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# GOAL-SETTING CHARACTERISTICS OF NUTRITION-RELATED MHEALTH SYSTEMS: A MORPHOLOGICAL ANALYSIS

*Research Paper*

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## Abstract

*Setting and pursuing goals plays a major role in health behavior change. As an elementary component of interventions and mHealth apps, goals can support people in pursuing and attaining a desired outcome or behavior. Despite its widespread use and indicated effects on behavioral performance, there is no guidance on how to design and implement goal setting, planning and evaluation for mHealth nutrition promotion. We investigate goal setting and related components in the context of mHealth and health behavior change in a structured literature review. By utilizing morphological analysis, we develop a design framework for goal setting and pursuit. We validate and refine the framework by application on popular commercial nutrition apps. As a result, we identify the coverage of goal-setting and -pursuit characteristics as well as current gaps in the implementation of commercial mHealth nutrition apps, which offer the potential for future effective development of goal setting in mHealth nutrition promotion.*

*Keywords: goal setting, goal pursuit, mHealth, nutrition, morphological analysis, framework.*

## 1 Introduction

Due to an increased intake of energy-dense foods and decreased physical activity, the number of people being overweight or obese is constantly rising (World Health Organization, 2020). Alone in the US, the prevalence of obesity in adults increased from 30.5% to 42.4% in the years from 1999/2000 to 2017/2018 (Centers for Disease Control and Prevention, 2021). Similar trends have also been observed in European countries such as Germany, where 54% of adults were overweight or obese in 2014/2015 (Schienkiewitz et al., 2017). As a raised BMI is seen as a major risk factor for the so-called non-communicable diseases such as cardiovascular diseases, diabetes and even cancer (Guillou and Matheron, 2014), actions have to be taken. Since traditional nutritional consultations are expensive, digital solutions promise to be a favorable approach to reach many people. With smartphones becoming more and more ubiquitous, many mobile applications (apps) aiming at promoting a healthier lifestyle have been developed. Nevertheless, current mobile health (mHealth) apps frequently face high dropout rates (Thompson and Subar, 2017). Nutrition is often connected to emotional (e.g. stress eating) and social (e.g. family gatherings) context factors that have a huge influence on the final food choices. For this reason, behavioral changes in the area of nutrition must not only struggle against habits that have often been imprinted for many years but are also exposed to further potential hurdles. Thus, ways to support the behavior change approach of these apps have to be found. One of the most

frequent and relevant techniques to improve behavior change in nutrition interventions and mHealth apps is goal setting (Ammerman et al., 2002, Bardus et al., 2016, Villinger et al., 2019). However, research in relation to goal setting for nutrition is scarce and most papers solely focus on single use cases and apps. Structured or standardized knowledge on goal-setting components remains abstract or missing. Although work on reevaluating goals in the field of physical activity (PA) has been made, pure nutritional interventions or combined PA and nutritional interventions or apps have been investigated rarely (Baretta et al., 2019, Swann et al., 2021). The question remains how this knowledge can be extracted and transferred to mHealth nutrition promotion. The goal of following a healthy nutrition poses an even more complex undertaking as it integrates knowledge or the ability to judge food content, portion sizes, distribution and impact of nutrients on bodily outcomes and cannot be automatically measured with wearables such as smartwatches, unlike PA. Thus, it is our aim to gather structured knowledge in terms of a design framework for goal-setting and pursuit components that allows for the identification of useful strategies for mHealth nutrition promotion. To achieve this research goal, we proceeded as follows: (1) we conducted a structured literature review on how goal setting has been applied in studies that focus on health promotion and health behavior change in the context of mHealth, (2) identified gaps among goal-setting implementations from scientific literature and commercial apps targeting nutrition promotion, (3) highlight knowledge for future mHealth designs including goal-setting and complementary components for behavior change in nutrition. Thus, we contribute towards mHealth design for nutrition anchored in a theoretical goal-setting perspective by offering a structured overview on existing approaches and a development basis for both researchers as well as practitioners.

## 2 Background

Goal setting has been studied widely regarding personal development, task performance as well as motivation and self-regulation. The goal-setting theory (Locke and Latham, 1994, Latham and Locke, 1979) refers to goals as “immediate regulators of behavior”. Initially, it was developed as a framework to predict and evaluate the performance of individuals in the workplace, which mainly builds on four mediators that positively influence task performance such as goal choice, effort, persistence, and goal pursuit. Additionally, individual abilities (knowledge and skills) and commitment moderate goal setting and attainment. Feedback plays an essential role in goal-setting theory to inform or guide individuals on increasing or maintaining effort, or changing the initial goal strategy. Further, individual goal attainment is dependent on required resources that refer to the situational factors and context of the individual. Finally, task complexity moderates the performance to reach a goal. In later work, Latham and Locke (1991) updated their former theory focus and highlighted goal setting not only as a motivational technique related to task performance but also as a self-management technique to pursue certain goal behaviors. According to this theory, goal *specificity*, *difficulty* and the *time context* are required when setting a goal. Thus, the goal specification needs to be clear and simple rather than vague or too complex. The goal difficulty influences goal effort and performance and, thus, should be adapted to individual knowledge and skills. More recent theoretical literature on goal setting for behavior change suggests a distinguished view of goal setting and goal striving as purely setting a goal displays no guaranty for successful goal striving and achievement (Gollwitzer and Oettingen, 2012).

Goal setting belongs to one of the most used and effective behavior change techniques (BCTs) in health promotion, including interventions targeting healthy nutrition behaviors (Bardus et al., 2016, Villinger et al., 2019), diabetes care (Miller and Bauman, 2014) and physical activity or sedentary behaviors (Baretta et al., 2019, Schoeppe et al., 2017). Goal setting is an elementary part of the behavior change taxonomy (Abraham and Michie, 2008, Michie et al., 2011), which distinguishes two types of goal setting either targeting a specific outcome or behavior. These and other related techniques are summarized under the category of *goals and planning*. The use of BCTs such as goal setting and self-monitoring has been shown to be effective for nutrition and physical activity promotion (Samdal et al., 2017). Previous research mainly investigated app quality in terms of

evidence and effectiveness from the presence or absence of BCTs (Antezana et al., 2020, Direito et al., 2014). However, prior studies did not examine detailed information regarding the implementation of goal setting and pursuit in nutrition. Studies in this area explored goal setting for solely physical activity or diabetes apps (Baretta et al., 2019, Miller and Bauman, 2014). There remains a need to systematically categorize different implementation specifics for BCTs to make studies comparable and guide mHealth developers in their design decisions. In the remainder of the presented research, we therefore investigate the development towards a framework for goal-setting and pursuit implementations that focus on nutrition-related goals.

### 3 Methodology

#### 3.1 Structured Literature Review

In order to review how goal setting has been applied in previous studies focusing on mHealth promotion for behavior change, we conducted a structured literature review based on the framework by Webster and Watson (2002). The databases used for the structured literature review were *PubMed*, *EbscoHost* and *Scopus*. Our keyword search contained the following query parameters: “mhealth” AND “goal setting” AND “behavior change”. We refrained from using “nutrition” as a search term since the literature on this focus area is still scarce and would have limited our search results by excluding successful samples from related domains. To maintain quality and research focus, we included only peer-reviewed journals and conference papers. Our initial set of results contained 244 documents. We further limited the search results to open access. After the removal of duplicates, we screened titles and abstracts and later the selected full text with a focus on valuable information contributing to the improvement of the goal-setting process. Articles not relating to goal setting were discarded, as well as articles about failed trials. Together with one additional article from an external source this resulted in 47 records. We then searched backward and forward which resulted in 4 additional articles. Our final selection resulted in a literature set of 26 articles (Figure 1).

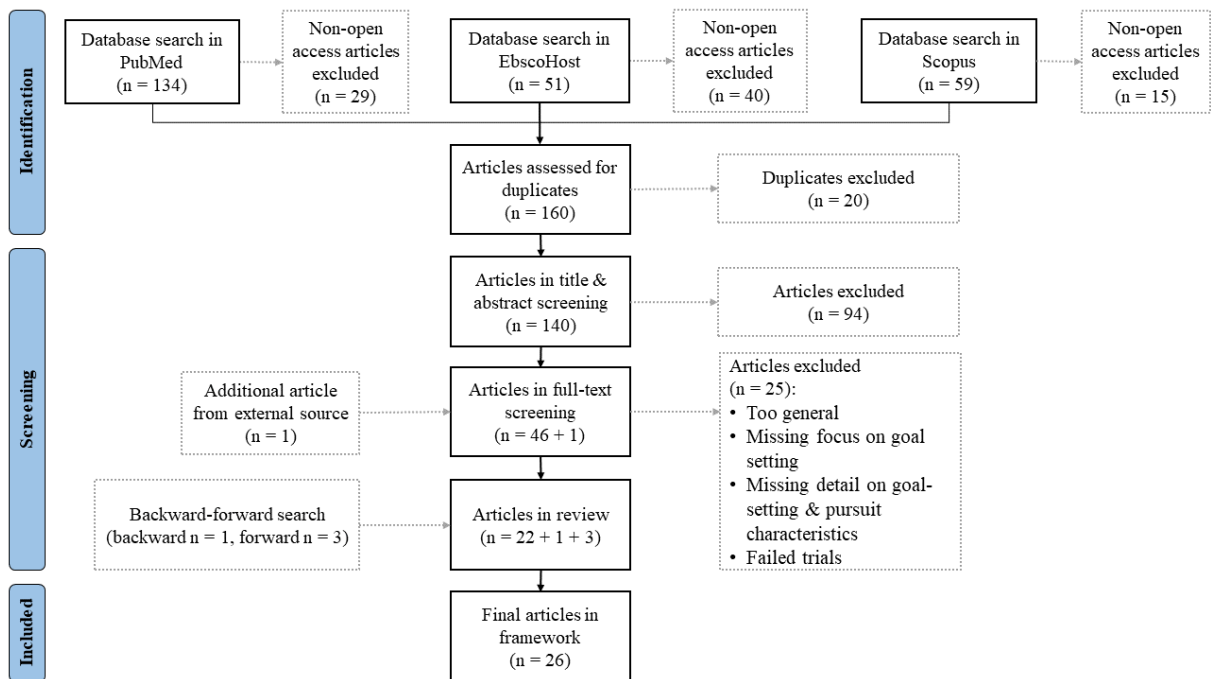


Figure 1. Prisma Diagram of the Database Search and Article Selection

We structured the final selection of articles regarding the prominence of goal setting in the research and the type of conducted research. Five papers directly investigated goal setting. Six papers were qualitative studies, which contained information about user feedback concerning relevant goal setting and BCT elements. Seven articles described the development and implementation of mHealth projects, which incorporated important goal-setting elements. The remaining eight papers were randomized controlled trials evaluating previously developed mHealth projects and contained relevant information about goal setting and BCTs. We also categorized which target behavior the articles relate to. Eight articles focused exclusively on physical activity, while five others related to both physical activity and nutrition. Five articles focused exclusively on nutrition, while three considered weight management. Four papers had a broader view on health behavior change in general, and one paper investigated drug use and alcoholism. We further gathered information on study populations. Out of 26 papers, 24 articles described studies. 11 studies specifically focused on obese or inactive adults, while five were conducted with adults in general. Four studies investigated people with health conditions, while two focused on adolescents, one on young adults, and two on old adults. The sample sizes varied considerably, with one case study only having three participants, and one study standing out with a high sample size of 1,000 participants. The results of the literature review form the basis for the morphological analysis described in the next section, which aims to identify the structure of goal setting and its related components.

### 3.2 Morphological Analysis

To structure the problem space towards mHealth design characteristics for behavior change through goal setting and goal pursuit, we apply the method of a morphological analysis as known from modeling complex systems with a multidimensional and non-quantifiable nature (Ritchey, 2011). We captured the elements of our morphological analysis within two morphological boxes (Zwicky, 1948) for the dimensions *goal setting* and *goal pursuit* according to Gollwitzer and Oettingen (2012). We further organized the dimensions into a more granular layer with the meta-characteristics of *Goal Specificity & Goal Difficulty* and *Action Planning & Goal Evaluation*, which are rooted in goal-setting theory (Locke and Latham, 1994, Latham and Locke, 1979) and were further highlighted and utilized in the work from Baretta et al. (2019) as important factors contributing to goal setting and pursuit. Then, we iteratively identified entities from selected literature that we organized into predefined or summarizing categories in terms of characteristics along the dimensions that build possible configurations and constraints. We selected effective solutions (entities) from literature and marked them within the boxes. Finally, we evaluated them against existing commercial solutions (features) (see 3.3). The final iteration resulted in a structured framework building on four different layers: dimensions (*goal setting & goal pursuit*), meta-characteristics (*goal specificity & difficulty, action planning & goal evaluation*), characteristics and entities. The applied structure offers a possible solution space in terms of an overview on design elements for *goal setting* and *goal pursuit* to assess existing solutions or to implement future designs (see Table 2, Table 3). To assure usability, quality and to avoid bias in the development of the morphological boxes, we obtained the opinion of three experts with a background on public health, mHealth promotion and nutrition education and medicine. For this purpose, we sent them a version of the morphological boxes (including the commercial app analysis, see 3.3) with a short description of how they were determined. After viewing the initial version, we further provided a description of each entity. Afterwards, we conducted 30-minutes semi-structured interviews with each expert, where we asked them to report basic issues regarding the overall readability, comprehensibility, reasonable scope and objectivity. This yielded in the boxes presented in section 4.1 and 4.2.

### 3.3 Comparative Validation by Commercial Apps

After reviewing how goal setting has been applied in the research area, we compared the extracted data to commercially available apps. As identified literature focused not solely on nutrition apps or interventions, but also PA or combinations of PA and nutrition, we tried to apply and validate the

boxes' entities (Table 2, Table 3) with content from commercial apps targeting nutrition promotion. To offer a reliable sample of apps with regard to coverage, target use, rating and download, we defined the following inclusion criteria: (1) The app had to be available in the German versions of the Apple App Store *and* the Google Play Store, (2) The primary goal of the app had to be an improvement of the nutritional behavior of the user, (3) The app had to be able to track a user's nutrition behavior, (4) The app had to be available for free (in-app purchases for premium versions etc. were allowed). In order to achieve the best possible coverage in terms of distribution and good user experience, we followed a multi-step selection process. First, we filtered the top chart list from the stores' category "Health & Fitness" as well as results from a search with the keywords "Nutrition", "Diet" and "Diary" with respect to the inclusion criteria. Afterwards, we ordered the filtered apps two times: Then, we selected the top 15 of the best-rated apps (for this purpose, we calculated the average of the ratings of the App Store as well as the Play Store) and then the top 15 of the most downloaded apps. Following this, we created the intersection of the two lists. This resulted in a set of 10 apps for final analysis, as shown in Table 1.

App Name	Developer	Rating (iOS)	Rating (Android)	Downloads (Android)
Kalorienzähler von FatSecret	Fat Secret	4.7	4.7	10.000.000
Fitatu Kalorienzähler und Diät	Fitatu Sp. z o.o.	4.7	4.7	1.000.000
YAZIO Kalorienzähler & Fasten	YAZIO	4.7	4.6	10.000.000
Kalorien, Fett & Eiweißzähler	Virtuagym.com	4.8	4.5	1.000.000
Lose It! - Kalorienzähler	FitNow	4.6	4.6	10.000.000
Cronometer · Nutrition Tracker	Cronometer Software Inc	4.7	4.5	1.000.000
FDDB Extender - Kalorienzähler	Malte Voigt-Schier	4.7	4.4	1.000.000
Kalorienzähler - EasyFit	Mario Herzberg	4.5	4.6	5.000.000
MyFitnessPal	Under Armour, Inc.	4.6	4.4	50.000.000
Lifesum: Diät Planer & Tracker	Lifesum AB	4.5	4.4	10.000.000

Table 1. Selection of Commercial Nutrition Apps

Two independent researchers downloaded and installed the selected apps on an appropriate device (Android or iOS) and tested the different app functionalities with a focus on the framework dimensions *goal setting* and *pursuit* for at least seven days. Before coding the apps' functionality, the researchers made themselves familiar with the structure and content of the framework using the definitions of the meta-characteristics and descriptions from literature (see 4.1, 4.2). They tested the apps independently and coded the presence or absence of each entity for each app. We assessed Cohen's Kappa cut-off values based on McHugh (2012) for the codings of each entity to assure inter-rater reliability between the two coders. Our calculated Kappa values mostly ranged from moderate (.60-.79) to almost perfect (>.90) (see Table 2, Table 3). Remaining inconsistencies were resolved in later discussions to reach consensus. Following, we only listed app names in the framework for which both coders identified the respective entity. We color-coded each entity of the two morphological boxes in one of four shades representing the agreed amount-ranges of apps that included the respective entity: 0-25%, 26-50%, 51-75% and 76-100%.

## 4 Results

In this section, we present our aggregated results in a structured framework resulting from the literature review combined with a morphological analysis and a feature content analysis of commercial nutrition apps. The framework consists of two morphological boxes – *goal setting* and *goal pursuit* – offering a distinguishing view on elements to focus on when designing for mHealth nutrition promotion. Cells marked with an asterisk (\*) display the recommended practice derived from the

scientific literature. Superscripts <sup>(x)</sup> highlight entities that we added after validating the framework emerging from literature by a content analysis of popular commercial apps from iOS and Android app stores. We did not mark cells if we did not have any information on their usability nor effectiveness. The right column contains the referencing literature. Further, we display the frameworks' entities with a color saturation to indicate the implementation percentage across the evaluated apps as a result from the app feature content analysis. Additionally, inside the entities we include a list of the app names in brackets for which we identified the respective entity.

## 4.1 Goal Setting

**Goal Specificity:** Goals should have an accurate definition that allows for precise measurements of behavioral objectives (Baretta et al., 2019). In our iterative analysis of the reviewed literature, we identified additional characteristics that relate to goal specificity:

*Framing:* The *framing* or objective of a goal can be either to increase or decrease a certain intake of a food item or food group. Mummah et al. (2016a) recommend framing a *positive* goal perspective such as *increasing healthy foods* rather than *decreasing or avoiding unhealthy foods*. The authors recommend having a *holistic* focus on whole foods rather than a *reductionist* goal such as decreasing calories.

*Formulation:* Mann et al. (2015) suggest providing goals formulated in a *clear* and *simple* way to support the understanding by users. The use of additional *explanatory* information on the goal helps to avoid confusion or misunderstanding (Mann et al., 2015).

*Precision:* Goals should be *specific* and *measurable* rather than too general to be effective (Baretta et al., 2019, Mann et al., 2015).

*Guidance:* The relevance of autonomous goal setting and self-efficacy is pointed out by Boulton et al. (2019), who promoted users to examine their ambitions and aspired results while adjusting their goals. The importance of self-determination for goal setting is further highlighted by Zieve et al. (2017) who demonstrate that most users place a high value on *self-directed* goal setting. An alternative way to provide automated or semi-automated goal setting compared to fully *self-determined* goals is algorithms that generate and supply users with goals. Foley et al. (2016) implemented an algorithm that generates tailored behavior goals from a goal library. Adams et al. (2013) apply a similar version of this algorithm in the randomized controlled trial. However, choosing *pre-defined* goals from a goal library addresses less self-efficacy. Individuals often face problems when setting goals without any guidance or support all by themselves (Brandt et al., 2018, Sporrel et al., 2021). Former authors recommend *guided* goal setting with an expert for more sustainable results. The users in the study by van der Weegen et al. (2013) also favor guided goal setting with an expert who helps them to more accurately estimate realistic goal outcomes. Sporrel et al. (2021), on the other hand, suggest the consideration of combining self-set with assigned goals.

**Goal Difficulty:** Goals need to be balanced between their challenging nature and their achievability. For this reason, it is crucial to adjust goals to the capabilities of the user (Baretta et al., 2019).

*Adaptation:* A goal's difficulty should be flexible to meet the users' capabilities, which is underlined by the study results of a randomized control trial by Adams et al. (2017) indicating that *adaptive* goals are more effective than static goals. This is further supported by Hurley et al. (2015), who recommend that goals should be continually and individually adjusted to user performance. The difficulty of a goal should adapt based on the ongoing performance of a user. Adaptive goals offer a possibility to react to individual variability in user performance, which can occur due to individual life circumstances and changes. We distinguish different types of goal adaptation: *automated*, *counseled*, and *individually feedback-based*. *Automated adaptation* using AI by a percentile rank algorithm by Adams et al. (2017) helps adapt the goals' difficulty and outperforms static goals. Utilizing the fundamental dietary behavior in the first weeks allows for an automated adaptation towards a personal, difficult, yet achievable goal (van der Weegen et al., 2013). *Counseling sessions with a human expert coach* helped

study participants to ensure realistic goals for their caloric objectives (Stein et al. 2019). Users prefer to set a goal based on recent feedback (Zieve et al., 2017) and have the opportunity to modify the difficulty of their goal themselves (Mann et al., 2015, van der Weegen et al., 2013).

		Characteristics	Entities (Cohen's Kappa κ), (App)		Source	
Goal Setting	Goal Specificity	Framing	Positive holistic* (κ=1), (Yazio, Lifesum)		Reductionist κ=1), (all)	(Mummah et al., 2016a)
		Formulation	Clear* (κ=1), (all)	Simple* (κ=1), (all)	Explanatory* (κ=.60), (Yazio, Kalorien, Fett & Eiweißzähler, Lifesum)	(Mann et al., 2015)
		Precision	Specific* (κ=1), (all)		Measurable* (κ=1), (all)	(Baretta et al., 2019, Mann et al., 2015)
		Guidance	Self-determined* (κ=1), (none)	Guided* (Agreed upon) (κ=1), (none)	Selective (Pre-defined) (κ=1), (all)	(Adams et al., 2013, Boulton et al., 2019, Brandt et al., 2018, Foley et al., 2016, van der Weegen et al., 2013, Zieve et al., 2017, Sporrel et al., 2021)
	Goal Difficulty	Adaptation	Automated* (κ=1), (none)	Counseled* (κ=1), (none)	Individual* (κ=1), (all)	(Adams et al., 2017, Hurley et al., 2015, Mann et al., 2015, Stein et al., 2019, van der Weegen et al., 2013, Zieve et al., 2017)
		Ranking	Multiple Goals with Different Priorities* (κ=1), (MyFitnessPal)		Multiple Goals without Priorities x (κ=1), (Fatsecret, Fitatu, Yazio, Kalorien, Fett & Eiweißzähler, Lose it!, Cronometer, Fddb, EasyFit, Lifesum)	(Stein et al., 2019)
Temporality		Short-term* (κ=1), (all)	Long-term* (κ=1), (all except MyFitnessPal)	Configurable x (κ=.62), (Fitatu, Kalorien, Fett & Eiweißzähler, Lose It!, Lifesum)	(Baretta et al., 2019, Mummah et al., 2016b, van der Weegen et al., 2013, Waterlander et al., 2014, Van Lippevelde et al., 2016)	
Color Legend for Number of Apps: <span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; background-color: white; margin-right: 5px;"></span> 0 - 25% <span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; background-color: #e0e0e0; margin-right: 5px;"></span> 26 - 50% <span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; background-color: #a0c0ff; margin-right: 5px;"></span> 51 - 75% <span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; background-color: #0070c0; margin-right: 5px;"></span> 76 - 100%						

Table 2. Dimension Goal Setting (structured along Meta-Characteristics, Characteristics and Entities)

**Ranking:** The difficulty of a goal relates to the number of intended related goals or sub-goals. Based on research by Stein et al. (2019), *multiple goals* should preferably be ranked by prioritizing them according to 1) the highest need for change, 2) the participant's high self-efficacy and readiness to change, 3) the number of barriers and 4) appropriateness (e.g. fulfilling the intended impact on energy-balance).

**Temporality:** Goal difficulty is associated with a goal's *temporality*, which is either short-term or long-term. In their formative study on weight management, Waterlander et al. (2014) found that easily achievable *short-term* goals should be favored over *long-term* goals, which might be too difficult and disappointing. Based on their review of PA interventions, Baretta et al. (2019) suggest a combination of both short-term and long-term goals, where short-term goals help the continuous monitoring and



reflection of the goal process to finally achieve the overarching long(er)-term goal. The study from van der Weegen et al. (2013) favors daily goals over weekly goals as those tend to delay immediate actions into the future. To decrease goal difficulty, the app-based intervention to change snacking behavior from Van Lippevelde et al. (2016) reminded participants to set only one weekly goal. Mummah et al. (2016b) successfully demonstrated a combination of daily goals and one weekly goal in the “Vegethon” app-based trial study.

## 4.2 Goal Pursuit

**Action Planning:** An action plan involves the formulation of precise steps that are required to achieve a goal (Baretta et al., 2019). In the following, we present additional sub-characteristics to describe action planning more granularly.

*Plan creation:* We identified two methods of *plan creation* for a previously set goal: *automated* follow-up information with practical next steps and *guided manual* action planning with a coach. Participants of the study by Zieve et al. (2017) preferred the former, whereas Boulton et al. (2019) used guided manual creation in *conjunction with a coach* and digital resources such as an app-based daily routine chart and activity planner in the PreventIT project. The study by Estabrooks et al. (2005) provides another example. There, users created their personal action plan based on a pre-formatted plan, which users could tailor by feedback based on assessment questions regarding their physical activity, fat intake and fruit and vegetable consumption in conjunction with minimal coaching.

*Plan Structure:* Baretta et al. (2019) provided a structure for an action plan and refer to the required content of an action plan by defining *timing (when to act)*, *target (where to act)* and *achievement steps (how to act)*. This structure can help users to achieve their goals more quickly.

*Coping Plan:* Identifying and addressing contextual barriers in a *coping plan* helps to pursue or maintain a goal (Boulton et al., 2019). Barriers emerging from the social environment or individual stress can hinder maintaining and achieving a goal. Family gatherings are one social barrier towards a healthy diet, as mentioned by Meeker et al. (2019), since they tend to be centered on unhealthy food. Another social barrier is the absence of support from peers, who might lack empathy to appreciate the relevance of dietary changes (Brandt et al., 2018). In the context of stress barriers, Mummah et al. (2016a) identified the difficulty of integrating a healthy meal schedule within busy work schedules. Busy work schedules often constitute a stress barrier and can hinder goal pursuit or maintenance (Mummah et al., 2016a, Brusoski and Rosen, 2015). As a response to this problem, Mummah et al. (2016a) suggest the introduction of *healthy meal planning routines*.

**Goal Evaluation:** Goal evaluation encompasses a continual tracking of the goal performance, which allows pointing out goal achievements and failures. This provides the basis for goal readjustments (Baretta et al., 2019).

*Self-Monitoring Content:* Goal evaluation *content* should constantly contain monitoring and evaluation of current *goal achievements* and progress in terms of *past performance* to allow for adjustments in goal effort and strategies, to match goal requirements or redefine a goal based on success or failure (Foley et al., 2016, Stein et al., 2019, Chevance et al., 2021). In cases of frequent exceeding of goals, *behavior goals* should be reviewed in an ongoing way to keep the user’s motivation by little recurring events of successes (Baretta et al., 2019).

*Self-Monitoring Progress:* Self-monitoring feedback supports users with monitoring their behavior and lets them evaluate their past and current performance towards a goal behavior or goal outcome. Self-Monitoring feedback in the “Vegethon” app by Mummah et al. (2016b) was identified to contain *short-term* and *long-term progress* of nutrition behavior. While short-term progress captured the performance gaps of the daily consumption compared to the current day’s goal, long-term progress covered the consumption of the past seven days and weeks. These terms of progress were further identified in the work on physical activity by van der Weegen et al. (2013).

		Characteristics		Entities (Cohen's Kappa $\kappa$ ), (App)		Source	
Action Planning	Plan Creation	Automated* ( $\kappa=.52$ ), (Fatsecret, Fitatu, Yazio, Lose it!, MyFitnessPal, Lifesum)		Manually Guided* (with Expert, i.e. Coach) ( $\kappa=1$ ), (none)		(Boulton et al., 2019, Zieve et al., 2017, Estabrooks et al., 2005)	
	Plan Structure	Time Context* ( $\kappa=.55$ ), (Fatsecret, Fitatu, Yazio, Lose It!, MyFitnessPal, Lifesum)	Target* ( $\kappa=.80$ ), (Fatsecret, Fitatu, Yazio, Cronometer, Lifesum)	Achievement Steps* ( $\kappa=.55$ ), (Fatsecret, Fitatu, Yazio, Lose It!, MyFitnessPal, Lifesum)		(Baretta et al., 2019)	
	Coping Plan	Social Support* (e.g. from Peers, Friends or Family) ( $\kappa=1$ ), (Fatsecret, Lose It!, MyFitnessPal)		Healthy Meal Planning Routines* ( $\kappa=1$ ), (Fatsecret, Fitatu, Yazio, MyFitnessPal, Lifesum)		(Boulton et al., 2019, Brusoski and Rosen, 2015, Mummah et al., 2016a, Brandt et al., 2018, Meeker et al., 2019)	
Goal Pursuit	Goal Evaluation	Self-Monitoring Content	Goal Achievements* ( $\kappa=1$ ), (all)	Past Performance* ( $\kappa=1$ ), (all)	Behavior Goals* ( $\kappa=1$ ), (Yazio, Lifesum)	(Baretta et al., 2019, Foley et al., 2016, Stein et al., 2019, Chevance et al., 2021)	
		Self-Monitoring Progress	Short-term ( $\kappa=1$ ), (all)		Long-term ( $\kappa=1$ ), (all)	(Mummah et al., 2016b, van der Weegen et al., 2013)	
		Self-Monitoring Representation	Visualized Number Statistics ( $\kappa=1$ ), (all)		Abstract Representations ( $\kappa=.80$ ), (Fitatu, Yazio, Lose It!, FDDDB, Lifesum)		(Appleton et al., 2019, Mummah et al., 2016b)
		Focus	Qualitative ( $\kappa=1$ ), (Lifesum)		Quantitative ( $\kappa=1$ ), (all)		(Mummah et al., 2016b, Tay et al., 2017, Van Lippevelde et al., 2016, Mummah et al., 2016a)
	Granularity	Estimated ( $\kappa=1$ ), (Fatsecret, Lifesum)		Measured ( $\kappa=1$ ), (all)		(Appleton et al., 2019, Mummah et al., 2016b, Tay et al., 2017)	
	Supervision	Supervised* ( $\kappa=1$ ), (MyFitnessPal, Lifesum)		Unsupervised ( $\kappa=1$ ), (all)		(van der Weegen et al., 2013, Pirolli et al., 2021)	
	Interpretation	Non-Hedonic Editing* ( $\kappa=1$ ), (all)		Readability* ( $\kappa=1$ ), (all except Easyfit)		(Imschloss and Lorenz, 2018, Perski et al., 2017)	
	Timing	Daily* ( $\kappa=1$ ), (all)	Weekly* ( $\kappa=.80$ ), (all except EasyFit)	Monthly* ( $\kappa=.80$ ), (Fitatu, Yazio, Lose It!, Cronometer, Lifesum)		(Adams et al., 2013, Appleton et al., 2019, Maher et al., 2020, Mummah et al., 2016b, Stein et al., 2019, van der Weegen et al., 2013, Van Lippevelde et al., 2016, Adams et al., 2017, Foley et al., 2016)	
Color Legend for Number of Apps: <input type="checkbox"/> 0 - 25% <input type="checkbox"/> 26 - 50% <input type="checkbox"/> 51 - 75% <input type="checkbox"/> 76 - 100%							

Table 3. Dimension Goal Pursuit (structured along Meta-Characteristics, Characteristics and Entities)

*Self-Monitoring Representation:* The “Vegethon” app from Mummah et al. (2016b) presented both types of self-monitoring content by *visualized number statistics* in graph displays. Appleton et al. (2019) implemented an alternative number representation in a ring bar, which progressively fills up until the daily goal is achieved.

*Focus:* The *focus* of goal evaluation can be either *qualitative* or *quantitative*. An option for *quantitative* nutrition tracking, besides calorie tracking, offers the “Calci-app” that focuses on increasing the calcium content of foods (Tay et al., 2017). Examples for a *qualitative* focus are provided by the “Snack Track School app” where adolescents track and evaluate their nutrition by obtaining high or low credit points for healthy or unhealthy snacks to offer extrinsic motivation (Van Lippevelde et al., 2016). Further, Mummah et al. utilize a qualitative focus on tracking and evaluation by emphasizing eating a variety of whole fruits and vegetables instead of caloric or nutrient deficits (Mummah et al., 2016a, Mummah et al., 2016b).

*Granularity* of goal evaluation was found to be either exactly *measured* or *estimated*. Examples of exact measures are cups or bowls, gram or ml (Tay et al., 2017) as well as spoon (Appleton et al., 2019). Vegetable portions were estimated by fist size in the study from Mummah et al. (2016b) to ease estimation and tracking effort.

*Supervision:* van der Weegen et al. (2013) showed that users perceive a health coach who *supervises* self-monitoring as encouraging and motivating. Pirolli et al. (2021) suggest the incorporation of a virtual chatbot that collaborates with the user/ team in terms of tips, previews and comments on daily activities.

*Interpretation:* The evaluation of goal progress or achievement (e.g. from self-monitoring displays) relies on its interpretation by the user. In this context, Imschloss and Lorenz (2018) investigated *Hedonic Editing*, which refers to how users view their gains and losses. Hedonic editing appears when users have an opportunity to view their results in a more positive perspective than they actually are. Hedonic editing is associated with a decrease in health motivation, especially among users with low health encouragement (Imschloss and Lorenz, 2018). Thus, the authors suggest an effective way to avoid hedonic editing by using a displaying mechanism of results that adjusts spatial distances in response to whether an outcome is a mixed loss or a mixed gain. In cases of a mixed gain, meaning a mainly positive outcome in addition to a small negative one, they recommend maximizing the spatial distance between those two. Otherwise, users tend to incorporate the small negative within the larger positive outcome to avoid feelings of discomfort. A spatially close representation of both outcomes could lead to users substituting the small negative outcome with the larger positive outcome. If there is a mixed loss, meaning a mainly negative outcome in addition to a small positive outcome, the authors suggest that it is best to minimize spatial distancing between those two outcomes, as users tend to sort out the small positive from the larger negative outcome. In this case, a spatially distant representation could lead the user to split and highlight the small positive outcome as greater than it actually is. Furthermore, evaluating a goal relies on the readability of presented goal evaluation content. For reasons of *readability* and understanding, evaluation content such as self-monitoring displays should be simple and efficient rather than too complex (Perski et al., 2017).

*Timing:* We distinguish three different time points for goal (re-)evaluation: *daily*, *weekly*, and *monthly*. The fruit and vegetable app from Appleton et al. (2019) reveals that users value the app for enabling a daily review in the evening. The evening goal review is also encouraged by the “Vegethon” trial by sending reminders to enter all consumed vegetables at 9 pm (Mummah et al., 2016b). The studies by Adams et al. showed that users text their next PA step goal either in the evening or morning in response to a notification (Adams et al., 2013, Adams et al., 2017). Daily goal reviews are also supported by user interviews from the study by van der Weegen et al. (2013), in which users proclaim that they feel different every day, highlighting the importance of daily goal (re-)evaluation. The Snack Track project applies weekly intervals to evaluate the goal-setting process (Van Lippevelde et al., 2016). Weekly goal reviews are combined with monthly reviews in a notable amount of successful studies (Adams et al., 2013, Foley et al., 2016, Mummah et al., 2016b, Stein et al., 2019).

### 4.3 Commercial App Analysis

When comparing the characteristics found in the literature to the results of our app analysis, differences in their manifestation were found. Thus, we extended the literature-based boxes by three entities to allow better representation of the goal-setting aspect in mHealth nutrition applications: 1. The *ranking* characteristic (Table 2) was extended with “*multiple goals without priorities*”, as many apps did not support a priority setting despite supporting multiple goals. 2. The *temporality* characteristic (Table 2) was extended with “*configurable*” as users could enter an individual temporality. The characteristic *self-monitoring representation* (Table 3) was extended with “*abstract representations*” as some apps used different generalized visualizations (colors and symbols) in relation to goal achievement. After the extension, all apps were reviewed again concerning the new characteristics. During both app evaluation cycles, free and premium features were taken into account.

**Goal Specificity:** The studied apps mostly built on a calorie-counter-based system with a *reductionist* goal framing. The feedback to users consisted mainly of information on whether or not the calorie budget (or the budget for other nutrients, if the app allowed for additional targeting) had already been exceeded. Only two apps (Yazio, Lifesum) included a desirable *positive holistic framing* approach. Due to the calorie-budget-based approach, goal *formulation* was clear and simple among all apps. Regarding *explanatory information*, detailed explanations on why a certain goal should (not) be considered realistic was seldom present, mostly only little descriptions were given (e.g. “You should contact your doctor before reaching for this goal”). Due to the aforementioned calorie-based systems, goal *precision* was perceived as specific for all apps. The *guidance* during the goal-setting process was mainly limited to *pre-defined* goals or markers indicating which goal was considered recommendable.

**Goal Difficulty:** All apps provided the option to set multiple goals, but *ranking* was only possible in one app (MyFitnessPal). Although the calorie budget was always shown prominently, clear prioritization was not communicated to or customizable by the user. Regarding *adaptation*, apps respected more general settings (e.g. five different activity levels ranging from low to high), or did not include any options regarding personal behavior. In terms of *temporality*, all apps included short-term goals (i.e. daily and/or weekly goals). Only MyFitnessPal did not support monthly goals as they focus on week-based weight-loss goals. The *configurability* of goal temporality varied from directly customizable (Fitatu, Lifesum), to only indirectly adjustable by means of third values such as weight loss rate, to fixed time periods (e.g. Cronometer).

**Action Planning:** Regarding *plan creation*, many apps provided daily budgets for energy intake as automatically created steps to achieve the overall goal of weight change or maintenance. Nevertheless, most did not provide further action suggestions in an automated way. The *plan structure* was mostly existent, but not clearly pronounced. Apps provided rudimentary targets mostly in the form of calorie and nutrient goals but differed in if and how clearly they defined a timeframe and achievement steps. A notable example (FatSecret) provided detailed 7-day meal plans, whereas other apps (EasyFit, Fddb), for instance, defined neither time context nor steps. *Coping plans* were integrated to some degree. Several apps provided social support through community features, like groups where users can interact with like-minded users. A user’s real life social circle, however, was not considered specifically. Several apps (e.g. Fatsecret, Fitatu, Yazio, MyFitnessPal, Lifesum) included healthy meal planning routines.

**Goal Evaluation:** Regarding the *self-monitoring content* of the goal evaluation aspects of the investigated apps, all supported the ability to evaluate goal achievement, mainly by numeric performance displays related to certain targets (e.g. “calorie target was exceeded by 127 kcal”). All apps were able to display past performance in weekly and/or monthly views. Only one app (Lifesum) supported the ability to evaluate behavioral goals. *Self-monitoring representations* included a number-based evaluation in all apps, while some apps also used more abstract representations such as glasses to measure fluid intake, arrows or color representations (e.g. coding using traffic light colors). *Self-monitoring progress* based on the values from *self-monitoring content* was supported by all apps for short-term periods, but not fully for long-term periods for which views with reduced details were often

used (e.g. only a calorie value for the weekly or monthly views, no information about other parallel goals regarding macro or micro nutrients). Regarding the *granularity*, only two apps (Fatsecret, Lifesum) based values on estimated data (such as portion sizes instead of solely precise weight information), and all apps offered a detailed, measured review. Only two apps (MyFitnessPal, Lifesum) *supervised* the evaluation process and include features such as direct feedback after entering values. Other apps offered information about reaching or overstepping nutrient budgets only after active checking by the user. Looking at the characteristics of *interpretation*, none of the apps followed a more positive approach of displaying a user's performance, but simply used entered data to represent the current status of goal achievement. Regarding *readability*, most apps had clear and easy to understand visualizations of a user's performance. Only one app (EasyFit) included visualizations which were perceived as confusing. Most problems were based on inconsistent or misleading color coding. EasyFit always used a green color coding even if a quantity budget (e.g. for saturated fatty acids, with the set goal "lose weight") was exceeded. Regarding *timing*, all apps supported daily reviews, although these varied in detail. Only one app (EasyFit) did not support a weekly review, although some apps only supported it for users with a paid subscription. Only five apps supported the ability of reviewing the goal achievement over a monthly period.

## 5 Discussion and Conclusion

As our main objective, we offer a structured and more detailed overview on relevant characteristics for goal setting and pursuit by approaching a design framework. We applied this framework in a content analysis on existing popular mHealth nutrition apps from commercial app stores to identify the presence of goal-setting characteristics and potential for health behavior change in nutrition. Despite the potential of goal setting for behavior change, existing research is limited to a very abstract perspective on this topic. Current research mostly investigates the presence or absence of goal setting as a term used in interventions. In the area of mHealth promotion, it is yet limited to investigations on physical activity or diabetes care. Thus, we made efforts to reveal goal-setting and pursuit characteristics relevant to health behavior change via mHealth nutrition promotion.

Based on our results, we offer several recommendations for future app design or assessment. A key finding regarding *goal difficulty* is that the majority of evaluated apps rather offer a reductionist *goal framing*, i.e. reducing quantitative calorie outcomes, than a positive holistic goal framing. However, allowing for the formulation of more positive goals while reducing threatening effects affects goal motivation and commitment, which again moderates performance towards a goal (Coote and MacLeod, 2012, Latham and Locke, 2007, Locke and Latham, 2006). A careful consideration of the formulation of a goal towards clarity and its framing is recommended. In cases of missing guidance, *explanatory information* can help to improve the clarity of a goal formulation. Regarding goal difficulty, we identified a potential lack of *counseling* in adapting goals to personal abilities, which in cases of missing abilities or knowledge could lead to demotivation in achievement when setting too difficult or unrealistic goals. We recommend offering an *action plan* with a time-bound target and concrete steps to follow as it shows to be an effective strategy for users who lack the abilities, knowledge or motivation of pursuing a goal. Furthermore, we identify the remaining potential in determining contextual barriers emerging from stress or the social environment. As stress has been shown to have an impact on the eating behavior of most people (Björntorp, 2001) and social context has also been linked to a person's eating behavior (Robinson et al., 2013), such factors might influence the achievement of the set goal(s). Thus, barrier identification in terms of *coping strategies* could serve motivation and self-efficacy. Specifically, in cases of frequent lack of *goal achievements* or failures related to the social or working environment, apps should consider the integration of social support from peers, friends or family and support the development of daily routines. Apps mainly covered goal evaluation by self-monitoring feedback including visual screens on goal achievements and past performance. We highlight the evaluation of *behavioral goals* instead of pure performance-focused goal outcomes (Swann et al., 2021) to reflect and optimize individual goal strategies, specifically in cases of frequent goal mismatches. Feedback on behavioral goals, (re-)evaluation of

current action plans by identification of potential barriers might offer additional knowledge for users on what went wrong or could be improved. This functionality could be offered as part of a digital *coach*, who *guides* or even *supervises* the user in the steps to be taken, how to cope with barriers or how to adjust a previously set goal. Regarding the *focus* of goal evaluation, we suggest consideration of a *qualitative focus* (i.e. healthy snacks, variety of fruits and vegetables) as this can positively influence extrinsic motivation. A consideration of qualitative alternatives to quantitative tracking methods (the favored approach in selected commercial apps) could help reduce efforts of granular tracking, which displays a motivational barrier for many users. Scientific approaches offered alternative strategies such as estimating portion sizes (Mummah et al., 2016b, Mummah et al., 2016a), which could eliminate demotivating tracking efforts and help to shift from counting single calories and nutrients.

Our research offers a practical contribution towards a design framework, which allows for consideration of specific characteristics that support setting and pursuing goals for healthier nutrition. By highlighting the discrepancy between research and current commercial apps, the presented framework also shows prescriptive qualities. It might offer practical help for designers of mobile nutrition apps, who are interested in designing effective goal-setting components to promote healthy nutrition. Researchers might use this framework as an overview of the core elements of existing approaches in health behavior change using goal setting in their interventions. This work also represents an important basis for quantitative empirical meta-analyses, as it enables a comparison of the goal-setting implementation of different intervention studies. It can serve scholars to characterize, implement or report goal setting used in mHealth interventions. Furthermore, the framework offers a base for investigating the potential and effectiveness of specific combinations of goal-setting characteristics concerning related BCTs such as feedback, rewards and social support.

We are aware of the potential limitations of our approach. By restricting the article selection to open-access, we might have lost articles that are relevant to our eligibility criteria. The assessment of app content might be limited due to analyzing visual screens and functionality rather than textually mapping scientific descriptions of BCTs in interventions. Although the apps were installed and remained running for a minimum of seven days, we may have missed features related to goal setting or planning. Furthermore, the number of evaluated apps is limited in number and characteristics as we primarily selected highly downloaded, rated and reviewed apps. The number of databases for our literature review might potentially limit our findings and may be extended in the future. Finally, this work is limited to findings from literature but can be extended by additional evaluations with users to determine effective solutions.

Suggestions for future work are to expand the existing work by including incentive or motivational mechanisms related to goal pursuit as well as team goals. Additionally, effective nutrition-based interventions and specific target or age groups, which could be displayed as different instances of the boxes could be included. As goal setting and planning displays an effective BCT, the extension of our provided framework could be conceivable to related and complementary techniques, which provide potential in moderating goal motivation, commitment, performance and pursuit. Additional evaluations with mHealth app designers could support the development of a practice guide.

Goal setting belongs to one of the most frequent and effective BCTs, but detailed and structured knowledge for transferring to the design and implementation of apps or interventions is limited due to an abstract or simplified perspective. Our work offers a structured overview of the literature on health behavior change utilizing mHealth for goal setting, planning and monitoring as a promising and effective technique for guiding human nutrition behaviors. Structuring mHealth design through a theoretical lens of goal setting and pursuit by a total of 18 characteristics (7 for goal setting and 11 for goal pursuit) and a comparison with commercial apps reveals the unused potential of current implementations of nutrition-related apps regarding goal setting and achievement.

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