Smart Food Intake: Development of a 2-hour recall methodology to measure context-specific food intake and underlying food choice motives

Overview of the project

Wageningen University & Research - January 2022 - Muriel Verain, Jos van den Puttelaar & Desiree Lucassen

Preface

Insights in what people eat, where, when, with whom and why can be useful in the pursuit of a more healthy and sustainable food system. In the Public-Private Partnership **Smart Food Intake** we developed and evaluated a methodology to measure food intake and underlying food choice motives in context. This report provides an overview of the work that has been conducted in the project. The project was built up from seven Work Packages covering four phases (see project structure). Results of several of the steps taken in these phases have been published in scientific articles or other types of publications (see project output). This overview is intended as a reference guide of the steps that were taken and informs the reader what the methodology includes, how it is evaluated and how and for what applications it can be used. The report can be helpful for fundamental and applied food researchers to understand the opportunities and boundaries of the methodology and the accompanying system.

We would like to thank Anouk Geelen (Wageningen University) for her efforts in setting up this project and Arvind for the development of the app (Arvind Datadien). In addition, we would like to thank the advisory panel for the constructive feedback: Pieter van 't Veer (Wageningen University) Marga Ocké (RIVM), Patricia van Assema (Maastricht University) and Dick Heylen (Universiteit Twente).

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Contents

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Summary

Summary

An energising smoothie for breakfast, a convenient sandwich for lunch at work and a healthy and tasty curry for the family dinner. During the day, we make different eating choices, depending on where we are and with whom we eat. To better collect insights in the what, where, when and why of food consumption, the food industry has expressed the need for more advanced data collection methods for food intake and its determinants. Current methods of monitoring food intake and food choice motives come with a range of drawbacks, including 1) a lack of linkage between food intake and its determinants, 2) a lack of inclusion of contextual variability, 3) high measurement errors, 4) time-consuming data collection and 5) a high burden for the consumer and the researcher. Therefore, **Smart Food Intake** aimed to develop an innovative flexible methodology that enables to collect reliable **food intake data** and underlying **food choice motives** as important determinants of food intake.

For that purpose, this project successfully developed a **2-hour recall** ("snapshot") methodology. The methodology has proven to provide an adequate estimate of actual dietary intake and an acceptable estimate of habitual dietary intake via different sampling strategies. In addition, the measurement of food choice motives showed stable results in similar contexts and showed variability across different eating contexts, indicating the added value of measuring in-context. The test-retest reliability and the content validity of the food choice motives was satisfactory. The integrated methodology, combining assessment of food intake, the eating context and food choice motives, is positively evaluated. The SFI-Traqq app has been developed to function as a tool to apply the integrated methodology in combination with survey software and is evaluated by users as easy and nice to use, and not too lengthy.

The modular approach ensures the flexibility to easily adjust to specific research questions and enables to research 1) what people eat, 2) why they eat that, and 3) how this differs across eating contexts. These insights could help the food industry to stimulate more healthy and sustainable food consumption, by tailoring food formulations, communication and interventions towards various target groups and eating contexts better than before.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 5

Samenvatting

Een smoothie voor de energie als ontbijt, een makkelijke boterham voor de lunch op het werk en een gezonde en smakelijke curry voor het avondeten met het gezin. Door de dag heen maken we verschillende eetkeuzes, afhankelijk van waar we eten en met wie we eten. Om beter inzicht te krijgen in wat, waar, wanneer, met wie en waarom we eten, heeft de levensmiddelenindustrie de behoefte aan geavanceerdere onderzoeksmethoden geuit, voor het verzamelen van data over voedselinname en de determinanten daarvan, zoals voedselkeuzemotieven. De huidige methoden voor het meten van voedselinname en voedselkeuzemotieven hebben een aantal nadelen: 1) voedselinname en onderliggende determinanten worden niet aan elkaar gekoppeld, 2) contextuele variatie wordt niet meegenomen, 3) meetfouten zijn hoog, 4) dataverzameling is tijdrovend en 5) de belasting voor de respondenten en de onderzoekers is hoog. Daarom stelde **Smart Food Intake** ten doel om een innovatieve, flexibele methodologie te ontwikkelen die het mogelijk maakt om **voedselinname** en onderliggende **voedselkeuzemotieven** als belangrijke determinanten van voedselinname, op een betrouwbare manier te verzamelen.

Daartoe heeft dit project met succes een methodologie ontwikkeld op basis van **2-uurs recalls** ('snapshots') om context-specifieke voedselinname en onderliggende voedselkeuzemotieven te meten. De 2-uurs recall-methodologie geeft een adequate schatting van de werkelijke inname via de voeding en een aanvaardbare schatting van de gebruikelijke inname via de voeding door middel van verschillende sampling strategieën. Bovendien laten de voedselkeuzemotieven stabiele resultaten zien wanneer het gaat om vergelijkbare contexten, en variatie wanneer het gaat om verschillende eetcontexten, wat de toegevoegde waarde laat zien van het context-specifiek meten. De test-hertest betrouwbaarheid en de content-validiteit van de voedselkeuzemotieven voldoet. De geïntegreerde methodologie, waarin voedselinname, de eetcontext en context-specifieke voedselkeuzemotieven worden gecombineerd, wordt positief beoordeeld. De SFI-Traqq-app is ontwikkeld als een tool om in combinatie met survey software de geïntegreerde methodologie toe te passen en wordt door gebruikers beoordeeld als makkelijk en prettig in gebruik, en niet te langdradig.

De modulaire aanpak zorgt voor flexibiliteit en maakt de methode makkelijk toepasbaar voor verschillende typen onderzoeksvragen en maakt het mogelijk om te onderzoeken 1) wat mensen eten, 2) waarom ze dat eten, en 3) hoe dit varieert tussen eetcontexten. Deze inzichten kunnen de levensmiddelenindustrie helpen om gezondere en duurzamere voedselconsumptie te stimuleren, doordat product-herformuleringen, communicatie en interventies beter dan voorheen kunnen worden afgestemd op verschillende doelgroepen en eetcontexten.

WAGENINGEN
UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 6

Introduction

- Background & aim

- Project structure

- Project outcomes

- Mission & content

WAGENINGEN
UNIVERSITY & RESEARCH

Background & aim

This report provides an overview of the Public-Private Partnership 'Smart Food Intake' that has been conducted between 2017 and 2021. The project was initiated as a reaction to the need expressed by the food industry for more advanced data collection methods for food intake and its determinants. To stimulate more healthy and sustainable food consumption, better insights in the what, where, when, and why of food consumption were needed. Such insights would be of value in the design of food formulations, communication and interventions, to better tailor them to various target groups and eating contexts than before.

Therefore, the **aim** of Smart Food Intake was to develop an innovative flexible methodology that enables to collect reliable **food intake data** and underlying **food choice motives** as important determinants of food intake. For that purpose, a modular system based on a **2-hour recall** ('snapshot') methodology was developed. Such a method enables to research 1) what people eat, 2) why they eat that, and 3) how this differs across eating contexts.

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Project structure

The project consisted of seven work packages:

1. Design of Food Intake method (phase 1)

2. Design of Food Choice Motives method (phase 1)

3. Validation of Food Intake method (phase 2)

4. Validation of Food Choice Motives method (phase 2)

5. Data Integration (phase 3)

6. ICT Backbone (phase 3)

7. Governance, ownership and procurement (phase 4)
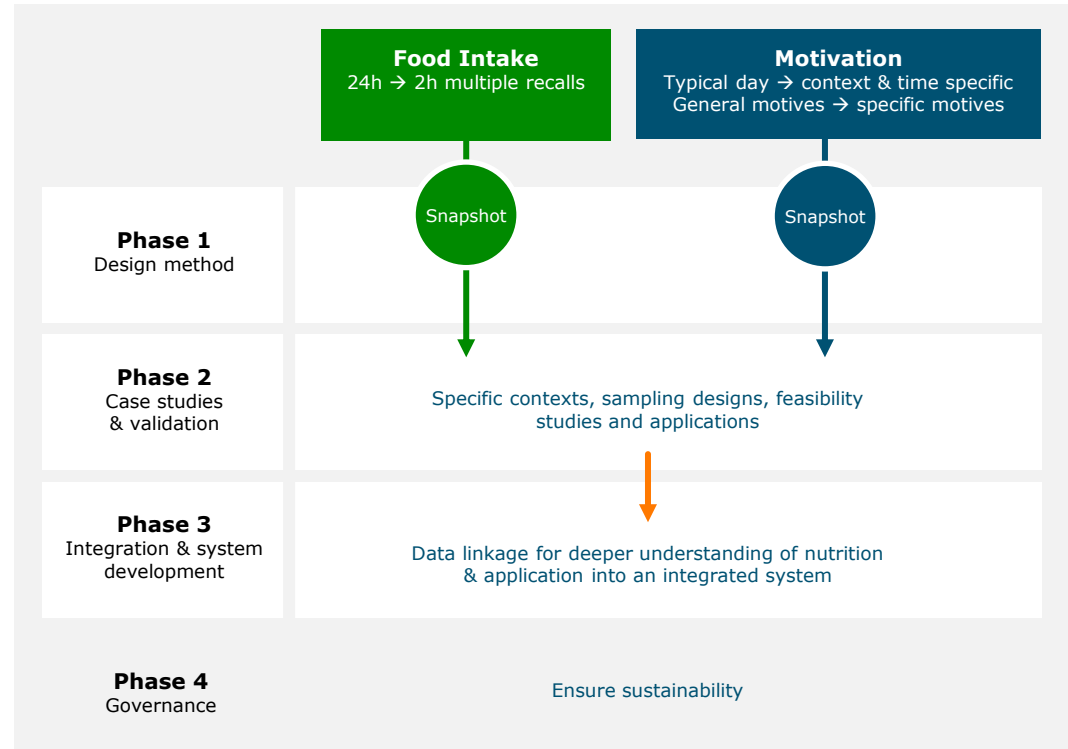
Background & aim

Traditional methods to assess food intake and food choice motives come with a range of drawbacks, which can mostly be overcome by replacing general assessments with context-specific assessments. Ecological Momentary Assessment (EMA) is an interesting body of literature in this respect. EMA embodies detailed and valid approaches to capture the complexity of food intake in the natural setting and thus maximising ecological validity while avoiding retrospective recall. EMA studies can generate a large variety of data (e.g. eaten products, motivation of choice, social context, time of day, location). The large variety of data can be complicated for researchers due to the many possibilities and for the participants due to the burden to enter all their data. The 2-hour recall methodology that has been selected in this project is an operationalisation of such a momentary assessment.

Drawbacks of traditional methods

- A lack of linkage between food intake and its determinants
- A lack of inclusion of contextual variability
- High measurement errors
- Time-consuming data collection
- A high burden for the consumer and researcher

Advantage of 2-hour recall methodology

- Food intake and food choice motives are linked for the particular context
- Variations across contexts can easily be identified
- Short recall periods reduce measurement errors
- Data collection for the specific moment is fast and easy
- The burden can be spread across respondents or spread out over time

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 10

Project outcomes

The Smart Food Intake project envisioned to result in three main project outcomes:

1. The 2-hour recall methodology to provide insights in food intake and its determinants,* based on a flexible system and methodology,** adjustable to specific research questions.

2. A proof of principle of the methodology with a case study, to evaluate the methodology and show the usability, acceptability and technical feasibility.

3. A governance structure for data accessibility in an established ICT backbone, including the rules and regulations for using the methodology and the resulting data.

In this research we focused on food choice motives as important determinants of food intake. Food choice motives are defined in this project as conscious deliberations about the decision to eat a certain food product. We did not look at additional concepts that are important in food choices, but are not motives, such as habits or emotions. In addition, note that the method is developed to measure food choice motives at the point of consumption, and not at the point of purchase.

*** Note that during the project, it was decided to develop an app (SFI-Traqq app) to be able to use and test the developed methodology. The app was not an official deliverable of the project but must be regarded as a tool to apply the methodology. The methodology, or parts of it, can also be applied without using the app.*

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information

11

Mission and content

The mission of Smart Food Intake is **to improve understanding of food consumption**. The Smart Food Intake methodology will enable the food industry as well as the research community to collect data on food intake in a faster, flexible, and in a more reliable way compared to the traditional methods. In addition, food intake data is linked to context-specific food choice motives, as we know that motives differ across eating contexts. Considering the context will therefore lead to an increased understanding of food consumption. Eventually this concept should help researchers and industry to collect necessary insights faster and cheaper that can be used to develop food products and interventions that better fit the needs of a diverse range of consumers in a wide range of eating contexts and lead to an on average higher intake of healthy and sustainable foods.

In the remainder of this document, the steps that were taken in the four phases of the development of the methodology will be discussed. The first phase entailed the design of the methodologies for food intake and food choice motives separately. The second phase involved the evaluation of both parts, in order to evaluate the methodology on reliability and validity. In the third phase, the food intake module and the food choice motives modules were combined in an integrated 2-hour recall methodology, with an ICT backbone. Usability of the integrated methodology was assessed. In parallel, in phase four, a governance structure has been developed, describing the rules and regulations for the use of the methodology and the data that it collects. Furthermore, this report includes a section on the applications of the methodology, conclusions and discussion and an overview of the project output. Finally, the survey questions that are used in the methodology are included in the appendix.

WAGENINGEN UNIVERSITY & RESEARCH

Summary Introduction Design Evaluation Integration Applications Governance Conclusions Project output Appendix References More information 12

Design

- Food intake

- Food Choice Motives

- Practical relevance

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Design: Food Intake

Accurate dietary assessment is crucial in nutrition and health or health behaviour research, where 24-hour recalls, food frequency questionnaires and food records are most commonly used. However, these methods are charged with a range of drawbacks, e.g., memory-related bias, social desirability bias, and are burdensome. Smartphone-based technologies offer the opportunity to reduce some of these biases by enabling more real-time data collection. Therefore, Work Package 1 aimed to design a 2-hour recall 'snapshot' method for measuring food intake. To achieve this, the following sub-tasks were completed and combined in a design plan (Lucassen et al., 2018):

1) **Food list development:** The food list plays an important role in the searchability of foods which not only affects usability, but also accuracy of the data. To develop a full-fledged food list, it is important to ensure that food items can be linked to their respective food composition data.

   - The food list was based on the **Dutch Food Composition Database** (NEVO version 2016). The original database was thoroughly checked and cleaned by trained dieticians. A *cleaning protocol* was written for transparency and justification of choices made.

2) **Portion size estimation:** Accurate portion size estimation is essential for quantification of food intake. A *literature review* was conducted on existing portion size estimation aids. Following, a *pilot study* was conducted comparing the accuracy of portion size descriptions and portion size images.

   - The use of **portion size descriptions** (i.e., household measures, standard portions) **and estimation in gram** turned out to be the most effective portion size estimation aid for the Dutch setting.

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Design: Food Intake

3) Sampling scheme development: Exploration of the EMA principles resulted in three possible sampling strategies: event-contingent sampling, interval-contingent sampling, signal-contingent sampling.

- An **interval-contingent sampling** scheme fits best with the 2-hour recall (2hR) approach, of which two variations were developed: prespecified complete days of 2hRs and random 2hRs over a predefined time period.

4) Design of the 2hR app: Above-mentioned points were all included in the design of the app. In addition, decisions were made on the (visual) design of the app, functionalities (e.g., routing, search engine), and additional features (e.g., My Dishes function, eating occasions, time of consumption).

Design: Food Choice Motives

Food choice motives (FCM) are traditionally measured with lengthy questionnaires that measure FCM on a general level (e.g., for 'a typical day'), rather than on a context-specific level (e.g., 'for my lunch at work that I just consumed'). But food intake varies across eating contexts, and it is likely that underlying FCM vary as well. Therefore, Work Package 2 aimed to design a short method for context-specific measuring of FCM. To achieve this, the following sub-tasks were completed and combined in a design plan (Verain and van den Puttelaar, 2018):

1) **Mapping of FCM**: A *quick scan of the literature* was performed to map existing methods to measure FCM, in order to select a suitable basis for our methodology and to construct a list of FCM as a starting point of our methodology development.

   - The Food Choice Questionnaire, developed by Steptoe, Pollard and Wardle (1995) is often used to measure FCM and was selected as a suitable basis. A single-item version was preferred because of length (Onwezen, Reinders, Verain and Snoek, 2019). Extensions were considered as several important motives are lacking in the Food Choice Questionnaire (e.g., sustainability (Lindeman and Väänänen, 2000; Verain, Snoek, Onwezen and Reinders, 2021) and energy (Renner, Sproesser, Strohbach and Schupp, 2012).

Design: Food Choice Motives

2) Variability of FCM across context: In this step, we wanted to investigate whether FCM vary across eating contexts and if so, which aspects of the eating context are important to consider. A *quick scan of the literature* was performed to get an overview of what is already known on variability of FCM across eating contexts, in order to select characteristics of the eating context. In addition, *secondary data analysis* was performed to further investigate variability of FCM across consumption moments and locations. Finally, a *consumer survey* (N=1006) has been conducted in a representative sample of Dutch adults to test variability of FCM across eating occasions, locations and social contexts.

- FCM differ across contexts, specifically across eating occasions but also across locations and social contexts, and it therefore seems important to consider the context in studying FCM.

3) Design of the methodology: the different elements that are necessary to build the methodology where selected.

- Structure of the FCM, answering scales, contextual factors, routing, randomisation structure, item selection and sampling schemes should be considered.

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Summary Introduction Design Evaluation Integration Applications Governance Conclusions Project output Appendix References More information 17

Design: Practical relevance

In sum, the 2-hour recall methodology was designed with five key elements:

- **Food list:** A country-specific food composition database was selected as the optimal basis for the food list; within SFI this was the NEVO 2016. However, extensive revisions of the included food descriptions was needed to optimise searchability of foods in the food list.

- **Portion size estimates:** Currently, for the Dutch setting, consumed amounts can best be estimated when portion size descriptions are provided (as opposed to pictures).

- **Food choice motives:** the single-item Food Choice Questionnaire (Onwezen et al., 2019), extended with some missing motives, seems a suitable basis for a context-specific methodology.

- **Eating contexts:** FCM are not a constant, but rather change from moment to moment. This implies that in measuring FCM, the following aspects of the eating context should be considered:
  1. eating occasion
  2. location
  3. social context

- **Sampling schemes:** An interval-contingent sampling scheme fits best with the 2-hour recall approach. Two schemes were designed:
  1. consecutive 2hRs that build up to complete days to measure actual intake
  2. 2hRs spread out over a predefined time period to measure habitual intake

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Evaluation

- Food Intake

- Food Choice Motives

- Practical relevance

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Evaluation: Food Intake

Work Package 3 aimed to evaluate and further develop the 2hR methodology for dietary assessment. The 2hR methodology was built into an existing dietary assessment app 'Traqq®' to enable application of the method. Therefore, evaluation of the app is intertwined with the evaluation of the methodology as the quality of the app directly influences the quality of the methodology. This entire Work Package was an iterative process. Results of the evaluations were used to further develop the app and the method (Lucassen et al., 2021).

1) **Expert review (April 2018):** experts (N=10) in the field of dietary assessment evaluated the app by cognitive walkthroughs to simulate a first-time user experience. Experts explored the app individually and without guidance while performing a set of predefined tasks.

    x   Experts indicated that the first version of the app was not intuitive, e.g., the menu-structure was judged unclear due to vague buttons/icons, and the search engine generated an illogical order of results. Conclusion: *major revisions needed.*

2) **Usability (November 2018):** 22 think-aloud interviews were conducted among intended users (M/F, 20-70y) to assess usability and likeability. Additionally, the participants completed the System Usability Scale (SUS).

    ✓   All participants completed the tasks without or with minimal instruction.

    ✓   Traqq scored high on the usability scale: mean SUS of 79/100.

    x   The 'Mijn Gerechten' function (i.e., Traqq's recipe function) was unclear to some participants.

    x   Participants missed an option to report consumed amounts in grams.

    x   Scaling of the app was not correct on smaller older smartphones.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information   20

Evaluation: Food Intake

3) **Validation (June 2019-May 2020):** Dietary intake from 215 adults was collected in two 4-week study periods, with a 2-week wash-out period in between. One study period assessed actual intake with a 'full-day 2hR scheme' (i.e., three random full-days of 2hRs), and three random 24hRs. In the other period, habitual intake was assessed with a 'random 2hR scheme' (i.e., 24 random 2hRs), and an FFQ. Additionally, chemical biomarkers from blood and urine were gathered from 69 of the 215 participants. At the end of the validation participants completed an evaluation questionnaire.

   a) **2hR days for actual intake**:

   - The 2hR days on average estimated a 6% higher energy intake and a 17% higher macronutrient intake as compared to the 24hRs.

   - Spearman's rank correlation coefficients ranged between 0.41 (acceptable) for the polyunsaturated fatty acids to 0.74 (good) for the plant-based proteins (mean correlation 0.58).

   - Comparisons of dietary protein results with urinary protein levels showed a 9% underestimation by the 2hR days and a 12% underestimation by the 24hRs.

   - The majority of the participants (87%) indicated to prefer the 2hR days over the 24hRs; they perceived them as more convenient (86%), less time consuming (89%), and easier to recall their food intake (92%).

   - Conclusion: the 2hR days provide an **adequate estimate of actual intake** of energy and macronutrients.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 21

Evaluation: Food Intake

3) **Validation (June 2019-May 2020):** Dietary intake from 215 adults was collected in two 4-week study periods, with a 2-week washout period in between. One study period assessed actual intake with a 'full-day 2hR scheme' (i.e., three random full-days of 2hRs), and three random 24hRs. In the other period, *habitual intake was assessed with a 'random 2hR scheme' (i.e., ~24 random 2hRs), and a FFQ.* Additionally, chemical biomarkers from blood and urine were gathered from 69 of the 215 participants. At the end of the validation participants completed an evaluation questionnaire.

   b) **Random 2hRs for habitual intake:**

   - The random 2hRs on average estimated a 12% higher energy intake and a 12% higher macronutrient intake as compared to the FFQ.

   - Spearman's rank correlation coefficients ranged between 0.33 for β-Carotene and 0.70 for alcohol (mean correlation 0.50).

   - Again, the majority of the participants (77%) indicated to prefer the random 2hRs over the FFQ; they perceived them as more convenient (78%), less time consuming (77%), and easier to recall their food intake (85%).

   - Conclusion: the random 2hRs provides an **acceptable estimate of habitual intake** of energy and macronutrients.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 22

Evaluation: Food Choice Motives

Work Package 4 aimed to further develop and evaluate the context-specific method for measuring food choice motives, in an iterative way. First, the single-item Food Choice Questionnaire (Onwezen et al., 2019) was **evaluated for completeness and extended** with omitted motives that we judged as important in researching context-specific FCM. Three steps were taken:

1. **Long list of additional motives**: A long list of possible additional motives was created based on a <u>literature review</u>, an <u>expert workshop</u> and results of a <u>survey</u> in which respondents could type in motives that they missed.

2. **Short list of additional motives**: Based on <u>selection criteria</u> of fit with definition and proposed added value in terms of consumption and variation across contexts, we selected eight motives that seemed to be the most relevant additions to the original scale.

   - Energy, variety, satiety, food safety, innovation (newness), digestion, cosiness and craving.

3. **Evaluation and final selection**: The relevance of adding the eight motives to the original single-item Food Choice Questionnaire was <u>empirically tested in two samples</u> of the Dutch adult population (N=642 (representative) and N=384 (older adults)). The final selection was based on 1) the added value in explaining consumption and 2) the extent to which the motives vary across contexts.

   - All additional motives show variation across at least one contextual factor (eating occasion, location and social context).

   - Digestion, cosiness and variation had only limited additional value in explaining food consumption.

4. **Scale selection:** With a <u>quick scan of the literature</u> we investigated the optimal answering scale for Food Choice Motives on a smartphone application.

   - Food Choice Motives are typically assessed with Likert-type ordinal scales. Alternatives that minimise cognitive load (e.g. selecting the motives that apply) are mainly used when the number of items is large (>20). We use a 7-point Likert scale.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information   23

Evaluation: Food Choice Motives

Second, the methodology was evaluated on technical feasibility and usability for the respondent and the researcher.

1. **Feasibility**: The method was first applied on smartphones in 2018 with a *survey with two waves* in a representative sample of Dutch adults (Wave 1: N=1006, Wave 2: N=531). Invitations were sent via SMS on 7 consecutive days either at 8.00, 13.00 or 19.00

   ✓ The scheme resulted in an acceptable sample and good spread in entries over days, time, and eating occasions.

   ✓ The 2hR period seems useful, as about 93% indicated to have consumed something during the past two hours.

   ✓ It takes only a few minutes to fill out the survey and respondents evaluate the survey as easy.

   ✗ Consumption at home was slightly overrepresented, which could be detrimental for studies focusing on out of home.

   ✗ Some respondents took a long time or started at a later moment, which could lead to biased results.

   ✗ Not all motives seemed completely clear.

2. **Usability:** *15 online interviews* were conducted to test the understanding of the questions on FCM and context in our developed SFI-Traqq app. Additionally, the participants completed the System Usability Scale (SUS).

   ✓ Respondents were positive and indicated that they enjoyed using the app (score 3.9/5).

   ✓ Sufficient usability score: Mean SUS of 65.5/100. The SFI-Traqq app is evaluated as rather easy to use (score 3.7/5).

   ✗ Respondents missed options to monitor calories and macronutrient intake, a personal profile, personal goals and advice.

   ✗ Some points for improvement were raised, such as the lay-out of some buttons and lack of clarity of the aim of the app.

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Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 24

Evaluation: Food Choice Motives

Third, the methodology was evaluated on stability, context validity and test-retest reliability.

1. **Evaluation of stability over time across contexts:** A *survey with two waves* (N=1006; N=531) was conducted among Dutch adults. Paired samples t-tests were performed to compare FCM-ratings for all possible combinations of eating occasions (e.g., lunch – dinner).

   - FCM are stable over time for the same eating occasion.

   - FCM differ over time for different eating occasions (specifically for dinner and lunch vs. snacks) except for taste, familiarity and mood.

2. **Content validation:** *15 online interviews* were conducted to assess content validity of the 20 FCM.

   - Participants only think extensively about the FCM they find important → add a 'not relevant' button.

   - Large variation in interpretation of the FCM satiety and safety → remove satiety; change safety into food safety.

   - Familiar, natural, animal welfare, fair trade, environment and safety were evaluated as difficult → adapt wording.

3. **Test-retest reliability:** A *survey* was conducted across Dutch adults (790 completed surveys of 227 participants) to test for test-retest reliability in the lunch context. 178 respondents were included in the test-retest analysis of their 'stable' lunch context.

   - Intraclass Correlation Coefficient (ICC): poor for satiety and digestion; fair or good for the other FCM.

   - The percentage of exact agreement was also poor for satiety and digestion. Satiety was removed from the FCM list, as content validity was also questionable. Digestion was not removed, as ICC was fair in the 'home-alone' context, but it is a borderline case and should be treated with care.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 25

Evaluation: Practical relevance

In sum, the Smart Food Intake methodology shows to be reliable and user-friendly.

- **Food intake:**

  - Consecutive 2hRs on specific days provide an adequate estimate of actual intake.

  - Random 2hRs spread out over a predefined time period provide an acceptable estimate of habitual intake.

- **Food choice motives:**

  - The SFI methodology measures twelve single-item motives from the single-item Food Choice Questionnaire (Onwezen et al., 2019) and seven additional motives: energy, variety, food safety, innovation, digestion, cosines and craving.

  - Food choice motives are assessed on a 7-point Likert scale from (1) not at all important to (7) very important.

  - Assessment of food choice motives is reliable: the method provides stable results or the same eating occasion; differences are captured across eating occasions

  - Assessment of food choice motives is valid: the 19 selected motives show similar interpretations across respondents.

- **User experiences:**

  - The methodology is user-friendly, easy and enjoyable to use and requires only a few minutes to fill out.

  - The 2-hour recalls methodology is preferred by users over traditional methods to measure food intake.

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Integration

- Survey

- Infrastructure

- SFI-Traqq App

- Usability evaluation

- Practical relevance

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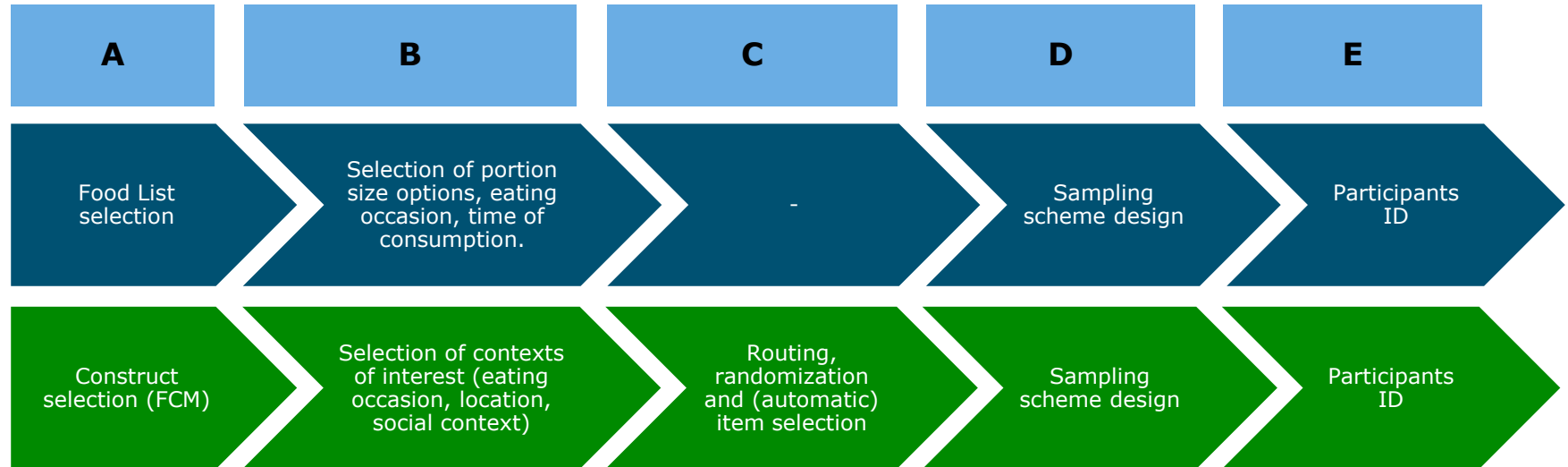
Integration: Design of the survey

The SFI project delivered a methodology than can be implemented on multiple platforms. However, due to the complex structure of having diverse sampling schemes, multiple food intake lists and dynamic survey questions, we developed a mobile phone app called SFI-Traqq that works together seamlessly with survey software. In the following slides we show:

i.   The process for an integrated design.

ii. An overview of the whole systems functionality.

iii. How the two modules of FI and FCM work together

iv. Example of what it looks like for the users of the app.

v.   An evaluation from the perspective of participants.

Integration: Survey

The two disciplines follow similar procedures, but are in essence two individual modules that can work separately with 2hRs. Below processes are shown for both FI and FCM. Note that this view is simplified to illustrate the similarities. For both FI and FCM steps A and B are flexible, while D is strictly dependent on the research question. For FCM there are optimisation advantages for routing and standards for randomisation of items and questions. The last step (E) involves applying participants IDs, which is fully integrated for both methods.

A	B	C	D	E
Food List selection	Selection of portion size options, eating occasion, time of consumption.	-	Sampling scheme design	Participants ID
Construct selection (FCM)	Selection of contexts of interest (eating occasion, location, social context)	Routing, randomization and (automatic) item selection	Sampling scheme design	Participants ID

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information   29
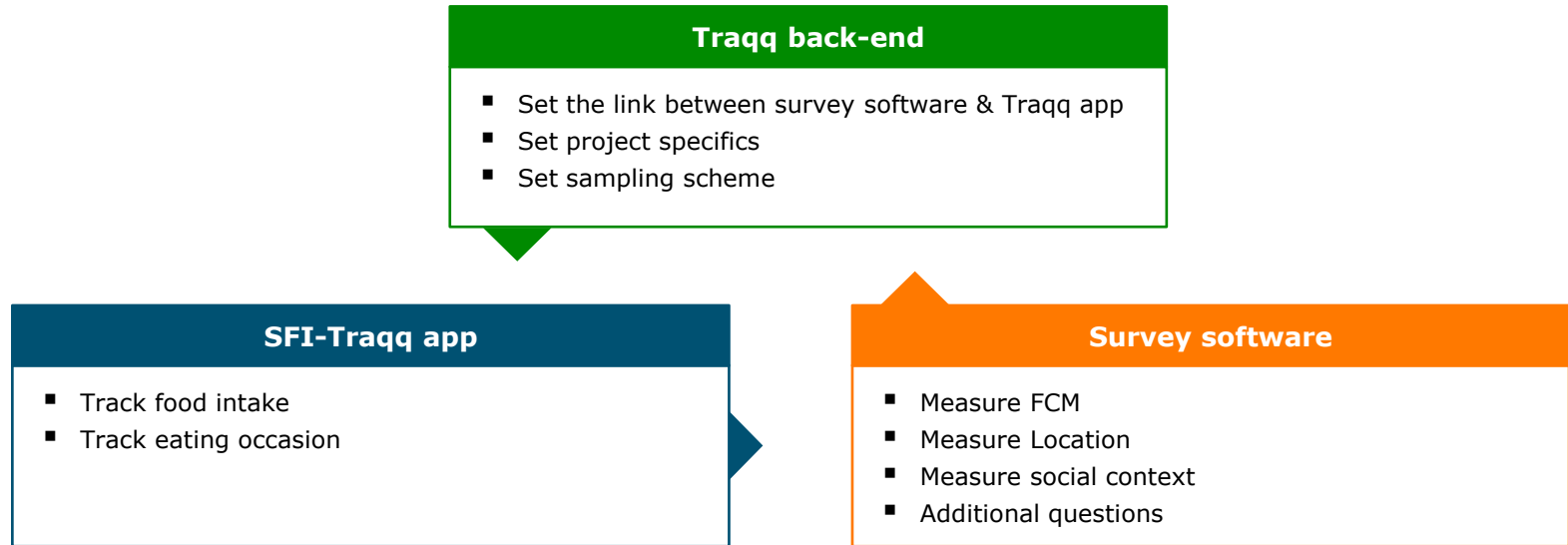
Integration: Infrastructure

To maintain flexibility for different research purposes, the app and its infrastructure consists of several linked modules of which the main modules can also function individually. Below the complete infrastructure is visualised including its dependencies. The figure gives an indication of the complexity of the integrated methodology. Yellow represents the research process, blue the modules and green the data sets. The two outlined modules are the main modules for FI (blue outline) and FCM (red outline). In the next slide we focus on how these modules can integrate.
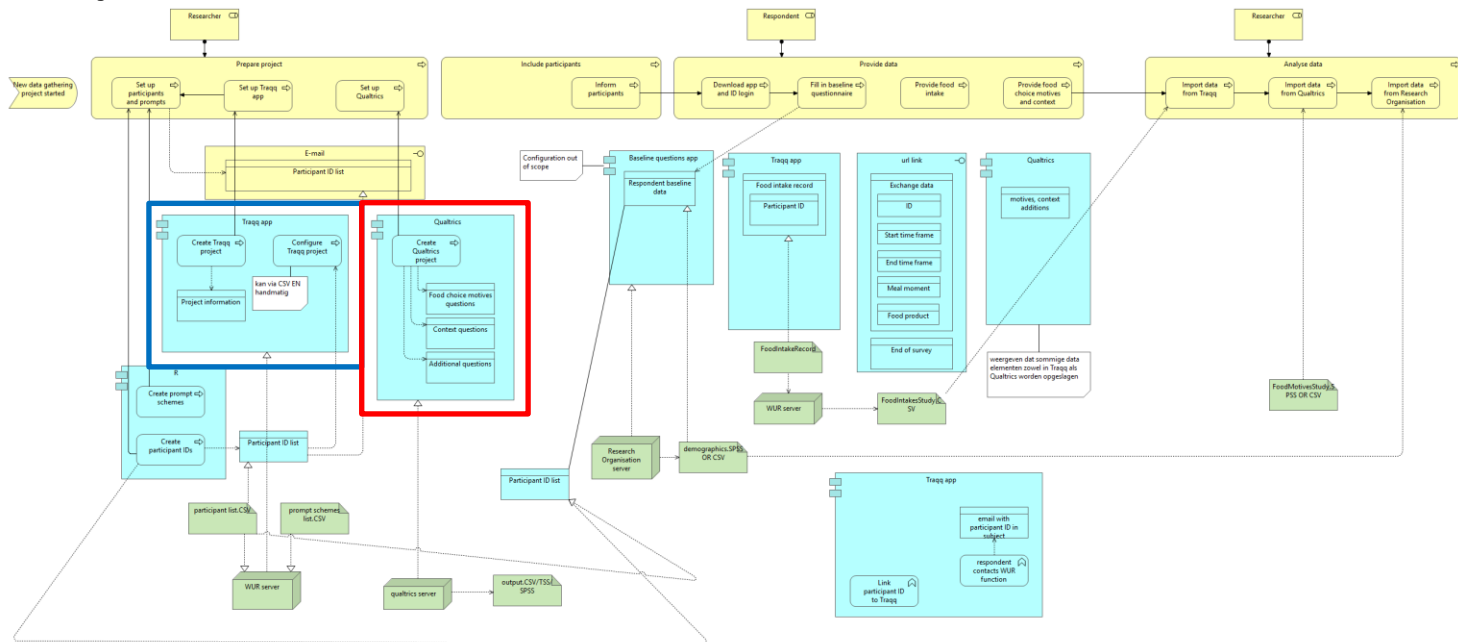
Integration: Infrastructure

The two main modules are the SFI-Traqq app and the survey module. In the back-end the two modules can be linked (by web address coding and participant IDs). The back-end drives the SFI-Traqq app. The app itself can push information to the survey software so that it can integrate the answers to the questions related to food intake seamlessly. So if peanut butter was reported for breakfast in the Traqq app, the survey can ask for the respondents' motives behind the choice for this peanut butter.

Traqq back-end

- Set the link between survey software & Traqq app
- Set project specifics
- Set sampling scheme

SFI-Traqq app

- Track food intake
- Track eating occasion

Survey software

- Measure FCM
- Measure Location
- Measure social context
- Additional questions

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Integration: SFI-Traqq App

Below a few screenshots of the Traqq app including integration to the survey software are shown. A participant follows the following steps:

1. Receives prompt

2. Reports on consumed products and classification of meal moment

3. Confirms & moves to survey (the survey opens in app for seamless experience)

4. Data is sent to Traqq back-end and survey software back-end.
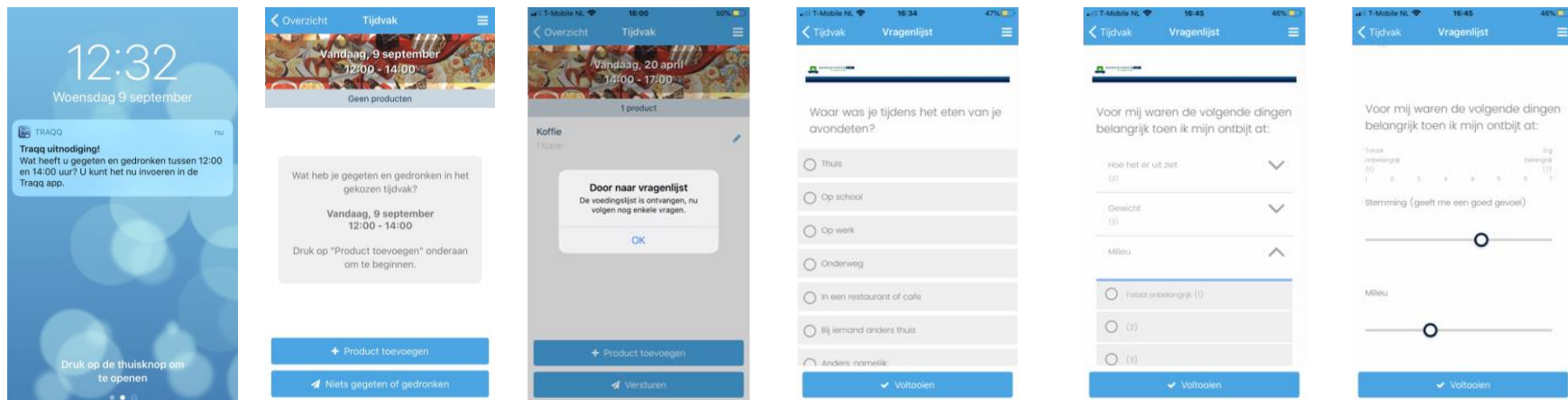
Integration: Usability evaluation

Evaluation (2020): The usability of the integrated method was evaluated in a representative sample of the Dutch adult population. Participants completed a baseline survey (N=653), received eight 2hR prompts (N=511), and finally were invited to complete the Eetscore (N=277).

- ✓ Participants responded on average within 16 minutes to a prompt.

- ✓ Participants responded more often than requested. Participants received eight prompts and a minimum of six responses was required to include the participant in the analyses, but participants had the opportunity to continue with entering their data after the eight prompts (see graph).

- ✓ Participants scored good on the Systems Usability Scale: Mean SUS of 69/100.

- ✓ Participants evaluated the SFI-Traqq app as nice to use (score 3.8/5).

- ✓ Participants evaluated the length of the survey as good:

  - ✓ Entering food data (3.1/5)

  - ✓ Questions on eating contexts and FCM (3.2/5)

- ± With regards to feasibility for researchers, the set-up and data are more complex than for regular surveys, but the opportunities are also more varied.

Responses histogram
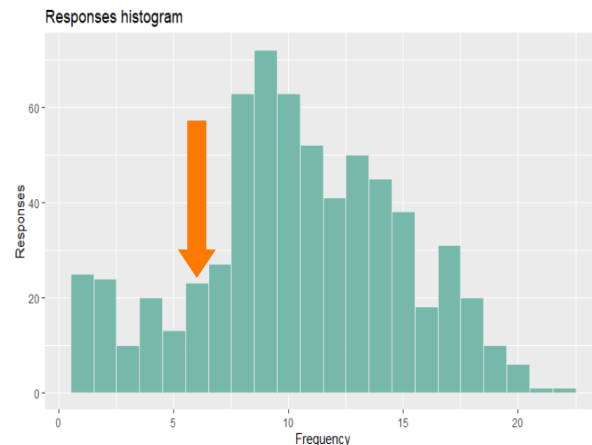
Integration: Practical relevance

Depending on the research question the right integration and setting of the different modules can be chosen. The main degrees of freedom in setting up the methodology are:

- Focus on Food Intake and/or Food Choice Motives (both are applicable independently)

- Sampling schemes: changing the focus on certain time series or times of day

- Adding question about specific products or (e.g. after consuming a milk alternative asking specifically what type)

- Dynamically altering survey questions depending on the meal moment

The integration opens up opportunities for new insights as shown in the next section.

Applications

- Example

- Other applications

Example: nutrient intake and FCM of vegans, vegetarians, flexitarians and omnivores

A case study has been conducted at FrieslandCampina to evaluate the application of the developed methodology for a commercial research question. The case study aimed to:

1. investigate the nutrient intake of vegetarians, vegans, flexitarians and omnivores among Dutch healthy adults.

2. investigate FCM of the four populations and to assess whether these are related to food groups, with a specific focus on protein consumption.

A market research agency aimed to recruit 200 healthy Dutch adults (>18y). The participants first received a baseline survey, measuring their general FCM and some background characteristics. Next, they were asked to register their food intake and FCM via three full days of 2hRs (i.e., two weekdays and one weekend day) via the SFI-Traqq app on their smartphone. If the participant indicated to have consumed a product that belonged to an important food group when it comes to protein consumption (e.g., drinks at breakfast), FCM were asked for that product choice.

In this study, the differences in nutrient intake between vegans, vegetarians, flexitarians and omnivores, will be analyzed, with a focus on intake of proteins and specific nutrients that could be insufficient when meat and/or other animal-based products are omitted from the diet (e.g., iron, vitamin B12, calcium, vitamin D). In addition, differences in product-specific FCMs across the consumer groups will be analyzed.

This case study is an example of a practically relevant application of our methodology, as it enables to combine insights in context-specific food intake and underlying FCM to better understand differences in food choices of specific consumer groups, such as vegetarians and vegans.

Other applications

The Smart Food Intake methodology is developed to measure context-specific food intake, context-specific FCM and characteristics of the eating context (i.e., eating occasion, eating location, social context). The methodology is envisioned to be flexible and modular to be adapted to different types of research questions. Some possible applications are:

- Monitoring of dietary intake for a specific time period to assess (nutritional) intervention effects (e.g., for a weight loss intervention).

- Investigating of consumption patterns for specific target populations (e.g., students, athletes, patients).

- Investigating differences in FCM across eating contexts for consumers with a high versus a low socio-economic status.

- Gaining insights in FCM of restaurant visitors.

- Investigating differences in FCM between people with a low, healthy and high calorie intake in different eating contexts.

- Investigating FCM related to the consumption of vegetables at home versus out of home.

Governance

- Insights
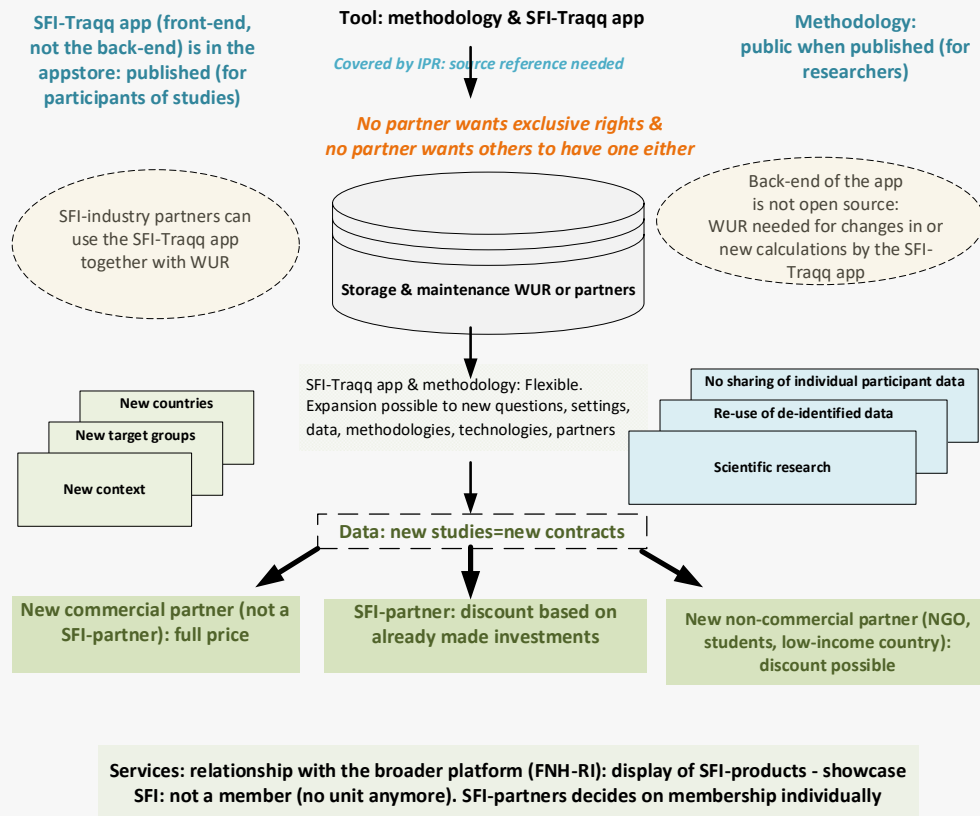- Arrangements
- Practical relevance

Governance: Insights

Work Package 7 aimed to deal with the codes, rules and policies (conditions) for data access, openness of data, ownership and procurement of data and methods, including links to e-science and the ICT backbone. Results of this Work Package are presented in a separate report (see project output). A short summary is presented below:

1. **A literature review** was conducted on Research Infrastructures and resulted in the identification of barriers and opportunities for data sharing and identification of important principles and legal demands to take into consideration.

   - FAIR principles and GDPR regulations should be considered, trust is important.

2. **Expert interviews** were conducted to learn from existing and emerging Research Infrastructures.

   - The Smart Food Intake methodology could be embedded in the Research Infrastructure for Food, Nutrition and Health.

3. **Interactions within the project team (workshops, one-on-one consultations, pilots)** were set-up to develop a joint understanding of how to use the Smart Food Intake methodology and resulting data.

   - Added value of collaboration is acknowledged.

   - Interest is shared in use of common methodology, as developed in Smart Food Intake.

   - Several barriers need to be overcome with regard to data sharing between actors (companies and/or research institutes): strict data policies (GDPR) and lack of established modes of working/routines in data sharing.

WAGENINGEN UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 39

Governance: Arrangements

Based on the consortium agreement and discussions with the legal department of Wageningen Research and the project partners, the rules and codes of conduct after the end of the Smart Food Intake project, with regards to the use of the 2hR methodology, the use of the SFI-Traqq app and use of data collected with the methodology/app, have been established. The results are presented in the figure.
For a more detailed explanation, please read the WP7 report on governance (see project outcomes).

SFI-Traqq app (front-end, not the back-end) is in the appstore: published (for participants of studies)

Tool: methodology & SFI-Traqq app

Covered by IPR: source reference needed

Methodology: public when published (for researchers)

No partner wants exclusive rights & no partner wants others to have one either

SFI-industry partners can use the SFI-Traqq app together with WUR

Back-end of the app is not open source: WUR needed for changes in or new calculations by the SFI-Traqq app

Storage & maintenance WUR or partners

New countries
New target groups
New context

SFI-Traqq app & methodology: Flexible. Expansion possible to new questions, settings, data, methodologies, technologies, partners

No sharing of individual participant data
Re-use of de-identified data
Scientific research

Data: new studies=new contracts

New commercial partner (not a SFI-partner): full price

SFI-partner: discount based on already made investments

New non-commercial partner (NGO, students, low-income country): discount possible

Services: relationship with the broader platform (FNH-RI): display of SFI-products - showcase
SFI: not a member (no unit anymore). SFI-partners decides on membership individually

Governance: Practical relevance

The Work Package on governance aimed to gain insights into practical implications of working together with the same methodology and sharing data with multiple partners during and after the project. We found that:

- The involved parties acknowledged the added value of collaboration and are interested in a common methodology.

- General agreements on the use of the methodology and the resulting data are difficult to make, as needs and possibilities largely depend on the research question (e.g. confidentiality of the topic, personal data, which computations are required etc.).

- There is no clear consensus on a broad informed consent form yet. This means that the personal data a participant is willing to share can only be used for the specific purposes as stated in the consent form, or that consent needs be given again when the purpose changes.

- Data sharing agreements are difficult to establish between different (types of) parties. The legal agreements are not always in line and neither are the protocols for practically sharing the data in line or sometimes even in place (e.g. conflicting requirements in # years of data storage).

WAGENINGEN
UNIVERSITY & RESEARCH

Summary | Introduction | Design | Evaluation | Integration | Applications | Governance | Conclusions | Project output | Appendix | References | More information | 41

Conclusions and discussion

- General discussion

- Limitations and future research

- Conclusions

General discussion

The Smart Food Intake project aimed to develop an innovative flexible methodology that enables to collect reliable food intake data and underlying food choice motives as important determinants of food intake. For that purpose, a modular system based on a 2-hour recall ('snapshot') methodology was developed.

The methodology largely overcomes the drawbacks of traditional methods as context-specific food intake and food choice motives are combined and as such, variations across contexts both in food consumption and the underlying motives can easily be identified. The choice for short recall periods (2 hours) have resulted in a fast and easy methodology, and the sampling schemes make it possible to spread out the burden over a longer time period. The SFI methodology is even preferred by users over traditional methods for measuring food intake.

The modularity in combination with the sampling scheme possibilities have resulted in a flexible methodology that can be adapted to a wide range of research questions. The strength of the 2hR methodology lies in its flexibility, user-friendliness, but also in the context-specific way of measuring. This makes the method very suitable to gain insights into the what, where, when and why of food consumption, in a range of eating contexts. Such insights are of particular interest to the food industry, food researchers and other food professionals that aim to understanding food consumption, and to apply these insights in food formulations, communication and interventions that are targeted to different eating contexts or consumer groups in the pursuit of a more healthy and sustainable diet.

Limitations and future research

We developed a flexible methodology that can broadly be applied, though it is important to beware of the boundary conditions. The methodology leaves room for all kinds of further extensions and adaptations and the flexible modular nature supports that.

- The methodology is positively evaluated and well validated for the Dutch setting but needs adjustment for use in other countries or cultures (i.e., implementation of country-specific databases; translation, adaptation and validation of FCM; app translation).

- The methodology is developed for and evaluated by representative samples of Dutch adults. If one desires to apply the methodology in specific target groups, such as youngsters or elderly, additional development and validation steps are needed.

- Food choice motives are included in the methodology as important determinants of food intake, but in future research other determinants could be added, such as mood states that are more affective in nature than food choice motives. The flexibility of the methodology that was created by linking the app to survey software makes it possible to add such determinants easily.

- The sampling schemes that have been applied in this project aim to lead to representative sampling of eating contexts. Beware that this results in unbalanced group sizes, as people consume more often at home than in a restaurant for example. In the future, the methodology could be applied with different sampling strategies if this is desired for research questions that need a balanced design in terms of eating contexts. In addition, some of the studies in Work Package 4 showed a slight overrepresentation of the home context.

- The 2hR methodology is designed to assess context-specific food intake (i.e., on food item level). However, the link between the app's food list and the Dutch Food Composition Database does enable extensive nutrition calculations on a more detailed level (e.g., intake of food groups, energy, macro- and micronutrients). For this, WUR-HNH's nutrition experts can connect to the computation module of Compl-eat™.

- In the future, the SFI-Traqq app could be extended with feedback, advice and tailoring options, as suggested by our respondents.

Conclusion

The Smart Food Intake project successfully developed a flexible, modular methodology, based on 2-hour recalls ('snapshots'), that enables to collect reliable **food intake data** and underlying context-specific **food choice motives**.

- **Food intake:** The 2hR methodology has proven to provide an adequate estimate of actual dietary intake and an acceptable estimate of habitual dietary intake via different sampling strategies.

- **Food choice motives:** Test-retest reliability was fair or good for all FCM and interpretation of the FCM showed only small or medium variations across respondents. In addition, FCM showed to be stable over time for the same eating context, but differed across different eating contexts, underpinning the relevance of measuring FCM in context.

- **Integrated methodology:** The integrated methodology, combining assessment of food intake, the eating context and context-specific food choice motives are positively evaluated on usability (by respondents) and feasibility (for the researchers). The SFI-Traqq app, which functions as a tool to apply the methodology in combination with survey software, is evaluated by users as easy and nice to use, and not too lengthy.

Overall, the Smart Food Intake methodology can be applied to answer all kinds of research questions on what, why and when people eat, and, with that, contributes to a better understanding of food consumption. Eventually, such insights can help in the transition towards healthier and more sustainable diets.

Project output

- Scientific papers

- Reports

Scientific papers

Lucassen, D. A., Brouwer-Brolsma, E.M., van de Wiel, A.M., Siebelink, E., and Feskens, E.J.M (2021). Iterative Development of an Innovative Smartphone-Based Dietary Assessment Tool: Traqq. *JoVE (Journal of Visualized Experiments)*, (169), e62032.

Lucassen, D.A., Willemsen, R.F., Geelen, A., Brouwer-Brolsma, E.M., and Feskens, E.J.M (2021). The accuracy of portion size estimation using food images and textual descriptions of portion sizes: an evaluation study. *Journal of Human Nutrition and Dietetics, 34*(6).

Lucassen, D.A., Brouwer-Brolsma, E.M., Slotegraaf, A.I., Kok, E., Feskens, E.J.M. (under review for publication in Nutrients). DIetary ASSessment (DIASS) study: Design of an evaluation study to assess validity, usability and perceived burden of an innovative dietary assessment methodology.

Lucassen, D.A., et al. (in preparation). Validity of the smartphone-based dietary assessment tool 'Traqq' for assessing actual nutritional intake by 2h recalls in adults: comparison with 24h recalls and urinary biomarkers.

Lucassen, D.A., et al. (in preparation). Validity of the smartphone-based dietary assessment tool 'Traqq' for assessing habitual nutritional intake by 2h recalls in adults: comparison with FFQ and biomarkers.

Van den Puttelaar, J., Verain, M.C.D., et al. (in preparation). A Mobile Ecological Momentary Assessment Tool for Food choice and underlying Motives: A mixed methods evaluation.

Verain, M.C.D., van den Puttelaar, J., Zandstra, E.H., Lion, R., de Vogel-van den Bosch, J., Hoonhout, H.C.M., and Onwezen, M.C. (2022). Variability of Food Choice Motives: Two Dutch studies showing variation across meal moment, location and social context. *Food Quality and Preference, 98*: 104505.

WAGENINGEN UNIVERSITY & RESEARCH

Summary   Introduction   Design   Evaluation   Integration   Applications   Governance   Conclusions   Project output   Appendix   References   More information   47

Reports

Public reports

Selnes, T. (2022). *Governance of Smart Food Intake.*

Verain, M.C.D., van den Puttelaar, J. and Lucassen, D.A. (2022). *Smart Food Intake: Development of a 2-hour recall methodology to measure context-specific food intake and underlying food choice motives.*

Internal reports and PPT-reports

Lucassen, D.A., Welhuis, E., Siebelink, E., Marteijn, R., Feskens, E.J.M., and Geelen, A. (2018). *Design Plan – Food Intake Methodology*.

Verain, M.C.D. and van den Puttelaar, J. (2018). *Design of a 2-hour recall method for food choice motives in specific contexts.*

Appendix I: *Survey*

Appendix I: *Survey*

Indien gegeten: Voor mij waren de volgende dingen belangrijk toen ik mijn [**ontbijt/middagmaaltijd/avondmaaltijd/tussendoortje**] at:

	Helemaal niet belangrijk						Heel belangrijk	Niet van toepassing
	1	2	3	4	5	6	7	
Gezond voor me								
Gemoedstoestand (geeft me een goed gevoel)								
Gemakkelijk (bereidingsgemak)								
Goede smaak								
Sensorisch aantrekkelijk (geur en uiterlijk)								
Natuurlijk								
Betaalbaar								
Gewichtscontrole (goed voor mijn lijn)								
Bekend voor me								
Rechtvaardig (eerlijke arbeidsomstandigheden)								
Diervriendelijk								
Voedselveiligheid								
Milieuvriendelijk								
Geeft mijn lichaam energie								
Gezelligheid								
Variatie (een gevarieerd dieet)								
Iets nieuws proberen								
Goed voor mijn spijsvertering								
Lekkere trek								

Bronnen

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Appendix I: *Survey*

Indien gegeten: Waar was je/u tijdens het eten van je/uw [**ontbijt/middagmaaltijd/avondmaaltijd/tussendoortje**]**?**

- ☐ **Thuis**
- ☐ **Op school**
- ☐ **Op mijn werk**
- ☐ **Onderweg**
- ☐ **Bij een horeca gelegenheid**
- ☐ **Bij anderen thuis**
- ☐ **Anders, namelijk …**

Appendix I: *Survey*

Indien gegeten: Met wie was je/u samen tijdens het eten van je/uw [**ontbijt/middagmaaltijd/avondmaaltijd/tussendoortje**]**?**

☐ **Ik was alleen**

☐ **Met mijn partner**

☐ **Met mijn gezin**

☐ **Met familie**

☐ **Met vrienden**

☐ **Met collega's**

☐ **Anders, namelijk ...**

Appendix I: *Survey*

Je hebt/ u heeft niks gegeten in de afgelopen 2 uur. Waar was je/u tijdens deze periode?

☐ **Thuis**

☐ **Op school**

☐ **Op mijn werk**

☐ **Onderweg**

☐ **Bij een horeca gelegenheid**

☐ **Bij anderen thuis**

☐ **Anders, namelijk ...**

Appendix I: *Survey*

Indien NIET gegeten:

Met wie was je/u tijdens deze periode?

- ☐ **Ik was alleen**
- ☐ **Met mijn partner**
- ☐ **Met mijn gezin**
- ☐ **Met familie**
- ☐ **Met vrienden**
- ☐ **Met college's**
- ☐ **Anders, namelijk ...**

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Steptoe, A., Pollard, T.M., and Wardle, J. (1995). Development of a measure of the motives underlying the selection of food: The Food Choice Questionnaire. *Appetite, 25*(3), 267-284. doi:10.1006/appe.1995.0061

Verain, M.C.D., Snoek, H.M., Onwezen, M.C., Reinders, M.J., and Bouwman, E.P. (2021). Sustainable food choice motives: The development and cross-country validation of the Sustainable Food Choice Questionnaire (SUS-FCQ). Food Quality and Preference, 93, 104267. doi:https://doi.org/10.1016/j.foodqual.2021.104267

Verain, M.C.D. and van den Puttelaar, J. (2018). *Design of a 2-hour recall method for food choice motives in specific contexts.* (internal report)

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This study was carried out by Stichting Wageningen Research and Wageningen University as part of the public-private partnership Smart Food Intake (project number 2282100201) and was commissioned and financed by the Dutch Topsectors Agri & Food, Unilever Foods Innovation Centre Wageningen, FrieslandCampina and Danone Nutricia Research.

This report can be downloaded for free at https://doi.org/10.18174/566401, or at www.wur.eu/economic-research (under Wageningen Economic Research publications).