Appetite 81 (2014) 102–107

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

Scents boost preference for novel fruits ☆

Yuki Yamada [a,*], Kyoshiro Sasaki [b], Satomi Kunieda [c], Yuji Wada [d,**]

[a] *Faculty of Arts and Science, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan*
[b] *Graduate School of Human-Environment Studies, Kyushu University, 6-19-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan*
[c] *Advanced Materials & Technology Research, Corporate Research & Development Division, Takasago International Corporation, 1-4-11 Nishiyawata, Hiratsuka, Kanagawa 254-0073, Japan*
[d] *Sensory and Cognitive Food Science Laboratory, National Food Research Institute, National Agriculture and Food Research Organization, 2-1-12 Kannondai, Tsukuba, Ibaraki 305-8642, Japan*

A R T I C L E I N F O

Article history:
Received 31 March 2014
Received in revised form 3 June 2014
Accepted 4 June 2014
Available online 13 June 2014

Keywords:
Visual–olfactory interaction
Awareness
Edibility
Morphing

A B S T R A C T

When faced with a novel food, multisensory information that includes appearance and smell is a very important cue for preference, categorization, and the decision of whether or not to eat it. We elucidated whether olfactory information leads to biased visual categorization of and preference for fruits, even when odors are presented subliminally. We employed morphed images of strawberries and tomatoes combined with their corresponding odorants as stimuli. Participants were asked to categorize the images into either of two categories, to evaluate their preference for each visual image, and to judge the presence/absence of the odor. Results demonstrated that visual categorization was not affected by the odor manipulation; however, preference for uncategorizable images increased when odors were presented regardless of the participant's awareness of the odor. Our findings suggest that visual preference for novel fruits is based on both conscious and unconscious olfactory processing regarding edibility.

Introduction

Humans are omnivores. Omnivores can adapt to dynamic and diverse environments by eating highly diversified foods. In a natural environment, the availability of food sources alters depending on seasons and habitats. For example, brown bears primarily eat insects and herbs in the summer months but eat nuts in the autumn months to adapt to the season-based changes in food sources. However, one limitation to being an omnivore is the risk of accidental ingestion of harmful foods, especially when a food is novel. Food neophobia is an ingestion-avoidance response toward novel foods, and is considered to be characteristic of omnivores such as humans (Pliner & Salvy, 2006). Food neophobia is deemed to serve a protective function to prevent the ingestion of potentially harmful foods by evoking negative emotional reactions to unfamiliar foods. Humans use multisensory information, such as appearance and smell, to prevent themselves from ingesting potentially harmful foods.

Vision and olfaction interact with each other. So far, many previous studies have reported that olfactory processing is affected by visual information (e.g., DuBose, Cardello, & Maller, 1980; Garber, Hyatt, & Starr, 2000; Gottfried & Dolan, 2003; Morrot, Brochet, & Dubourdieu, 2001; Stillman, 1993; Zellner, Bartoli, & Eckard, 1991; Zellner & Kautz, 1990; for a review see Spence, Levitan, Shankar, & Zampini, 2010). Recently, it has also been found that olfactory information affects visual processing. For example, olfactory information corresponding to a visual object influences visual attention in space (Seo, Roidl, Müller, & Negoias, 2010) and time (Robinson, Mattingley, & Reinhard, 2013). Likewise, in a binocular rivalry situation, visual stimuli corresponding to odor information becomes perceptually dominant for a relatively longer time, based on the nostril–visual field correspondence (Zhou, Zhang, Chen, Wang, & Chen, 2012). Furthermore, a subliminally presented cleaner scent induces faster identification of cleaning-related words (Holland, Hendriks, & Aarts, 2005). Moreover, infants looked for a longer time at an object when an odor stimulus corresponding to the object was presented (Wada et al., 2012). These previous studies commonly suggest that the categorical consistency between visual and olfactory information is key to increasing the saliency of, preference for, or associated representations of visual objects. However, it is still unclear whether olfactory information induces a shift of visual categorization judgment, and whether enhancement of categorization caused by olfactory information bias is a necessary component of enhancement of visual preference caused by olfaction.

Here, we investigated whether olfactory information modulates categorization of visual objects, and whether the preference

☆ *Acknowledgements:* This research was supported by the KAKENHI (Grant-in-Aid for Scientific Research) Application Encouragement Program awarded to YY and the Grant-in-Aid for Scientific Research on Innovative Areas (25135735) awarded to YW.
* Corresponding author.
E-mail address: yamadayuk@gmail.com (Y. Yamada).
** Corresponding author.
E-mail address: yujiwd@affrc.go.jp (Y. Wada).

http://dx.doi.org/10.1016/j.appet.2014.06.006
0195-6663/

for visual objects that correspond to olfactory information stems from the categorization bias. In addition, we aimed to elucidate these issues by using perceptible and imperceptible odor stimuli because previous studies have shown that olfactory information modulates human cognition and behavior even when the odor stimuli are presented subliminally (Holland et al., 2005; Li, Moallem, Paller, & Gottfried, 2007; Seigneuric, Durand, Jiang, Baudouin, & Schaal, 2010). This experimental condition will help clarify at what stage in mental processing the visual–olfactory interaction occurs.

Visual stimuli with a multilevel categorical ambiguity are necessary in order to examine a visual categorization bias. Therefore, we employed 11-step morphed images generated by superimposing photos of a strawberry and a tomato (Yamada, Kawabe, & Ihaya, 2012). Yamada et al. found that observers disliked fruit images with ambiguous categorical information. Furthermore, they reported that participants with high food neophobia produced lower scores for eatability and preference for novel fruit than those with low food neophobia. They claimed that this aversive reaction was due to a mechanism for avoiding the risk of ingesting strange foods.

In their study, Yamada et al. (2012) manipulated only visual information using morphed images, but the effect of additional information from other modalities on visual categorization has been examined using a two-alternative forced choice (2AFC) for morphed images (de Gelder & Vroomen, 2000). In this paradigm, it can be assumed that the effect of other modalities becomes prominent for the most ambiguous stimulus, in which visual information is less reliable. In the present study, we presented the same visual stimuli used in Yamada et al. to participants, and simultaneously presented a strawberry or tomato odor in the background at a subliminal or supraliminal level. Participants were asked to categorize the images into one of two categories (strawberry or tomato). If visual categorization were biased by the background olfactory information, the point of subjective equality (PSE) of categorization would shift in the direction of the corresponding category. Conversely, if a visual preference enhancement occurred, as in previous studies, independently of categorization enhancement, categorization bias would not occur in the present experiment but a preference shift would be observed.

We also measured participants' preferences for the morphed images. If olfactory enhancement of visual preference were due to the enhancement of categorization by overlapping multisensory information, an increment of preference would occur in visual objects that were moderately hard to categorize but that corresponded to the olfactory category, but not in a visual object at the PSE, which would appear novel to participants. If odors of fruits without a strict categorical correspondence between vision and olfaction generally increased the "foodness" of the uncategorizable objects, we could expect that a preference increment of the morphed images at and around the PSE would occur.

Materials and methods

Participants

Fifty-six graduate and undergraduate students attending Kyushu University participated in the experiment. The participants were unaware of the purpose of the experiment and all reported that they had normal olfaction and vision. The experiment was conducted according to the principles laid down in the Helsinki Declaration. Written informed consent was obtained from all participants after the nature and possible consequences of the study were explained to them. The ethical committees of Kyushu University and the National Food Research Institute approved the protocol. In a pre-experiment screening, three participants were excluded from the experiment because they disliked strawberries or tomatoes. In a post-experiment screening, another three participants were excluded because they explicitly perceived the odor in the subliminal condition or could not perceive the odor in the supraliminal condition. Ten participants were randomly assigned to each of the five conditions: subliminal-strawberry (two males, mean age ± SEM = 21.5 ± 0.48 years), subliminal-tomato (two males, 24.4 ± 1.53 years), supraliminal-strawberry (two males, 24.3 ± 1.52 years), supraliminal-tomato (four males, 22.2 ± 1.08 years), and odorless conditions (six males, 22.8 ± 0.59 years), which will be described later.

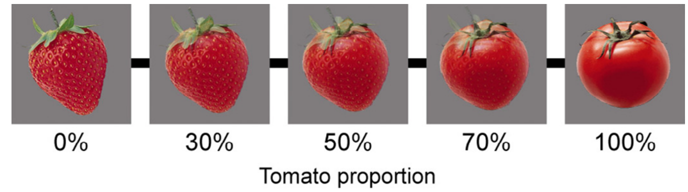

Fig. 1. Examples of visual stimuli used in this study.

Apparatus and stimuli

The stimuli were presented on a 19 in. CRT monitor (RDF193H; Mitsubishi, Japan) with a resolution of 1024 × 768 pixels, and a refresh rate of 100 Hz. The presentation of stimuli and the collection of data were controlled using a computer (Mac Pro; Apple, CA, USA). The visual stimuli were generated by Matlab with a Psychtoolbox extension (Brainard, 1997; Pelli, 1997).

Visual stimuli consisted of a fixation point, command cursors for rating, and images made up of morphed photographs of tomatoes and strawberries (Fig. 1). Stimuli were presented at a viewing distance of 40 cm. The fixation point was composed of two concentric rings, one small and one large, with radii of 0.24° and 0.47° in visual angle, respectively. The luminance of each ring was 91.0 cd/m^2. The command cursors were white boxes surrounding each rating value (0.95 × 1.89°; 91.0 cd/m^2) and the selected box was filled in white. We employed color pictures (12.1° × 12.1°) of a tomato and a strawberry. We generated 11 equally stepped morphed images with tomato percentages ranging from 0% to 100%. Each stimulus was displayed on a gray background (43.5 cd/m^2).

Odor stimuli were water solutions of strawberry and tomato odorants. These odorants were used in Wada et al. (2012) and, although the tomato odor was more difficult to categorize than the strawberry odor in the pilot experiment, the previous study has confirmed that most adults can successfully identify the olfactory categories of the odorants. In the subliminal condition of the present study, a 0.015% water solution was diffused by means of an aroma diffuser (CCP Co., Ltd., Tokyo, Japan). In the supraliminal condition, a 0.2% water solution was diffused. A divider plate was installed beside the computer. The diffuser was set behind the plate and out of sight of participants. Diffusion of the water solution began 1–2 h before the experiment and continued until the end of the experiment.

Procedure

The experiment was conducted in a darkened room. Each participant's visual field was fixed using a chinrest. The experiment consisted of two task blocks: a categorization task and an evaluation task. The order of the blocks was counterbalanced across the participants.

Participants initiated each trial by pressing the spacebar on a computer keyboard. The fixation point was presented throughout the experiment whenever there was no image on-screen. For each trial in the categorization task, after a delay of a random duration between 800 and 1200 ms, a morphed image was presented and remained