How Do Smart Device Apps for Diabetes Self-Management Correspond with Theoretical Indicators of Empowerment? An Analysis of App Features

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Abstract

Objectives. Smart device apps for diabetes have the potential to support patients in their daily disease management. However, uncertainty exists regarding their suitability for empowering patients to improve self-management behaviors. This paper addresses a general research gap regarding theoretically based examinations of empowerment in diabetes research, by examining how diabetes app features correspond with conceptual indicators of empowerment.

Methods. We examined features of 121 apps for diabetes self-management available in Singapore, with the second highest proportion of diabetes among developed nations, for psychological empowerment (feeling of empowerment) and for behavioral empowerment (social support).

Results. Diabetes apps studied offered a narrow range of features, with limited feature-sets corresponding to indicators of empowerment. Customization as a strategy to improve perceived relevance of diabetes self-management as an indicator of psychological empowerment was especially limited. Moreover, there was a lack of features supporting patients’ communication with healthcare professionals and within their private social networks.

Conclusions. Mobile apps for diabetes self-management failed to provide relevant features for empowering patients. Specific practical recommendations target improved adoption, sustained usage, and effectiveness of diabetes self-management apps.

Diabetes care programs increasingly include advanced mobile-based technological devices. These technologies entered the market aiming to supplement traditional diabetes healthcare and to support self-management by patients (1). Consequently, smart applications on mobile devices for diabetes self-management proliferated, increasing exponentially in app stores (2). Diabetes apps are designed to support self-management activities like blood glucose (BG) and complication monitoring, medication adherence, healthy eating, exercise, and problem-solving (1). With the increased availability of apps targeted at consumers, research began examining their potential for diabetes self-management.

Current trends in mHealth, “the use of mobile communications for health information and services” (3, p. 1), focus on effects research (4), contrasting overly optimistic study results on diabetes app use effects (5) with a more critical view toward mHealth effectiveness (6;7). A meta-analysis showed that such interventions “that have statistically significant effects are small and of borderline clinical importance” (4, p. 25). The potential of mHealth for diabetes self-management, including diabetes apps, requires further investigation, especially in theoretical terms. We focus on the concept of empowerment as a fundamental predictor of self-management behaviors (8), particularly in relation to diabetes (9;10), to evaluate the potential of diabetes apps for empowered self-management. Specifically, this study examines how technological features of apps for diabetes self-management correspond with theoretical indicators of psychological and (RQ2) behavioral empowerment.

The paper first defines two sub-concepts of empowerment for diabetes self-management, then addresses extant gaps regarding empowerment in mHealth research, particularly in relation to diabetes apps. To address research gaps, we examined features of 121 diabetes apps corresponding to indicators of empowerment.

Diabetes Self-Management and Empowerment

The introduction of home BG monitoring possibilities in the 1970s led to a shift in responsibility from healthcare professionals (HCPs) to patients, emphasizing the relevance of self-management in diabetes care (11). Clark and Houle define patient self-management as “the conscious use of strategies to manipulate situations to reduce the impact of disease on daily
life” (12, p. 27). Gomersall et al. (13), in a meta-synthesis of thirty-eight papers, report that type 1 and type 2 diabetes self-management (T1DM/T2DM) includes BG testing, medication adherence, regular exercise and the adoption of specific diets (compare AADE7 Self-Care Behaviors) (14). The recent 2017 National Standards state that it is necessary to learn how to self-manage diabetes to prevent or to delay complications (14). If self-management is poor over time, the risk for potential complications increases (15).

A growing body of literature notes the relevance of empowerment for diabetes self-management (16;17). According to Gutschoven and van den Bulck (18), “(...) empowerment is expected to enhance the capacity for self-management and to promote the adoption of healthier lifestyle” (18, p. 7). However, a variety of interpretations leave an unclear understanding of empowerment (9). Different scientific disciplines offer varied conceptualizations, with an overarching agreement regarding empowerment as a motivational construct (19;20), including management research (21), community psychology (22), and clinical practice (e.g., 23).

Rappaport describes a multilevel construct comprising a combination of “psychological empowerment” for the individual, and social influence from others (24), referred to as “behavioral empowerment” (or “role empowerment”) (25). While somewhat similar to the concepts of intrinsic and extrinsic motivation, empowerment is a unique concept (24).

First, early approaches in management studies (26) and in diabetes research (27) comprehended psychological empowerment as related to self-efficacy, the “belief in one’s agentive capabilities, that one can produce given levels of attainment” (28, p. 382). Thomas and Velthouse (21) noted that such a one-dimensional approach did not go far enough, and argued for a multidimensional approach to psychological empowerment, based on four empowerment indicators of perceived meaningfulness (relevance), perceived competence (self-efficacy), self-determination (choice), and perceived impact.

Schulz and Nakamoto (19) translated these indicators to a health context. According to them, perceived relevance suggests that the health activities the patient performs are seen as worthy, potentially leading to higher commitment, while perceived competence describes confidence about the ability to manage one’s own health condition. Self-determination concerns the possibility of actions initiated by the patients themselves, and, perceived impact comprises feelings about making a difference in health outcomes, for example, exercises that result in weight loss.

Second, behavioral empowerment, or the empowering support by others, has been shown to influence the feeling of psychological empowerment (25;29). In a diabetes care context, social support can derive from HCPs, being the first source of professional medical support for patients (e.g., diabetes educators, 30), or from private social patient networks (31;32).

For the former, Emanuel and Emanuel (33) suggest different models of the doctor-patient relationship with varying HCP decision-making styles defined as “the propensity of physicians to involve patients in treatment decisions” (34, p. 246). The ideal empowering doctor-patient relationship comprises neither exclusive control by the physician (“paternalistic” model) nor absolute autonomy by the patient (“informative” model), but a collaborative process of shared decision making with active contribution by both parties (“deliberative” model, 33). Shared HCP decision-making, empowering patients (19), can be considered an indicator of behavioral empowerment. Likewise, communication is part of HCP–patient interaction (35), and HCPs can empower patients by willingly sharing greater medical information (36).

The latter case of support by members of the private social patient networks on self-management outcomes (37;38) has been compared with professional HCP support (31;32). Isaksson et al. (39) found that higher psychological empowerment was not just associated with support from HCPs but also support from relatives. Shao et al. (40) found that support by private social networks was positively associated with self-efficacy in diabetics, and that self-efficacy mediated the relationship between support and glycemic control.

To summarize, two dimensions of empowerment, psychological (16;41;42) and behavioral (38;43;44), have ample empirical support as predictors of (diabetes) self-management behaviors as well as of health outcomes. Indicators of psychological empowerment include perceived relevance, perceived competence, self-determination, and perceived impact, while HCP decision-making, HCP–patient communication, and the social support by private patient networks are indicators of behavioral empowerment. We next address the missing consideration of empowerment in mHealth research (45).

**Research Gaps linking Empowerment and App Features**

Despite literature discussing the potential of apps for diabetes self-management (46), specific conclusions for empowerment, lacking empirical evidence, rarely go beyond general overviews (45;47), or are not based on a comprehensive theoretical explanation (e.g., 48). Most diabetes-related mHealth projects focusing on empowerment are of applied character and/or do not have much explanatory value (48–50). Studies of empowerment in mHealth practice are both limited and inconclusive (e.g., 49;50). Conceptually, empowerment is mainly understood as an outcome of mHealth use (48;49). For example, Park et al. (51) found that empowerment could occur when T2DM patients shared information or received social support using their mobile devices, when patients realized the outcomes of mHealth supported activities, or when the mobile devices were used for improved activity planning. Krosel et al. suggest that mHealth is “(...) offering different means for introduction of the concept of empowerment into patients’ everyday life” (47, p. 35), yet conclude it still plays a minor role in diabetes self-management, with apps lacking perceived benefit and ease of use.

There is a limited literature relating mHealth use to psychological empowerment outcomes (52;53), with the associated Web-based eHealth literature proving inconclusive, both finding effects of food label-training (54) and failing to find any significant impact of functional eHealth interactivity (55) on psychological empowerment. On the other hand, the literature focusing on social support outcomes by using m/eHealth tools mostly does not refer to empowerment. Moreover, most studies did not examine social support as an outcome of mHealth use, but viewed social support delivered through mHealth influencing health and self-management outcomes (56).

We note that, while empowerment is conceptually under-studied in an mHealth context, a fair amount of research has focused on features of diabetes apps. Our study aimed to link these two streams of research.

Diabetes app features reported in previous research included insulin, diet, weight, exercise and medication recording, data export, data sharing and communication, data storage and analysis, reminders or automated feedback, education, and medication
use (7,57–59). Demidowich et al. (60) examined forty-two Android diabetes apps to find that 86 percent included BG recording, followed by medication tracking (45 percent), and insulin dose calculators (26 percent). Some diabetes apps could be connected to external devices like sensors or BG meters (61), or used cloud-based systems for health data storage and exchange (62). Overall, most diabetes apps offered similar functionalities and combined at most two functions (63), prompting Brzan et al. (64) to comment that apps with a greater variety and combination of features were needed to attract long-term users.

El-Gayar et al. (46) reported that "limitations of the applications include lack of personalized feedback; usability issues (…); and integration with patients and electronic health records" (46, p. 247). The (composite) usability scores of apps were relatively low, showing an average score of 11.3 of thirty (60). Fu et al. (6) pointed toward low satisfaction ratings in diabetes apps, while others found that apps did not cater to the needs of low literacy diabetics (65). Rossi and Bigi (66) reported that diabetes apps "do not seem to be based on solid theoretical models (…), [nor] intended as devices to be integrated in the ecology of the doctor–patient relationship" (66, p. 1).

To address existing research gaps, we combined empowerment research with research on diabetes app features and investigated how diabetes app features corresponded with theoretical indicators of psychological and behavioral empowerment.

Methodology
Operationalization
We first collected available diabetes app types and features, adapting app coding schemes by Arnhold et al. (63) and the Mobile App Rating Scale (MARS) app classification, which is based on 372 criteria for assessing apps from twenty-five published papers, conference proceedings, and online resources (67). The chosen app analysis method offers a high level of validity (63), with the MARS seen as one of the most comprehensive tools for app analysis, having exhibited good internal consistency with \( \alpha = .90 \), and inter-rater reliability of intraclass correlation = .79 (67;68). Next, using an interpretive and exploratory approach, app features were preliminarily assigned to theoretical psychological and behavioral indicators of empowerment, then compared versus prior research results. For example, features were expected to support perceived relevance of self-management behaviors when enhancing a diabetic’s feeling that a specific behavior (e.g., app use) is worth investing energy in.

The final codebook contained the (i) information on the app search, (ii) background app information from respective app stores, (iii) app feature assessment, and (iv) app user target group.

App Collection Procedure
An app search, using the keywords diabetes, blood sugar, and glucose, was conducted by means of Apple App Store and Google Play, comprising 97 percent global market share (69), on two mobile Android and iOS devices from October 29 to November 7, 2015 by a trained researcher. Inclusion criteria were English free-to-download diabetes apps that were frequently downloaded and used by Singaporean end-users in 2015 (70). English is the most spoken language in Singaporean homes (71). Most app users use free-to-download apps (70), with paid apps accounting for .05 percent of app downloads (72). App store ranking was used as an indicator for usage frequency due to lack of established criteria.

To mitigate reported country differences in commercial app stores (73), an iPad (offering larger variety in search settings than an iPhone; iPad mini model ME276GP/A, iOS 9.1) with the latest operating system was registered anew with a dummy Singaporean account to ensure the inclusion of local search results (not necessary for Android; Samsung Galaxy S4, Android 4.3).

Similar to the app review by Arnhold et al. (63) (wide variation in sample sizes in previous studies) (73), the search included diabetes specific apps addressing both T1DM and T2DM, excluding apps not specifically designed for diabetics (such as calorie counters). We selected the first fifty apps listed for each search term, assuming them to be most frequently downloaded by users as prior research reported that the top 10 percent of most downloaded apps accounted for over 96 percent of the total downloads (72) and that users searching for apps tended to pick the apps shown in the top positions (74). Our study did not aim to provide full coverage of all available apps in 2015/2016 due to a dynamic app market, but rather be amenable to testing of the conceptual research questions. We acknowledge that app data get outdated quickly; however, a follow-up check in 2018 suggested that the diabetes self-management app market did not alter drastically since data collection in 2016.

After removal of duplicate apps and those that failed to meet inclusion criteria, the final app list contained 121 diabetes apps, with twenty-four iPad-specific apps, fifty-one iPhone apps, and forty-six Android apps for diabetes self-management (Table 1) that were coded using the developed codebook (available upon request). An additional twenty-two diabetes apps included diabetic recipes, magazines, and journals, which were recognized but not used for further coding due to a general lack of features (Table 1). The resulting app sample contained both international and Singaporean apps, with the majority of the apps offered by international developers.

Pretesting and Coding Procedure
Coders received training on the codebook and the procedure before the pretests and main coding. Several pretests on forty-five apps were run with three academic coders to ensure consistency. Inter-coder reliability (75) had an acceptable average agreement of \( M = .82 \) (SD = .190; Min = .33; Max = 1.00) among all forty-three included variables. Sixteen variables showed full agreement of \( M = 1.00 \), fifteen variables an agreement of \( M = .83 \), eight variables an agreement of \( M = .67 \), one variable an agreement of \( M = .50 \), and three variables an agreement of \( M = .33 \).

The main app coding took place in February 2016 by three trained academic coders, using an Android smartphone, an iPad, and iPhones with the latest operating systems for coding (Coder 1: Mi4, Android 5.0; Coder 2: Apple iPad Air Wi-Fi-16GB, iOS 9.2.6 and iPhone 6, iOS 9.2.1; Coder 3: iPhone 6, iOS 8.2).

Data Analysis
Based on previous app assessment (63;67), feature availability was analyzed using numeric (mainly binary) and text variables. Coder comments were entered where additional information on the coded data was available. Ninety-nine was defined as missing data. Descriptive quantitative data analysis was undertaken in IBM SPSS version 25. An interpretive and qualitative exploratory
analysis approach assigned app features to theoretical indicators of empowerment, confirmed by means of previous literature.

Results

Technological Features of Diabetes Apps

Almost two-thirds (62 percent) of the 121 apps analyzed included diabetes or health data logbooks for patients to record and analyze BG and other health data as part of diabetes monitoring (trackers/diaries, Figure 1). An eighth (12 percent) included learning tools and information apps for education. The sample contained BG or other data conversion calculators (7 percent, e.g., calculators to convert mmol/L to mg/dl) and diabetes community apps (3 percent, e.g., forum/chat apps). Marginal diabetes app categories comprised nutrition apps (e.g., databases for carbohydrate content in food) and exercise apps, and specific diabetes apps for children (logbooks) or gaming/quiz apps (Table 2; Figure 1). Table 2 provides an overview on types, target groups, and features of included diabetes apps (detailed data are available upon request).

App Features Corresponding to Psychological Empowerment Indicators

Specific app features (Table 2) corresponded specifically with theoretical indicators of empowerment (see Table 3 for link). App features such as customization, rewards, and interactivity were assigned to psychological empowerment indicators of perceived relevance; educational and data monitoring features (including reminders) were assigned to perceived competence, while analytical and graphic features were assigned to perceived impact.

Table 1. Diabetes App Collection Procedure Results

| Apple App Store – iPad only | Apple App Store – iPhone only | Google Play Store |
|-----------------------------|-------------------------------|------------------|
| any age group, sorted by relevance | any age group, sorted by relevance | search in apps only (category) |
| 142 | 150 | 150 |
| 442 free-to-download apps in English | 141 duplicates removed (same app name and provider name in same app store) | |
| 301 apps | 61 | 128 |
| 57 excluded: | 71 excluded: | |
| 2 duplicates | 0 duplicates | |
| 40 not diabetes specific | 10 not diabetes specific | |
| 3 not available anymore | 6 not available anymore | |
| 1 not free to download (paid) | 1 not free to download (paid) | |
| 0 prank apps* | 49 prank apps* | |
| 0 prank apps* | 0 require specific devices | |
| 1 requires specific devices | 3 technical failure | |
| 9 technical failure | 2 other reasons | |
| 1 other reason | | |
| 30 excluded: | 57 excluded: | |
| 6 duplicates | 2 duplicates | |
| 12 not diabetes specific | 40 not diabetes specific | |
| 3 not available anymore | 3 not available anymore | |
| 2 not free to download (paid) | 1 not free to download (paid) | |
| 0 prank apps* | 0 prank apps* | |
| 3 require specific devices | 1 requires specific devices | |
| 3 technical failure | 9 technical failure | |
| 1 other reason | 1 other reason | |
| 31 | 55 | 57 |
| 7 not coded (features) due to static character: | 4 not coded (features) due to static character: | |
| 3 diab. journal/magazine | 1 diab. journal/magazine | |
| 4 diab. recipe apps | 3 diab. recipe apps | |
| 24 iPad | 51 iPhone | 46 Android |
| 121 apps coded (features) |

Note. * Prank apps are apps that just pretend to deliver a certain service (e.g., fake blood pressure measurement through the device screen).

Tailoring features appeared important for perceived relevance by providing an opportunity to individualize and adapt an app. Most apps analyzed failed to tailor services to specific patient subgroups with differing needs (e.g., young versus elderly). Eighty-five percent did not target any specific type of diabetic patient, but were meant for general use by all diabetics (Table 2). Only 13 percent of the analyzed apps specifically targeted T2DM patients, and an equal 13 percent targeted T1DM patients. A twelfth of apps had specific functionality for other forms of diabetes (8 percent) and a twentieth for prediabetics (5 percent). Adult diabetes patients were primary customers (4 percent), with a mere one percent aimed at diabetic children (Table 2). Furthermore, there was hardly any tailoring for disease characteristics, such the period since diagnosis, nor for demographic categories of age (in 14 percent of the apps, Table 2) and gender.

Reward features (7 percent) aligned with perceived relevance of diabetes apps, for example, bonus point systems for regular app use as part of a diabetes self-management regimen. These included interactive features like gaming elements (5 percent), possibly enhancing the relevance for specific target groups, such as adolescents.

Perceived competence for self-management was supported by app learning features that potentially enhanced diabetes knowledge. Improved knowledge could strengthen perceived diabetes self-management competence. A quarter of the apps (25 percent) provided features supporting learning processes and diabetes-specific knowledge through textual or video educational content (Table 2). We conclude that diabetes education was not the primary aim of most diabetes apps in the sample.

Facilitated data input through structured self-monitoring was assigned to the empowerment indicator perceived competence. Features for structuring BG documentation could promote...
improved diabetes monitoring, in turn leading to perceived competence for self-management. The available app features confirmed typical characteristics of diabetes logbooks, with a majority of apps (69 percent) supporting structured documentation of health data, such as storage of regularly measured BG values (Table 2). Documentation options included automatic data upload from the BG meter to the app by means of Bluetooth, taking pictures of the meter screen, or using the device keyboard to type BG and health data. Almost a fifth (18 percent) allowed a connection to external devices (e.g., BG meter, Table 2). Another quarter of the apps included reminders (to test BG) or automatic notifications (26 percent), that could support structured self-monitoring.

Features corresponding to perceived choice in self-management, such as information on various treatment alternatives, insulin options, or oral medication differences, were not found. There were few choices for the patient to feel better informed and better able to take own decisions. Regarding lack of perceived choice, no information was found on voluntary or obligatory use of apps as part of specific programs (e.g., DAFNE, http://www.dafneonline.co.uk). An obligatory use of diabetes apps could potentially hinder perceived choice regarding self-determined technology-supported self-management. However, an obligatory app use could also act as extrinsic motivation to regularize app use supporting diabetes self-management and, thus, create the necessity to use the app as part of an overall diabetes program.

Data monitoring was frequently accompanied by an option to analyze the entered data and/or to receive graphic data outputs (59 percent). Graphical data outputs and analysis features potentially support perceived impact of self-management activities. Such analytical features allow patients to interpret health data easily, and view outcomes of lifestyle changes. A visible improvement in BG values from app data could directly communicate effectiveness of self-monitoring to the patient. Thus, graphic and output features were expected to provide an opportunity to enhance the perceived impact of the app use.

### App Features Corresponding to Behavioral Empowerment Indicators

Features that included apps in on-going diabetes programs (automatic data access for HCPs), forwarding and export features to provide HCPs with health and lifestyle data, and HCP contact information were assigned to the behavioral empowerment indicators shared decision-making and HCP–patient communication, and features to communicate with other users and the individual patient networks were assigned to the indicator of social support by private networks.

The results indicated that only a small percentage of apps (3 percent) were part of a larger therapeutic program for diabetes care (Table 2). While almost two-thirds of apps provided logbooks for data monitoring (62 percent, Figure 1), one-third were found to provide export features (33 percent) or data-forwarding features (29 percent). These features allowed the app user to provide HCPs with patient data, for example, by means of email or print (Table 2). Most apps did not enable automatic access to patient data for the HCPs, and thus user-friendliness

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**Fig. 1.** Types of diabetes apps in the sample (N=121).
Table 2. Diabetes App Types, Target Groups, Features, and Tailoring

| Variable                          | Type                                      | % of N |
|----------------------------------|-------------------------------------------|--------|
| App type                         | Logbook/tracker/diary for data monitoring | 62.2   |
|                                  | Learning tool/info app/guide (e.g., educational videos) | 11.8   |
|                                  | BG conversion calculator                   | 6.7    |
|                                  | Community app/patient forum                | 3.4    |
|                                  | Diabetic nutrition app                     | 2.5    |
|                                  | Clinical guidelines                        | 2.5    |
|                                  | Exercise/physical activity app             | 1.7    |
|                                  | Gaming/quiz app                            | 1.7    |
|                                  | Kids app for diabetes                      | .8     |
|                                  | Unspecific/others                          | 6.7    |
| Target group I                   | Adult patients                            | 94.2   |
|                                  | Other users                                | 7.5    |
|                                  | Physicians/qualified health personnel      | 5.8    |
|                                  | Children/adolescents                       | .8     |
| Target group II                  | Not specified diabetes type                | 85.1   |
|                                  | Type 2 diabetes                            | 13.3   |
|                                  | Type 1 diabetes                            | 12.5   |
|                                  | Other diabetes types (e.g., gestational)   | 7.6    |
|                                  | Pre-diabetes                               | 5.0    |
| App features                     | Documentation (monitoring)                 | 69.2   |
|                                  | Data analysis                              | 59.2   |
|                                  | Feedback to app provider                   | 45.8   |
|                                  | Login                                     | 39.2   |
|                                  | Export                                    | 32.5   |
|                                  | In-app purchases                           | 31.1   |
|                                  | Mandatory registration                     | 30.8   |
|                                  | Data forwarding                            | 29.2   |
|                                  | Reminder/notifications                      | 25.8   |
|                                  | Learning/education                         | 25.0   |
|                                  | Advertising                                | 24.4   |
|                                  | Connection to external devices             | 17.8   |
|                                  | Optional registration                      | 15.0   |
|                                  | Communication with app users               | 10.8   |
|                                  | Recipe suggestions                         | 9.4    |
|                                  | Communication with private social network  | 9.2    |
|                                  | Pictures/videos                            | 9.2    |
|                                  | Rewards                                   | 6.7    |
|                                  | Gaming                                    | 5.0    |
|                                  | Therapy support                            | 3.3    |
|                                  | Inclusion in therapy/care program          | 2.5    |
| Tailoring                        | Tailoring for demographics                 | 14.2   |
|                                  | Tailoring for disease                      | 9.2    |
|                                  | Tailoring for other                        | 0      |

Note. N = 121, the values do not sum up to 100% because of partly mixed forms of apps.

Discussion

The analytical review of app features corresponding to theoretical indicators revealed that the potential of the analyzed diabetes apps for empowerment is far from being realized. Empowerment considerations were limited to a small set of infrequently applied features (e.g., limited tailoring).

Previous research on app features assigned to indicators of psychological empowerment has shown that tailoring (as a means for perceived relevance) could enhance individual message relevance (76). Indeed, diabetes research has frequently demonstrated differences in self-management requirements in T1DM or T2DM patients (77). Likewise, differences in age groups requires diverse tailoring strategies for age specific content. Researchers and developers need to tailor app information more specifically to the type of diabetes and other characteristics of specific patient groups (78). In particular, the lack of diabetic children as an app target group in the sample (Table 2) suggests that current app developers fail to realize the potential of technology for young “digital native” target groups highlighted by previous studies (79). A case for stronger inclusion of interactive elements for selected target groups can be made on the basis of prior mHealth studies on effects of gamification (80;81), such as reward systems implemented in mobile games (82).

The perceived competence indicator of psychological empowerment suggests that app features comprising educational elements and structured self-monitoring are important. Previous studies have found significant relationships between knowledge and perceived competence (e.g., 83), demonstrating that structured patient training can improve both perceived and actual (glycemic) control (84;85), and that knowledge can be promoted by interactive features (86). However, it is also possible that educational content might not just promote but also reduce perceived competence, for example, when a person is educated on something too complex to understand. Extant research is unclear whether...
structuring self-monitoring elements can enhance perceived self-management competence, yet shows potential improvements in self-determination (84;85) (perceived control is used synonymously with the empowerment indicator self-determination/choice) (18).

Prior studies confirmed that graphic elements influence perceived impact and health-related behavioral intentions (87), as well as data interpretation (88). Our sample reiterated existing research, finding that analytical and graphic output features frequently went along with self-monitoring features in the sample (assigned to perceived impact of a diabetes app use).

The literature is quite established regarding features supporting indicators of behavioral empowerment, with the relevance of both HCP and social network support having been proven for diabetes self-management (31;37;89). Research hints to the fact that mobile health applications are not efficient as standalone means for self-management support, but have to be included into the HCP–patient relationship to guarantee long-term use and effectiveness (90). Apps need to be officially approved to facilitate inclusion into diabetes care programs (e.g., government promotion) (91). Inclusion of apps in diabetes programs provides synergetic effects, with a stronger obligation for app use, facilitated app selection and informed app use, facilitated (technology supported) HCP–patient cooperation, timesaving feedback procedures, improved data monitoring, and improved patient data collection (92). Moreover, diabetes apps, having been proven effective for self-management motivation (29;93), should provide features to enable support by private patient networks; however, noting privacy issues involving personal medical records.

This analysis led to certain interpretive conclusions on the likelihood of maintained long-term use of the provided diabetes apps (app “stickiness” 94). The feature analysis revealed few strategies proven effective (reward systems, gaming elements, or entertainment features in less than 10 percent of apps) (95) used by app providers to gain sustained users. Further obstacles that hindered sustained app use, such as frequent technical app failure (Table 1), required in-app purchases (31 percent), frequent advertising (25 percent; Table 2) and an unstable market dynamic (apps being removed from stores), prevented the apps from being viewed as reliable and trustworthy tools for diabetes self-management.

Overall, active and evidence-based strategies to motivate diabetics to sustain app use over time (78) and more sophisticated mobile tools within the context of the HCP–patient relationship should be advanced (96). However, advanced diabetes apps cannot be designed by simply including multiple features to satisfy all theoretical concepts for all target audiences, leading to a laundry list of must-have app features. From a technical perspective this is not feasible or practical, with multiple features including social networking and gaming making a diabetes self-management app unwieldy and confusing for less tech-savvy target groups. Thus, instead of including all required features at once, segmenting, targeting, and positioning strategies can selectively improve diabetes app. Features have to be thoughtfully selected for specific target audiences, or target audiences have to be given choices in feature selection. App series or app "packages" provide an opportunity, offering several apps that can be individually selected and combined by the diabetic user (e.g., MySugr app series). However, the idea of combined apps has to be taken one step further with giving a choice to patients in selecting specific features relevant to them, to enhance usage and effectiveness of diabetes apps for self-management.

### Study Limitations

Although this study situated empowerment as a predictor of self-management behaviors, we acknowledge that empowerment can be conceptualized as a process rather than a state (22), and further conceptual refinement is needed. The process perspective suggests that an initial level of patient empowerment continuously changes, and develops during the course of a patient’s self-management process.

There was some concern about reliability and comparability of coding in the app analysis due to the dynamic nature of the diabetes apps and the marketplace. Accessibility to app features and functions, as well as displayed content, varied considerably. Acceptable inter-coder reliability was arrived at by means of appropriate strategies. Similarly, the fluctuating app market created stability problems for app selection (4 percent of apps had...
been removed from the app store between the app collection and the main coding); this needs to be addressed in future research.

The inclusion criteria potentially created bias by only examining free-to-download apps for diabetes self-management. For example, free-to-download apps may not be designed to support behavioral empowerment, because allowing shared decision making with HCPs would require virtual private network capabilities due to confidentiality issues and data protection. Further research should evaluate whether pay-to-download apps are more theoretically relevant than free-to-download apps. Similarly, including the top fifty apps in app stores might create bias in the evaluation. While it is likely that apps frequently downloaded appear at the top of the stores, this is an assumption, because ranking algorithms were nontransparent especially for the Apple App Store.

In conclusion, the study revealed that the diabetes self-management apps field is at a nascent stage of development, with current implementation failing to live up to the potential. Only a narrow set of app features supported psychological and behavioral empowerment in the sample, despite literature pointing toward the relevance of these features for empowerment. Further research is needed that examines app features corresponding to empowerment dimensions in greater detail, as well as what empowerment means for different users of apps.

Future research should further examine machine-based empowerment delivered through algorithms. Machine-based empowerment is not included in extant definitions of empowerment. It is worth contemplating whether behavioral empowerment can also be delivered by apps using automatic algorithms. In this regard, we can consider in what sense empowerment by a machine is still “behavioral” (being currently understood as influence from another individual).

The feature analysis revealed a scarcity of implemented strategies promoting app use and “stickiness.” Results suggested low app quality (technical failures, frequent advertising, lacking features); hence, further research is needed that combines aspects of app quality with the analysis looking into empowerment. It can be expected that app quality enhances or hinders the potential of apps for empowerment, by influencing its use (97:98).

**Conflicts of interest**

None.

**References**

1. Hunt CW (2015) Technology and diabetes self-management: An integrative review. World J Diabetes 6, 225–233.
2. Research2guidance (2016) Diabetes app market report 2016–2021. 2016 [access May 28, 2018]. http://research2guidance.com/wp-content/uploads/2016/10/req_2016_diabetes_-_app_market_report-Preview.pdf.
3. Nacinovich M (2011) Defining mHealth. J Commun Healthc 4, 1–3.
4. Free C, Phillips G, Galli I, et al. (2013) The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: A systematic review. PLoS Med 10, e1001362.
5. Wu Y, Yao X, Vespasiani G, et al. (2017) Mobile app-based interventions to support diabetes self-management: A systematic review of randomized controlled trials to identify functions associated with glycemic efficacy. JMIR Mhealth Uhealth 5, e35.
6. Fu H, McMahon SK, Gross CR, Adam TJ, Wyman JF (2017) Usability and clinical efficacy of diabetes mobile applications for adults with type 2 diabetes: A systematic review. Diabetes Res Clin Pract 131, 70–81.
7. Veazie S, Winchell K, Gilbert J, et al. (2018) Rapid evidence review of mobile applications for self-management of diabetes. J Gen Intern Med 33, 1167–1176.
8. Yang S, Hseu C, Lou Q (2015) Does patient empowerment predict self-care behavior and glycosylated hemoglobin in Chinese patients with type 2 diabetes? Diabetes Technol Ther 17, 343–348.
9. Asimakopoulou K, Gilbert D, Newton P, Scambler S (2012) Back to basics: Re-examining the role of patient empowerment in diabetes. Patient Educ Couns 86, 281–283.
10. Funnell MM, Anderson RM (2004) Empowerment and self-management of diabetes. Clin Diabetes 22, 123–127.
11. Snook FJ (2007) Self management of type 2 diabetes. BMJ 335, 458–459.
12. Clark NM, Houle CR (2009) Theoretical models and strategies for improving disease management by patients. In: Shumaker SA, Ockene JK, Riekert KA, eds. The handbook of health behavior change. New York: Springer, p. 19–38.
13. Gomersall T, Madill A, Summers LKM (2011) A meta-synthesis of the self-management of type 2 diabetes. Qual Health Res 21, 853–871.
14. Beck J, Greenwood DA, Blanton L, et al. (2017) National standards for diabetes self-management education and support. Diabetes Care 40, 1409–1419.
15. American Diabetes Association (2015) Living with diabetes: Complications. [access February 21, 2015]. http://www.diabetes.org/living-with-diabetes/complications/.
16. Tol A, Alhani F, Shojaeazadeh D, Sharifirad G, Moazam N (2015) An empowering approach to promote the quality of life and self-management among type 2 diabetic patients. J Educ Health Promot 4, 13.
17. Meer M (2015) Empowering patients with diabetes. Br J Nurs 24, 828.
18. Gutschoven K, van den Bulck J (2006) Towards the measurement of psychological health empowerment in the general public. In: Annual Conference of the International Comm. Association. Dresden, Germany.
19. Schulz PJ, Nakamoto K (2013) Health literacy and patient empowerment in health communication: The importance of separating conjoined twins. Patient Educ Couns 90, 4–11.
20. Spreitzer GM (1995) Psychological empowerment in the workplace: Dimensions, measurement, and validation. Acad Manage J 38, 1442–1465.
21. Thomas KW, Velthouse VA (1990) Cognitive elements of empowerment: An “interpretive” model of intrinsic task motivation. Acad Manage Rev 15, 666–681.
22. Rappaport J (1987) Terms of empowerment/exemplars of prevention: Toward a theory for community psychology. Am J Commun Psychol 15, 121–148.
23. Funnell MM, Anderson RM, Arnold MS, et al. (1991) Empowerment: An idea whose time has come in diabetes education. Diabetes Educ 17, 37–41.
24. Lee M, Koh J (2001) Is empowerment really a new concept? Int J Hum Resour Manage 12: 684–695.
25. Logan MS, Ganster DC (2007) The effects of empowerment on attitudes and performance: The role of social support and empowerment beliefs. J Manag Stud 44: 1523–1550.
26. Conger JA, Kanungo RN (1998) The empowerment process: Integrating theory and practice. Acad Manage Rev 13, 471–482.
27. Anderson RM, Funnell MM, Fitzgerald JT, Marrero DJ (2000) The diabetes empowerment scale: A measure of psychosocial self-efficacy. Diabetes Care 23, 739–743.
28. Bandura A (1997) Self-efficacy: The exercise of control. New York, NY: Freeman.
29. Oh HJ, Lee B (2012) The effect of computer-mediated social support in online communities on patient empowerment and doctor-patient communication. Health Commun 27, 30–41.
30. Burke SD, Sherr D, Lipman RD (2014) Partnering with diabetes educators to improve patient outcomes. Diabetes Metab Syndr Obes 7, 45–53.
31. Rosland AM, Kieffer E, Israel B, et al. (2008) When is social support important? The association of family support and professional support with specific diabetes self-management behaviors. J Gen Intern Med 23, 1992–1999.
32. Heisler M, Vijan S, Makki F, Piette JD (2010) Diabetes control with reciprocal peer support versus nurse care management: A randomized trial. Ann Intern Med 153, 507–15.
33. Emanuel EJ, Emanuel LL (1992) Four models of the physician-patient relationship. JAMA 267, 2221.
34. Heisler M, Bouknight RR, Hayward RA, Smith DM, Kerr EA (2002) The relative importance of physician communication, participatory decision making, and patient understanding in diabetes self-management. J Gen Intern Med 17, 243–252.
35. Roter DL, Hall JA (1989) Studies of doctor-patient interaction. Ann Rev Public Health 10, 163–180.
36. Omboni S, Caserini M, Coronetti C (2016) Telemedicine and m-health in hypertension management: Technologies, applications and clinical evidence. High Blood Press Cardiovasc Prev 23, 187–196.
37. Whitehead L, Jacob E, Towell A, Abu-Qamar M, Cole-Heath A (2018) The role of the family in supporting the self-management of chronic conditions: A qualitative systematic review. J Clin Nurs 27, 22–30.
38. Strom JL, Egede LE (2012) The impact of social support on outcomes in adult patients with type 2 diabetes: A systematic review. Curr Diab Rep 12, 769–781.
39. Isaksun U, Hajdarevic S, Abramsson M, Stenvall J, Hornsten A (2015) Diabetes empowerment and needs for self-management support among people with type 2 diabetes in a rural inland community in northern Sweden. Scand J Caring Sci 29, 521–527.
40. Shao Y, Liang L, Shi L, Wan C, Yu S (2017) The effect of social support on glycemic control in patients with type 2 diabetes mellitus: The mediating roles of self-efﬁcacy and adherence. J Diabetes Res 2017, 2804178.
41. Kleier JA, Dittman PW (2014) Attitude and empowerment as predictors of self-reported self-care and A1c values among African Americans with diabetes mellitus. Nephrol Nurs J 41, 487–493.
42. Camerini L, Schulz PJ, Nakamoto K (2012) Differential effects of health knowledge and health empowerment over patients’ self-management and health outcomes: A cross-sectional evaluation. Patient Educ Couns 89, 337–344.
43. Grant RW, Schmittelja JA (2013) Adults with diabetes who perceive family members’ behaviour as unsupportive are less adherent to their medication regimen. Evid Based Nurs 16, 15–16.
44. Bennich BB, Roder ME, Overgaard D, et al. (2017) Supportive and non-supportive interactions in families with a type 2 diabetes patient: An integrative review. Diabetol Metab Syndr 9, 57.
45. Anshari M, Almunawar MN (2015) mHealth technology implication: Shifting the role of patients from recipients to partners of care. In: Adibi S, ed. mHealth multidisciplinary verticals. Boca Raton: CRC Press.
46. El-Gayar O, Timsina P, Nawar N, Eid W (2013) Mobile applications for diabetes self-management: Status and potential. J Diabetes Sci Technol 7, 247–262.
47. Krosel M, Søgv L, Vidmar L, Dinevski D (2016) Empowering diabetes patients with mobile health technologies. In: Bonney W, ed. Mobile health technologies – theories and applications. InTech.
48. Park S, Burford S, Lee JY, Toy L (2016) Mobile health: Empowering people with type 2 diabetes using digital tools. Canberra: News & Media Research Centre, University of Canberra.
49. Bradley M, Arsend E, Grotland A (2015) Mobile health: Empowering patients and driving change. Trends Endocrinol Metab 26, 114–117.
50. Cumming TM, Strnadova I, Knox M, Parmenter T (2014) Mobile technology in inclusive research: Tools of empowerment. Disabil Society 29, 999–1012.
51. Park S, Burford S, Hanlen L, et al. (2016) An integrated mHealth model for type 2 diabetes patients using mobile tablet devices. J Mobile Health Technol 5, 24–32.
52. Li Y, Owen T, Thimbleby H, Sun N, Rau P-LP (2013) A design to empower patients in long term wellbeing monitoring and chronic disease management in mHealth. In: Beuscart-Zéphir MC, Jaspers M, Kuziemsksy CE, Nehr C, Aarts J, eds. Context sensitive health informatics: Human and sociotechnical. Amsterdam: IOS Press, p. 82–87.
53. Mantwill S, Fiordelli M, Ludolph R, Schulz PJ (2015) EMPOWER – support of patient empowerment by an intelligent self-management pathway for patients: Study protocol. BMC Med Inform Decis Mak 15, 18.
54. Miller LMS, Sutter CA, Wilson MD, et al. (2017) An evaluation of an eHealth tool designed to improve college students’ label-reading skills and feelings of empowerment to choose healthful foods. Front Public Health 5, 359.
55. Camerini L, Schulz PJ (2012) Effects of functional interactivity on patients’ knowledge, empowerment, and health outcomes: An experimental model-driven evaluation of a web-based intervention. J Med Internet Res 14, e105.
56. Burner E, Lam CN, DeRoss D, et al. (2018) Using mobile health to improve social support for low-income Latino patients with diabetes: A mixed-methods analysis of the feasibility trial of TEXT-MED+ FANS. Diabetes Technol Ther 20, 39–48.
57. Conway N, Campbell L, Forbes P, Cunningham S, Wake D (2016) mHealth applications for diabetes: User preference and implications for app development. Health Inform J 22, 1111–1120.
58. Drincic A, Pralahal P, Greenwood D, Klonoﬀ DC (2016) Evidence-based mobile medical applications in diabetes. Endocrinol Metab Clin North Am 45, 943–965.
59. Statista (2014) Prevalent features of the diabetes apps on the United Kingdom (UK) market in 2014, by factor. [access September 21, 2017]. http://www.statista.com/statistics/450086/diabetes-management-by-health-app-united-kingdom-uk/.
60. Demidowich AP, Lu K, Tamlar R, Bloomgarden Z (2012) An evaluation of diabetes self-management applications for Android smartphones. J Telemed Telecare 18, 235–238.
61. Heintzman ND (2016) A digital ecosystem of diabetes data and technology: Services, systems, and tools enabled by wearables, sensors, and apps. J Diabetes Sci Technol 10, 35–41.
62. Beckman D, Reechor CM, Henrikens A, et al. (2016) Better glucose regulation through enabling group-based motivational mechanisms in cloud-based solutions like Nightscout. Int J Integr Care 16, 4.
63. Arnhold M, Quade M, Kirch W (2014) Mobile applications for diabetics: A systematic review and expert-based usability evaluation considering the special requirements of diabetes patients age 50 years or older. J Med Internet Res 16, e104.
64. Brzan PP, Rotman E, Pajnikihar M, Klansjek P (2016) Mobile applications for control and self management of diabetes: A systematic review. J Med Syst 40, 210.
65. Rodriguez JA, Singh K (2018) The Spanish availability and readability of diabetes apps. J Diabetes Sci Technol 12, 719–724.
66. Rossi MG, Bigi S (2017) mHealth for diabetes support: A systematic review of apps available on the Italian market. mHealth 3, 16.
67. Hides L, Kavanagh D, Stoyanov S, et al. (2014) Mobile application rating scale (MARS): A new tool for assessing the quality of health mobile applications. Melbourne: Young and Well Cooperative Research Centre.
68. Chavez S, Fedele D, Guo Y, et al. (2017) Mobile apps for the management of diabetes. Diabetes Care 40, e145–e146.
69. International Data Corporation (2015) Smartphone OS market share, q2 2015. [access October 22, 2015]. http://www.idc.com/prodserv/mobile-os-market-share.jsp.
70. Statista (2015) Number of free and paid mobile app store downloads worldwide from 2011 to 2017 (in billions). [access October 15, 2015]. http://www.statista.com/statistics/271644/worldwide-free-and-paid-mobile-app-store-downloads/.
71. Department of Statistics Singapore (2015) General household survey 2015. Singapore: Department of Statistics Singapore.
72. Viennot N, Garcia E, Nieh J (2014) A measurement study of Google Play. In: ACM International Conference on Measurement and Modeling of Computer Systems.
73. Grundy QH, Wang Z, Bero LA (2016) Challenges in assessing mobile health app quality: A systematic review of prevalent and innovative methods. Am J Prev Med 51, 1051–1059.
74. Dogruel I, Joeckel S, Bowman ND (2015) Choosing the right app: An exploratory perspective on heuristic decision processes for smartphone app selection. Mob Media Commun 3, 125–144.
75. Holsti OR (1969) Content analysis for the social sciences and humanities. Reading, MA: Addison-Wesley.
76. Kreuter MW, Wray RJ (2003) Tailored and targeted health communications: Strategies for enhancing information relevance. Am J Health Behav 27(Suppl 3), 227–232.
77. American Diabetes Association (2010) Diagnosis and classification of diabetes mellitus. *Diabetes Care* 33(Suppl 1), S62-S69.
78. Thabrew H, Stasiak K, Garcia-Hoyos V, Merry SN (2016) Game for health: How eHealth approaches might address the psychological needs of children and young people with long-term physical conditions. *J Paediatr Child Health* 52, 1012–1018.
79. Lau PWC, Lau EY, Wong DP, Ransdell L (2011) A systematic review of information and communication technology-based interventions for promoting physical activity behavior change in children and adolescents. *J Med Internet Res* 13, e48.
80. Lister C, West JH, Cannon B, Sax T, Brodegard D (2014) Just a fad? Gamification in health and fitness apps. *JMIR Serious Games* 2, e9.
81. Johnson D, Deterding S, Kuhn K-A, et al. (2016) Gamification for health and wellbeing: A systematic review of the literature. *Internet Interv* 6, 89–106.
82. Lewis ZH, Swartz MC, Lyons EJ (2016) What’s the point?: A review of reward systems implemented in gamification interventions. *Games Health J* 5, 93–99.
83. Glajchen M, Bookbinder M (2001) Knowledge and perceived competence of home care nurses in pain management. *J Pain Symptom Manage* 21, 307–316.
84. Barengo NC, Debussche X, Besançon S, et al. (2018) Structured peer-led diabetes self-management and support in a low-income country: The ST2EP randomised controlled trial in Mali. *Plos One* 13, e0191262.
85. Howorka K, Pumplra J, Wagner-Nosiska D, et al. (2000) Empowering diabetes out-patients with structured education. *J Psychosom Res* 48, 37–44.
86. Cook DA, Levinson AJ, Garside S (2010) Time and learning efficiency in internet-based learning: A systematic review and meta-analysis. *Adv Health Sci Educ* 15, 759–770.
87. Villanti AC, Cantrell J, Pearson JL, Vallone DM, Rath JM (2014) Perceptions and perceived impact of graphic cigarette health warning labels on smoking behavior among U.S. young adults. *Nicotine Tob Res* 16, 469–77.
88. Jansen J, McCaffery KJ, Hayen A, Ma D, Reddel HK (2012) Impact of graphic format on perception of change in biological data: Implications for health monitoring in conditions such as asthma. *Prim Care Respir J* 21, 94–100.
89. Ramirez AG, Turner BJ (2010) The role of peer patients in chronic disease management. *Ann Intern Med* 153, 544–545.
90. Katz R, Mesfin T, Barr K (2012) Lessons from a community-based mHealth diabetes self-management program: “It’s not just about the cell phone”. *J Health Commun* 17(Suppl 1), 67–72.
91. Kwong W (2015) What is government’s role in medical apps? CMAJ 187, E339.
92. Miller KH, Ziegler C, Greenberg R, Patel PD, Carter MB (2012) Why physicians should share PDA/smartphone findings with their patients: A brief report. *J Health Commun* 17(Suppl 1), 54–61.
93. Maki KG, O’Mally AK (2018) Analyzing online social support within the type 1 diabetes community. In: Sekalala S, Niezgoda BC, eds. *Global perspectives on health communication in the age of social media*. Hershey, PA: IGI Global, p. 59–84.
94. Furner CP, Racherla P, Babb JS (2016) What we know and do not know about mobile app usage and stickiness. A research agenda. In: Information Resources Management Association, ed. *Geospatial research: Concepts, methodologies, tools, and applications*. Hershey, PA: Science Reference, p. 117–141.
95. DeShazo J, Harris L, Turner A, Pratt W (2010) Designing and remotely testing mobile diabetes video games. *J Telemed Telecare* 16, 378–382.
96. Brahambhatt R, Niakan S, Saha N, et al. (2017) Diabetes mHealth apps: Designing for greater uptake. In: Lau F, et al. eds. *Building capacity for health informatics in the future*. Amsterdam: IOS Press. p. 49–53.
97. Dutta MJ, Pfister R, Kosmoski C (2010) Consumer evaluation of genetic information online: The role of quality on attitude and behavioral intentions. *J Comput Mediat Commun* 15, 592–605.
98. Inukollu VN, Keshamon DD, Kang T, Inukollu M (2014) Factors influencing quality of mobile apps: Role of mobile app development life cycle. *Int J Softw Eng Appl* 5, 15–34.