# Towards Persuasive AI for People with Olfactory Dysfunction

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## Abstract

Olfactory dysfunction is a complication arising from various factors, including neurodegenerative disorders, aging, and viral infections like COVID-19. It can adversely affect appetite and food enjoyment, potentially leading to malnutrition. Food tailored to the sensory preferences of such patients can be an effective intervention. However, the utilization of artificial intelligence for suggesting suitable food and persuasive designs for presenting such suggestions has yet to be researched in this context. To address this gap, we conducted a co-creation workshop with patients and multidisciplinary experts to identify food-related goals and challenges faced in daily contexts. The emerging solutions are personalized food recommendations, flavor enhancements, and food sensory descriptors. However, the current databases and models are not suitable for producing these solutions. This is due to the complex feature set required to produce such recommendations. Moreover, such a system needs to incorporate factors such as health, enjoyment, and practical limitations to provide adequate support. Therefore, we outline a research roadmap toward providing personalized and persuasive artificial intelligence for people with olfactory dysfunction.
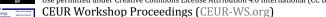
## Keywords

olfactory dysfunction, food enjoyment, persuasion, artificial intelligence, personalization, food recommendation, co-creation.

## 1. Introduction

Olfactory dysfunction (OD) refers to the partial or complete loss of the ability to smell, which can occur due to various factors, including aging, neurodegenerative disorders, and viral infections. OD can significantly impact eating behavior and overall health, as it can reduce a person's enjoyment of food [4], decrease appetite, and lead to possible malnutrition, reduced immunity, and the worsening of other diseases [8,6]. Moreover, smell and taste are interconnected as senses and together create flavor perception, a significant driver in determining what people choose to eat, regardless of various other influences, such as cost, accessibility, appearance, hunger levels, and social and economic factors that affect food selection and consumption [18]. Additionally, OD negatively affects social food-related activities, such as going out for dinner [4,29].

The literature suggests a few strategies to cope with the diminished perception of flavor, such as eating with family and friends, adding spices to stimulate trigeminal sensations (i.e., tingling or burning feeling), and focusing on the texture, temperature, and visual presentation of the food [17,16]. Recent experiments suggest that personalized foods tailored to meet individual users' unique needs and preferences could serve as an effective intervention for individuals with OD of various etiologies [1]. This approach also aligns with literature suggesting that personalization enhances users' perceived relevance of a solution and increases their motivation to engage with

it [1]. Therefore, food with sensory characteristics appealing to these patients and tailored to their individual sensory profile, including taste, texture, temperature, color, and design, could persuade and encourage patients toward healthy eating. Persuasive technology can be used to maximize the likelihood of successful dietary changes.

Understanding the needs and preferences of individuals with OD is essential to creating an effective and persuasive artificial intelligence (AI). Personalized and context-aware recommendations that consider the user's current situation and preferences have been found to engage users and promote healthy eating habits [38]. We aim to gain an overview of the relevant contexts and personal factors to design a personalized persuasive AI that genuinely meets the needs of people with OD through user-centered design methods, such as co-creation workshops. This paper presents the results of our co-creation workshop involving multidisciplinary experts and end-users with OD. Our workshop first identifies potential solutions to the daily challenges of end-users with OD. Second, it collects possible data requirements for realizing the proposed solutions, such as high-quality data on meal composition, nutritional value, health outcomes, and user profiles. Unfortunately, such data is still often incomplete, inconsistent, or outdated [3], making it challenging to develop accurate AI solutions [40]. Based on the data requirements extracted during our co-creation workshop, we propose a research roadmap for creating, combining, and modeling the missing data to provide a holistic persuasive AI.

## 2. Related Work

The following section discusses prior research in the areas of OD and eating behavior, as well as personalization, persuasion, and recommendation systems, which are relevant to our proposed approach.

### 2.1. Olfactory Dysfunction and Eating Behavior

The sense of smell plays a critical role in our daily lives, from social communication to food enjoyment [4]. OD has been found to have a considerable impact on an individual's quality of life, including eating behavior [39]. Studies show that individuals with OD tend to choose bland, low-fat foods, have a reduced interest in eating, and consume more processed foods, which may be due to a decreased enjoyment of food and ability to detect and appreciate flavors [9, 34]. While some strategies have been proposed to address this challenge, such as flavor enhancement techniques [22] and exposure to new flavors [9], research has mainly focused on providing nutritional recommendations for patients with OD rather than enhancing food enjoyment [5]. Personalized, persuasive AI has great potential to address this gap with tailored recommendations that promote healthy eating habits and enhance the enjoyment of food.

### 2.2. Personalization and Persuasion

Persuasion and behavior change apps for eating have primarily focused on weight loss and disease management [15,32], with some attention given to sustainable eating [33]. However, little research has been conducted on persuading people with OD and lack of food enjoyment to adopt healthier eating behaviors and avoid malnutrition. Existing studies mainly target the elderly and focus on increasing the intake of vital nutrients [44], whereas, for people with OD, personalized food recommendations that prioritize food enjoyment are more crucial. Personalized recommendations have been found to be more effective in promoting healthy eating behaviors than non-personalized recommendations [31] and have better user acceptance and adherence to dietary recommendations than generic advice [7,42]. Therefore, in the persuasive system design framework [28] and among behavior change techniques [24], personalization, tailoring, and suggestion are the most relevant strategies for our target user group's challenges.

### 2.3. AI for Healthy Eating

AI plays a central role in predicting appropriate items for persuasive strategies such as personalization, tailoring, and suggestions. In recent years, AI has already gained increasing attention in the general domain of healthy eating. Furthermore, recent advancements in interaction technology, including augmented reality [13, 30], sensor technology, such as smart fridges [21,19] or electronic noses [35], and AI, such as food recommender systems [25,36,37] or food image recognition [20, 23], have shown promise supporting healthier eating choices. Many of these AIs support users by suggesting food, grocery, or recipe options and can thus be seen as food recommender systems. While the earlier recommender systems focused on the recommendation of recipes with classical collaborative, content-based, and hybrid algorithms [12], more recent work is getting more diverse in terms of the food to be recommended (e.g., substitutes [2], groceries [13], meal plans [10]), the attributes to focus on (e.g., sustainability [33], microbiome [41], mood [27], visuals [43]) and the algorithmic approaches (e.g., deep learning based on images and language [26]). However, many open research questions still exist regarding, e.g., health personalization, accurate representation of users' eating behavior, preference modeling, and persuasion or behavior change [11].

## 3. Multidisciplinary Co-Creation Workshop

The use of co-creation in designing solutions recognizes the importance of involving users and diverse experts in the design process to gain insights into the problem and solutions space [14]. In December 2022, a co-creation design workshop was conducted at Wageningen University in the Netherlands to explore ways of supporting individuals with OD in their daily food interactions. The workshop brought together 18 participants providing the perspective of patients with OD and of multidisciplinary experts, including nutrition science, sensory science, consumer behavior, food culture, food safety, and food design, as well as culinary practitioners and a practicing ENT (ear, nose, and throat) doctor with regular contact with patients with OD. The workshop was divided into two halves. In the first half, the participants focused on exploring design solutions to challenges faced in three everyday scenarios: cooking dinner at home, eating at restaurants with friends, and doing groceries for a meal with family or friends. The participants were asked to sketch solutions individually in three 2-minute rounds alternated by short joint discussions for mutual inspiration. In the second half, the participants focused on collecting data requirements for building effective real-life solutions to the designs of the first half. During a poster walk in three smaller groups, the participants provided incremental input to three different perspectives: health and well-being, enjoyment and food experience, and practical aspects and limitations.

## 4. Results of the Workshop

We grouped over 100 sketches from the first co-creation activity into three themes that reoccurred in solutions across all scenarios: 1) Flavour Enhancement, 2) Food Recommendation, and 3) Food Sensory Description. Examples of proposed solutions for each theme and scenario are presented in Table 1. The first theme involved solutions that focused on enhancing a food or recipe's taste or trigeminal sensations by adding an optimal amount of suitable ingredients either to the whole meal or only the plate of the respective user. The second theme centered on using AI to suggest personalized food recommendations in restaurants and for recipes or ingredients fitting the user's sensory profile. The third theme aimed to mitigate the problem of understanding and communicating olfactory characteristics by automatically generating descriptions of the sensory characteristics of food using visuals, audio, and references to prior personal experiences. All presented solutions aim to enhance the food experience of individuals with OD and provide them with information for making informed food choices.

**Table 1**
**This table shows examples of different proposed solutions from the workshop divided by their respective theme and their usage scenario.**

| Themes/ Scenarios | Cooking dinner | Eating at restaurants | Doing groceries |
|---|---|---|---|
| Flavour Enhancement | A taste spray that gives the effect of smell through taste. | An app that suggests the spiciness level the user should order. | Enhanced flavor recipes on online groceries websites. |
| Food Recommendation | An app for flavor pairing or recipe recommendations. | A system that can analyze eating habits and create the user's sensory profile. | Personalized recommendations in online grocery stores using food and user sensory profile. |
| Food Sensory Description | A robot to help with taste checking while cooking. | An app taking pictures of food and describing how it tastes. | A handheld device to scan products and describe their smell. |

**Table 2**
**This table shows the data requirements collected during the poster walk.**

| Health & Wellbeing | Enjoyment & Experience | Practical Limitations |
|---|---|---|
| 1.User Health Profile | 1.User Sensory Profile | 1.Availability |
| 2.Demographic Profile | 2.Culinary Motivators | 2.Cost |
| 3.Cultural Habits | 3.Social Media Trends | 3.Time |
| 4.Social Context | 4.Temporal Context | 4.Kitchen Appliances |
| 5.User's Food Literacy | 5.Social Context | 5.Motivational Strategies |
| 6.Psychological Impact | 6.Group Preference | 6.Digital Literacy |
| 7.Recipes Details | 7.Food Presentation | 7.Food/Health Literacy |
| 8.Food Sustainability | 8.Shared Experiences | 8.Nutritional Food Profile |

Table 2 displays the summarized outcomes of the poster walk that investigates the various data requirements for developing a persuasive AI. Regarding data on health and well-being, the workshop emphasizes the significance of knowing the users' health conditions, such as diabetes or allergies, demographics, cultural habits, and knowledge about the health impact of food. Additionally, health in the sense of well-being led to the inclusion of the positive psychological effects of food, such as comfort food or enjoying food in a social setting. Regarding data on food enjoyment experience, the workshop highlights the importance of considering the user's food preferences, sensory impairments, culinary motivators (e.g., popular food trends), and social media influence in the AI solution to increase food enjoyment. The system must inspire users to try new foods, provide tips for others, and consider the social aspect, including family preferences and the distribution of cooking tasks. Moreover, an experience-sharing platform, such as a website where all users with OD are registered, can enhance the overall user experience. Regarding data on practical limitations, the workshop emphasizes the need for a persuasive AI to consider all practical constraints to be effective in real life, such as availability of food in the current context, cost, available time, kitchen appliances, as well as the motivation and effort of using the system, especially for users with limited digital or health literacy.

The insights gathered from the workshop emphasized the need for a comprehensive food recommendation system that considers multiple factors such as health, enjoyment, and practical limitations to provide effective recommendations for individuals with sensory impairments. The workshop's outcomes can inform the development of personalized food recommender systems

that consider user autonomy, inspire to try new food and consider the challenges faced in everyday contexts such as grocery shopping, cooking, or restaurant visits. The participation of diverse experts and patients with sensory impairments provided a valuable and inclusive perspective for designing such systems.

## 5. Results of the Workshop

The current state of databases and models is insufficient for providing the proposed solutions to patients with OD. This highlights the need for more comprehensive and personalized data to improve the accuracy and effectiveness of persuasive personalized food recommender systems. Based on our workshop, we suggest the following five steps for future research:

1. Creating a dataset to provide comprehensive taste, texture, and trigeminal data on an ingredient level. This will allow for a more detailed understanding of the sensory properties of different foods and ingredients, which can be used to develop more accurate and personalized food recommendations.
2. Creating a model to translate ingredient-based data to recipe or meal data based on combining their sensory properties and the recipe's processing steps. This will enable food recommender systems to provide more practical and actionable recommendations that take into account the complex interactions between different ingredients and cooking methods.
3. Creating an assessment tool to identify the individual sensory preferences of people with OD. This tool should focus on minimizing reporting burden and be tailored to patient preferences regarding the interaction design to ensure accurate and comprehensive data collection.
4. Creating machine learning algorithms to model the patient's eating behavior (i.e., individual taste preferences and habits when it comes to the types of foods they like to eat) and compare it with the eating behavior of a healthy reference population. This will help to identify distinct personas based on dietary behaviors and sensory profiles, which can be used to develop personalized recommendations.
5. Creating persuasive measures to empower users to understand the recommendations, such as personalized explanations explaining why certain foods are being recommended and how they taste. By providing users with clear and understandable explanations, we can help to build trust in the system and increase adherence to recommended dietary changes.

In conclusion, the workshop identified several challenges and potential solutions related to personalized persuasive food recommender systems for patients with OD. By creating a comprehensive dataset, developing a translation model, and creating an assessment tool to identify individual preferences, we can improve the accuracy and effectiveness of food recommender systems. By analyzing personal dietary data and developing personalized persuasive measures, we can empower users to make dietary changes and improve their overall health and well-being.

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