orange-like cake size covered by tangerine-flavoured icing (OT) and (iv) orange-like cake size covered by orange-flavoured icing (OO). The experimental population was evenly divided into 4 subgroups that differed in the target product (e.g. TT) that was provided to them on Day 1. The three size and flavour combinations not presented on Day 1 were used as distractors on Day 2 (e.g. TO, OT, OO for group TT). It should be noted that, in order to avoid the influence of everyday familiarity, we used a product that in this particular form differed somewhat from the usual Dutch market products. In order to evaluate visual implicit memory, bidimensional black and white figures were presented as target and distractors. The sizes (small: $4 * 4$ cm; large: $6 * 6$ cm) and the shapes (decagon vs. dodecagon) were varied across stimuli. Decagon and dodecagon were selected because the choice of simpler polygons (e.g. pentagon, hexagon, heptagon and octagon) would have led to a ceiling effect in the discrimination of a target among distractors, as revealed by a pilot study. The combination of size and shape attributes determined four visual conditions: (i) small-sized decagon-shaped logo (S10); (ii) small-sized dodecagon-shaped logo (S12); (iii) large-sized decagon-shaped logo (L10) and (iv) large sized dodecagon-shaped logo (L12). Please note that to the experimenter's knowledge, internet-based queries performed at the time of testing did not provide evidence of existing logos similar to those used in the present experiment. To test this hypothesis, a brief pilot study ($N = 10$) was also conducted. None of the participants interviewed recognized the images presented as familiar figures or related to any company logo.

Procedure

In order to conceal the real purpose of the experiment (i.e. studying incidental food and visual memory and measuring hand kinematics in selecting food items), participants were invited to take part in a study investigating the relationship between personality and sensory performance. They were asked to participate in two experimental sessions, the first occurring on Day 1 and the second two days later (Day 2). During the first experimental session, participants were incidentally exposed to both the food and the visual targets. On Day 2 they were unexpectedly asked to indicate the targets they had eaten and seen on Day 1 among food and visual distractors. Recordings of kinematic performance were also taken both on Day 1 and on Day 2.

Day 1: implicit learning session

Participants were asked to complete a number of paper-and-pencil tests regarding personality (NEO-FFI, (Costa & McCrae, 1992), chemosensory performance (adapted from Zucco, Amodio, & Gatta, 2006, Appendix A) and neophobic traits (Pliner & Hobden, 1992). Following the completion of the questionnaires, they were presented with both the food target and the visual target. To conceal the real aim of food target presentation (i.e. implicit food learning), participants were asked to taste a food product recently developed by a Dutch producer and to rate it in terms of pleasantness (i.e., liking) and novelty before it would enter the Dutch market. Each participant was asked to close her/his eyes in order to be 'surprised' by the food target. While vision was occluded, the experimenter positioned the target in the middle of a flat plastic disc (diameter 7 cm) placed at a 33-cm-distance from the starting pad upon which the participant's right hand was resting with index finger and thumb touching. Participants were instructed to wait for the experimenter's signal as to start the movement and subsequently open their eyes. Participants were requested to position their right hand with thumb and index finger touching on the starting pad, reach and grasp the piece of cake presented, hold it and bite directly into the cake for a maximum of three regular bites. The experimenter visually monitored the trial to ensure that the participant complied with these requirements. A breach of instructions determined the exclusion of the trial from the final analyses. Participants reported not to have previously experienced the "product" and provided their ratings. Subsequently, the visual target was shown. In accordance with the cover story, participants were asked to look at and sign a paper sheet on which the logo (i.e. visual target) of the 'fake' Dutch producer was printed. The size of the food product could be the same or different from that of the visual target. Size combinations were randomized and counterbalanced across participants. The experimental session lasted approximately 1 h.

Day 2: recognition session

In accordance with the cover story, participants were administered a paper and pencil test on imagery abilities (The Betts QMI Vividness of Imagery Scale, Sheehan, 1967). Then, in order to control whether the real purpose of the study was discovered, participants were asked to describe what, in their opinion, was the aim of the study. None of the participants declared that the aim of the study was linked to memory or motor aspects. Subsequently, participants were asked to carefully think for a few seconds about the target-product they had eaten at Day 1. Then, they were requested to perform a reach-to-grasp movement towards the remembered target-product as if it was positioned in front of them, on the yellow plastic disc, even though in reality it was not (i.e., perceptual-motor representation test). Immediately after this, they were asked to perform an absolute memory test, assessing their ability to recognize the food target among the distractors. Participants received a series of 8 samples, presented in sequential monadic order each on the yellow plastic disc, consisting of two identical targets and 6 distractors. For example, if the food target presented on Day 1 was TT, on Day 2 the same participant would be presented with two identical targets, namely two TT stimuli (same size and same flavour) and six distractors, that is two TO stimuli (same size but different flavour as compared to the target), two OT stimuli (different size but same flavour) and two OO stimuli (different in both size and flavour). Therefore, with respect to size or flavour only, the series always contained 4 samples that were equal to the subject's target and 4 samples that differed from the size or flavour of the target presented on Day 1. The reasons for the choice of a target/distractor ratio of 1/4 in the first identification condition (e.g. identical targets) and 1/2 in the size and flavour conditions were twofold. First, it assured that the response bias was not too strongly directed towards negative responses. Second, it prevented the target from becoming evident as a repeated stimulus and thus cause unwanted learning effects, which could have invalidated the memory test. Participants were asked to perform the reach-to-grasp movement towards the object (one at a time) positioned in front of them. Instructions were identical to those explained at Day 1. After they grabbed and tasted each sample, participants were asked to answer the following questions presented in a booklet: (i) "How much do you like this product?" (ii) "Is this product similar to the one you ate on Day 1 or is it different?", (iii) "How confident are you about your response?", (iv) "Has it the same SIZE as the one you ate on Day 1?", (v) "How confident are you about your response?", (vi) "Has it the same FLAVOUR as the one you ate on Day 1?" and (vii) "How confident are you about your response?". A 9-point Likert scale anchored to 'Very little' and 'Very much' as extremes was used to rate food liking (question i) whereas 5-point Likert scales anchored to 'Not at all' and 'Very much' as extremes were used for questions (from question iii, v, and vii). Questions ii, iv, and vi required a yes or no response. After a short break, participants performed the visual memory test. This test assessed the participant's ability to remember the visual target among distractors. The visual memory test corresponded well to the flavour memory test except for the fact that the distractors varied in shape instead of flavour. Questions were adapted to this difference; the scales used were the same as in the flavour task. At the end of the experimental session on Day 2 participants were debriefed about the real purpose of the experiment and they received a compensation for their participation.

Apparatus

The experimental sessions were conducted in a quiet and dimly-lit room. Participants were seated at a $100 * 70$ cm table positioned orthogonally below a ceiling-set camera (Dome camera on ceiling: Observer TM software Noldus, Wageningen). The whole experimental session was video-recorded in order to obtain the videos for the reach-to-grasp movements performed towards both the food targets and distractors. Hand kinematics was measured post hoc by means of digitalization techniques. Markers were digitally applied to (a) the wrist, (b) the tip of the index finger, and (c) the tip of the thumb of the right hand. The wrist marker was used to have a kinematic description for the reaching component of the action, whereas the index and the thumb markers were used to obtain a kinematic description of the measures concerned with the grasp component of the action.

Dependent variables and data analysis

Memory data were analysed by using Signal Detection Theory (SDT), which allowed us to produce a recognition index which was (i) independent of the participant's response bias to say 'yes' or 'no' (decision criterion), (ii) based on the difference between the familiarity feeling generated by a previously presented stimulus (signal) and the familiarity feelings presented by a new stimulus (noise; Macmillan & Creelman, 2004). The percentages of hits (saying 'yes' to a target), false alarms (saying 'yes' to a distractor), correct rejections (saying 'no' to a distractor) and misses (saying 'no' to a target) were determined and then transformed in z scores. The recognition index [$d' = z_{\text{hits}} - z_{\text{false alarms}}$] and the decision criterion [$C = -(z_{\text{hits}} + z_{\text{false alarms}})/2$] were calculated for each participant. Following the Macmillan and Creelman's (2004) procedure proportions of 0 and 1 were converted to $1/(2\,N)$ and $1-1/(2\,N)$ respectively, in order to avoid infinite values. To evaluate whether recognition outperformed chance guessing, one-sample t-tests were used to verify that the d's differed from 0. Kruskall–Wallis tests and univariate ANOVAs were applied to study gender effects on the participants' decision criteria and the recognition index and to assess whether liking played a role in recognition. In order to investigate the impact of recognition and liking on flavour memory and visual memory performance, participants were divided into groups on the basis of their d' ($d' > 0$: "good memory performers"; $d' < 0$: "bad memory performers"). Movement time was calculated as the time elapsing from the first approaching movement of the wrist until the fingers contacted the target. Kinematic variables related to the reaching phase were (i) the maximum velocity attained by the wrist during the movement; (ii) the time at which the maximum wrist velocity was detected; (iii) the percentage of movement duration at which maximum wrist acceleration occurred, and (iv) the percentage of movement duration at which maximum deceleration occurred. With regard to the grasping phase, we considered (i) the maximum distance between the index finger and the thumb and (ii) the percentage of movement duration at which the index finger and the thumb were most distanced. These parameters of the reaching and the grasping phase have been recognized as effective measures in delineating the kinematical profile of arm and hand movement towards target differing in size (Paulignan, MacKenzie, Marteniuk, & Jeannerod, 1990) and in studying how the planning and control of hand movements is affected by chemosensory stimulation (e.g. Castiello et al., 2006; Parma et al., 2011). Normalized rather than absolute measures were preferred because kinematic differences may be better understood when the occurrence of kinematic events is expressed in terms of relative to the overall movement or grasping phase duration, respectively (e.g., Soechting & Lacquaniti, 1981). Spearman correlations were also applied to investigate the link between confidence ratings, recognition indices, liking ratings and kinematic parameters. Special concern will be given to gender differences, since women are known to perform better in chemosensory tasks (Koelega & Köster, 1974; Larsson, Nilsson, Olofsson, & Nordin, 2004; Olofsson & Nordin, 2004; Sulmont, 2000). Statistical analyses were performed using SPSS 17.0 statistical package.

Results

First, we shall report the results for the measurement of flavour memory focusing on the recognition of the food target presented at Day 1. Second, we will show the results for the analyses on visual memory focusing on the recognition of the visual target presented at Day 1. Finally, we shall present the findings stemming from the kinematic analysis.

Flavour memory

Flavour recognition

Based on the 'flavour' information only, participants did not show evidence of learning to discriminate the target amongst distractors, d'[0.09 ± 1.66; $t(44) = 1.87$; $ps > .05$]. No differences in performance were reported between men (−0.01 ± 1.63) and women (0.19 ± 1.71; $F(1,43) = 0.15$, $p_s > .05$, $\eta^2_p = .02$). When analysing hit proportion, participants showed a learning effect in favour of the target (hit proportion: 0.60 ± 0.29), $Z = -2.31$, $p < .05$. To this end, gender differences were evident in favour of men's performance (Hit proportion men: 0.62 ± 0.30; Hit proportion women: 0.57 ± 0.27, $Z = -2.03$, $p < .05$: Fig. 1a). Moreover, a significant liberal decision criterion was reported only in the male subgroup (−0.47 ± 0.68, $Z_{men} = -2.5$, $p < .01$: Fig. 1b). This indicated that male participants predominantly answered "yes" both when the target was present and when it was absent. Confining the analyses to the "good performers" group (i.e. participants whose d' was higher than chance level), participants could recognise significantly that the food item was not the one they had previously eaten (Correct rejection proportion: 0.44 ± 0.30, $Z = -2.48$, $p < .05$). In other words, they were guided by the 'feeling of not knowing'. Liking did not influence memory indices (percentage of hits, correct rejections; Table 2).

Size recognition

When considering only 'size' information, according to a Student t-test, participants' recognition index was significantly higher than zero, d' [2.39 ± 1.68; $t(44) = 9.5$; $p_s < .001$]. This means that participants could easily discriminate the target from the distractors. Moreover, the analyses of hit and correct rejection proportions in the overall group showed a significant deviation from chance guessing (Hit proportion: 0.70 ± 0.30, $Z = -3.45$, $p < .001$; Correct rejection proportion: 0.91 ± 0.19, $Z = -6.00$, $p < .001$). With respect to the decision criterion, 59% of the participants behaved in a conservative fashion, $Z = -3.75$, $p < .001$. In other words, participants produced more correct rejections and misses, answering "no" to most of the questions. An interesting finding is that confidence ratings for the majority of the targets were inversely related to hit proportion (TT: rho = −.48, $p < .001$; TO: rho = −.50, $p < .001$; OT: rho = −.41, $p < .01$) and for all the targets directly related to correct rejection proportion (TT: rho = .59, $p < .0001$; TO: rho = .54, $p < .0001$; OT: rho = .41, $p < .005$; OO: rho = .31, $p < .05$). Thus, participants were less confident while recognizing the target (i.e. 'feeling of knowing') rather than recognizing that the product was not the target they had previously eaten (i.e. novelty, 'feeling of not knowing').

Flavour and size recognition

The recognition index (d') calculated over all participants did not significantly differ from chance guessing [0.40 ± 1.45; $t(44) = 1.87$; $p_s > .05$}. No significant differences were found when comparing d' for men (0.25 ± 1.38) and women [0.54 ± 1.53; $F(1,43) = 0.46$; $p_s > .05$]. This indicated that participants did not learn, on average, to discriminate the target amongst the distractors. No significant differences were reported when considering the target to which participants were exposed on Day 1 ($p_s > .05$). Participants' decision criteria were equally distributed within the sample – that is, almost half of the participants had a tendency to answer "yes" ($C < 0$, $N = 21$), three participants did not show any bias ($C = 0$, $N = 3$) and the remaining participants answer "no" ($C > 0$, $N = 21$). No effect of liking was reported on flavour memory measures, when considering the recognition indices (percentage of hits, correct rejections; Table 1). Only when considering the OO target (orange-like shaped and orange-flavoured cake) the hit proportion was inversely correlated with the liking for the target (rho = −.30, $p < .05$).

Liking

Participants rated the tangerine-flavoured pieces of cake (5.6 ± 0.30) as significantly more pleasant than the orange-flavoured items (5.9 ± 0.29) [$F(1,43) = 6.84$, $p_s < .05$, $\eta^2_p = .14$]. No main effect of size [$F(1,43) = 3.25$, $p_s > .05$, $\eta^2_p = .07$] or interaction [$F(1,43) = 1.09$, $p_s > .05$, $\eta^2_p = .03$] were retrieved.

Visual memory

Shape recognition

Considering the correct rejection proportion, good performers could discriminate between target and distractors better than chance level, $Z = -2.21$, $p < .05$. No gender [$F(1,43) = 0.76$; $p_s > .05$, $\eta^2_p = .04$] or target differences were found [$F(1,43) = 0.84$; $p_s > .05$, $\eta^2_p = .03$]. Correlations between confidence ratings and memory variables did not reach significance ($p_s > .05$).

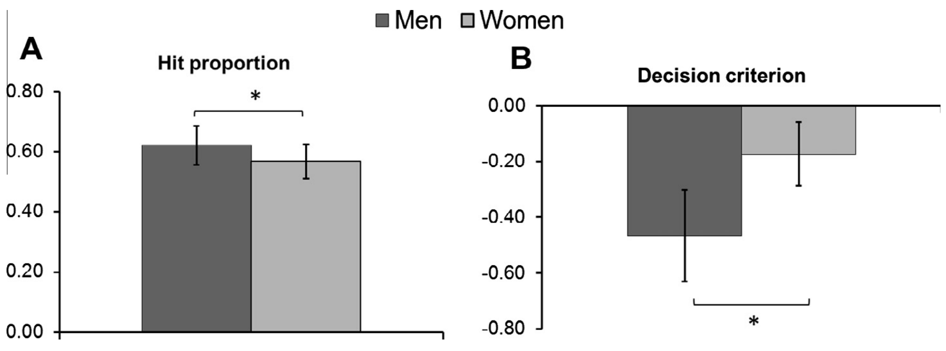

Fig. 1. Panel A shows the average proportion of hits across gender in the food flavour recognition task. Panel B depicts the decision criterion across gender in the same task. Error bars represent the Standard Error of Mean.

Table 1
Spearman rank correlation values between the percentage of correct rejections (CR), the percentage of hits (H), the confidence rating and the liking ratings for the flavour and size recognition of each target.

	% of CR	% of H	Confidence	Liking
TT				
% of CR	1.00	−.532**	0.15	−0.15
% of H		1.00	−0.23	0.01
Confidence			1.00	−0.10
Liking				1.00
TO				
% of CR	1.00	−.362*	−0.25	−0.25
% of H		1.00	0.10	0.34
Confidence			1.00	0.03
Liking				1.00
OT				
% of CR	1.00	−.544**	0.08	−0.13
% of H		1.00	0.04	0.16
Confidence			1.00	−0.05
Liking				1.00
OO				
% of CR	1.00	−.497**	.347*	−0.22
% of H		1.00	−0.28	−0.30**
Confidence			1.00	−0.04
Liking				1.00

* $p < 0.05$.
** $p < 0.01$.

Table 2
Spearman rank correlation values between the percentage of correct rejections (CR), the percentage of hits (H), the confidence rating and the liking ratings for the flavour recognition of each target.

	% of CR	% of H	Confidence	Liking
TT				
% of CR	1.00	−.548**	0.049	0.128
% of H		1.00	−0.003	0.188
Confidence			1.00	−0.034
Liking				1.00
TO				
% of CR	1.00	−.631**	0.01	−0.008
% of H		1.00	0.038	0.031
Confidence			1.00	−0.013
Liking				1.00
OT				
% of CR	1.00	−.502**	0.283	−0.078
% of H		1.00	−0.247	0.034
Confidence			1.00	−0.086
Liking				1.00
OO				
% of CR	1.00	−.501**	−.338*	−0.232
% of H		1.00	0.139	−0.015
Confidence			1.00	0.041
Liking				1.00

* $p < 0.05$.
** $p < 0.01$.

Size recognition

Results show that d' was not significantly different from zero (0.13 ± 1.26; $Z = 0.905$, $p > .05$), supporting the fact that participants used a liberal criterion by using the size information only. Hit proportion was significantly higher than chance level in both men and women (Hit proportion: $Z_{men} = -2.24$, $p < .05$; $Z_{women} = -1.97$, $p < .05$; Fig. 2). The decision criterion was significantly lower than 0, $Z = -2.31$, $p < .05$. Confidence ratings did not correlate to any of the considered memory indices ($p_s > .05$). No effect of target was reported ($p_s > .05$).

Shape and size recognition

On average, participants were not able to differentiate target from distractors (d': -0.19 ± 1.14; $t(44) = -1.120$, $p > .05$). No effect of target type [$F(1,43) = 0.53$; $p_s > .05$, $\eta_p^2 = .04$] or gender resulted to be significant ($F(1,43) = 0.55$; $p_s > .05$, $\eta_p^2 = .02$). No significant correlation between confidence ratings and memory recollection indices was found ($p_s > .05$). Also, no significant differences were reported when considering the target to which participants were exposed at Day 1 ($F(1,43) = 0.46$; $p_s > .05$, $\eta_p^2 = .03$).

Flavour and visual memory

Regardless of the target to which participants were exposed on Day 1, the participants used a more conservative criterion when judging food-related topics than when they were asked to judge the visual targets, C_{food}: -0.25 ± 1.01; C_{visual}: -0.10 ± 1.04, $t(44) = 2.03$; $p_s < .05$. Moreover, although not significantly different, the confidence ratings reveal that participants tended to be more confident in flavour-related rather than in visual-related questions (Flavour memory: 4.16 ± 0.11, Visual memory: 3.57 ± 0.13 $t(44) = 2.12$; $p_s < .05$).

Kinematics

Perceptual-motor representation test

Comparing the reach-to-grasp movement performed on Day 1 (with the real to-be-grasped target) with the reach-to-grasp performed on Day 2 (without the real target), no significant differences emerged for any of the considered kinematical measures (Table 3). This finding might indicate that grasping the 'Day 1' target and reproducing the previously performed movement on Day 2 were both dominated by the same global learning experience.

Movement time

By means of a within ± -subject ANOVA, a main effect of dimension was revealed on movement time, $F(1,39) = 10.96$, $p < .01$, $\eta_p^2 = .22$. In contrast to previous evidence (Castiello, 1996), this indicated that movement time was longer for larger than for smaller targets (1584 vs. 1454 ms, respectively).

Reaching phase

No significant interactions were found when considering maximum wrist velocity [Flavour: $F(1,38) = 0.08$, $p > .05$, $\eta_p^2 = .002$; Size: $F(1,38) = 0.58$, $p > .05$, $\eta_p^2 = .02$; Flavour by Size: F (1, 38) = 0.03, $p > .05$, $\eta_p^2 = .001$]. Below, we report the results for the variables that reached the significance level.

Time of maximum wrist velocity

As shown in Fig. 3, the within subjects ANOVA, revealed a significant 'size' by 'flavour' interaction, $F(1,39) = 8.47$, $p < .01$, $\eta_p^2 = .18$. Post hoc contrast showed that the time of maximum wrist velocity was reached earlier for tangerine-flavoured objects when the size was object-congruent (TT, 525 ms) rather than incongruent (TO, 577 ms).

Normalized time of peak wrist acceleration and deceleration

A significant two-way interaction between size and flavour was found, $F(1,42) = 6.44$, $p < .05$, $\eta_p^2 = .13$ (Fig. 4a). As revealed by post hoc contrasts, orange-flavoured targets peak acceleration occurred earlier for orange- rather than tangerine-shaped targets (40 vs. 45%, respectively), suggesting that flavour-size congruency played a role in modulating this kinematic parameter. Given that the peak wrist acceleration and deceleration are complementary measures, as represented in Fig. 4b, results for the deceleration component complemented those reported for wrist acceleration ('dimension'

Table 3
Descriptive and inferential statistics for each kinematical variable explored at Day 1 and Day 2.

	Day 1		Day 2				
	Mean	SD	Mean	SD	t	df	Sig. (2-tailed)
TT							
Peak wrist velocity (mm/s)	0.70	0.35	0.68	0.21	0.14	10	0.89
Time to peak wrist velocity%	509.10	457.50	458.18	307.95	0.32	10	0.75
Normalized time peak wrist acceleration%	29.94	16.23	36.69	13.43	−1.82	10	0.10
Normalized time peak wrist deceleration%	70.06	16.23	63.31	13.43	1.82	10	0.10
Maximum hand aperture (mm)	79.68	13.93	85.30	25.67	−0.96	10	0.36
Time of maximum hand aperture (ms)	1374.55	675.82	1458.18	307.96	1.13	10	0.06
Movement time (ms)	1930.90	781.61	1498.18	758.39	1.35	10	0.21
TO							
Peak wrist velocity (mm/s)	0.69	0.09	0.67	0.21	0.18	7	0.86
Time to peak wrist velocity%	380.00	229.28	555.00	317.45	−1.37	7	0.21
Normalized time peak wrist acceleration%	34.17	14.09	40.00	19.12	−0.67	7	0.52
Normalized time peak wrist deceleration%	65.83	14.09	60.00	19.12	0.67	7	0.52
Maximum hand aperture (mm)	85.54	6.70	90.69	15.56	−0.80	7	0.45
Time of maximum hand aperture (ms)	740.00	264.47	555.00	317.45	1.27	7	0.24
Movement time (ms)	1405.00	400.25	1895.00	1068.60	−1.21	7	0.27
OT							
Peak wrist velocity (mm/s)	0.69	0.32	0.71	0.25	−0.17	9	0.87
Time to peak wrist velocity%	944.00	757.82	684.00	828.91	0.79	9	0.45
Normalized time peak wrist acceleration%	45.35	18.24	43.50	13.39	0.26	9	0.80
Normalized time peak wrist deceleration%	54.65	18.24	56.50	13.39	−0.26	9	0.80
Maximum hand aperture (mm)	93.41	7.34	88.08	23.23	0.76	9	0.46
Time of maximum hand aperture (ms)	1416.00	906.71	684.00	828.91	1.88	9	0.09
Movement time (ms)	2080.00	958.52	1728.00	1431.43	0.60	9	0.56
OO							
Peak wrist velocity (mm/s)	0.60	0.14	0.63	0.17	−0.63	8	0.55
Time to peak wrist velocity%	782.22	368.30	666.67	379.47	0.77	8	0.46
Normalized time peak wrist acceleration%	49.69	12.50	40.51	20.07	1.03	8	0.33
Normalized time peak wrist deceleration%	50.31	12.50	59.49	20.07	−1.03	8	0.33
Maximum hand aperture (mm)	93.43	13.97	94.81	27.00	−0.15	8	0.89
Time of maximum hand aperture (ms)	1066.67	448.11	966.67	379.47	2.65	8	0.06
Movement time (ms)	1724.44	496.57	2173.33	1304.61	−1.07	8	0.32

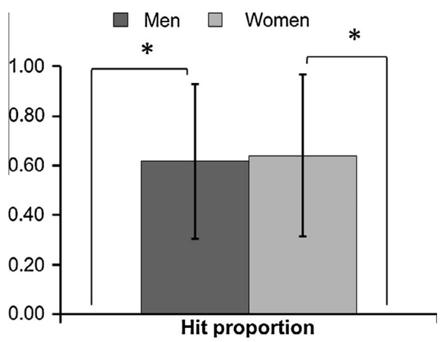

Fig. 2. Average proportion of hits across gender in the visual size recognition task. Error bars represent the Standard Error of Mean.

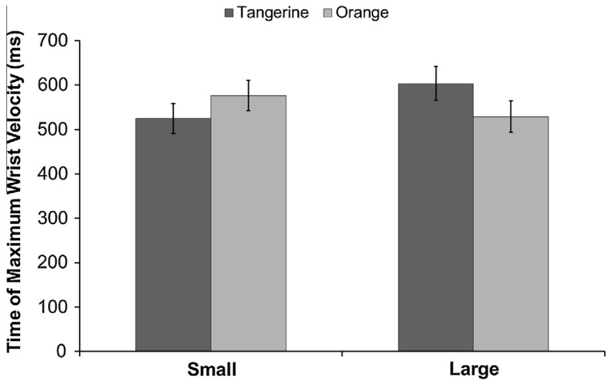

Fig. 3. Bars represent the significant two-way interaction ‘dimension’ by ‘flavour’ for the time at which maximum wrist velocity occurred. Error bars indicate the Standard Error of Mean.

by ‘target interaction: $F(1,42) = 6.44$, $p < .05$, $\eta_p^2 = .13$; TO: 55% of movement time; OT = 60% of movement time).

Grasping phase

Normalized time of maximum hand aperture

A main effect of dimension was revealed, $F(1,42) = 5.47$, $p < .05$, $\eta_p^2 = .12$. In line with previous evidence, post hoc contrast showed that maximum hand aperture was reached later for larger than for smaller targets (65 vs. 62%, respectively). As Fig. 5 shows, the two-way interaction ‘dimension’ by ‘flavour’ was reported to be significant, $F(1,42) = 5.47$, $p < .05$, $\eta_p^2 = .12$. Specifically, for the orange-shaped targets, time of maximum hand aperture occurred later for the orange-than for the tangerine-flavoured object (63 vs. 61%, respectively).

Maximum hand aperture

Within subjects ANOVA showed a significant main effect of dimension, $F(1,39) = 269.95$, $p < .001$, $\eta_p^2 = .87$. As classically found, the maximum grip aperture was greater for the large (here, orange-shaped) targets when compared to small (tangerine-shaped) targets (90 vs. 76 mm, respectively).

Kinematic parameters and memory

Only one partial relation between kinematic measures (referring both to the reaching and grasping phase) and recognition indices was found by using Spearman’s correlations. Specifically, for the group exposed to the OO target in Day 1, a reduced correct rejection proportion is linked to an increased maximum wrist velocity (rho = −.35, $p < .05$), supporting the idea that in a highly uncertain situation reaching speed towards a target is reduced.

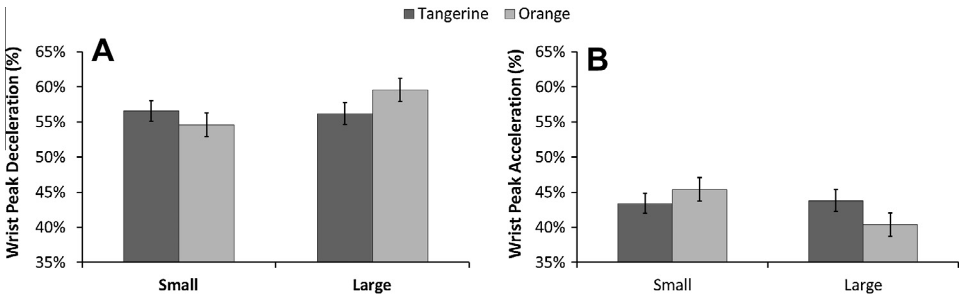

Fig. 4. Panel A shows bars representing the significant two-way interaction 'dimension' by 'flavour' for the peak wrist deceleration. Panel B shows bars representing the significant two-way interaction 'dimension' by 'flavour' for the peak wrist acceleration. Error bars indicate the Standard Error of Mean.

When considering the grasping phase, a direct correlation between flavour recognition accuracy (hit and correct rejection proportions) and time at which maximum hand aperture occurs is revealed for the OO target (rho = .40, $p < .05$).

Kinematic parameters and liking

Spearman correlations revealed a significant proportionally inverted relation between liking rating for the orange-shaped and orange –flavoured target (OO) and the time at which maximum wrist velocity is measured (rho = −.41, $p < .05$). This result seems to indicate that reaching-related kinematic measures can reflect flavour-liking judgements, even if it applies to a limited number of cases.

Discussion

The present findings indicate how an implicit exposure to the size and the flavour of a food as well as to the visual features of geometrical 2D figures shapes peculiar memory experiences. Let us first consider the general ability to recognize a previously experienced target, either food or visual. In both cases, *d'* values were not significantly higher than chance guessing, meaning that participants did neither significantly discriminate the food nor the visual target from distractors. For the flavour memory component, this seems to be in line with a previous study (Laureati et al., 2008) which was, however, contrasting with other studies on incidental food learning and memory, reporting *d'* higher than chance guessing (Köster et al., 2004; Mojet & Köster, 2002, 2005; Møller, Wulff, & Köster, 2004; Møller et al., 2007). Different hypotheses could be taken into account to explain this poor flavour memory finding. In the first instance, it is possible that the methodology applied (i.e. target/distractor ratio) could have confounded the results. However, this option can be rejected since it has already been demonstrated that the target/distractor ratio does not affect recognition ability (Morin-Audebrand et al., 2007). In the second instance, the lack of memory effects might depend on the lack of distinguishability between the stimuli, due to the strong food sweetness reported. Although plausible, this is in contrast to the preliminary triangle study in which participants were able to accurately (i.e. 70% accuracy) discriminate between comparable sweetened targets and distractors. In the third instance, the poor flavour memory performance could be accounted for by the limited variability between target and distractors, which had been varied only across two dimensions (i.e. flavour and size). This led to the formation of a narrow category (i.e. citrus fruits) in which both the target and the distractors were grouped and resulted in a more difficult recognition task.

When considering visual memory, one might suggest different explanations for the lack of implicit visual learning evidence. First, a poor visual memory performance could depend on a short exposure to the target. But, in the present experiment this seems not to be case, given that the logo sheet remained on the workspace where the participant sat for a few minutes. At this stage it could be hypothesized that the poor recognition was due to the fact that participants did not pay any attention to the sheet, even though it was within their visual field (Seger, 1994). However, this can be excluded since the participants were required to put their signature right below the visual target image. In our opinion, it seems more likely that the structural complexity of the visual images presented is responsible for the bad visual recognition performance (Inui & McClelland, 1996). Decagons and dodecagons are unusual figures with a high number of sides, greater than the number we can approximate without explicitly counting (Dehaene, Dehaene-Lambertz, & Cohen, 1998). But the number of sides (i.e. shape) is one of the crucial features to be used as to discriminate the target amidst the distractors.

Here, for the first time, we directly compared food and visual memory. When taking into consideration size recognition tasks, a dissociated pattern of results for the food and visual memory domain was revealed. On the one hand, participants were able to distinguish the flavour of the food target from its distractors, showing a higher percentage of correct rejections rather than hits. In this respect this result is in line with previous evidence reporting that with food, people are better at detecting what they have not previously experienced rather than at recognising what they have experienced before (Köster et al., 2004; Mojet & Köster, 2002, 2005; Møller et al., 2004, 2007). According to this view, participants used a conservative decision criterion and were also more confident when saying which food item was not the target.

On the other hand, with regard to the visual stimuli, participants were not able to discriminate between the target

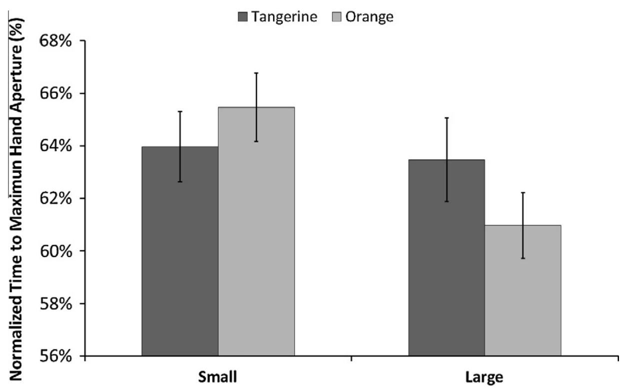

Fig. 5. Bars represent the significant two-way interaction 'dimension' by 'flavour' for the normalized time at which maximum hand aperture occurred. Error bars represent the Standard Error of Mean.

and the distractors. However, a higher number of hits was reported, indicating that people based their visual memory judgements more on the 'feeling of knowing' rather than on the 'feeling of not knowing' as they did in the case of the flavour. This was also confirmed by the liberal decision criterion applied by participants when answering to the visual memory questions.

Taken together, these results support the idea that implicit flavour memory is highly based on a novelty detection mechanism, whereas visual memory relies more on recollection and/or familiarity. The fact that novelty detection plays a dominant role in memories involving the proximal senses (such as olfaction and gustation) should not be surprising. We are evolutionarily tuned to detect changes within the environment in order to be prepared to face whatever danger we may come across. Since eating is a common action strictly linked to survival, the evolution of food selection mechanisms has developed some strategies to prevent errors resulting in the ingestion of harmful compounds. Moreover, as clearly demonstrated by LeDoux (LeDoux, 1998), no time for a precise identification of the danger is requested and the paleocortex (where olfactory cortex resides) provides the instinctive reaction aimed at surviving. In contrast, information from the 'far' senses (such as vision) requires higher cortical involvement as to produce a pretty detailed (but also time consuming) representation of the environment. At this stage, it is tempting to suggest that food and visual memory are systems based on different signal detection mechanisms: flavour memory is aimed at detecting survival-relevant warning stimuli, whereas visual memory is involved in restoring past experiences in an organized fashion (Köster, 2005; Morin-Audebrand et al., 2012; Møller, Köster, Dijkman, de Wijk, & Mojet, 2012).

In accordance with previous evidence, no evident gender effects were reported for both food and visual memory tests (Mojet & Köster, 2005; Møller et al., 2007). Seemingly no modulatory effects of food liking on the flavour memory recognition indices were reported (Köster et al., 2004). However, given the controversial nature of the results reported on these topics, it is worth suggesting that further research is needed to clarify these issues (Köster et al., 2004; Laureati et al., 2008; Mojet & Köster, 2002).

A novel aspect of the present study is the attempt to assess whether flavour memory indices and food liking ratings are able to modulate the action selection process, such as the reach-to-grasp movement towards a food item. Previous research on chemosensory-motor integration, showing that odours and flavours have the ability to influence the motor control of the hand, had paved the way for the investigation of motor-mediated food selection processes (Castiello et al., 2006; Parma et al., 2011; Tubaldi et al., 2008). In the present study the accurate measurements of hand kinematics revealed that some of the reaching and grasping variables were modulated in accordance to the level of congruency of the to-be-grasped target. As an example, the time of maximum wrist velocity occurred earlier when the congruent rather than the incongruent objects were to-be-grasped. Similarly, when reaching towards a congruent object, the acceleration peak occurred earlier (and subsequently, the deceleration peak occurred later) than when reaching towards incongruent objects. This interactive effect between the size and the flavour of the object on the kinematics of the arm was evident before participants tasted the food item. This means that the present results could not be accounted for by the flavour experience. However, it might well be that participants smelled the odour of the food item before eating it and used that orthonasal olfactory cue (along with the size information) to guide the action towards the object. Along these lines, maximum hand aperture occurred earlier when grasping a congruent rather than an incongruent object. Thus, the present results suggest that people are able to create detailed representations of the external world on the basis of a few numbers of features. Specifically, in the present experiment, participants were exposed to very similar prototypical stimuli referring to the same semantic category – citrus fruits. To date, tangerines and oranges clearly differ in size and flavour, but are thoroughly similar in all the other features (e.g. colour, texture).

With respect to the relation between hand kinematics and flavour memory recognition, a moderate correlation was reported. Although only observed for one of the four targets (i.e., orange-flavoured orange-shape piece of cake), a higher number of correct rejections correlated with the slowing down of an arm reaching parameter (i.e., time to maximum wrist velocity). Moreover, grasping phase indices were also reported to be linked to participants' flavour memory performance. Specifically, for the OO stimulus, a direct correlation was found between memory accuracy (the sum of hits and correct rejections) and time of maximum hand aperture in the flavour recognition task. These results might suggest that when people cope with extremely uncertain situations, hesitation – reflected here in slowed and delayed movements – is a rather normal response. However, we are not certain about the reason why these effects are only evident when reaching and grasping for the OO target. One possible explanation might be that the OO target showed more overlap with the participant's 'everyday orange representation'. Future research will be needed to clarify this issue.

Food liking was also compared with hand kinematics, in order to ascertain whether motor-related measures might reflect food-liking ratings. Results showed that the reaching parameters were faster when food selection was guided by the liking for the food item. Once again, the present results support the idea of a flavour memory mechanism based on danger prevention. It is reasonable to think that the more a food is appreciated, the less potentially dangerous it should be (Morin-Audebrand et al., 2012).

Conclusions

In conclusion, (i) flavour and visual memory performance similarly produced poor incidentally learned recognition indices. In general, however, memory recollection indices seem to provide some evidence of different key mechanisms underlying flavour memory and visual memory linked to novelty and familiarity, respectively; (ii) food liking was not a reliable index to be connected with food recognition; (iii) moderate evidence of relationships between flavour memory recognition and the motor control of the hand was shown; (iv) the present results might help to advance the idea that, to a moderate extent, kinematics could function as implicit factor in the food selection process. Future research should investigate these issues more deeply.

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Appendix A. Chemosensory performance questionnaire (adapted from Zucco, Amodio, & Gatta, 2006)

Please, answer these questions as sincerely as possible by fulfilling with a cross the appropriate cell.

	GOOD	SUFFICIENT	BAD
1. How do you think your ability to smell is?			
2. How do you think your ability to taste is?			
	YES		NO
3. Have you ever experienced allergic reactions when exposed to strong-smelling substances?			
3a. If YES: Which substances are you allergic to?			
4. Have you ever experienced allergic reactions when exposed to strong-tasting substances?			
4a. If YES: Which substances are you allergic to?			
5. Because of your job or for other reasons are you exposed to irritating substances like, powders, acids, gases, smokes?			
6. At present are you suffering from allergic or infective rhinitis?			
7. At present are you suffering from infections to the upper respiratory tract (e.g. pharyngitis, laryngitis, tonsillitis)?			
8. Have you suffered from head cold in the last three days?			
9. At present have you got any stomatological problems in your mouth (e.g. ulcer, abscesses)?			
10. In the last month have you assumed antineoplastic, antirheumatic or ACE inhibitor drugs orally?			
11. Have you ever been exposed to radiotheray or chemotherapy?			
12. Have you got experience of been sick in the last 3 h?			
13. Have you ever had head or nose surgery (e.g. because of sinusitis)?			
14. Have you ever experienced a nose trauma (e.g. a bash hit against a surface)?			

(*continued on next page*)

Appendix A (*continued*)

	GOOD	SUFFICIENT	BAD
	GOOD	SUFFICIENT	BAD
14a. If YES: How do you judge your olfactory sensibility before the accident?			
14b. If YES: How do you judge your olfactory sensibility after the accident?			
14c. If YES: How do you judge your taste sensibility before the accident?			
14d. If YES: How do you judge your taste sensibility after the accident?			
	YES		NO
15. Have you been diagnosed with a deviated septum?			
16. Are you taking or have you ever taken significant quantities of drugs such as cocaine or morphine nasally?			
17. Have you ever been diagosed with one of the following pathologies	YES		NO
Multiple scleroris			
Diabetes mellitus			
Gastroesophageal reflux disease			
Facial palsy			
Renal insufficiency			
Cirrhosis			
Alcoholism			
Adrenocortical insufficiency			
Coeliac disease			
18. Have you ever smoked?			
18a. If YES: How long have you been smoking?			
18b. If YES: How many cigarettes per day?			
19. When did you stop smoking?			
	YES		NO
20. At present are you smoking?			
FOR WOMEN ONLY			
21. Have you been diagnosed with an estrogenic deficiency?			
21a. If YES, are you following an estrogenic therapy?			