

# Development and Evaluation of a Decision-tree Based Dietary Monitoring Chatbot

## A conversational agent facilitating long-term dietary behavior self-management for Cardiovascular Patients

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### BACKGROUND

Cardiovascular diseases (CVDs) are currently the leading cause of death worldwide. Accumulated evidence indicates that a healthy diet contributes significantly to health promotion and an increase in quality of life for those living with CVDs. While dietary intake management plays an integral part in cardiac rehabilitation (CR), tracking dietary intake is burdensome, resulting in measurement errors caused by low adherence, incomplete data, or erroneous information. In this research, we developed a decision-tree based chatbot to facilitate cardiovascular patients in the self-management of their dietary behavior by capturing their dietary intake and providing feedback to support them in understanding their dietary choices.

### CHATBOT DEVELOPMENT

The chatbot aims to offer a flexible and reliable way of food tracking and provide real-time feedback to support users in understanding and self-reflecting on their food choices and dietary patterns. In addition, the target population of the chatbot is cardiovascular patients in THE NETHERLANDS. To ensure the chatbot can be used among this population and meet the requirements of creating a decision-tree based chatbot, we firstly developed a simplified food database.

**Food Database:** Based on the Dutch Food Composition Database (NEVO), we conducted several co-creations with nutritionists to determine the inclusion and exclusion of each food group and detailed inquiries according to the Dutch food-based dietary guidelines (RGV-2015) and the intake of the target group-related nutritional risk factors (e.g., salt, fatty acids, and sugar).

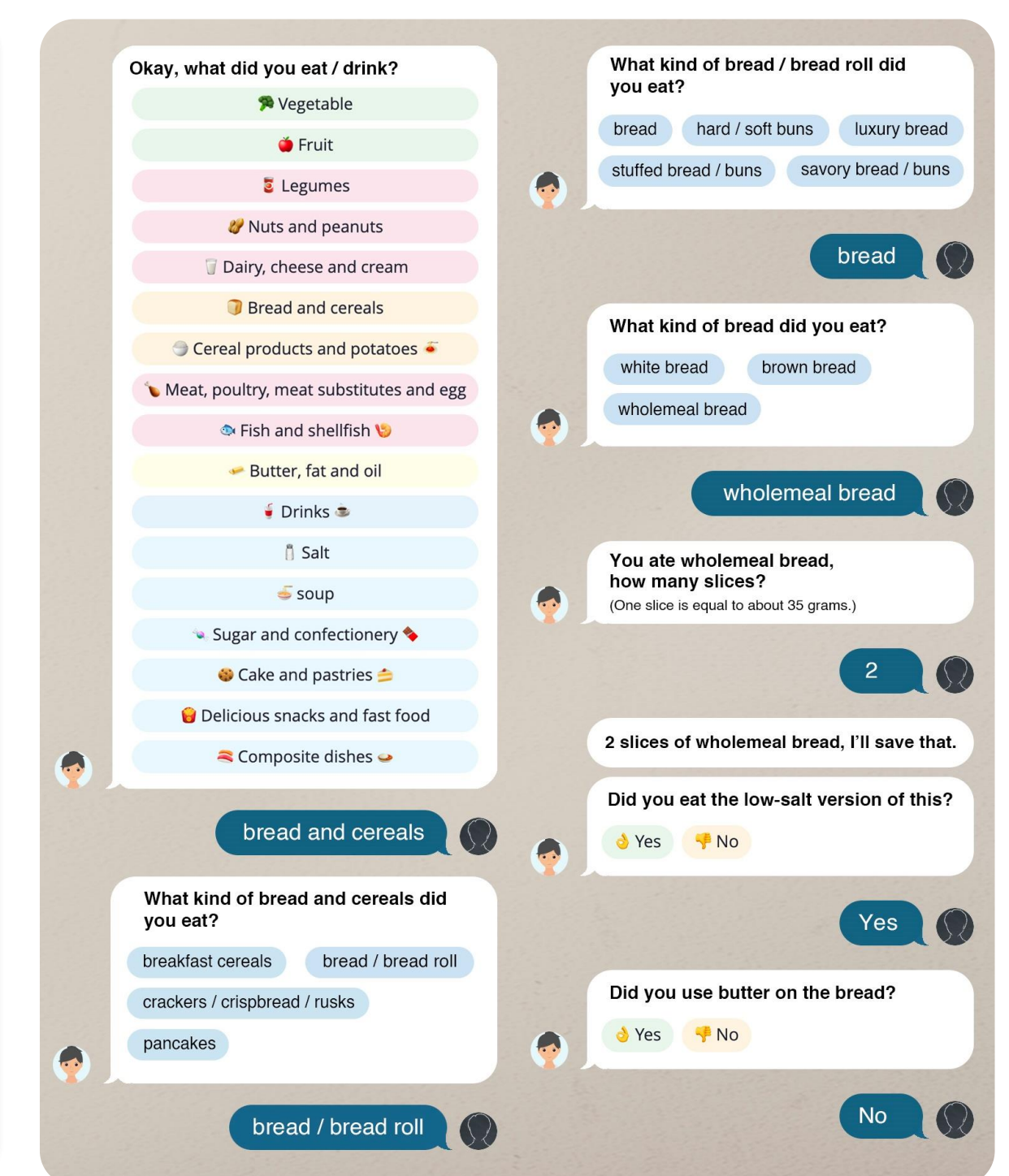
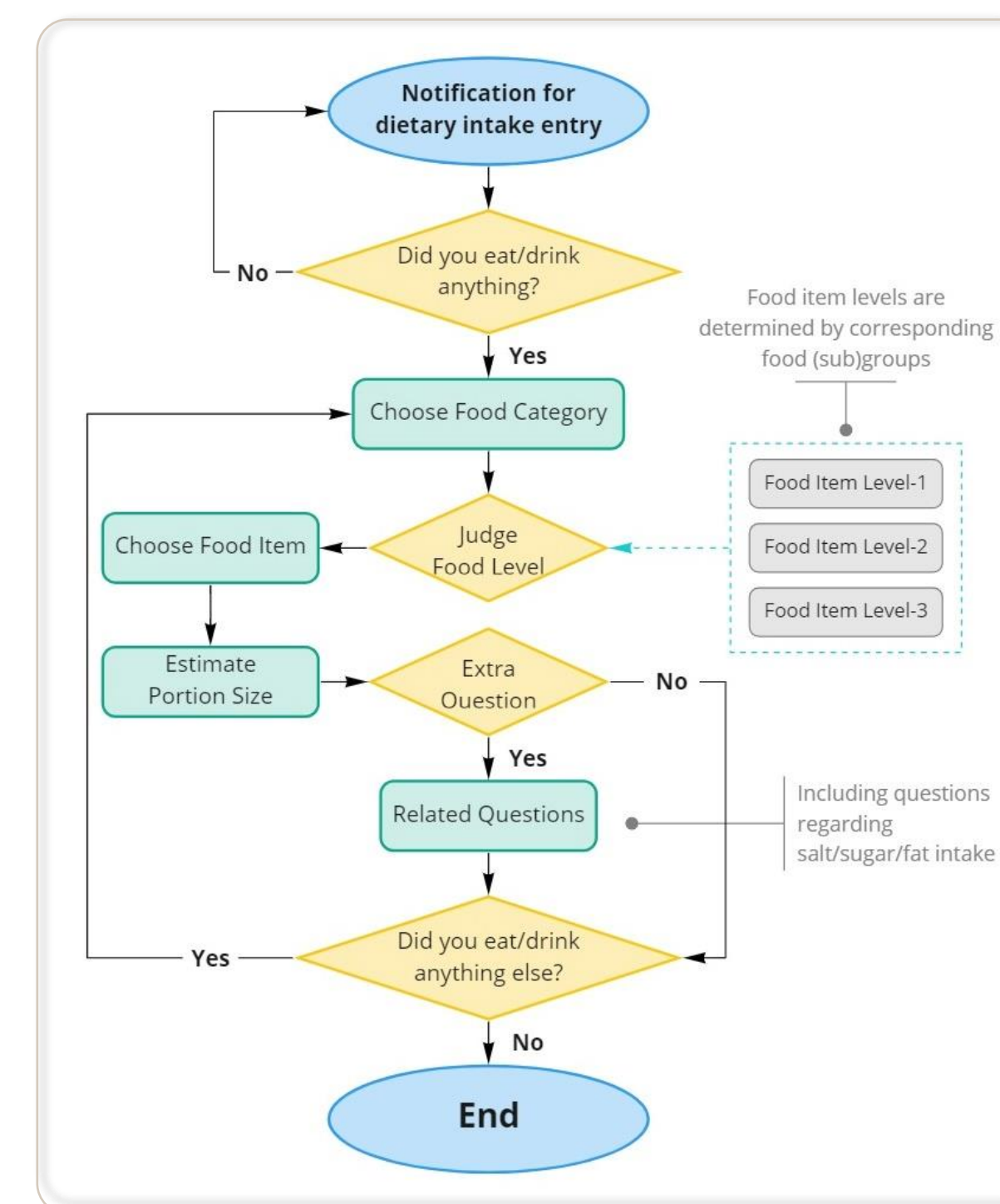
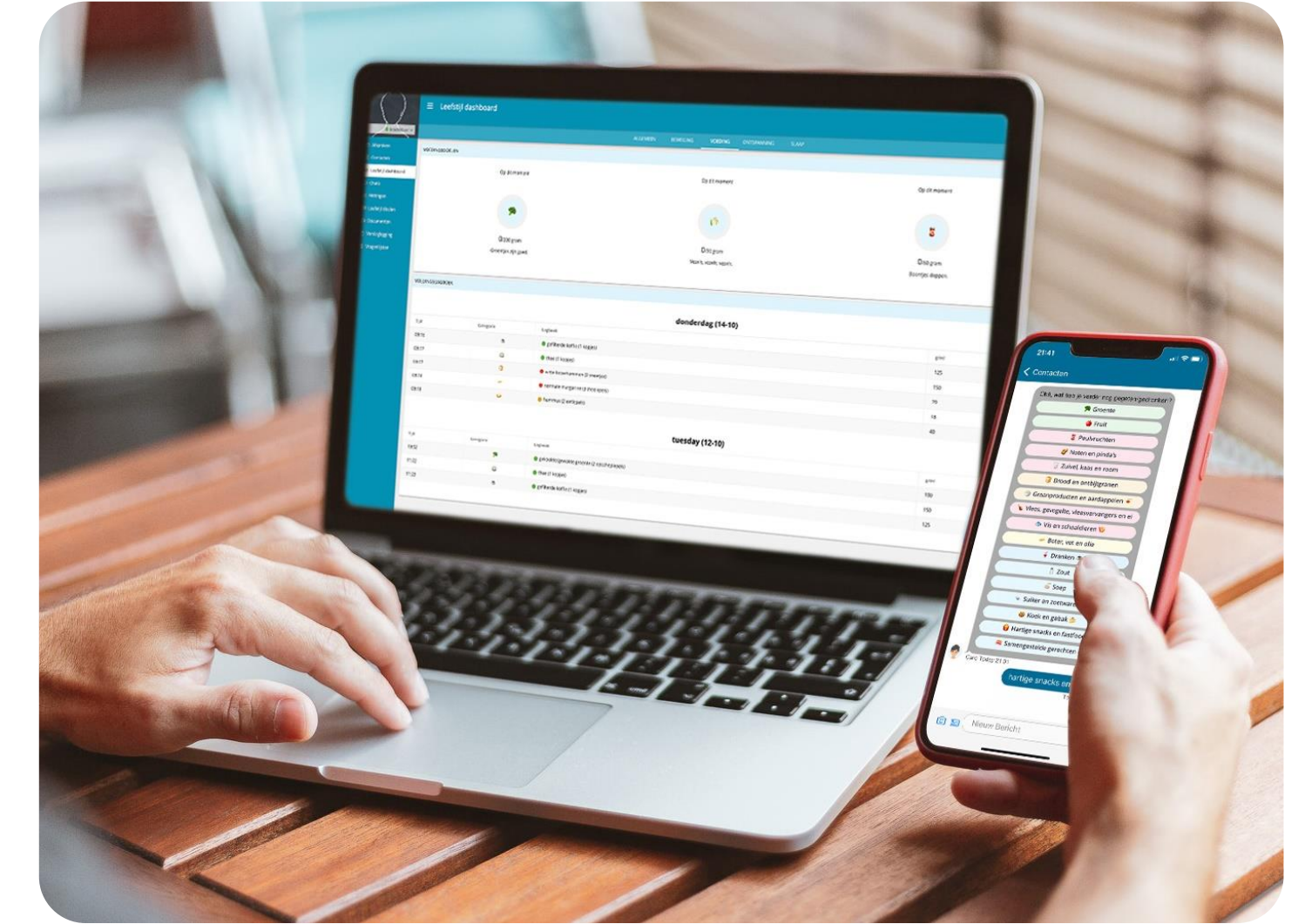
**Chatbot:** We developed a chatbot with multi-layered user interfaces for dietary monitoring on the food group level and screening the healthiness of food choices and dietary patterns. We applied *Fuzzy Terminology Recognition*, which enabled users to enter the food groups, reducing overall selection time.

#### Dietary Intake self-tracking

- Food Database: 17 main food groups & 204 sub-groups, including 71 first-level and 133 second-level subgroups
- Portion Size Estimation: in household measures (e.g., tablespoon, bowl, glass), standard portion or weight in grams
- Report Method: 3-hour recall method, or tailored recall periods

#### Feedback

- Preferred: healthy choices for a good diet
- Intermediate: eat as a variation from time to time
- Exceptional: unhealthy choices contains a lot of fat and/or sugar.



### STUDY-1 EXPERT REVIEW & EVALUATION STUDY

**Expert Review:** To first evaluate the concept with experts and health practitioners, we conducted an expert review with nine experts, specializing in the field of Cardiac Rehabilitation (CR) or dietary behavior management, who were asked to use the chatbot to self-report their dietary intake for one week.

#### User Engagement

- Easy to interact with
- Intuitive conversation flow
- Reduce the memory bias
- Increase the self-tracking adherence

#### Behavior Management

- Bridge the cognitive gap
- Raise awareness
- A positive influence in healthy diet promotion
- Reflect on the intake for nutritional risk factors

**Evaluation Study:** To explore the feasibility of dietary monitoring via the chatbot, as well as evaluate the tracking experience and rule out the usability issues with the chatbot, we conducted a lab-based evaluation study with 31 non-patient participants (age range 18-44 years). They were asked to explore and experience the use of the chatbot by reporting all foods and beverages consumed for the latest meal.

#### Insights for Improvement

- Present better communication of the food group classification while chatbot onboarding
- Options to create regularly consumed food combinations
- Customize the food groups based on different meals and dietary constraints

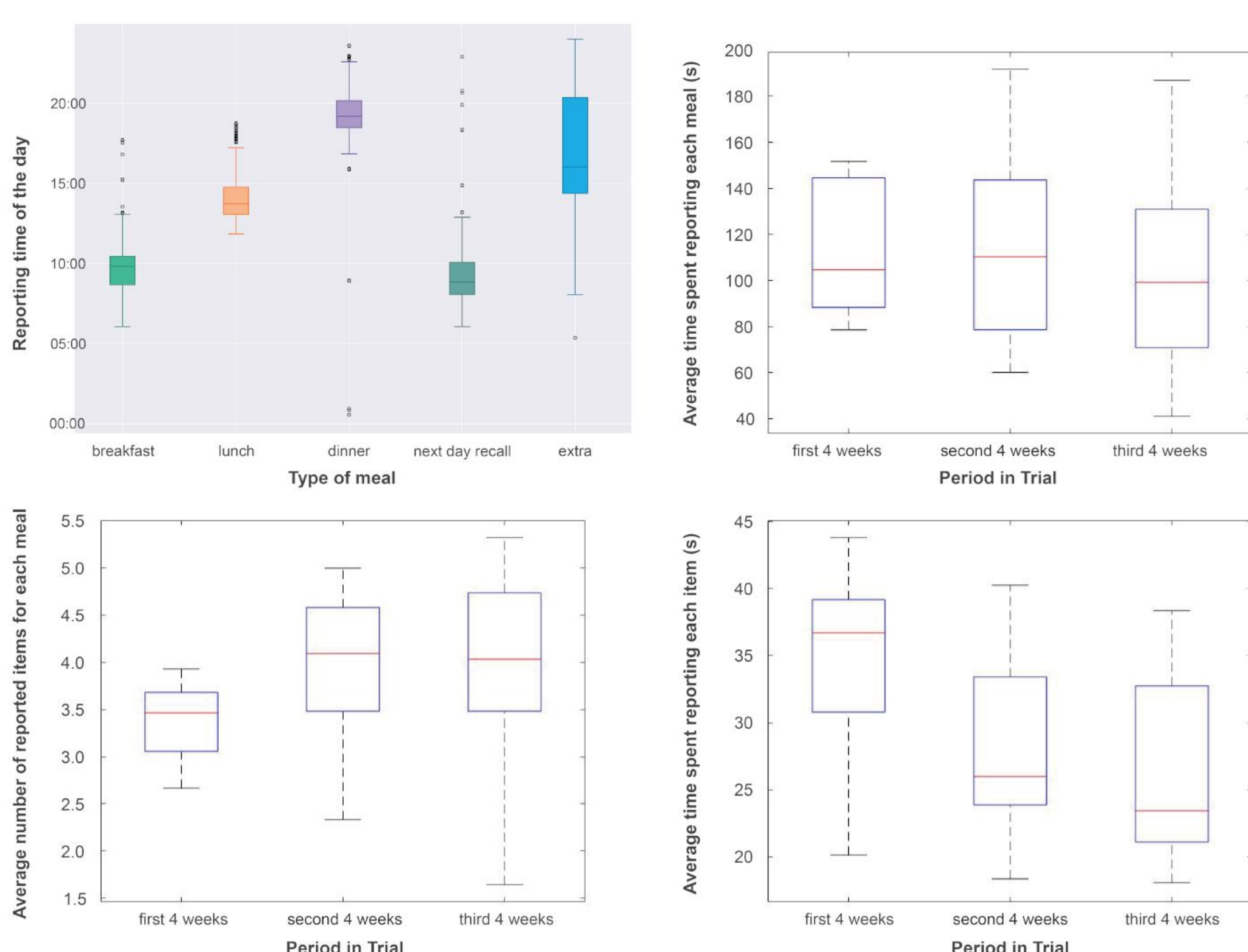
#### Insights for presenting real-time feedback

- Present data visualization on the food intake and dietary patterns
- Elaborate on the traffic light system and provide advice on better alternatives
- Deliver evidence-based personalized recommendations based on the reported data

### STUDY-2 CLINICAL TRIAL

The chatbot is involved in a monocenter prospective observational trial with cardiovascular patients. The recruitment of this study started in November 2021 and is expected to complete in June 2023, in which 100 participants are expected. The primary objective is to examine the usability and long-term adherence of dietary monitoring via the chatbot among cardiovascular patients. The secondary objective is to explore the effectiveness of self-monitoring in improving self-awareness and nudging the dietary behavior change toward a healthy diet.

Until January 2023, 61 participants (male=55, M\_age=63.0, SD\_age=10.6) were onboarded, and 34 (male=31, M\_age=64.0, SD\_age=10.7) of them at least finished their first 3-month experiments. The average response rate is 87.83%, with the average self-perceived accuracy as 8.05. During the interview, the participants shared their enthusiasm about using the chatbot for food tracking and praised its simplicity. Meanwhile, they gave suggestions to improve the chatbot: 1) involving their partners when using the chatbot; 2) knowing the dietary behavior of their peers; 3) receiving recognition with anonymous competitions.



Data analysis on the chatbot usage

### STUDY-3 CARD-BASED ONBOARDING FOR FOOD TRACKING

To increase adherence and the effect of food tracking, it is necessary to onboard patients and ensure they understand the complexity of tracking their own data. In this study, we developed food category cards to interactively introduce the food group classification and simplify the onboarding processes. We conducted 31 individual onboarding sessions with non-clinical participants. Our work contributes food category cards and discusses the value of onboarding participants into clinical studies using a card-based human-centered approach.

- Intuitively gain an overview and learn about the relationship between different categories
- Helpful for onboarding to the food-tracking chatbot and applying their knowledge in food-tracking tasks
- Benefits in the cards being used for multistakeholder investigation of food tracking
- Provide detailed insights into patients' dietary patterns and food combinations, and allow to identify opportunities for dietary behavior change

### STUDY-4 CHATBOT CUSTOMIZATION

**Creating dietary behavior profiles:** We interviewed participants about their eating behavior and asked them to map their regularly consumed food groups with different meals, using the food category cards. This study explored the frequently consumed food combinations for each meal, including in-between and last-night snacks. Meanwhile, we created dietary behavior profiles that can be used to customize the chatbot user experience.

#### According to Meal Patterning

- Regular Eaters: eat at least three main meals daily
- Meal Skippers: only skip one meal a day
- Snack Eaters: always have at least one additional meal

#### According to Regular Food Combinations

- Fixed Eaters: fixed types of food combinations
- Creative Eaters: frequently try new recipes and always eat creatively
- Hybrid Eaters: partly fixed and partly creative
- Constrained Eaters: due to health-related factors, religious beliefs, decisions to go vegetarian or vegan



**Applying customization to the tracking experience:** We conducted an exploratory study to investigate to what extent the chatbot customization based on personal food choices can lower the workload of food tracking. Chatbot A remained the same, whereas chatbot B was adapted and customized based on the questions regarding their food choices. Participants were randomly divided into two groups. The first group started with chatbot A and then continued with chatbot B, while the others interacted with the chatbots in the opposite order. Both the qualitative and quantitative results look promising as they indicate that the workload can indeed be lowered.

### STUDY-5 DIETARY BEHAVIOR DETERMINANTS

**Clinical Trial:** Within the ongoing clinical trial, the chatbot is also used to collect qualitative data regarding dietary intake, stress level, and sleep condition, while the activity level was collected automatically by Philips Health Band. With these data, we aim to find correlations between dietary intake behavior and other lifestyle-related factors.

**Semi-structured Interview:** Semi-structured interviews have been conducted to investigate the determinants of dietary behavior and food choices.

#### These lifestyle-related factors affect

- Time for having meals
- Numbers of the meals
- The intake amount of certain food categories (e.g., vegetables, fruits, snacks)
- Food/Nutrition composition
- Health level of the food choices