Food Quality and Preference 68 (2018) 304–314

Contents lists available at ScienceDirect

Food Quality and Preference

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

Aroma effects on food choice task behavior and brain responses to bakery food product cues

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ARTICLE INFO

Keywords:
Aroma
Food choice behavior
Functional magnetic resonance imaging
Reward
Bakery products

ABSTRACT

Bread, and especially whole grain bread is an important source of dietary fibers. It was tested with behavioral and fMRI measures whether bread becomes more attractive when it is presented with bread aroma.

Twenty-eight healthy normal-weight women were exposed to images of bakery products (brown bread, white bread and cookies) without aroma or with a congruent (bread aroma) or non-congruent ("warm wood") aroma.

In general, product effects were larger than aroma effects. Images of brown bread were preferred over images of white bread as shown by direct comparisons, choice reaction times, as well as liking and wanting scores. Aroma had no effect on liking and wanting, but did affect food choice task behavior, where images of brown bread were preferred more often in the presence of warm wood aroma and images of cookies were preferred more often in the presence of bread aroma. The fMRI data suggest that bread aroma may increase the salience of bakery products compared to no aroma and a non-food aroma. Specifically, bread aroma induced greater activation for cookies in areas related to reward anticipation. The correlations between behavioral measures and brain responses suggest lower attention for and a habitual response to brown bread and higher attention and a more goal-directed response to white bread.

In conclusion, aroma can affect choice task behavior for brown and white bread albeit in an incongruent manner. The more habitual response to brown compared with white bread suggested by the neural data underscores that nudging towards brown bread consumption with (bread) aroma will probably not be effective.

1. Introduction

Bread is a basic food product that is largely consumed all over the world. Bread is an important contributor to grain and fiber intake, which in general is too low.

A possible strategy to increase the bread consumption is to make bread more attractive, for example by using bread aroma. Supermarkets and bakeries have long been using bread aromas to facilitate sales of bread in general. The smell of freshly-baked bread is supposed to guide consumers towards the bread department and increase sales. Even though this kind of use of aromas has to the best of our knowledge not been scientifically tested, other effects of bread aroma such as improving mood have been demonstrated (Zhou, Ohata, & Arihara, 2016). More in general, food aromas have been shown to increase food appetite for congruent products, in terms of both taste and energy density, irrespective of hunger state (Zoon, de Graaf, & Boesveldt, 2016). Food aromas also affected food choice, where for example exposure to citrus aroma reduced selection of cheese (de Wijk & Zijlstra, 2012). Also, aromas have been found to affect behavior in restaurants (Guéguen & Petr, 2006), and shops (de Wijk, Maaskant, Kremer, Holthuysen, & Stijnen, 2017). The reported effects of aromas on food appetite, food choice and behavior in an eating environment motivated the hypothesis that bread aroma may increase bread liking and wanting, and affect choice behavior of bakery products.

Not all bread is equally healthy. Different studies have shown a protective effect of whole grain intake on prevention of several non-communicable diseases (Aune, Norat, Romundstad, & Vatten, 2013; Jonnalagadda et al., 2011; Slavin, 2003; Wu et al., 2015), contributing to the recommendation to replace refined grains with whole grains (Aune et al., 2013). Despite these recommendations, whole grain intake is generally lower than recommended. Approximately 38% of Dutch bread sales is whole grain bread while about 15% of bread sales

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https://doi.org/10.1016/j.foodqual.2018.03.015
Received 12 October 2017; Received in revised form 16 February 2018; Accepted 26 March 2018
Available online 09 April 2018
0950-3293/

concerns white flour bread (de Wijk et al., 2016). A shift from the consumption of bread made from refined white flour to 100% whole grain flour bread would be ideal from a health recommendation perspective. However, changing intake of refined bread to brown bread, which contains a mixture of refined white and whole grain flour, would already increase whole grain intake. Thus, increasing the consumption of brown or whole grain bread can contribute to the increase of whole grain and fiber intake, and thereby to a healthier diet. Thus, a second hypothesis for this study is that bread aroma may differentially affect liking, wanting and choice of refined and whole grain (brown) bread.

Functional MRI (fMRI) can be used to gain insight in the brain processes underlying food evaluation and food (Smeets, Charbonnier, van Meer, van der Laan, & Spetter, 2012). The most common fMRI approach is to measure brain reactivity towards food cues, such as visual, odor, and gustatory cues. Such food cues are commonly considered a proxy for exposure to real food-related sensory signals such as seeing foods, however, food aroma's and food images are also present in the environment. Several studies have shown relationships between neural food cue reactivity and food preference and food choice behavior. For example, in a study using visual cues of food products differing in hedonic value, it was shown that foods of high hedonic value elicited greater activation of brain reward regions than neutrally rated foods (Cornier, Von Kaenel, Bessesen, & Tregellas, 2007). Similarly, Griffioen-Roose and colleagues have shown that after protein depletion the brain response to savory combined visual and olfactory food cues was greater in areas related to reward and preference (Griffioen-Roose et al., 2014). These and other studies show that the hedonic value and salience of foods can affect brain responses in reward-related areas (van der Laan, de Ridder, Viergever, & Smeets, 2011). In line with this, food cue reactivity has been shown to predict subsequent food choice. In an fMRI study with visual cues, Mehta and colleagues found relations between activation of reward-related brain areas such as the striatum and orbitofrontal cortex by visual cues of high- and low calorie foods, and subsequent food choice and food intake (Mehta et al., 2012). Lawrence et al. have shown that visual food cue related activity in the nucleus accumbens, a key brain region for food motivation and reward, was associated with subsequent snack food consumption, but not with self-reported hunger, or explicit wanting and liking for the snack. In contrast, food cue reactivity in the ventromedial prefrontal cortex was associated with subjective hunger/appetite, but not with consumption (Lawrence, Hinton, Parkinson, & Lawrence, 2012). These studies illustrate that differences in neural food cue reactivity can be linked with subsequent food choice.

The present study aimed to assess the effects of bread aroma on liking of, choice task behavior and brain responses to bakery food products using a combination of behavioral measures and neuroimaging (fMRI). More specifically, this combined approach aimed to elucidate the role of bread aroma in food choice, liking and wanting for brown bread, white bread and cookies. Briefly, the study combined two approaches in the presence of a bread aroma, a non-food aroma (wood) and in the absence of aroma. Firstly, food choice behavior was examined with the use of images of bakery products, i.e. brown bread (whole grain meal or whole grain meal mixed with refined white flour), white refined bread and cookies. In addition, brain activation in response to viewing these bakery products in the presence and absence of the same aromas was measured. It was hypothesized that bread aroma would increase liking, wanting and choice for bread and that this would be paralleled in increased activation of reward anticipation-related brain areas such as the striatum and orbitofrontal cortex.

2. Materials and methods

2.1. Participants

This study was conducted in accordance with the Declaration of Helsinki and approved by the Medical Ethical Committee of Wageningen University & Research (NL53942.081.15). All participants signed an informed consent form before participation. Participants were 28 healthy, normal-weight, right-handed women (age 22.0 ± 2.9 years, range: 18–31 years, body mass index (BMI) 21.99 ± 1.74 kg/m^2, range 18.96–24.84 kg/m^2, mean ± SD). They were recruited from the participant pool of Wageningen University & Research. Exclusion criteria included a BMI < 18.5 or > 25; being under 18 or over 35 y of age on the study day; smoking; drinking on average > 14 units of alcohol per week; lack of appetite, having an energy restricted diet during the last two months; a change in body weight > 5 kg in the past two months; having difficulties with swallowing/eating; having a taste or smell disorder; stomach or bowel diseases, diabetes, thyroid disease or any other endocrine disorder; diabetes, use of daily medication other than oral contraceptives, aspirin and paracetamol, eating bread less than 4 times a week, disliking cookies, and being pregnant or lactating. In addition, there were MRI exclusion criteria such as claustrophobia and having metal implants or metal objects on the body that cannot be removed. Participants were informed that the study measured brain responses towards images of bread and cookies in the presence or absence of aroma with the overall aim to gain insight in the drivers of eating behavior.

2.2. Experimental procedures

Participants participated in three sessions in chronological order: a training session, an fMRI session, and a food choice session. The training and food choice sessions were conducted in the Wageningen University & Research facilities of the Restaurant of the Future (Wageningen, The Netherlands). The fMRI session was conducted at the Gelderse Vallei Hospital (Ede, The Netherlands). The time between the fMRI session and the food choice session was 2–3 weeks.

2.2.1. Training session

During the training session BMI was measured, part of the experimental fMRI procedure was practiced in a dummy MRI scanner, aroma identification was tested, and several questionnaires were administered.

2.2.2. MRI practice session

During the fMRI training session participants were placed in a dummy MRI scanner to get familiarized with the fMRI procedures. They were presented with three blocks of five food-related images either combined with a low concentration bread aroma (block 1), no aroma (block 2) or a high concentration bread aroma (block 3). The aroma was a bread flavor (Bread flavor liquid sc513519, International Flavors & Fragrances I.F.F. (Nederland) B.V, Hilversum, the Netherlands) diluted with propylene glycol to 0.05% v/v and 1% v/v for the low and high concentration respectively. Aromas were presented using a Lundström olfactometer (Lundström, Gordon, Alden, Boesveldt, & Albrecht, 2010) and delivered through a nose piece in each nostril (3 L/min). Participants were instructed to look at the images and to remember for each of the three blocks whether an aroma was present, the type of aroma, the intensity, and how pleasant it was. The total time it took to place the participant in the dummy MRI scanner, perform the task and take the participant out of the scanner was 15–20 min. After the dummy scan session, participants filled in a questionnaire regarding the presence, nature, intensity, and pleasantness of the aromas.

2.2.2.1. Aroma identification test. Aroma identification was tested using the odor identification part of the 16-item Sniffin' Sticks test (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997) (mean score 13.39 ± 1.40). Participants had to correctly identify 11 of the 16 aromas. One participant identified only 10 aromas correctly, but since she was able to smell and identify the aromas used in the study it was decided to include her as well.