Dietary compliance in adolescents with Celiac Disease using Celi-app

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ABSTRACT

Celiac disease (CD) is a genetically conditioned autoimmune process that appears in about one in 250 people. The disease is caused by a reaction to gluten, a group of various proteins found in wheat and in other grains such as barley and rye. The only effective treatment is a lifelong Gluten Free Diet. Adherence to a Gluten Free Diet is a challenge especially for adolescents for various reasons. Transgressions in diet however, can lead to severe longterm illnesses like osteoporosis and cancer. Within the medical practice it is widely recognised that controlling the follow up of a GFD is important, however there are currently no clear guidelines or procedures to assess the adherence to GFD. This studies examines whether mHealth technology intervention can be used as a tool in the monitoring of Celiac patients. Three groups of adolescents with CD will take part. Two groups are given Celi-app to assess compliance to GFD, respectively a non-gamified and a gamified version, and a control group who is given no app. It is believed that CD patients will improve on GFD compliance without the burden of meeting with a physician or dietist by using the apps. The app highly relies on self-reporting, but also contains a feature for uploading GIP results. Because the app is based on selfreport highly, CD patients can indicate their beliefs about their exposure to gluten in two occasions: in interpretation of their GIP result and in logging their meals. Furthermore the gamified app adds self efficacy and knowledge about following a GFD by using gamification techniques. This research involves a mixed method experiment that compares data entry in both apps with standardized structural questionnaires measuring GFD compliance and sense of self control. This research shows that .... *"gamified version of monitoring celiac disease yield significantly higher scores on diet adherence as well as on reports of self control over the diet, meaning a significantly better experience in quality of life ..... or not....."*

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *User studies.*

KEYWORDS

Celiac, Gluten, Gluten free diet, adolescents, diet compliance, GIP, diet adherence, Mobile Health (mHealth)

1 INTRODUCTION

Celiac disease (CD) is a genetically conditioned autoimmune process that appears in about one in 250 people. The disease is caused by a reaction to gluten, a group of various proteins found in wheat and in other grains such as barley and rye [27]. Celiac disease can develop at any age, and slightly predominates in females [13]. Symptoms range from the classic signs of malabsorption syndrome — diarrhea, weight loss, growth failure, osteoporosis, and anemia — to nonspecific symptoms such as chronic constipation or abdominal pain [19]. Research has also indicated that a majority of people are asymptomatic, while having the disease. Therefore most people remain undiagnosed if they are not actively screened [29].

The only effective treatment is a strict and permanent gluten-free diet (GFD). The effectiveness of such a diet produces significant clinical improvement in not only digestive symptoms, but also in the extra intestinal symptoms associated with CD [5, 30]. However, the level of compliance to such a diet is difficult and poor, especially in adolescents between ages of 12 and 17[37, 40]. Compliance with GFD in adolescents has been reported to be between 52% and 81% [37]. Poor compliance is attributed to stigmatisation and isolated feelings in social situations, as well as lack of knowledge regarding CD an GFD [40]. Within the family environment adolescents seem to struggle with adherence to GFD al lot less than when socializing with friends. These situations may lead to transgressions, which are often associated with feelings of anger and envy. Thus, adhering to GFD has an impact on not only food consumption but also on the general lifestyle and quality of life (QOL) of individuals with CD. Wagner(2008) found that adolescents who were noncompliant with their GFD experienced a lower general QOL, especially lower physical health, with a higher feeling of ill-being, more family problems, and problems in their leisure time. CD-associated burden has been highest in patients with frequent dietary transgressions. They anticipated their future would be more difficult. [37].

Adolescents who were diagnosed with CD in their childhood seem to experience more dilemmas adhering to a GFD related to eating out, peer pressure and cross-contamination as they grow older. Cross contamination appears when people who ate or touched gluten products inadvertently drop fragments of gluten[28, 35]. Furthermore, patients diagnosed later in life, seem to have more difficulty adhering to a GFD than patients who have been diagnosed in early childhood [37].

Transgressions in diet delay patient recovery. If transgressions are frequent, various types of associated long term complications may appear [36]. Factors that improve chances of compliance are: early diagnose, presence of symptoms after ingestion, a good awareness in family and patient, frequent follow-ups by nutritionists or physicians. A study by Ciccocioppo (2015) states that *"patient 's education, close supervision with scheduled nutritional counselling and maintenance of dietary adherence when travelling or dining out, are all crucial factors needed to achieve full compliance"* [6]. Persistence of symptoms are generally related to irregular, or poor dietary compliance, or - clearly - with continued gluten consumption, specially in adolescents[28].

2 DIETARY COMPLIANCE MEASUREMENT

Although the importance of controlling the follow up of the GFD is widely recognised, there are no clinical guidelines that guarantee results, nor are there procedures to assess the adherence to a GFD

and the transgressions that occasionally occur. At the moment most clinical monitoring of diet compliance is done by

- clinical follow up visits
- visits to expert nutritionists (self reports)
- serological time controls of antibodies
- serial endoscopies
- structural questionnaires and
- determination of gluten peptides from gluten in faeces or urine.

All of these procedures have proven to be useful when applied, alone or in combination, depending on the cases. These methods are quite expensive and time consuming as they require specialist time and effort to consult the patient and analyse the results. Furthermore, Serological time controls of antibodies are not effective when changes in antibodies are small and endoscopies are quite unpleasant, next to it's effectiveness being maximised only for cases that are not associated with clinical improvement or serological changes [28].

2.1 Follow ups and Self reports

Monitoring of compliance is often done by repeated administration of questionnaires, but these are not always available in all centers[28]. Furthermore follow ups are often not visited. Patients indicate that they are managing their CD on their own, especially when symptoms reduce or disappear. When quality of life and disease specific symptoms worsen however, patients are more likely to visit a follow up. Remarkable however is, that when patients make dietary transgressions, they are less likely to visit a follow up [17].

Silvester (2017) noted an important finding concerning selfreports in GFD compliance: reports that do not facilitate for the possibility of unintentional gluten ingestion overestimate GFD adherence. Individuals who believe they are following a GFD are not readily able to correctly identify foods that are GF, which suggests ongoing gluten consumption may be occurring, even among patients who believe they are “strictly" adherent [34].

2.2 Structural Questionnaries

Structured short questionnaires are used as an alternative to consultations with a dietician to obtain a rapid assessment of the adherence to the GFD. It is easy to complete this type of questionnaire in the patient’s usual clinic. The responses are highly correlated with antibody levels and the presence of VA in duodenal biopsies and useful for monitoring. In general, questionnaires are easy to administer and often complement each other. They not only assess the quality of life, in a general or specific way, but also are able to estimate the changes occurring after the follow-up of the GFD[28].

2.3 Biomarkers

Biomarkers, also called gluten immunogenic peptides (GIP) are far less invasive and promising when it comes to accurately detecting gluten in food [28]. They look like a pregnancy predictor stick and are used in the same manner. A big advantage compared to other methods of selfreporting, questionnaires of follow ups is that this method generates an accurate measure of dietary adherence in an non invasive way and can be linked to gluten exposure directly. Therefore GIP, being easy to use and relatively inexpensive, enables a direct and quantitative assessment of gluten exposure [31].

3 GOALS

Former research on diet adherence by Celiac patients has made four things clear:

a) There is no clinical guideline or procedure to assess adherence to GFD, even though the necessity of monitoring CD patients is widely recommended.
b) Adolescents have difficulty adhering to a GFD for various reasons.
c) Follow ups are often not visited, especially in the case of diet transgressions
d) Some currently used methods for dietary compliance measurement are not always reliable, on top of being expensive, patient unfriendly and time consuming.

This study aims to improve GFD compliance by using Celi-app, which are two custom made health monitoring mobile apps as a new method for monitoring GFD compliance in adolescents with CD. The main research question is: *What effect does gamification have on GFD compliance in adolescents with celiac disease?*. Both apps aim to improve frequency of self-reporting in relation to food intake, experiencing symptoms, perceived energy levels and using a biomarker that indicates gluten intake in urine. In doing so, it is believed that patients will improve on GFD compliance without the burden of meeting with a physician or dietist. The apps highly rely on self-reporting, but also contain a feature for uploading GIP results. Because the app is based on self-report highly, patients can indicate their beliefs about their exposure to gluten in two occasions: in interpretation of their GIP result and in logging their meals. This way Silvester 's (2016) notion about unintentional gluten intake has been taken into account within the design of Celi-app. The gamified version tries to not only improve on self-reporting and insight, but also aims on improving on feelings of self efficacy. The concepts behind the designs will be layed out in chapter 5.

3.1 Definitions

Diet adherence The WHO defines adherence as *"the extent to which a person's behaviour – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider"* [25]. Studies over the years have conflicted with what they consider to be "safe" thresholds for gluten intake on a gluten-free diet. Some have suggested that 625 milligrams (mg) per day (roughly one-fifth a slice of bread) is perfectly fine, while others raise the red flag at anything over 10 mg per day (1350th of a slice). In general, if your gluten intake is less than 10 mg a day most people are fine. A typical western european diet contains about 20 grams of gluten per day[7].

mHealth Mobile Health (mHealth) aims at delivering healthcare services regardless of any mobility constraints, i.e. overcoming geographical, temporal, and organizational barriers. It supports direct access to health services regardless of time and place and allows to reduce high costs of existing national health services. Indeed, it empowers patients and families to self-care being suitable to help address chronic and lifestyle related diseases [2].

Health related Quality of Life (HRQoL) HRQoL focuses on the aspects of QoL that are affected by health. For example, HRQoL is defined as *"those aspects of self-perceived well-being that are related to or affected by the presence of disease or treatment"*. Many HRQoL measures are in fact measures of self-perceived health status [18, 42].

4 MONITORING HEALTH USING M-HEALTH TECHNOLOGIES

mHealth technologies have recently been implemented as patient self-management tools in the treatment of chronic diseases such as diabetes mellitus, lung disease, cardiovascular disease and kidney disease [41]. Researchers believe the ease of access to resources that mHealth technology provides can augment the patient's ability to engage in self-care activities, and may lead to better patient health outcomes, well-being, and QoL [38].

Hamine et al. (2015) conducted a systematic review looking at adherence rates and patient outcomes after using mobile device mHealth interventions (e.g., SMS, video messaging, electronic medication monitoring) in 107 studies on diabetes mellitus (67/107), chronic lung diseases (19/107), and cardiovascular diseases (27/107). Out the 107 studies reviewed, 50 of these were randomised controlled trials (RCT) with 56% showing significant effects on adherence. The other 67 studies were qualitative, providing user feedback and critical data on how and why mHealth tools impacted adherence behaviours [15].

Whitehead et al. (2016) reviewed the effectiveness of self-management mobile phone and tablet apps in long-term condition management in nine studies on diabetes mellitus (5/9), chronic lung disease (3/9), and cardiovascular disease (1/9) from 2005 to 2016. Six of the nine studies demonstrated statistically significant improvement in symptom control [41].

mHealth interventions used in CD patient management/monitoring are scarce. Some have used SMS text reminders, online educational courses, and evidence-based nutritional advice in the form of a smartphone application [11, 14, 32]. Other apps have been focusing around the social aspects surrounding CD in providing for support about food, restaurants and a patient sharing platform [3]. A qualitative study evaluated 17 apps around celiac disease on engagement, functionality, aesthetics and information. The apps scored high on functionality, but engagement scores were lowest and scores on health information were low. Apps designed with the help of Health Care Providers (HCP) scored highest. MyHealthyGut scored highest in this study, an app designed in collaboration with a HCP and monitors food intake and symptoms along with other functionalities about Celiac Disease [33]. This app has been used in a study addressing GFD adherence and came with interesting results. After using the MyHealthyGut app for a month, participants reported improvements in psychosocial outcomes, but dietary adherence over the time course of a month worsened in both experimental groups. However, symptoms in the first experimental group reduced significantly, which might be a strong indicator of the effectiveness of using apps for GFD monitoring [12].

5 APP DESIGN RATIONALE

Research on internet interventions (electronic health) and mHealth shows that they are more likely to be useful if they are firmly rooted in health behaviour change theory [9].In order to accomplish GFD adherence in adolescents, it is important to think about what features are most important to achieve a change in behaviour and what the target audience deems important. To accomplish this there are four relevant steps.

(1) Describe the behavioural target: what is the aim and the context in which the behavioural change has to take place?
(2) Analyse what is needed for it to be attained
(3) Choose from available intervention options based on the analysis
(4) Construct specific behaviour change techniques to make up the interventions

[24].

Theories on behavioural change and gamification are helpful in conducting all of these steps, because it helps us identify behavioural targets and construct digitized behavioural change techniques that match these targets.

5.1 Behaviour Change Theory and PRIME Theory

Behaviour occurs as an interaction between

- capability: the psychological or physical ability to enact the behaviour,
- motivation: reflective and automatic mechanisms that activate of inhibit behaviour and
- opportunity: the physical and social environment that enables the behaviour.

In literature this concept is referred to as the COM-B model (figure 1) [24]. In this model, capability and opportunity are described as influencing motivation and behaviour, rather than influencing behaviour directly. They could be interpreted as requirements to generate behaviour and have a large influence on motivation. Therefore motivational intervention lies at the heart of this model, as it is important to increase motivation towards the desired behaviour as well as reduce motivation continuing with the undesired behaviour. Therefore, getting insight into the consequences of behaviour, developing positive feelings toward the change and getting confidence to change are important aspects in order to accomplish this. [39].

PRIME theory of motivation strives to capture models and theories on motivation with focus on choice processes, emotions and drives, habit and instinct, into one framework. According to this framework impulses or inhibitions of behaviour (response) are generated from sensory or perceptual processes through learned or innate associations, or generated by motives. Motives are feelings of 'want or need'. All goal directed behaviour have either wants: anticipated pleasure or statisfaction or needs: anticipated relief from mental or physical discomfort. PRIME theory recognises a fundamental principle of human behaviour in that at every moment we act in pursuit of what we most want or need at that moment. Therefore, in attempting changing behaviour by changing motivation, one of the targets is to manipulate momentary wants and needs. Those wants and needs are driven by positive and negative

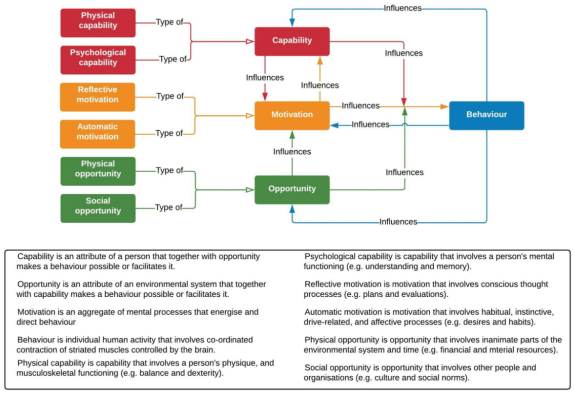

Figure 1: COM-B model

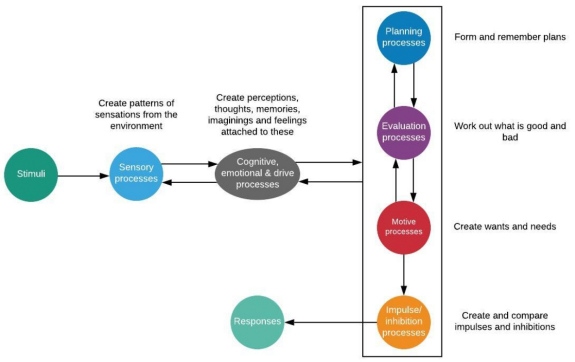

Figure 2: The structure of human motivation according to PRIME Theory

emotions, as well as by evaluations and beliefs about good or bad, harmful or beneficial. These thoughts can also be generated by plans: self-conscious intentions to enact behaviours under certain conditions. Personal rules are plans that represent practical and moral concepts governing our behaviour. Plans and personal rules can only influence behaviour if they are activated at the relevant moment. If plans are activated, they generate beliefs, which then generates wants or needs that leads to an impulse or inhibition, that we recognise as a response and thus as behaviour being executed 2. As this model is rather simplified, there is big competition between plans, beliefs or wants and needs at any point in time, which complicates the actual outcome of the desired behaviour [39].

5.2 Designing interventions

PRIME theory is useful for developing behaviour change interventions, because it has boiled down the concept of motivation into processes and aspects that enables us to translate them into behavioural targets, which is described as the first step [24]. In a systematic review of 19 frameworks on behaviour change, the COM-B model was elaborated upon with 9 intervention functions of which each function includes one or more behaviour change techniques. The functions include for example education, enablement, training, modelling. Around these are 7 policy categories, that enable or support the interventions to occur. This results in a Behaviour Change Wheel (BCW) [24]. The BCW is a tool that may help in step two: analyzing what is needed to achieve behavioural targets and thus deciding upon intervention functions that lead us to a more limited set of options to choose from. Abraham and Michie [1] and Michie et al. [23] suggest 23 behaviour change techniques (BCT) as a result of a review of many health behaviour theories, which can be used in step three. Ultimately, the last step is about translating these options into digitized intervention techniques. De Korte et al [9] have studied different health apps to see which of these 23 BCT are most frequently used. These are:

- provide feedback on performance
- prompt self monitoring of behaviour
- prompt specific goal setting
- provide opportunities for social comparison
- plan social support or social change

According to Michie et al.[22]interventions targeting diet and physical activity that include feedback on performance, combined with selfmonitoring, goal setting, intention formation and review of goals are associated with greater effectiveness.

5.3 Implementation of PRIME Theory in Celi-app

In summary, two main behavioural targets (BT's) are important considering Celi-app:

(1) establishing or improving GFD compliance
(2) establishing or improving HRQoL, such as self-efficacy.

The first BT will be addressed in both versions of Celi-app. The second one will only be implemented in the gamified version. Not surprisingly, goal setting and feedback on performance reoccur in app studies as frequently used BCT's since PRIME theory states that planning and evaluation of the process or two important steps that influence motivation that lead to possible changes in behaviour (wants and needs) if it occurs at the right moment. In case of diet compliance it is important to encourage self monitoring and give feedback upon goals and performance. That's why self monitoring features about food intake, perceived energy levels and symptoms are at the core of Celi-app. Encouragement is done by asking the user to set daily goals, in order to create a sense of commitment, feedback on performance of these daily goals is provided for, as well as an overview of your diet and a weekly report, which shows feedback on mastering your GFD. Participants will receive notifications (once a day) as a means to remind them of their plans. The BCT's that have been implemented according to the taxonomy of Abraham and Michie [1] are listed below, behind those you can read where or how it is implemented in Celi-app, for a more comprehensive overview of the app-flow see figure 3

- provide feedback on performance -> mainscreen and weekly report
- provide information about behaviour - health link -> weekly report
- prompt self-monitoring of behaviour -> notifications and logging screens

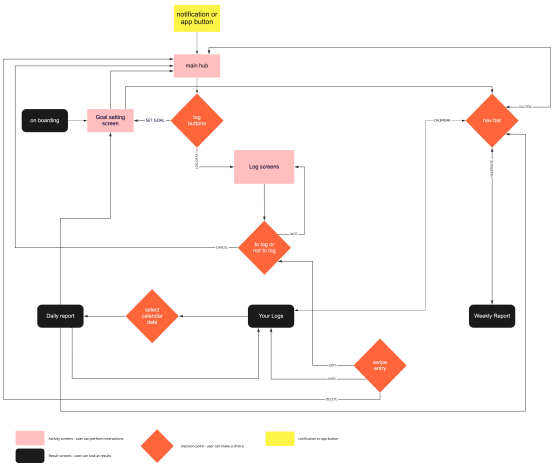

Figure 3: Flowchart of non-gamified Celi-app

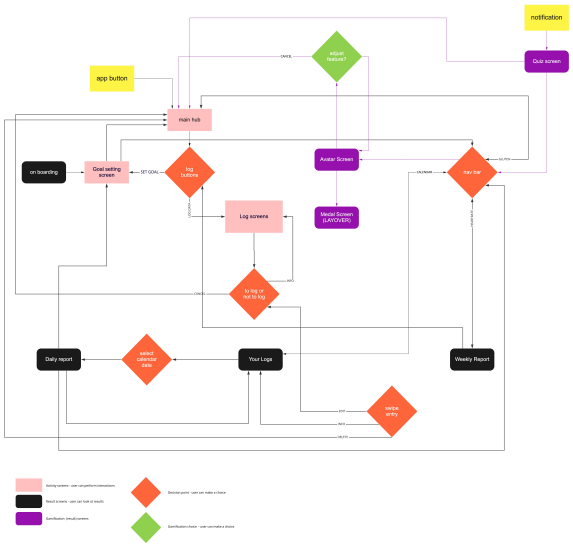

Figure 4: Flowchart of gamified Celi-app

- prompt specific goal settings -> goal setting screens and notifications
- provide general encouragement -> main screen, avatar
- prompt review of behavioural goals -> calendar overview and weekly reports

5.4 Implementation of Gamification theory in Celi-app

The second version of Celi-app focuses on improving HRQoL, next to all features present in the non gamified version. Gamification relies on the assumption that ingredients of games such as leaderboards, badges, levels, communities and avatars that make games addictive can be applied to non-game environments as to encourage beliefs, thoughts or behaviour change [10]. Often gamification apps are based on Self Determination Theory (SDT) of motivation, which separates intrinsic from extrinsic motivation and divides all motivation into three key drivers: autonomy, competence and relatedness. It has both been applied successfully and unsuccesfully. Unsuccessful application of gamification techniques are mainly due to misinterpretations of SDT [21]. Therefore, gamification should be applied to have value to the user. One way to achieve that is to give meaning to badges and experience points in such a way that the user feels more competent, autonomous or related toward following a GFD [8]. Cugelman (2013) lists seven ingredients of gamification that have clear linkages to proven BCT's:

(1) goal setting: committing to achieve a goal
(2) growth, learning, development : capacity to overcome challenges
(3) providing feedback on performance
(4) reinforcement: gaining rewards, avoiding punishments
(5) compare progress: monitoring progress with self and others
(6) social connectivity: interacting with other people
(7) fun and playfulness: paying out an alternative reality

For the gamified version the BCT taxonomy these seven are preferred above Abraham and Michie's taxonomy of BCT's, since according to this taxonomy only one BCT can be added, being 'provide contingent rewards'[1]. Fun and playfulness, and capacity to overcome challenges are not listed as explicitly. Thus, in both versions of Celi-app 1, 3 and 5 are implemented. In the gamified version 2, 4 and 7 are added through respectively quiz questions, achievements and levels, and a customizable avatar. Figure 4 shows a flowchart of the screens within the gamified version of Celi-app, in which the gamified screens are indicated in purple.

6 METHOD

A systematic and iterative approach was adopted by (1) forming an expert multidisciplinary development team with the support of an HCP: St.Luke's General Hospital in Carlow, Ireland. In this setting the apps were designed and iteratively developed. (2) In doing so, the four steps as described by Michie (2013) were applied to reassure that the app be grounded in theory on Behaviour Change.(3) Then gamification techniques were decided upon and integrated and lastly (4) the apps were user tested during *The 21 day Challenge*. The apps were used during 21 days by X adolescent celiac patients, members of the Celiac society of Ireland.

The subjects of the experiment were divided into three groups: (a) control group using no app, a group that is using non-gamified Celi-app and a third group that is using the gamified Celi-app. Screenshots of the gamified and non gamified app can be found in Appendix A and B, respectively. Before the start and at the end of the 21 days, subjects were asked to fill in standardized questionnaires on celiac diet compliance and patient activation.

In all groups a selective amount of X subjects will be given a box of GIP sticks to take home. The amount is limited because at current time of the experiment, not enough GIP sticks are available to provide for all participants. The exact amount of GIP sticks that will be provided for is at time of writing unclear. Subjects not receiving GIP will be given a version of the app without the GIP logging feature.

6.1 Participants

This experiment is executed within a medical context. Therefore ethical approval will be obtained from the Ethics board at Institute of Technology, Carlow. Recruitment will be facilitated by the Celiac Society of Ireland who provides assistance contacting willing participants. Participants should be between 12 and 25 years old and in possession of a confirmed medical diagnosis of celiac disease with a positive blood test or biopsy by the participants' physician. Prior to the study each participant signs an informed consent form.

6.2 Procedure 21 day challenge

Subjects will be provided with an information sheet concerning the experiment and they will be asked to sign a consent form.

Subjects will be asked to fill in two validated structural questionnaires online before and at the end of the experiment, that will take 5 minutes alltogether.

CDAT (Celiac Dietary Adherence Test) CDAT consists of seven structured questions about compliance and is scored on a Likert scale from 1 to 5, so that summing the values obtained gives an overall score from 7 to 35. Values less than 13 are considered to show good compliance, while those over 17, represent intermediate or low adherence [20].

PAM (Patient Activation Measure) The Patient Activation Measure is a valid, highly reliable, unidimensional, probabilistic Guttman-like scale that reflects a developmental model of activation. It consists of 13-items and scores range from 0 to 100; higher scores indicate greater patient activation. Activation appears to involve four stages: (1) believing the patient role is important, (2) having the confidence and knowledge necessary to take action, (3) actually taking action to maintain and improve one's health, and (4) staying the course even under stress. The measure has good psychometric properties indicating that it can be used at the individual patient level to tailor intervention and assess changes[16].

After having filled in the standardised questionnaires subjects are asked to download and install the app on their phones. From that moment on, the 21 day challenge has started and data entry may begin. During the challenge the app groups will both receive notifications at set times and at the end of each week they will receive a weekly report by mail, which can also be found in the app itself.

At the end of 21 days, subjects will again be asked to fill in CDAT and PAM questionnaires, in addition to an app usability questionnaire. The latter, ofcourse will not be given to the control group. The usability questionnaire consists of fifteen questions that are divided into two sections and is used in a previous version of the 21 day challenge with web-based apps. The first section (questions 1-7) is designed to identify each healthcare practitioner's experience with technology and electronic devices, whereas the second section of the questionnaire (questions 8-15) looks to identify their attitudes beliefs of mHealth technology. The questions included in the questionnaire are influenced by similar themes used by [4, 26, 38] who looked at perceived positive effects and barriers of mHealth technologies, previous experience with technology, attitudes and beliefs towards mHealth technologies, and current knowledge of mHealth technologies/telemedicine, respectively.

6.3 Hypotheses

Control group and app groups will be compared on the following aspects with the goal to find out what effect gamification has on GFD adherence in Celiac adolescents. The app were designed with two main behaviour targets. BT1 : Establish or improve GFD compliance over the course of 21 days BT2 : Establish or improve feeling of self-efficacy and knowledge about celiac disease. (HRQoL) Hypothesis A is that there will be a significant difference concerning BT1 between both appgroups and the control group, in which both app groups score higher on GFD compliance. Hyopthesis B is that there will be a significant difference concerning BT2 between the non-gamified and the gamified group, in which the gamified group scores higher on PAM, which is a standardized measure of self-efficacy in healthcare.

Next to scores on PAM and CDAT, usage of features in the app will be analyzed as well to ground our findings

- logging intervals and frequency on all 4 input features (statistically analysed per feature)(3 features for the groups without GIP): data, food, energy level and GIP. These may give additional information on adherence scores, commitment and engagement.
- perceived diet adherence based on data submitted in food feature of the app; these may be linked to PAM scores, as they indicate their beliefs about exposure to gluten or not.
- actual GFD compliance based on data about symptoms and GIP feature, compared with data from CDAT for correlations.
- perceived energy based on energy level feature in the app, compared with PAM data for correlation.
- app usability based on questionnaire.
- influence of notifications based on logging intervals and frequency after notifications have been send.
- transgression frequency by looking at the GIP, symptom and food diary data. Both correlation within app, as well as comparison between apps.

Hypothesis is that the gamified app (C) will perform significantly better on all aspects mentioned above than the non-gamified version.

6.4 Statistics

The following statistical methods will be used:

(1) Bayesian AB testing to test control group against app group for CFD compliance and PAM scores. A vs. B and C. for hypothesis A.
(2) Bayesian AB testing on hypothesis B, involving comparison between above mentioned variables of versions B and C. for hypothesis B.
(3) Pearson's correlation within app between entered data about GIP results, symptoms, food intake and energy levels
(4) Pearson's correlation between entered questionnaires and entered app data within each testing group.

Correlation data tell us something about the usefulness of the app for measuring CFD compliance, whereas the Bayesian AB testing tells us something about the usability of certain implemented features.

7 RESULTS

8 DISCUSSION AND CONCLUSION

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