Original Paper

Challenge to go: Systematic development of a theory-based and target group-adapted mobile app intervention to improve eating habits of adolescents and young adults

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Abstract

Background

Due to the widespread use of smartphones, dietary mobile apps are promising tools for preventing diet-related non-communicable diseases early in life. But, most of currently available nutrition apps lack scientific evaluation and user acceptance.

Objectives

The objective of the present study was the systematic design of a theory-driven and target group-adapted dietary mobile app concept to promote healthy eating habits with a focus on drinking habits as well as consumption of fruits and vegetables in adolescents and young adults, especially in deprived life situations.

Methods

The design process was guided by the behaviour change wheel (BCW). The development process consisted of three stages. In stage 1, the target behavior was specified, and facilitators and barriers were identified. Furthermore, important insights into target group interests, needs and values in the field of nutrition and apps were revealed. To this end, two empirical studies were conducted with the target group. In stage 2, results of stage 1 were translated into behavior change techniques (BCTs) and finally into app functionalities and features. Consequently, in stage 3, the concept was evaluated and optimized through expert interviews.

Results

Facilitators and barriers for achieving the target behavior were psychological capabilities (e.g. self-efficacy), reflective motivation (e.g. fitness), automatic motivation, social support, and physical opportunity (e.g. time). Target group interests, needs and values in the field of nutrition were translated into target group preferences for app usage, e.g. low usage effort, visual feedback or recipes. Education, training, incentives, persuasion, and enablement were identified as relevant interventions functions. Together with the target group preferences, these were translated via 14 BCTs, such as rewards, graded tasks or self-monitoring, into the app concept Challenge to go (C2go). The expert evaluation suggested changes of some app features for improving adherence, positive health effects and technical feasibility. The C2go concept consists of three worlds: (i) drinking, (ii) vegetable, and (iii) fruit world. In each world, the users are faced with challenges including feedbacks and a quiz. Tips were developed based on the health action process approach and help users to gain challenges and thereby achieve the target behavior. Challenges can be played alone or against someone in the community. Due to different activities, points can be collected, and levels can be achieved. Collected points open access to an infothek, where users can choose content that interest them. An avatar guides user through the app.

Conclusions
C2go targets adolescents and young adults and aims to improve their fruit and vegetable consumption as well as drinking habits. It is a theory-driven and target group-adapted dietary mobile intervention concept that uses gamification and was systematically developed using the BCW.

**Key words:** Adolescents; young adults; smartphone; mobile application; mHealth; health behavior; healthy eating; design; theory; motivation
Introduction

Background
Diet-related non-communicable diseases (NCDs) are globally the leading cause of death and disease burden [1,2]. Numerous studies emphasize the association between a suboptimal diet and deaths due to NCDs such as stroke, heart disease or type 2 diabetes [3–6]. Among dietary risk factors for NCDs are the low consumption of fruits and vegetables [7–9], and the high consumption of sugar-sweetened beverages [10–14].

German survey data highlight the high prevalence of overweight and obesity. Almost 60% of the population is overweight or obese (women 51%, men 66%) [15]. In the younger population, about 17% of girls (16%) and boys (18.5%) in the age between 14 and 17 years are overweight or obese [16], likely due to a more sedentary lifestyle characterized by decreased physical activity and unbalanced dietary behavior [15]. Only 7% of the girls and boys in Germany in the age between 14 and 17 years reach the dietary recommendations for the consumption of fruits and vegetables: On average, 0.9 portions of each vegetables and fruits per day are consumed [17]. Nearly 23% of boys and 17% of girls drink sugar-sweetened beverages daily [18]. Data from the US revealed similar results. Here, less than 50% of children and adolescents meet dietary recommendations for any food group [19]. The level of education has a positive influence on food consumption and thus the quality of the diet [20,21]. Higher school education and higher income result in lower body mass index (BMI) [15,16].

To sum up, nutrition surveys highlight that adolescents and young adults eat unbalanced diets [17,22,23], especially adolescents and young adults in deprived circumstances [17]. As adolescence is characterized by cutting ties with parents' household and the development of one's own lifestyle, this could be a reasonable stage of life for behavior change interventions [24], in particular for focussing on adolescents and young adults with lower education levels.

Digitalization and mHealth
State-of-the-art smartphones create new possibilities for dietary interventions. Mobile health (mHealth) is an emerging field and describes various health services offered on portable devices. These include health apps in various areas, such as nutrition, fitness, wellness, diagnostics or therapy [25], but systematic studies in the area of mHealth are scarce [26–28], and studies also highlight missing user acceptance of nutrition apps, for which the relatively high usage effort might be a reason [29,30]. Rohde et al. concluded that app usage in the long-term is influenced by user- and app-related
acceptance factors. The former highlights the importance of knowing the target group for designing accepted mHealth interventions; the latter emphasizes the importance of considering different app characteristics, e.g. implementing instructions or motivators for engagement and adherence in app-based interventions [29].

In the context of long-term adherence and acceptance of mHealth interventions, gamification is an emerging field. Gamification means that playful elements such as points, or leader boards are used in a context that is normally not played [31,32]. Gamification can be a motivational component of digital behavior change interventions by playfully making uninteresting topics interesting and thereby engage users in the long-term [32].

**Theory guidance for intervention development**

Effective interventions need theory guidance [33,34]. Firstly, because theories as frameworks help researches to derive factors that need to change. Secondly, theory-based interventions help to understand which and how techniques are effective. Thirdly, results can be used to optimize theoretical concepts. Furthermore, using theory in research is also helpful for the communication between researches and disciplines [33]. The present study uses the behaviour change wheel (BCW) as a framework for developing health interventions [35] and the health action process approach (HAPA) as a health behavior model. The BCW proposes a systematic design process of behavior change interventions that helps to translate theory into practice [28]. The HAPA as stage model is an interesting template for the theory-based development of dietary health messages that can be adapted to persons at different stages of the behavior change process [38] and was successfully applied in several nutrition behavior change interventions, e.g. [39–41].

**Objective**

How to develop a theory-driven app is, despite of the growing interest in mHealth research, not well described in the scientific literature [28]. Therefore, the aim of this study was to describe the iterative concept development of a theory-based and target-group adapted mobile app for motivating adolescents and young adults (14-25 years), especially in deprived life situations, to improve their dietary habits regarding the consumption of fruits and vegetables as well as their drinking behavior.

**Methods**

The app design process was guided by the BCW [36].
After defining the problem and three target behaviors, the app design process followed three stages (Figure 1): Phase 1: specifying the target behavior and identifying what needs to be changed to reach it. Phase 2: translating research results into app functionalities and features: Phase 3: evaluation of the concept by experts. Three empirical studies were conducted to derive relevant app features and content as well as to optimize the concept.

Figure 1. Systematic design process of the dietary mobile app for adolescents and young adults (black marked steps will be discussed in the following; grey marked steps are or will be carried out).

Phase I: Understanding behavior and target group preferences

Step 1: Specify target behavior

Having specified the target group, the problem behavior and the target behavior, the next step is focused on specifying the target behavior in detail and context: who, when, where, how often and with whom will the target group perform the target behavior?

Step 2: Identify what needs to be changed to reach target behavior

a) Behavioral diagnosis

The next step uses the COM-B (reasons of behavior: capability, opportunity, and motivation) model to identify what needs to be changed for adolescents and young adults to reach the target behavior.
Two empirical studies (described in the following section) helped to explore barriers and facilitators of target group’s capabilities, motivation and opportunity to reach the target behaviors. Next, every capability, motivation and opportunity were evaluated as feasible or not for implementing in dietary mobile app.

b) Target groups preferences (sampling from empirical studies 1 and 2)

Besides informing the behavioral diagnosis, study results were also analysed to explore the target group’s preferences for app characteristics, BCTs, features and content. The ethics committee of the Friedrich Schiller University noted no ethical concerns (processing number 4850-06/16).

- **Study 1: Nutrition and apps from the target group’s perspective**
The objective of this study, conducted in 2016, was to get insights into nutrition habits, values and needs, and to get ideas how nutritional behavior and health among adolescents and young adults could be improved through mobile apps. Study participants (n=11) tested the German dietary mobile app *Was ich esse* [37] for one week prior to face-to-face interviews. The participants were between 14-21 years (average age: 18 years, s = 2.4) and mostly women (n=8). A total of five participants went to secondary school at the time of the study. Others were university students (n=3), trainees (n=1), volunteers (n=1) or were looking for an apprenticeship (n=1). The audio-recorded material was transcribed and analysed by means of content analysis [38]. Data segments were coded into the following topics: (i) smartphone and app usage, (ii) test app experiences, (iii) nutritional habits, (iv) nutrition values, (v) nutritional improvement wishes and strategies, and (vi) understanding of health.

- **Study 2: Nutrition and smartphone apps: interests, needs and values among adolescents and young adults**
This study aimed for better understanding of available smartphone resources, app use and needs as well as interests and values in the field of nutrition of adolescents and young adults. To this end, a questionnaire was developed that included the following topics: mobile operating system, mobile phone rate, favourite apps, and experiences with dietary mobile apps, importance of different app characteristics (e.g. importance of customizability, sharing of videos/photos, no costs for app use), and nutritional interests (e.g. sports nutrition, health, food waste) and nutritional values (e.g. freshness of food, self-cooked meals, little time-consuming). Data were analysed descriptively. The inclusion criterion for participations was an age between 14-25 years. Teachers and social workers in the city of Jena were contacted via mail to win them as gatekeepers. 210 participants from five
different organizations took part (female n= 99, men n= 108, no information provided n=3). The average age was 18 years (n= 208, s= 2.4; no information provided n=2). The youngest and oldest person were 15 and 25 years old. Participants went to vocational school (Berufs(fach)schule) (n= 164). Others stated that they had participated in vocational preparation classes (n=27) or went to high school (Gymnasium) (n= 11). One person each went to secondary school (Hauptschule) and regular school (Regelschule); four persons stated other (no information provided n= 2).

Phase II: Translation of research results into app contents and features

Step 3: Identify relevant target group’s preferences

Data from studies 1 and 2 were analysed (see step 2 for method) separately, then merged together in target group preferences and an acceptance-rejection-process followed (Figure 2). Decisions for rejection or acceptance of target group preferences were made based on APEASE criteria: Is the respective preference affordable, practicable, effective, and acceptable, are side-effects expected or offense against equity? Accepted preferences were further implemented as app content, app features or considered as important app characteristics.

Step 4: Identify intervention functions

This step aimed to move from understanding the behavior and identifying relevant COM-B components for reaching the target behavior to selecting intervention functions. This was supported by a matrix of links between COM-B and intervention functions [36]. Appropriate intervention functions were selected by rating according to APEASE criteria.
Step 5: Identify behavior change techniques

To choose which BCTs can deliver the intervention functions a linking was used [36]. The list of candidates BCTs (n = 118) was narrowed by APEASE criteria, evidence of effectiveness for promoting healthy food choices, and on basis of target group preferences (results of study 1 and 2).

Step 6: Concept development and final intervention (prototypes I and II)

Prototype I: Together with the study results, the BCTs were translated into app features. Content development of feedbacks was guided by HAPA for pre-intender and intenders and gamification aspects were implemented to enhance user engagement with the app [28,32].

Prototype II: Upon step 7, the concept was adapted to expert opinions (for method, see step 7).

Phase III: Evaluation (step 7: expert evaluation)

The aim of this study was to evaluate and optimize the concept using three evaluation criteria: (i) acceptance among the target group, (ii) positive health effects due to app use, and (iii) technical feasibility. To this end, professionals with knowledge of the target group, app development and/or nutrition behavior were recruited. Recruitment took place via e-mails and later personally by telephone. In the end, eight face-to-face interviews were conducted with experts of the following different professions: marketing, two social workers/teachers, dietician, app development, media psychology, psychotherapist and a person of the target group itself. The interviews started with the presentation of the concept by mock up’s. The semi-structured interviews were audio recorded and transcribed verbatim. Data were evaluated with a structured qualitative content analysis [38]. The following five topics were discussed: (i) important features and needs of a dietary mobile app among the target group; (ii) advantages and (iii) disadvantages of the concept; (iv) suggestions to improve the concept; and (v) technical feasibility.

In the next step, the obtained recommendations in the above described topics for improving the concept were rated using APEASE criteria and either accepted and implemented or rejected and not implemented. Based on the results, the concept was adapted by defining the final features and functionalities of the app.

Results

Phase I: Understanding behavior and target group preferences
Step 1: Specified target behavior

Upon selection of the three target behavior, these were specified in detail and context according to .

Table 1. Specified target behavior

<table>
<thead>
<tr>
<th>Target behavior</th>
<th>Drinking behavior</th>
<th>Fruit consumption</th>
<th>Vegetable consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who needs to perform the behavior?</td>
<td>Adolescents and young adults (14-25 years old)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What do they need to do differently to achieve the desired change?</td>
<td>Drink &gt;1.5l, sugar-free</td>
<td>Eat 2 portions/day</td>
<td>Eat 3 portions/day</td>
</tr>
<tr>
<td>When do they need to do it?</td>
<td>At mealtime or in between</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where do they need to do it?</td>
<td>Everywhere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often do they need to do it?</td>
<td>Often enough to achieve recommendation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With whom do they need to do it?</td>
<td>Alone or in community with others</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) In line with German intake recommendations [39]

Step 2: Identified what needs to be changed to reach target behavior

a) Behavioral diagnosis

The results of the behavioral diagnosis revealed facilitators and barriers to the target behavior in the following COM-B components: psychological capabilities (e.g. nutrition education, self-efficacy, risk perception), reflective motivation (e.g. weight loss, satiety, fitness, illness prevention), automatic motivation, social support, and physical opportunity (e.g. time, financial resources). An overview of the results with quotes from study participants is displayed in Multimedia Appendix 1.

b) Target group preferences: empirical study results

To get insights into the target group's interests, needs and values in the field of nutrition, two empirical studies were conducted. Results are presented below. Step 3 reports how data was used to derive app features.

- Study 1

An excerpt of results in four of the six main topics of study 1 is presented in Table 2.
Table 2. Excerpt of results from study 1

<table>
<thead>
<tr>
<th>Main topic</th>
<th>Subtopics</th>
<th>Quotes (translated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smartphone and app usage</td>
<td>Smartphone is used for entertainment and in boredom times (e.g. games, videos)</td>
<td>Jana: <em>I use my smartphone when I'm bored or when I must wait for the bus or something, then I play games.</em></td>
</tr>
<tr>
<td>Nutritional values</td>
<td>Cooking stands for independency</td>
<td>Caro: <em>Yeah, for later, if maybe I have a family and I cannot cook, that would be a bit ... And cooking is also important to me, so I do not always depend on someone.</em></td>
</tr>
<tr>
<td></td>
<td>Spending on food should be kept low</td>
<td>Leon: <em>We like to eat exotic fruits. But you always must see how much money you have at your disposal.</em></td>
</tr>
<tr>
<td>Nutritional improvement wishes and strategies</td>
<td>Eating healthier</td>
<td>Jana: <em>I often wish that I eat healthier.</em></td>
</tr>
<tr>
<td>Test app experiences</td>
<td>High usage effort through tracking</td>
<td>Daria: <em>So, I did not continue using the app because it was very time-consuming tracking everything and exactly. At the beginning it was a lot of fun, but eventually it got harder, because sometimes you do not think about tracking.</em></td>
</tr>
<tr>
<td></td>
<td>Visual feedback is used as consumption orientation and promotes self-control</td>
<td>Tino: <em>Through the app I’ve noticed that I do not eat enough vegetables. That’s why I bought some cucumbers or tomatoes.</em></td>
</tr>
</tbody>
</table>

- **Study 2**

The mostly used operating system was Android (n=160) and most of the participants used a mobile flat rate (n=124; no data provided n=6). Among the favourite apps of the participants were communication and social media apps (WhatsApp: n=186, Facebook: n=124; Instagram: n=88), video apps (YouTube: n=57), and gaming apps (Clash of Clans: n=12, Clash Royal: n=8). 26% (n=54, no information provided n=2) of the participants had experiences with apps in the field of nutrition, above all recipe apps (n=19). The most interesting subjects in the field of nutrition were health (true: n=142; not true: n=10; partly true: n=57; no data provided: n=1), cooking (true: n=133; not true: n=15; partly true: n=60; no data provided: n=2) and sports nutrition (true: n=87; not true: n=58; partly true: n=63; no data provided: n=2). Good taste (true: n=199; not true: n=0; partly true: 10; no information provided: n=1), satiety (true: n=163; not true: n=2; partly true: n=42; no data provided: n=3), freshness of food (true: n=124; not true: n=9; partly true: n=75; no data provided: n=2) were the most important nutritional values. The most important app characteristics were free of charge (true: n=175; not true: n=5; partly true: n=26; no information provided: n=4), contact to
friends/family (true: n= 159; not true: n= 5; partly true: n= 41; no information provided: n= 5), and fast use (true: n=157; not true: n=1; partly true: n=49; no information provided: n= 3).

**Phase II: Translation of research results into app contents and features**

**Step 3: Identified relevant target group preferences**

The results of the process of the identification and selection of relevant target group preferences for app characteristics and features is presented in Table 3. Results of study 1 and 2 to interesting nutritional aspects were compared and matched, too. Results of study 2 that were rated mostly "not important" were not considered as possible content. Finally, six topics were derived as acceptable, interesting content ideas: (i) health, (ii) recipes, (iii) sports nutrition, (iv) food waste, (v) food information, and (vi) beauty.

**Table 3. Excerpt of identified and selected target group preferences for app characteristics and features**

<table>
<thead>
<tr>
<th>Study 1 Topic: Smartphone and app usage</th>
<th>Study 2 results</th>
<th>Target group preferences for app characteristics and features</th>
<th>Accept or reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sup-topic: Smartphone is used for entertainment and in boredom times (e.g. games)</td>
<td>Important app characteristics: entertainment</td>
<td>Entertainment through features for use in boredom times</td>
<td>Accept</td>
</tr>
<tr>
<td>Listening to music</td>
<td>-</td>
<td>Music</td>
<td>Reject</td>
</tr>
</tbody>
</table>

**Nutritional improvement wishes and strategies:**

| Eating healthier | Nutritional interest: health (68% true; 27% partly true; 5% not true) | Goal: healthy eating | Accept |
| Less sweets | nutritional interest: health | Goal: less sweets | Reject |

**Test app experiences:**

| High usage effort through tracking (as result not everything was tracked) | Important app characteristics: fast use | Low usage effort | Accept |
| Excitement about app use falls rapidly | important app characteristics: entertainment | Ongoing entertainment | Accept |

| Test-app use for comparison visual feedback with others | Favourite apps are mostly communications apps | Social comparison | Accept |
| Visual feedback is used as consumption orientation and promotes self-control | Visual feedback (for orientation/self-control) | | Accept |
More feedback through different evaluation charts

Reason for acceptance/rejection:
(a) maintain suspense & adherence,
(b) not relevant for target behavior/ not in line with target behavior,
(c) not affordable as incentive,
(d) in line with target behaviour;
(e) true; n= 157; partly true; n= 49; not true n= 1; no data provided; n= 3;
(f) true: n = 112; partly true: n= 79; not true: n = 13; no data provided: n= 6

Step 4: Identified intervention functions

Candidate intervention functions were education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement. The rating of the candidate intervention functions for both fruits and vegetables and drinking behavior led to the selection of education, persuasion, incentivisation, training, and enablement.

Step 5: Identified BCT

According to the APEASE criteria, 14 BCTs were derived to bring about behavior change (Table 4). The selection was supported by results of study 1 and 2 as well as by evidence of effectiveness.

Table 4. Intervention functions with COM-B components and BCT’s

<table>
<thead>
<tr>
<th>Intervention functions</th>
<th>BCT’s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education</strong></td>
<td></td>
</tr>
<tr>
<td>COM-B: psychological capability; reflective motivation</td>
<td>Information about health consequences [40–42]; feedback on behavior(^{(b)}) [40,43–45]; prompts/cues(^{(b)}) [46]; self-monitoring of behavior(^{(a)}) [47–49]</td>
</tr>
<tr>
<td><strong>Persuasion</strong></td>
<td></td>
</tr>
<tr>
<td>COM-B: automatic motivation; reflective motivation</td>
<td>Information about health consequences [40–42]; feedback on behavior(^{(b)}) [40,43–45]; verbal persuasion about capability [32]; social comparison(^{(e)}) [44,50,51]</td>
</tr>
<tr>
<td><strong>Incentivisation</strong></td>
<td></td>
</tr>
<tr>
<td>COM-B: automatic motivation; reflective motivation</td>
<td>Feedback on behavior(^{(b)}) [40,43–45]; self-monitoring of behavior(^{(a)}) [47–49]; non-specific incentive/reward (includes positive reinforcement)(^{(f)}) [44,52,53]</td>
</tr>
<tr>
<td><strong>Training</strong></td>
<td></td>
</tr>
<tr>
<td>COM-B: psychological capability; automatic motivation</td>
<td>Instruction on how to perform a behavior(^{(b)}); feedback on behavior(^{(b)}) [40,43–45]; self-monitoring of behavior(^{(a)}) [47–49]; graded tasks [54]</td>
</tr>
<tr>
<td><strong>Enablement</strong></td>
<td></td>
</tr>
<tr>
<td>COM-B: psychological capability; automatic motivation</td>
<td>Action planning(^{(g)}) [47]; coping planning(^{(g)}) [47]; goal setting (behavior)(^{(c)}) [55]; discrepancy between current behavior and goal(^{(d)}) [49]; self-monitoring of behavior(^{(b)}) [47–49]; graded tasks [54]; social support (unspecified) [51]</td>
</tr>
</tbody>
</table>

Matches with target group preferences: \(^{(a)}\) tracking for awareness; \(^{(b)}\) tips; \(^{(c)}\) goal setting; \(^{(d)}\) reminder; \(^{(e)}\) social comparison; \(^{(f)}\) gamification/ \(^{(g)}\) based on the HAPA [34]
Step 7a: Developed preliminary concept (prototype I)

The translation of BCTs and target group preferences into app content and features resulted in the development of the Challenge to go (C2go) app concept. Table 5 presents an excerpt of how target group preferences and BCTs were matched and jointly translated into app features. A full version of this translation procedure can be found in Multimedia Appendix 2. The final concept is described in step 7b.

Table 5. Excerpt of derivation of app features by matching target group preferences with BCT’s

<table>
<thead>
<tr>
<th>Target group preferences</th>
<th>BCT</th>
<th>Derived app feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entertainment (gamification); use time selectable</td>
<td>Information about health consequences, instruction on how to perform a behavior</td>
<td>Quiz</td>
</tr>
<tr>
<td>Social comparison; gamification</td>
<td>Social comparison</td>
<td>Community</td>
</tr>
<tr>
<td>Goal setting</td>
<td>Goal setting</td>
<td>Goal setting</td>
</tr>
<tr>
<td>Little usage effort</td>
<td>-</td>
<td>Different worlds where one food only must be tracked</td>
</tr>
</tbody>
</table>

Phase III: Evaluation (step 6: expert evaluation)

Data from expert evaluation and rating results suggested changes for the following app features: worlds, challenges, feedback, infothek, and quiz. Furthermore, the issue of usage motivation was discussed. An excerpt of the evaluation results is presented in the Table 6.

Table 6. Excerpt of results of expert evaluation

<table>
<thead>
<tr>
<th>App feature/characteristic</th>
<th>Prototype I</th>
<th>Prototype II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenges</td>
<td>Strict defined rules to reach goals</td>
<td>Easing the rules: more jokers for the users of the drinking world in the Big Master level</td>
</tr>
<tr>
<td>Feedback on the behavior</td>
<td>Visual, motivational, evaluative and informative feedback included</td>
<td>More integration of visual feedback e.g. a smiling avatar for rewarding consumption of water</td>
</tr>
<tr>
<td>Usage motivation</td>
<td>Focus on pre-intenders and intenders for feedback development</td>
<td>Informative feedback focusses on Intenders only, pre-intenders are not considered anymore. This decision was supported by literature as health apps are more likely used by health-conscious persons [30]</td>
</tr>
</tbody>
</table>

Developed concept (prototype II): final intervention (step 7b)
The steps described above led to the development of the final intervention C2go concept (Figure 3). After onboarding, among three worlds can be chosen: **drinking**, the **vegetable** or the **fruit world**. In each world users can accept **challenges** and participate in a **quiz**. To get access to the challenges users must go through self-tests. Consequently, in a challenge, the user must set a behavioral goal that he or she tries to achieve, e.g. in the fruit world, one portion of fruit per day for one week. Challenges can be played alone or against someone in a community. Different **feedbacks** are given to motivate and to empower the user to achieve his or her challenge goals, e.g. the informative feedback gives tips how challenge goals can be reached. Each tip is stored and always accessible for the user. For further support, **reminders** can be set. Through different activities users earn **points** and achieve **levels**. The points open access to the **infothek**, where users can choose content that interest them. The received infothek content is stored and always accessible. A leader board compares user scores in the **community**. Through passing challenges users ascend in levels up to ‘Big Master’. After completing a world, the next world can be selected. If the user has reached the highest level in every world he or she becomes a ‘Guru’. Through the whole app users are guided by an **avatar**.

The following sections describe the app features more in detail. Further information regarding interventions functions, BCT’s and COM-B components are given in the Multimedia Appendix 2.
Onboarding

The onboarding, hence the way a user is introduced into the app content, is important to motivate the user for adherence [31]. Therefore, the app starts with an introductory question (see Textbox 1).

Textbox 1. Introductory question

Where can “Challenge 2 go” support YOU the most?

- Live healthier
- Feeling good in my body
- More fitness and performance

The introductory question has been selected to make users curious and motivate them to use the app through connecting his or her personal aim with app usage and selecting a question that can only be answered correctly, so the user cannot lose and does not get demotivated [31]. Depending on the answer, a progress bar representing the guru status is implemented, and either titled “health guru”, “well-being guru”, or “performance guru”. A user reaches the “guru” level after succeeding in all three worlds.
Consequently, a tutorial gives a brief overview of the app and guidance [29,31]. Afterwards, profile setting shall enhance customization of the app [31] and is associated with the selection of the avatar in terms of age and sex. The avatar shall promote positive learning effects [32] and serves as identification tool for promoting adherence for app usage [32].

**Self-test**
Each world starts with a self-test, which is two-folded. The first part is a 24-hour dietary recall (e.g. vegetables in the vegetable world). Results of this recall are used to divide users into HAPA stages, either intender, if dietary guidelines [39] are not met, or actor, if guidelines are met. As the C2go app targets German adolescents and young adults, German dietary guidelines have been used [39]. The second part is a quiz for introducing into the world concept regarding challenge rules and basics of nutrition education. The answer of each question is formulated depending on the revealed HAPA stage of the user [34] and/or personal app aim as follows (see Textbox 2 for an example). After completing both parts of the self-tests, the user gets access to the challenges.

**Textbox 2. Example of a quiz question of the second part of the self-test.** Example for a user whose personal aim is to "live healthier".

```
How much should we drink at least a day?
  o 0.5 l
  o 1.5 l
  o 1 l
  o 3 l

Dissolution: Drinking (at least) 1.5 l per day of sugar-free drinks is good for you and helps you to get closer to your goal: to live healthier.
```

**Challenges**
The challenges are implemented for the user to reach self-imposed consumption goals, e.g. three servings of vegetables per day in the vegetable world and can be played alone or against others in the community to promote motivation for behavior change through social comparison and competition [50,56]. In the drinking world, a sugar mountain builds up additionally, while tracking sugar-sweetened beverages, which users must reduce through answering quiz questions before attacking the next challenge. In addition, in the fruit and vegetable world not only quantity but quality counts. Users are motivated to eat as many colours as possible. In every world it is the aim to get better in behavioral terms from challenge to challenge up to the highest level (see Table 7), which meets the
target behavior. To pass the challenges, users get support through visual, evaluative, informative and motivating feedback and tips. Furthermore, reminders can be set.

### Table 7. Levels in the drinking world

<table>
<thead>
<tr>
<th>Phase</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>After selecting first world</td>
<td>Beginner</td>
</tr>
<tr>
<td>After completing self-test B</td>
<td>Climber</td>
</tr>
<tr>
<td>After the first challenge (24-hour-Challenge)</td>
<td>Adept</td>
</tr>
<tr>
<td>3 portion challenge</td>
<td>Adept pro</td>
</tr>
<tr>
<td>4 portion challenge</td>
<td>Expert</td>
</tr>
<tr>
<td>5 portion challenge</td>
<td>Expert pro</td>
</tr>
<tr>
<td>6 portion challenge</td>
<td>Master</td>
</tr>
<tr>
<td>6 portion challenge + no sugary drinks</td>
<td>Big Master</td>
</tr>
</tbody>
</table>

### Feedback

Different feedbacks are implemented in the C2go app: visual, informative, motivational, evaluative, and competitive. An avatar, which is intended as social support [34], gives some visual and all informative, motivational and evaluative feedbacks. The avatar rewards user’s desirable behavior with a facial expression (smiling face). Other visual feedback is given through progress bars for different features (self-test, challenges, quiz, and overall progress in app that is the “guru status”) and a graph for an actual vs. target feedback for the target behavior.

Informative feedback contains messages relevant for intenders (based on HAPA [47]) by encouraging action coping (overcoming barriers, including reflexive questions) and action planning (when, how, where implementing behavior, including instructions on how to perform a behavior) to close the gap between intention and actual behavior [34,57]. Motivational feedback is given through encouraging messages that should sustain intention and self-efficacy [32,43].

Similarly, self-efficacy will be boosted by evaluative feedback [32,57]. When creating feedbacks, care was taken that these were formulated in a positive way [29,43] and in a colloquial language [57]. For examples, see Table 8. Furthermore, competitive feedback is given through a leader board in the community [32].

### Table 8. Feedback examples

<table>
<thead>
<tr>
<th>Feedback type</th>
<th>Time point</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivational</td>
<td>During challenges</td>
<td>Great first 7 days!</td>
</tr>
</tbody>
</table>
Evaluative
After a challenge
Try again: the next level beckons you already!

Informative
After a challenge
Drink a portion of un-sweetened beverage with each meal, e.g. (mineral) water or herbal/fruit tea (warm or cold)

Reminder
Reminders are push-notifications and can be set to support users on the way to the drinking goal. Furthermore, they function as a reengagement tool [46].

Quiz
In terms of content, the quiz aims to provide knowledge about the health-related value of each target behavior and the national intake recommendations. To this end, each world has its own quiz, e.g. the fruit world contains questions regarding fruit intake recommendations and associated health benefits and risks (see Textbox 3 for an example). All questions must be answered correctly to complete the respective world. Wrongly answered questions will be repeated later.

Textbox 3. Example of quiz question

<table>
<thead>
<tr>
<th>How long can humans survive without liquid intake?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: 2-4 days</td>
</tr>
<tr>
<td>B: 1 week</td>
</tr>
<tr>
<td>C: 1 day</td>
</tr>
<tr>
<td>D: 50 days</td>
</tr>
</tbody>
</table>

Dissolution: We (humans) can live without solid food for more than a month, but without drinking we die after 2-4 days!

Infothek
The infothek is an information desk where users get access to interesting information regarding six nutrition-related topics, which were derived from above described study results: health, food information, beauty, sports and food, food waste, and recipes. Users get access at certain scores to get motivated to app usage and reward it. Regardless of the score, once a week access to the infothek is given to reengage the user. Information is predominantly in written form (short messages). Also, short videos and podcasts are intended.

Gamification approach
The C2go app implements severely playful elements, such as points, levels, leader board, challenges, onboarding, feedback, progress bars and customization, to engage users.
Discussion

Overview

Smartphone-based interventions are increasingly used to promote a healthy lifestyle [28,58–61]. In this study, a smartphone app was considered as a very acceptable tool for the delivery of a nutrition intervention for adolescents and young adults, as smartphone usage is widespread across all education and income levels [62]. Furthermore, adolescents and young adults are in a period of life, where their own lifestyles, including “eating styles”, are developed and established. The above described empirical study results confirm the general openness for and interest of adolescents and young adults in a dietary mobile app. Next, other digital health interventions were rated as helpful and satisfactory by adolescents and young adults [53,63,64] and other age groups [65,66]. Further studies have demonstrated that smartphone apps are widely accepted by users for intervention delivery in the field of healthy eating [28,58,67]. However, to our knowledge, no dietary mobile app has been designed to meet the particular needs and interests of adolescents and young adults in Germany. Our study provides a step-by-step description how evidence (e.g. from empirical studies with the target group) and theory can be translated systematically into an app concept in the field of mHealth for contributing to the prevention of NCDs.

Systematic design process

Along the BCW and based on the input of the target group as well as literature analyses, the app concept for the C2go app was designed. The BCW has been used by other researchers to guide the development of mHealth interventions [28,68]. Using a framework helps designing interventions systematically and avoiding intervention development based on personal experiences, favourite theories or superficial analyses [36]. Often, the use of underlying theories and concepts in intervention trials is not well described. Theories are only mentioned as framework but descriptions of how they were integrated into the scientific design process are often lacking [69]. In the present study, the use of the BCW as framework permitted the systematic and comprehensive design process, which was underpinned by a model of behavior change and a behavioral diagnosis of the target behavior, before starting the design process. However, it is necessary to expand the BCW regarding the derivation of empirical study results and its translation into BCT’s and finally into mHealth app features [28]. This could minimize the influence of individual expertises, creativity, and reasonable decision of scientists on decisions which features should actually be implemented in the app [28].

A major strength of this study was the examination of the behavior, interests, needs and values of the target group, because digital interventions are most engaging, when they are matched to the target
group's characteristics, needs, expectations and skills [70]. Next, other studies revealed that involving the target group throughout all phases of intervention development is important to make it more relevant to their life [28,59,64]. Our study therefore aimed at focusing on adults in deprived life situations. Therefore, attempts were made to recruit study participants especially in (public) places with lower educational background, e.g. vocational school.

Three target behaviors were chosen in the beginning, because concentrating on many and/or unspecified target behaviors (e.g. whole nutritional intake) is assumed to be less effective than considering only a few and specified target behaviors, but then intensely [71]. The selection of the target behaviors were indirectly confirmed by the target group, as beverages, fruit and vegetables were voted as easy to track food. A further strength of choosing the three target behaviors is that they focus on promoting individual behaviors, e.g. more fruits, instead of forbidding food (e.g. ‘eat only 1 sweet per day’).

Altogether, study results along with literature research were used to support the behavioral diagnosis, the identification of intervention functions, and BCT’s. The behavioral diagnosis revealed that certain capabilities (e.g. psychological capability: awareness of consumption), opportunities and motivational aspects are needed to establish healthy eating habits. Furthermore, study results together with evidence from the scientific literature were used to identify five intervention functions and 14 BCTs. The latter were translated into features of the C2go app.

**Final intervention: the C2go app**

The C2go app concept targets improved drinking habits as well as increased fruit and vegetable consumption among adolescents and young adults. To this end, users choose among three worlds: the drinking, the vegetable or the fruit world. A core feature of the C2go app concept are challenges. They consist of goal-setting and self-monitoring for target behavior. Both techniques were desired by participants and are supported by evidence from the literature [34,48,54,72,73]. Focusing on BCTs for effective behavior change interventions is important. Nevertheless, considering determinants of engagement is also significant [70]. Therefore, the C2go app concept implements various game elements and process motivators, which reward the process of behavior change. Examples are points, levels for status gain, rankings or engagement loops through challenges aiming at edutainment and loyalty [31,32]. Gamification approaches can provide motivation in settings where information only is not sufficient to bring about change [32]. Various other mHealth interventions used gamification for promoting user engagement successfully [28,59,76]. Concentrating on process motivators instead of
long-term, logical outcome motivators (e.g. prevention of NCDs) is proposed to influence self-efficacy for behavior change positively and more effectively [74].

The individual choice of worlds and, *inter alia*, the setting of individual goals support customization [31] to satisfy different needs and motivation for app use (engagement). Reminders were implemented as well to increase user engagement [46]. Furthermore, the implementation of an avatar will improve user engagement and acceptance [75].

Different feedbacks were implemented to motivate app usage [50] and behavior change. Implemented informative feedbacks target intenders. This shall boost self-efficacy and thereby help to overcome barriers and to achieve target behavior [34,41]. Visual feedback through progress bars were used to replace possible missing intrinsic motivation for behavior change [32]. Evaluative feedback like congratulations if challenges are passed or encouraging feedbacks if challenges are missed were implemented to increase self-efficacy [76]. Motivating messages shall increase self-efficacy in encouraging that skills for succeeding are available [32]. Evaluative, informative and motivating feedback is given through an avatar that was implemented for identification and positive learning effects [32]. When formulating those feedbacks, it was important to select a positive language, for increasing self-efficacy and satisfaction of the user [43]. Through the leader board the community supplies a competitive feedback [32,76].

**Limitations and future research**

Several limitations must be considered when interpreting the findings of the present approach. Firstly, the design, development and implementation of mHealth concepts take time. Consequently, by the time of implementation, technology and target group interests may have evolved until then [28]. Secondly, regarding the target behaviors, the app focused on drinking, fruit and vegetable consumption only. Nevertheless, other food groups and nutrition behaviors (e.g. snacking) could be targeted later in the app, along with physical activity. This provides opportunities for future research and extension of the app. Thirdly, the participants who informed the app development were only from one region in Germany. Furthermore, they may have had a bigger interest in nutrition and/or apps as non-participants. Future investigation should include a more diverse collective.

The next step is the validation of the C2go app concept to proof its impact on drinking, fruits and vegetable consumption as well as its usability in a controlled intervention trial. Moreover, financial opportunities for sustainable maintenance possibilities of scientific applications must be investigated.
Conclusions

C2go is a theory-based and target group-adapted mobile intervention that was systematically developed using the BCW. C2go aims to improve drinking habits and the consumption of vegetables and fruits among adolescents and young adults especially in deprived life situations, using a gamification approach.
Multimedia Appendix

Multimedia Appendix 1. Behavioral diagnosis to derive what needs to be changed to achieve the target behavior and estimation of feasibility in a dietary mobile app

Multimedia Appendix 2. Bringing together behaviour change techniques and target group preferences for derivation of app features

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Authors contribution

AR designed studies 1, 2 and 3, developed the intervention, managed data collection and analysis of study 1 and 2, and wrote the manuscript.

AD co-developed study 3, managed data collection and analysis of study 3, wrote the respective part of the manuscript, and provided feedback on the manuscript.

CB, SL, JG and CD contributed guidance and consultation throughout the studies and discussed study designs and results. They provided feedback on the manuscript.

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare no conflict of interest.
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**Abbreviations**

APEASE: affordable, practicable, effective, acceptable, side-effects, equity

BCTs: behavior change techniques

BCW: behaviour change wheel

BMI: Body Mass Index

C2go: Challenge to go

COM-B: model: capability-opportunity-motivation-behaviour model

HAPA: Health Action Process Approach

mHealth: mobile health

NCDs: diet-related non-communicable diseases