

Behavior Change Techniques in Digital Interventions for Health Behavior Change: A Taxonomy of Popular Mobile Applications

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Abstract

Health behavior change interventions can support individuals in establishing habits beneficial to their health. Hence, they can help to prevent diseases and reduce mortality caused by unhealthy behaviors. The delivery of such interventions through mobile phones is promising. We developed a taxonomy of popular mobile applications for health behavior change, identifying the intervention's aim and applied behavior change techniques. We classified 63 popular mobile applications according to our taxonomy. Thereby identifying the most prevalent behavior change techniques and combinations of the application's aim and applied behavior change techniques. This result can be used to inform the design of future applications.

Keywords: Mobile Behavior Change Interventions, Health Behavior Change, Persuasive Systems, Taxonomy

1. Introduction

Although modern medicine is steadily advancing, life expectancy in Western countries has decreased by 1.2 years since 2019 (OECD & European Union, 2022). Lucero-Prisno III et al. (2023) identified health systems, the mental health crisis, substance abuse, infectious diseases, malnutrition and food insecurity, sexual and reproductive health challenges, environmental pollution, the climate crisis, cancer, and diabetes as the top ten public health challenges relevant in 2023. Among these public health threats, there are several, such as diabetes, mental health, or substance abuse, which can be influenced by or are caused by personal lifestyle decisions. In that vein, the OECD & European Union (2022) defined preventable risk factors for health. These include tobacco and cannabis consumption, alcohol consumption, illicit drug consumption, nutrition, physical activity, and overweight. Wang et al. (2019) further point out that

health behavior is responsible for 30 percent of variations in health. In addition, chronic diseases caused by unhealthy lifestyles are a leading cause of death. Therefore, supporting individuals in establishing healthy behaviors is critical to improving public health, reducing mortality, and enhancing the quality of life.

Behavior change interventions can support individuals in changing their behavior. Traditionally, these psychological interventions are delivered in non-digital settings such as coaching or therapeutic sessions (Evans et al., 2022). They consist of components aiming to “alter or redirect causal processes that regulate behavior” (Michie et al., 2013, p. 82). These observable, replicable, and irreducible components of an intervention are referred to as behavior change techniques (BCT; Michie et al., 2013). The underlying mechanisms and behavioral theories of behavior change interventions – which can aim at health-related behavior but are not limited to it – and the underlying behavioral theories have already been thoroughly researched, first and foremost in psychological research. Michie et al. (2013) systemized behavior change techniques by developing the behavior change technique taxonomy (BCT taxonomy), which consists of 93 behavior change techniques (BCT) in 16 cluster groups.

Because of their high scalability and low cost, in recent years, persuasive systems have been discussed as an option to promote health behavior changes among individuals digitally (Wang et al., 2019). The use of mobile phones to deliver behavior change interventions seems promising. As of 2020, already 3.6 billion people own a smartphone (Statista, 2018) and interact with it numerous times daily (Zippia, 2023). Using mobile phones could make behavior change interventions easily accessible for many people. Additionally, mobile applications – especially when connected to wearable devices – can collect and monitor health-related data, which could enhance the interventions further. Various mobile applications for

health behavior change support are currently available for individuals to use. Nevertheless, presently, only limited research regarding the composition and design of these interventions exists.

In this paper, we want to investigate what popular mobile applications for health behavior change currently exist and how they differ from each other regarding the intervention's aim. Additionally, we aim to answer which behavior change techniques categorized in the BCT taxonomy by Michie et al. (2013) popular mobile applications for health behavior change apply. By following this approach, we can identify existing patterns and determine possible correlations between the digital delivery of behavior change interventions and the applied BCTs and the design of behavior change interventions in the health context and the applied BCTs. Pelly et al. (2023) argue that the success of digital health technologies for health behavior changes depends on the effective application of behavior change principles. Therefore, it is essential to better understand the behavioral change components used in such interventions.

Therefore, this paper focuses on the following research question:

RQ: What health problems and behaviors are popular mobile health behavior change apps targeting, what components (BCTs) do these applications use to persuade users to change their behaviors, and how do these interventions differ?

Since our study aims to identify key differences between mobile applications and categorize them accordingly, developing a taxonomy presents a suitable method for this paper. We use the methodology proposed by Nickerson et al. (2013) to develop our taxonomy. This method is appropriate for our use case because it is designed iteratively and allows us to build upon pre-existing theoretical conceptualizations and empirical findings. This feature makes the method especially suitable for our needs since we base our analysis on the existing BCT taxonomy by Michie et al. (2013) while at the same time focusing on empirical objects. Furthermore, it is designed explicitly for the taxonomy development of information systems. Varshney et al. (2013) also showed that the method proposed by Nickerson et al. (2013) is also suitable for health IT.

2. Theoretical Background

2.1 Behavior Change Theories

Behavioral theories are the underlying social-psychological behavior change theories. They explain and predict human behavior by determining influencing factors of behavioral outcomes. These factors are called constructs in behavioral science (Wang et al., 2019). The health belief model (HBM) is among the most well-known behavioral theories (Wang et al., 2019) and has widely influenced the further development of health behavior models (Abraham & Sheeran, 2001).

2.2 Behavior Change Technique Taxonomy

Michie et al. (2013, p. 46) define a behavior change technique as “an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior”. The BCT constitutes the active component of behavior change interventions. Interventions for behavior change are typically complex interventions consisting of several interacting BCTs (Michie et al., 2013). The complexity of the interventions makes it difficult to replicate, implement, synthesize, and identify their active components, hindering the understanding and effective development of such interventions (Michie et al., 2013). To facilitate the consistent description of behavior change interventions, Michie et al. (2013) developed the behavior change technique taxonomy (BCT taxonomy) in a series of consensus exercises with 54 experts to facilitate the consistent description of behavior change interventions. The result is a hierarchically structured taxonomy comprising 93 distinct BCTs in 16 cluster groups.

3. Methodology

We conducted the taxonomy in two phases. First, we created a database containing empirical objects. The database should contain popular mobile applications for behavior change. Secondly, we developed the taxonomy in an iterative process.

3.1 Phase 1: Set up Database

We chose an exploratory approach to identify popular mobile applications for Apple and Android.

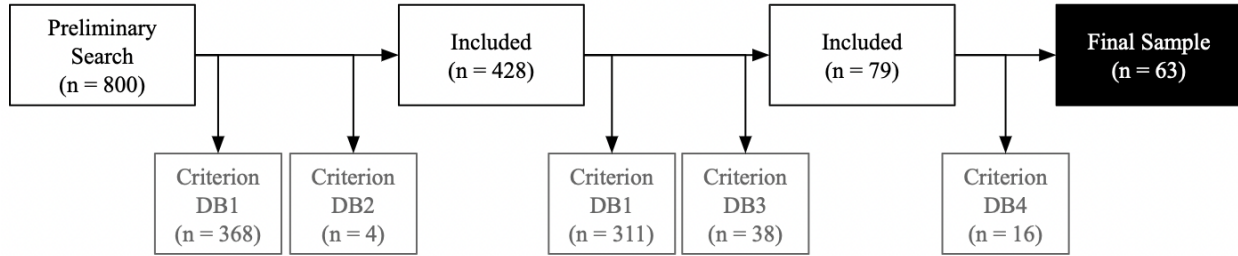


Figure 1. Application selection process.

We do not want to limit our study to specific target behaviors. Therefore, instead of developing a literature-derived search string for the database development, we evaluate relevant mobile app chart categories for the fitness of the applications. By doing so, we ensure that we include only popular mobile applications on the one hand. On the other hand, by following this approach, we can discover applications for target behaviors that have yet to be discussed in scientific literature.

The Apple App Store offers extensive chart rankings and is suitable for identifying applications through an exploratory approach. We identified the categories “Food & Drink”, “Health & Fitness”, “Lifestyle”, and “Medical” as relevant categories for our research project. A chart ranking for free and paid applications exists for each category. We extracted each category’s top 100 free and paid applications from the German Apple App Store between May 2 and May 31, 2023. We extracted a total of 800 applications.

In the application selection process, we evaluated the fitness and suitability of the extracted applications for our study. We defined the following exclusion criteria: the aim of the application is not to change user

behaviors to improve health (criterion DB1), the application is neither available in English nor in German (criterion DB2), the application is not marketed as health-related (criterion DB3), and the application is not available for Android (DB4). We define an application to be marketed as health-related if the application’s description in the App Store includes words with the word stem “health” or “gesund” or words related to concrete health problems (e.g., addiction, pain, visual strength) or if the application is a certified medical product.

Figure 1 shows the application selection process. After screening the application’s name, icon, and short description, we excluded 372 applications as 368 applications clearly and exclusively had a use case other than health behavior change (e.g., food delivery apps, dating apps, prayer timer) (criterion DB1), and four applications were neither available in English nor in German language (criterion DB2). In the second step, we evaluated the application description and an extensive preview of the application. We excluded 311 applications because the use case does not aim at helping users change health-related behavior (criterion DB1) and 38 applications that did not market

Chart Category	App Category							
	Free				Paid			
	Hits	After Screening Name & Icon	After Evaluation of Application	After Evaluation of Availability for Android	Hits	After Screening Name & Icon	After Evaluation of Application	After Evaluation of Availability for Android
Food & Drink	100	36	2	2	100	55	3	2
Health & Fitness	100	92	43	38	100	94	13	6
Lifestyle	100	20	3	3	100	25	3	0
Medical	100	71	8	8	100	35	4	4
SUM per Category	400	218	56	51	400	212	23	12
TOTAL	63							

Figure 2. Result of the application selection process.

themselves as health-relevant (criterion DB3). In the third step, we evaluated if the app is also available for Android. We excluded 16 applications that were not available for Android (DB4).

Figure 2 shows the result of the application selection process. Our final database consists of 63 mobile applications.

3.2 Phase 2: Develop Taxonomy

In the second methodological phase, we develop the taxonomy following the guidelines of Nickerson et al. (2013). The method is especially suitable for our study because it allows us to combine theoretical and empirical findings. The method structures the development process in three steps: first, the meta-characteristics of the taxonomy need to be defined; second, the ending conditions need to be

established; and third, the characteristics and dimensions of the taxonomy are developed in an iterative process until the ending conditions are met.

Since we want to investigate the extent to which the identified applications differ from each other in terms of the intervention's aim and the behavior change techniques used, we define these two targets as our meta-characteristics. We continue the iterative development process until the objective and subjective ending conditions proposed by Nickerson et al. (2013) are met.

Figure 3 shows the iterative development process of the dimensions included in the taxonomy. The characteristics were developed simultaneously and will be presented in section 4. For the first iteration, we chose the conceptual-to-empirical approach. Wang et al. (2019) define the aim of a behavior change intervention through the target group, health problem,

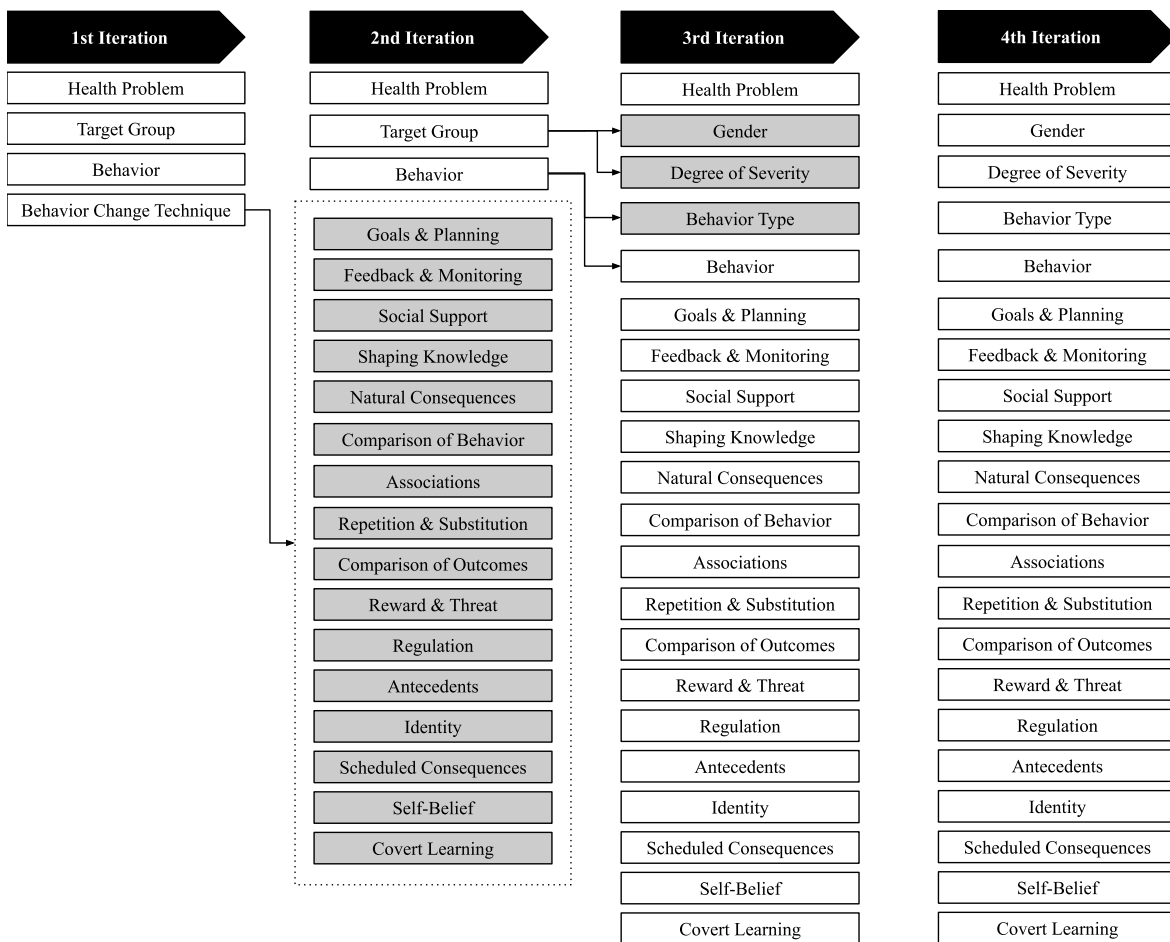


Figure 3. Taxonomy development process.

and behavior targeted. We examined all identified applications regarding these dimensions and defined corresponding characteristics.

In the second iteration, we again chose the conceptual-to-empirical approach to shift focus to the behavior change techniques used within the applications. Michie et al. (2013) define 93 behavior change techniques within 16 cluster groups. We added the 16 clustered behavior change techniques as new dimensions to our taxonomy and examined all identified empirical objects regarding these dimensions.

In the third iteration, we chose the empirical-to-conceptual approach because we identified that some applications aimed at promoting health-related behaviors while others aimed at reducing potentially harmful behavior. Additionally, we determined that the target group differed concerning the targeted gender and severity of the health problem. Hence, we added three new dimensions. In the fourth iteration, we used the empirical-to-conceptual approach to review whether we could identify additional dimensions or characteristics. No additional dimensions and characteristics could be detected, and the subjective and objective ending conditions were met.

4. Taxonomy

In this section, we present our final version of the taxonomy, which we developed in four iterations.

The meta-characteristics of the taxonomy are the aim and applied behavior change techniques in mobile applications for health behavior change.

The taxonomy is shown in Figure 4. We identified five dimensions for the meta-characteristic “Aim”: Health Problem, Gender, Degree of Severity, Behavior Type, and Behavior. Twelve distinct characteristics further describe the health problem. Additionally, we identified that the applications differ regarding the gender they target. While some applications specifically target female or male users, others do not target a specific gender.

Furthermore, some mobile applications aim at clinically relevant health problems, while others are preventive interventions. Applications can be further classified in terms of behavior type, as some applications aim to reduce harmful behaviors, while others aim to increase health-enhancing behaviors. We identified 19 behaviors that the interventions aim to help users change to prevent or improve related health problems.

Our second meta-characteristic was the use of BCTs in the applications. We found that all 16 BCT clusters from the BCT taxonomy are used in at least one of the applications. Therefore, the 16 cluster groups form the dimensions of our taxonomy. These dimensions are binary, and all possess the characteristics “BCT used” and “BCT not used”. This categorization allows us to differentiate the applications concerning the use of the BCT.

5. Principal Findings and Discussion

We identified 63 popular mobile applications for health behavior change in the German Apple App Store and the Google Play Store. We assigned all applications to exactly one characteristic for each dimension. In this section, we will present and discuss the principal findings of the assignment of the apps to the corresponding characteristics.

5.1 Intervention’s Aim

Over half of the identified interventions (n=34) are designed to help users manage overweight or obesity. The second largest category includes applications specializing in mental health (n=12), followed by those targeting substance use (n=3) and gastrointestinal disorders (n=3). The remaining nine categories all include fewer than three interventions. They address either specific health problems, such as chronic fatigue syndrome (n=1), or general areas, such as oral health (n=1) or overall health (n=2). It is also noteworthy that only 11 of the 63 mobile apps identified address clinically relevant medical conditions, while the remaining applications target preventive care. Notably, we have only classified those apps as clinically relevant, which have to be prescribed by doctors or refer to specific clinical pictures (for example, chronic fatigue syndrome). Most applications (n=58) address all genders equally. Only four applications for increasing physical activity address exclusively men (n=2) or women (n=2). In addition, one app to promote pelvic health is targeted only to female users.

We further distinguished the applications as to whether they aim to reduce behaviors that are harmful to health (n=6) or are designed to promote behaviors that are beneficial to health (n=57). Applications related to reducing unhealthy behaviors target the following behaviors: alcohol consumption (n=2), tobacco use (n=1), and the consumption of unhealthy products (n=3). At the same time, the first two categories both refer to the health problem of

Meta-Characteristic: Intervention Aim		Meta-Characteristic: Behavior Change Technique	
Dimension	Characteristic	Dimension	Characteristic
Gender	female	Goals and Planning	BCT used
	male		BCT not used
	not specified	Feedback and Monitoring	BCT used
Substance Use	BCT not used		
Health Problem	Chronic Fatigue Syndrom	Social Support	BCT used
	Exposure to Harmful Substances		BCT not used
	Eye Health	Shaping Knowledge	BCT used
	Gastrointestinal Disorders		BCT not used
	Mental Health	Natural Consequences	BCT used
	Overweight and Obesity		BCT not used
	Oral Health	Comparison of Behavior	BCT used
	Pain		BCT not used
	Pelvic Health	Associations	BCT used
	Therapy Adherence		BCT not used
	Overall Health	Repetition and Substitution	BCT used
	clinically relevant		BCT not used
Degree of Severity	preventive	Comparison of Outcomes	BCT used
	Increase in Health-Promoting Behaviors		BCT not used
Behavior Type	Reduction of Health-Risk Behaviors	Reward and Threat	BCT used
	Physical Activity		BCT not used
Behavior	Physical Activity & Precautionary Doctor Appointments	Regulation	BCT used
	Breathing Exercises		BCT not used
	Dental Care	Antecedents	BCT used
	Alcohol Consumption		BCT not used
	Diet	Identity	BCT used
	Healthy Eating		BCT not used
	Eye Exercises	Scheduled Consequences	BCT used
	Taking Medication		BCT not used
	Wellbeing Activities	Self-Belief	BCT used
	Healthy Eating and Physical Activity		BCT not used
	Journaling	Covert Learning	BCT used
	Meditation		BCT not used
	Pelvic Floor Muscle Exercises		
	Grocery Shopping		
	Sleep		
	Exercises for Pain Reduction		
	Tobacco Consumption		
	Walking		

Figure 4. Final taxonomy.

“substance use”. A further distinction must be made for the last category, as two apps refer to exposure to harmful substances (e.g., cosmetic products), and the other application targets overweight and obesity. Thus, this application differs from the other 33 applications, which also specialize in overweight and obesity in terms of behavior type. While the other applications try to encourage their users to increase physical activity, healthy eating, or fasting intervals in their lives, this application aims to reduce the consumption of unhealthy food by providing information during the shopping process to prevent people from buying unhealthy food.

Depending on the application design, the same health problem can be addressed by targeting different behaviors. Applications aiming at increasing mental health differ significantly regarding the targeted behavior. While some applications encourage users to journal, others try to persuade users to improve their sleeping habits or to include meditation in their daily lives. Interventions aiming at preventing or reducing overweight try to persuade users to increase fasting, healthy eating, physical activity, or a combination of healthy eating habits and physical activity. Sometimes, selecting the behavior users try to change to avoid health problems is a personal preference. The target behavior is apparent in other cases, such as alcohol consumption. This example also highlights that the differentiation between the health problem and target behavior is only sometimes clear. Especially for preventive applications, though, the underlying health problem might remain a mere possibility of the behavior.

5.2 Application of Behavior Change Techniques

Forty-nine applications apply the BCT “Goals and Planning”. Examples include setting a target weight as a goal or reviewing the outcome goals, such as the weight already lost.

“Feedback and Monitoring” is the BCT used in most applications (n=54) and for many target behaviors. Examples include technologically monitoring the behavior (e.g., steps taken, hours slept) and self-monitoring with digital journals (e.g., calories eaten, mood, days spent sober). Since mobile devices allow easy monitoring and tracking of indicators such as steps or heart rate, using digital devices as the delivery medium for behavior change interventions seems to encourage using “Monitoring and Feedback” as a BCT.

Interestingly, “Social Support” was only used in 8 applications. Some interventions include allowing users to give encouragement or praise to other users, while in other applications, one can reach out to coaches. Additionally, sometimes, the app “itself” praises the user. Social support seems challenging to apply to digital health behavior change interventions. In particular, the identified applications often do not include emotional or practical social support.

The BCT “Shaping Knowledge” was frequently (n=48) used. Many apps that promote healthy eating and fitness include guidance on how to perform the appropriate behavior by providing recipes, information on nutritional values, or instructions to perform specific exercises.

The BCT “Natural Consequences” (n=9) is often used in applications for overweight but is also included in interventions targeting gastrointestinal disorders and substance use or the consumption of harmful products. One application that aims at increasing physical activity asks users to record how they feel after their workout, making them aware of the emotional consequences of performing the behavior. In substance use applications, on the other hand, users are informed about the health consequences of performing the behavior.

The technique “Comparison of Behavior” (n=20) was applied in most cases in fitness apps by including videos demonstrating the correct execution of an exercise. The technical implementation of the interventions makes it possible to provide people with extensive information and instructions in different formats. Therefore, the digital mode of delivery could explain why mobile applications for health behavior change frequently use the BCTs “Comparison of Behavior” and “Shaping Knowledge”.

Twenty of the identified applications include the BCT “Associations”. One observed use case of this technique is in interventions targeting overweight and obesity, including a traffic light system to rank food, encouraging associative learning and behavior change. Another use case is to provide users with prompts or cues to prompt the behavior (e.g., prompt users to take medication or to go to bed).

The BCT “Repetition and Substitution” was used 13 times. It is used in applications for many different health problems, such as mental health applications (n=3) or applications targeting the reduction of substance use (n=2). Techniques include advising users to substitute their behavior or supporting them in forming habits by repeatedly prompting them in the same context. Two applications for the reduction of alcohol consumption and tobacco consumption

implement this BCT by advising users to reduce the consumed amount gradually. One intervention that tries to persuade users to buy and consume less harmful products proposes healthier alternatives while shopping and suggests substituting the targeted behavior with wanted or neutral behavior. This example emphasizes a key advantage of technical behavior change interventions: the digital delivery prompts users in real-life situations, whereas this is hardly possible with a human coach.

The BCT, "comparison of outcomes", is used in 20 applications. This technique is implemented by comparing the outcomes with other application users (e.g., fitness apps) or through the comparative presentation of future results (e.g., substance use apps).

The "Reward and Thread" technique is included in 12 applications, but none use threads or punishments. In most applications, the rewards are implemented using digital badges. Only four applications reward the users by providing material or financial rewards. Two of them are linked to insurance companies, which allow users to collect points for health-promoting activities and redeem them for money or material rewards. The other two applications aim at increasing the amount that users walk. One of the applications allows for the selection of cryptocurrency coins by walking, while the other grants users vouchers or the possibility for donations if enough steps have been collected.

The BCT "Regulation" is applied 20 times. In all cases, the technique is realized by supporting users in conserving mental resources. For example, some applications targeting weight loss allow users to easily track calories by providing them with a database containing relevant information that is easily accessible. Some mental health applications facilitate behavior change by simplifying journaling through the possibility of simply selecting specific emotions or activities. Mobile applications seem predestined to support users in changing their behaviors by reducing the mental load because they enable users to easily access the information they otherwise have to remember.

The technique "Antecedents" (n=7) is implemented by reducing exposure to cues for unwanted behavior in substance use applications by allowing users to track the triggers for the unwanted behavior and provide tips to avoid such situations. In pelvic health and pain reduction applications, the app advises doing exercises for bodily changes, facilitating behavior change.

The BCT "Identity" is used in only one application, which aims to reduce substance use by advising users to identify as role models.

"Scheduled Consequences" are included in 6 applications. They are implemented similarly to rewards and only include positive consequences. Compared to rewards, the possibility of obtaining badges is reduced in frequency over time. For example, users get a badge after walking 5,000 steps and another badge after 20,000 steps.

The BCT "Self-Belief" is only included in two applications for mental health promotion. Moreover, "Covert Learning" is among the least frequently used BCTs (n=1). This technique is included in one application targeting substance use. The technique is applied by advising users to focus on imaginary positive and negative consequences in the interventions to reduce substance use.

7. Conclusion and Further Research

This study aimed to identify popular mobile applications for health behavior change and examine which health problems and behaviors they address, which behavior change techniques the applications use as active components to facilitate behavior change, and how the interventions differ.

We identified 63 popular mobile applications for health behavior change and categorized the applications regarding the applications' aims by creating a taxonomy consisting of five distinct dimensions describing the aim. Approximately half of the identified applications target overweight and obesity, and 82 % aim to prevent health problems compared to treating already existing disorders or diseases.

Additionally, we found out that all 16 BCT cluster groups of the BCT taxonomy by Michie et al. (2013) are implemented in at least one of the identified empirical objects for health behavior change. As discussed in the last section, we found that some techniques are applied more frequently in the identified applications than others. Feedback and monitoring techniques are used most often in the investigated applications. The digital delivery mode could be why most applications use this particular BCT. Future research needs to investigate whether this is a causal effect of the digital delivery of the interventions.

Limitations of this study emerge from the methodological approach, which requires a trade-off between the degree of detail and clarity. We only categorized the applications by BCT cluster groups. Even though we considered the subordinate techniques

in the development process of the taxonomy and the assignment of the applications, we could not include all 93 behavior change techniques in the taxonomy while at the same time ensuring comprehensiveness. Additionally, we only investigated a sample of popular mobile applications. Regarding the application's aim, additional characteristics and dimensions might exist in less popular mobile applications for health behavior change. We only included applications that were available for Apple as well as for Android. By following this approach, we could have excluded popular mobile applications only available for either Apple or Android users. Additionally, we based our analysis of the applications on the application's description and an extensive preview of the application, including numerous screenshots of the features. While we believe that by following this approach, we were able to identify the core functionality of the application, some applications may have additional features besides the core functionality that can only be determined after longer use of the app.

In case additional relevant applications are discovered, researchers can easily extend our proposed taxonomy as the taxonomy provides a framework for analyzing mobile applications for health behavior change.

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