Motivational Design Techniques to Increase Adherence to a Telemonitoring Therapy

A Study with Adolescent Pectus Patients

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Abstract—The most common surgery for pectus patients is associated with severe acute and persistent postoperative pain. It is, therefore, important that patients are adequately monitored after their surgery to prevent the chronification of pain. This paper provides a deeper understanding of young adolescents when they are asked to use a telemonitoring platform for their postoperative follow-up. Motivational design techniques, such as gamification mechanics, were integrated into 17 alternative designs and evaluated via a mixed-method approach with eight pectus patients and nine parents. The quantitative scoring of all 17 designs on a seven-point Likert scale showed that participants appreciated the designs and were motivated to adhere to their telemonitoring therapy when adequately supported by the platform. A thematic analysis of in-depth interviews conducted in the context of their homes confirmed that pectus patients had the will to be adherent, were invested in their own well-being, appreciated technical feedback, valued their privacy, and requested a professional platform to support them in their daily telemonitoring activities.

Index Terms—Motivational design techniques, pectus, healthcare informatics, gamification.

I. INTRODUCTION

Funnel chest, a condition with a sunken appearance of the sternum, or pectus excavatum, occurs in one out of 400-1000 live births and is the most common chest wall deformity with an 80% to 90% incidence rate [1]. Pigeon chest, a raised appearance of the sternum, or pectus carinatum, is the second most common anterior chest deformity (15%) [2]. Since both patients with pectus excavatum and pectus carinatum require a similar follow-up, this paper will refer to both patient groups as *pectus patients*. Pectus patients may experience severe negative psychosocial effects and avoid activities

that expose the chest. As the symptoms become visible during childhood, surgery is frequently performed on younger patients. Moreover, the surgery is most likely performed for aesthetic reasons rather than as a necessary correction due to compression of underlying organs.

The most common surgical technique (minimal invasive pectus repair), is associated with severe acute and persistent postoperative pain, despite having a reduced surgical stress response, lower blood loss, and smaller incisions [3]. It is therefore important that patients are adequately monitored [4], [5]. However, “[d]espite the increased scientific interest in pain management after pectus surgery [6], [7], the provision of adequate pain management and the necessary antiemetic and psychological treatments during the whole perioperative period remain a challenge for health care providers.” [1] Both preoperative psychological screening and long-term postoperative patient follow-up are needed.

New advances in the domain of healthcare informatics, such as telemonitoring, allow for better biopsychosocial follow-up. Telemonitoring is defined in this paper as the usage of information technology for the tracking and monitoring of the physical well-being of patients, at a distance [8]. Although telemonitoring is highly automated, there are still actions that are left up to the patient. Typically, patients need to setup a Bluetooth connection, wear the sensor appropriately, and charge the batteries. A lack of adherence to telemonitoring actions is therefore well documented. For example, Eysenbach [9] states that there “*is the observation that in any eHealth trial a substantial proportion of users drop out before completion and stop using the application. [...] for many eHealth trials, in particular those conducted on the Internet and in particular with self-help applications, high dropout rates may be a natural and typical feature.*”

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The Economist's Intelligence Unit [10] reported on drop-out rates of 144 mobile health companies: 67% of the users of fitness or mobile health apps who needed to enter data manually, stopped within six months. Surprisingly, in the case of automated data capturing, e.g., tracking via sensors, an even higher dropout was reported, namely 74% [11].

To maximize the effect of telemonitoring, it is important that patients are motivated to adhere to their postoperative follow-up. Prior research suggests that the addition of motivational design techniques, such as gamification mechanics, can have a positive impact on health and well-being when it targets behavioral outcomes [12], [13]. Therefore, we researched how motivational design techniques can be added to a telemonitoring platform tailored to younger patients, but also used by their parents.

To the best of our knowledge, there has been no research that focuses on motivational design techniques applied to a telemonitoring platform for pectus patients, a patient group characterized by preoperative anxiety and low self-esteem [14]; neither on potential misalignments between pectus patients and their parents. In this study, we aimed to evaluate, in a quantitative and qualitative manner, how young pectus patients perceive motivational design techniques supporting telemonitoring actions. First, we aimed to understand which motivational design techniques are rated positively and which are perceived negatively. Secondly, we aimed to explore the underlying reasons young pectus patients provide to explain these ratings, in a qualitative manner. What are the reasons underlying positive or negative ratings? The broader goal of this research study is to inform researchers and developers of telemonitoring applications on which motivational design techniques can promote increased adherence to follow-up. Hence, this study provides implications for the design and application of motivational design techniques in telemonitoring platforms for young patients facing potential persistent postoperative pain.

II. RELATED WORK

In this section, we first describe three fields of motivational design. Second, we discuss enhanced recovery pathways that can be supported with telemonitoring. Finally, the potential of motivational design targeting young adolescents is discussed.

A. Improving adherence with motivational design techniques

The term *motivational design techniques* is used in this paper as an umbrella term for all strategies that aim to improve patients' adherence, which in turn is referred to as the capacity of a patient to abide by mutually agreed recommendations regarding daily monitoring [15], [16]. This study applied techniques from three major fields of motivational design: 1) gamification, 2) persuasive design, and 3) behavior change techniques.

1) *Gamification*: Perhaps, the best known motivational design techniques are the application of gamification mechanics. The most widely-used definition of gamification is "*the use of game design elements in non-game contexts*,"

as defined by Deterding [17] in 2011. Gamification harnesses the motivational affordances of gameful experiences to influence psychological outcomes and further behavioral outcomes [18] and already has multiple applications in the healthcare informatics domain [12].

Effective gamification is a combination of game design, behavioral economics, motivational psychology, and user experience and user interface design [19]. If implemented well, gamification can increase the motivation of user's trajectories [20], [21]. However, Hamari et al. [18] have shown that gamification is not a panacea. Different user groups and personality types necessitate different gamification mechanics [22]–[24]. Hence, there is a need for research with respect to which gamification mechanics are appropriate for specific personality types and patient groups [25]. Finally, it is less known how gamification can be used within a sensitive setting, e.g., where patients submit private health data to the hospital. Little research can be found on how and what principles to implement in such a context.

Multiple gamification frameworks have been proposed in the literature that enlist different suitable gamification mechanics. For example, the octalysis framework by Chou [26], the curated list of game mechanics by Mythily and Herger [27], Tondello et al. [28]'s gameful design elements, and Marczewski [29]'s 52 gamification mechanics. All frameworks have their strengths and weaknesses and there is much overlap between them. This paper will build on Marczewski's framework [29] as it provides the most fine-grained division between mechanics.

2) *Persuasive design*: The Persuasive System Design [30] assumes that technology can be designed to change attitudes or behaviors through persuasion and social influence [31]. The model contains 28 design principles grouped in four categories: 1) primary task support, e.g., setting tailored goals or supporting self-monitoring, 2) dialogue support, e.g., sending reminders or providing rewards, 3) social support, e.g., providing social norms or fostering competition, and 4) system credibility support, e.g., establishing authority or listing third-party endorsements.

Another approach to design motivational design techniques is based on Cialdini [32]'s six principles, i.e., authority, commitment, consensus, scarcity, reciprocity, and liking. In this paper, we focused on the subset made by Kaptein et al. [33] who showed that persuasion profiles can be effective using implicit or explicit measures. Kaptein et al. [33] focused on the first four of the principles aforementioned and showed that "*text messages that were personalized - tailored - on the level of influence strategy susceptibility were more effective*." [33] They did not only observe this effect at the behavioral level, but the personalized messages were also regarded as more useful by their participants. We will, therefore, build on their work to tailor telemonitoring reminders to the pectus patients.

3) *Behavior change techniques*: A third approach to inspire healthcare informatics researchers is Abraham

and Michie's [34] taxonomy of behavior change techniques incorporating 26 techniques. Rather than clustering techniques in overarching categories, Abraham and Michie [34] link their motivational techniques to the underlying theoretical concepts of behavior change. For example, the design technique to provide rewards is related to Operant Conditioning [35], providing praise is related to self-efficacy in the Social Cognitive Theory [36].

B. Enhanced recovery pathways and telemonitoring

Enhanced recovery programs are used by the surgical team to help ensure patients have the best possible outcome from their surgery. Important components of these protocols occur before, during and after a procedure [37]. They have been implemented worldwide as evidence-based standardized perioperative approaches [38]. The use of electronic health technology [39], such as telemonitoring platforms, may facilitate biopsychosocial, postoperative follow-up, especially in the long term after hospital discharge [40].

Findings from the motivational design literature suggest that the inclusion and use of gamification may increase engagement [41], enjoyment [42], and improve the user experience [43] of these apps used in enhanced recovery programs. After all, these studies suggest a positive outcome with respect to a better uptake of a product or compliance to intervention.

C. Young adolescents

Studies on motivational design techniques targeting adolescents have already show potential. Waite-Jones et al. [44] conducted semi-structured focus groups and individual interviews with nine adolescents, eight parents and eight care providers. They found that an app for self-management should provide the adolescents with the ownership and control of an engaging tool that 1) gives information, 2) monitors symptoms, 3) offers reminders, and 4) provides social support. Furthermore, eight main themes were identified by Cai et al. [45] who involved 29 younger patients, seven parents, and 21 care providers from the rheumatology team. Their themes were: remote monitoring, treatment adherence, education and support, providing incentives, privacy, ease-of-use, clinical support tools, and attractiveness of the design.

Koivosto and Hamari have shown that there are important demographic differences in the perceived benefits from motivational design techniques and that the "*ease of use of gamification is shown to decline with age.*" [46] However, this also indicates that there is an important potential for motivational design techniques targeting adolescents. Indeed, positive outcomes have been found with children [47], [48], adolescents [49], and young adults [50], [51].

III. METHODS

A. Study design and Appi@Home

The full medical procedure, that contextualizes this study, is described in [1] and follows Werner and Kongsgaard's [52] working definition. Pectus patients were followed up by the multidisciplinary pain center for maladaptive coping strategies

and pain-rehabilitation interference using their individual Appi@Home platform¹, a web-based diary evaluating pain and sleep quality app. The patients were asked to use Appi@Home for 10 weeks after their discharge from the hospital. Their rehabilitation progress was monitored via Bluetooth-connected telemonitoring devices. Measurements were complemented with subjective personal diary answers, such as daily pain and activity assessments on an 11-level scale, which was also gathered through the Appi@Home app on patients' smartphones.

This study was performed during the ten week follow-up and employed a mixed-methods approach; a quantitative analysis of how young adolescents rated motivational design techniques and a qualitative analysis of interviews.

B. Alternative design

Based on the extensive literature on motivational design in healthcare informatics [53]–[55], two lead researchers, in close collaboration with medical experts from the multidisciplinary pain center and technical experts, designed a final set of 17 alternative designs. The goal of these 17 alternative designs was to span the largest spectrum of motivational design techniques possible that was acceptable by all the stakeholders in this sensitive context. Designs that focused on sharing medical data, for example, were unacceptable for the hospital. Neither did we want to introduce additional stress for the pectus patients, so designs focusing on a higher perceived threat [56] were also not included. Fig. 1 provides an overview of the chosen motivational designs, while Table I provides the rationale and underlying mechanics.

C. In-depth interview

After a minimum of two weeks post-surgery, the researcher visited the patient and parent(s) for a semi-structured in-depth interview at their homes. This semi-structured, in-depth interview was conducted according to the Contextual Inquiry method as defined by Beyer and Holtzblatt [59]. The contextual inquiry method is based on a combination of semi-structured interviews and user observations and is based on four principles:

- 1) Context: the interviews and observations take place at the home of the pectus patient. Patients can easily show examples that they consider relevant in the discussion.
- 2) Partnership: the interviews are framed as a collaboration between the interviewer and the pectus patient (with their parent) during the activities or actions.
- 3) Interpretation: rather than a literal representation, the meaning is sought behind the words, shaping the behavior and perspective of the pectus patients.
- 4) Flexible focus: there is no a priori focus; during the interviews and observations, the focus can shift; above all available details, attention is paid to what is important for the research.

¹APPI; Appi@Home, a European Union registered trademark under registration #017610627

Fig. 1. Overview of all 17 designs that were rated by the pectus patients and their parents on a seven-point Likert scale. In this figure, the three motivational notifications were grouped in the last design (O) for illustration purposes: the authority, consensus, and commitment notification. Participants, however, were shown the individual designs.

TABLE I

THIS FINAL SET OF 17 DESIGNS WAS CAREFULLY SELECTED WITH TWO LEAD RESEARCHERS IN COLLABORATION WITH ALL STAKEHOLDERS. THE GOAL WAS TO SPAN THE LARGEST SPECTRUM OF MOTIVATIONAL DESIGN TECHNIQUES THAT WAS ACCEPTABLE IN THIS SENSITIVE CONTEXT.

Design	Fig. 1	Mechanic	Rationale
Authority	O	persuasion, reminder	This notification shows a motivational message based on Kaptein et al.'s [33] authority profile. It reminds patients that their doctor is checking their values, so they should submit their telemonitoring data.
Avatar	A	avatar	This design shows an avatar on the main screen. Similar to earning points, patients can unlock new styles for their avatar by submitting telemonitoring data.
Commitment	O	persuasion, reminder	This notification shows a motivational message based on Kaptein et al.'s [33] commitment profile. It reminds patients they themselves have configured when to submit their telemonitoring data.
Consensus	O	persuasion, reminder	This notification shows a motivational message based on Kaptein et al.'s [33] consensus profile. It communicates that other pectus patients also need to submit their telemonitoring data.
Easter egg	B	easter egg	This design shows a popup when participants have found a new, less obvious function in the app. It tries to stimulate patients to explore all functionality of the telemonitoring platform.
Goal	C	goal	This configuration design empowers patients to choose their own goals. It enables patients to set specific goals such as submitting telemonitoring data on a regular moment of day, individual days, specific time, or even stimulates them to be more adherent than other pectus patients.
Info	D	random reward, feedback	Every day, new random related medical information is shown. Participants are triggered to open the app every day to discover whether they are interested in the new information.
Medical insights	E	feedback, progress	This design enables patients to directly see the actual values of the telemonitoring data they submitted inside the application itself. Furthermore, it also shows the progress made.
Notifications	F	control	This configuration design empowers patients to control notification themselves, based on nearby devices, location, activity, or usage patterns.
Philanthropist	G	epic meaning, progress	This design is based on providing epic meaning [57]. Every measurement will contribute towards the goal of planting an actual tree. It aims to trigger patients to submit telemonitoring data for a good cause.
Points	H	points, levels, progress	This design shows a traditional point-based system where each measurement contributes a certain point value to the achieved total.
Progress	I	progress, commitment, competition	Provides the patients with an overview of the total number of measurements submitted per device. The grey bars in the background are used to visualize progress towards a goal and potentially the average number of measurements performed by peers.
Social	J	social	This design allows the patient to share their progress on social media. It aims to facility support from peers and friends.
Streak	K	loss aversion, progress	This design shows the total consecutive days a patient has submitted telemonitoring data and motives patients to uphold their streak of compliant days.
Ten-week quest	L	progress	This design shows the total number of days telemonitoring data should be submitted. Each row is a new week and each column a different day. Past days are colored based on the total number of telemonitoring data submitted. This design allows patients to check both their progress and their adherence.
Theme	M	theme, rewards	Similar to Stinson et al. [58]'s Pain Squad research, patients can unlock exclusive videos within a theme preferred by the patients.
Time pressure	N	time pressure, loss aversion	This design shows the patients how much time they have left to submit their telemonitoring data for the current day to be considered successful. It is based on the principles of time pressure and loss aversion as patients might want to be compliant.

To conduct the in-depth interview in a familiar environment, the main researcher visited each pectus patient at his/her home. These individual interviews were semi-structured according to a soft UX laddering [60] approach. Both pectus patients and their parents were asked to independently put each design that was printed on paper on a corresponding seven-point Likert score between - - - and + + + as shown in Fig. 2. By scoring each design, participants could signify their like or dislike of a motivational design technique. Care was given to avoid any influence of the parents on the pectus patients' rating, each of them first scored the motivational techniques without seeing the scoring of the other.

After the scoring, participants were invited to further comment on why they gave this scoring. The interviewer performed a semi-structured interview with the pectus patients and their parents for additional comments and whether they would like to add anything. After this, the interviewer thanked the participants for their efforts. Interviews ranged between 32 and 61 minutes, with an average of 45 minutes.

Fig. 2. Participants were asked to score each design on a seven-point Likert scale represented by colored sheets of paper. Dark green represented the most positive + + + designs, while dark blue the most negative - - -. Similar pictures were taken off all participants' ratings.

TABLE II
DEMOGRAPHICS OF THE PATIENTS, GENDER, AGE, AND WHETHER THEIR PARENTS WERE PRESENT. EACH PATIENT, MOTHER, AND FATHER IS LABELED AS Px, Mx, AND Fx. RESPECTIVELY.

Participant	Gender	Age	Parents
P1	Female	13	M1 + F1
P2	Male	18	M2
P3	Male	15	/
P4	Male	14	M4
P5	Male	15	M5
P6	Male	17	F6
P7	Male	16	M7 + F7
P8	Male	14	M8

D. Participants

All patients who underwent pectus surgery after February 2018 at the University Hospital of Antwerp (UZA), where informed about the study. Participants were informed and recruited prior to their surgery by medical professionals of the multidisciplinary pain center. Ethical approval for this study was granted by the hospital's ethics committee with number 17/08/082. Information was provided about the intent of the study and patients were asked to sign a consent form detailing the collection, processing and storing of data, photos, and audio recordings collected during the study. Patients could stop their participation at any time.

Important to note is that these pectus patients are burdened with an above-average pain experience. That is why we worked closely with the medical professionals at the multidisciplinary pain center. The suitability of participants in this study was determined on the basis of consultation with the relevant physicians of the multidisciplinary pain center of UZA. Inclusion criteria were:

- 1) patients have been treated for a pectus condition,
- 2) patients use the Appi@Home telemonitoring platform,
- 3) patients should be able to fully understand his or her participation and be at least 13 years old. In case of legal minority, consent of a legal guardian is also required.

Over the course of one year, 13 patients were recruited. However, due to both personal and medical reasons five patients dropped out. Hence, eight pectus patients, aged 13-18 years ($M = 15.3$, $SD = 1.7$) completed the study. As pectus excavatum affects four times more males than females [1] and pectus carinatum has an even more pronounced male predominance [2], we only had one female participant. In all but one interview, there was always a parent present. Two interviews had two parents present as shown in Table II.

E. Data collection and analysis

The researchers of this study had no access to the medical data, nor the medical patient file. During the interviews with the pectus patients, no medical information was shared, nor were medical aspects discussed. Only demographic data, such as gender, birth year and address were inquired.

The results (notes of the interview, possible audio recordings, transcripts of audio recordings and any photos)

were stored in a university database managed by the principal researcher. Only the researchers involved in this project had access to these data during the course of the project.

The qualitative data was entered and coded into a spreadsheet for qualitative coding. During a first coding round, two researchers independently conducted a thematic analysis of eight interviews, according to the procedure described by Boyatzis [61].

This coding round resulted in the creation of a coding dictionary. One additional coding round was conducted to improve the coding dictionary and derive the thematic groupings of the motivational design techniques. A final coding round was conducted by two principal researchers (DC and MB) to unearth the underlying central concept and derive the implications for design.

IV. RESULTS

In this section, we first report on the quantitative rating by both the patients and their parents. Second, we discuss the results of a thematic analysis of all the interview transcripts. Quotes were translated by the main researcher and labeled as Px, Mx, and Fx for patient, mother, and father respectively.

A. Likert scores

As illustrated in Fig. 3, both patients and parents perceived most designs favorably. In order to prioritize the designs, we define *positive* in this paper by a median score $\geq$ '+'. Within this definition, patients scored at least eight designs positive: the two configuration designs **notifications** and **goals**, two persuasive messages **authority** and **commitment**, and the **philanthropist**, **streak**, **time pressure**, and **progress** designs.

As shown in Fig. 3, parents often had a different opinion. Parents scored 12 designs positive: **avatar**, **commitment**, **consensus**, **easter egg**, **info**, **medical insights**, **points**, **ten-week quest**, **theme**, **progress**, **philanthropist**, and **streak**.

Interestingly, there was thus only an agreement between the patients and the parents with regards to four designs: **philanthropist**, **streak**, **commitment**, and **progress**.

The overall best-perceived design was the **philanthropist** design in which patients contribute to a good cause by consistently submitting their telemetry data.

P6: "The more [measurements] you do, the more plants, that is also a great idea!"

P4: "I really like that, I really like that tree, that you would plant a tree, because then you still do something good for the world"

P7: "Trees, yes, because I think that can stimulate people in a way."

Parents rated this **philanthropist** design as the best design. All parents gave it a positive score, resulting in a median score of '+ +'. "What does it cost you? Five minutes to do the measurement, and you keep a tree alive!" (F1). However, both patients and parents were skeptic and wanted verification that their contribution was carried out.

P1: "Yeah, I just don't know. Are you really going to plant a tree?"

Fig. 3. 100% bar chart visualizing how patients and their parents scored all 17 designs on a seven-point Likert scale. Sorted by patients' preference. When a group rated a design positive (median $\geq$ '+') it is colored green. If a design was rated positive by both patients and parents, the name of the designs is also displayed in green.

P8: "Is this really the case? That this is a goal that actually will be carried out?"

M2: "But then you should also see that something has happened with it afterward."

The second design that was perceived well by both groups was the **streak** design. Most patients and almost all parents (M2 did not understand it initially) perceived the design to be useful. Many patients made the link with the popular multimedia messaging app Snapchat. "That with the flames, yes that's something useful! You really want to avoid losing five days in a row, that's like Snapchat, right. You do not want to lose that, so you always get more and more, yes that's something cool." (P2) Patients were even saying it would motivate them to constantly take all telemonitoring devices with them (P5). Patients indicated that the streak design could help them to verify their adherence: "that's nice to know, of

course, to know how many days you have done in a row." (P4)

Parents also recognized the will of their children to keep their streak going: "yes, in the end, it works like that with those streaks. That those young guys, oh I have to do my streaks, yeah that works. Or, like if I have not done it, then I am back to zero." (M4)

The **commitment** design was the third preferred design. Remark that there is a clear difference between the rating of the **authority** and **commitment** designs, which were perceived rather positive, and the **consensus** design which scored lower. However, most participants indicated their rating was primarily guided by the need for reminders, not so much the actual persuasive messages. The designs might have scored higher "simply because they are notifications. I missed that." (P6) "I just put all three on the plus, because I did not really read which messages they were, I just have visual: it's notifications, short messages, I would like that." (F6)

The **progress** design was the final design perceived positive by both groups. This design integrates multiple motivational design techniques into one design, which is also reflected by the participants, who favor the competitive part, the feedback towards their own goal, and/or the visual progress.

P2: "To see that I have already done this, and others have not done this yet, that is also something competitive [...] that shows that you are doing a good job and that other people are not. Yes, something competitive [...] then I would like to do a bit more effort."

P3: "I think that's good too, because you know that, I have done so many measurements of that or that, which do I do the most, which the least?"

P5: "This also adds a little pressure and yes, such a goal, I think I had to do it just about every day, so yes [...] eh, yes, maybe this is useful, so to say, now I've done too little this week."

Although they did not qualify as positive by the parents, the designs with the highest perceived value by the patients were the configuration designs **notifications** and **goals**, mainly thanks to the ability to receive and configure notifications.

P4: "I think that reminder on location is easy, that you come home so that you get a message after a quarter of an hour or so, after you have put away your bag, taken your coat off, changed clothes."

P5: "it seems convenient that you say that time I am still awake anyway. I know that I then normally always use it, so I would like a reminder."

Finally, the biggest difference between the patients and the parents surfaced with the **avatar** and **theme** designs. Parents recognized the principle of using and customizing an avatar from other games they saw their children playing, therefore thinking their children would also like this feature in Appi@Home. On the other hand, patients, in general, did not like the avatar design, calling it too childish (P2, P6, P7, P8) or too *gamified*. The app's main purpose was to submit patients' telemetry data (P1, P2, P3, P5, P8). It should not be a

game. Similar remarks were made for the **theme** design, with an emphasis on it being too childish (P2, P3, P4, P5, P6, P8).

B. Thematic analysis

All interviews were coded twice for emergent themes in an open-coding round by one researcher to establish a coding dictionary. During this initial coding session, codes from previously coded interviews were constantly compared to new interviews. After coding these eight interviews, an additional researcher re-coded all interviews again to improve the coding tree. Based on the results of these coding rounds, a consensus could be established for the coding dictionary. The following five themes remained: 1) adherence, 2) medical insights, 3) technical support, 4) private life, and 5) means-to-an-end. However, themes might overlap. For example, technical support might help to increase adherence, which in turn might lead to more useful medical insights.

1) *Adherence*: Most participants indicated they had the will to adhere to their postoperative telemonitoring therapy. This made adherence the most frequently occurring theme.

P4: *"I actually find this a little [***], because you say I'm going to do that every day, then you should not say, oh, my parents are divorced, so I can not do that, You can put all the devices in your bag and take it with you."*

P6: *"That's nice that you can see ah oops, I forgot that day, I'm going to have to make up for it."*

M1: *"I think that is very important, yes important, it would be useful to have a quick overview, how far in the process are we and how often do you do it, are you doing well, or are you doing it less well, I think that is important."*

The will to be adherent was frequently addressed when discussing all designs related to reminders and notifications. Participants indicated they wanted to adhere, but with the best intentions, they sometimes just forgot. Participants explicitly indicated they were committed. *"If you say you do something, you do that."* (P4) and *"I would like more reminders, so you do not forget."* (P6)

Parents had similar remarks and even trusted their children to adhere without reminders: *"For me, that is actually no added value, he just does that every day, I trust that he does;"* (M8) or *"if it really would have helped, we would have set an alarm."* (F7) Other parents were more controlling: *"I go first, just before noon. Then I will check, and then the father. So two-time follow-up. We first let her do it, and then us."* (M1) Parents argued that they let their child choose to participate or not, but when they agreed, they had to sit it through (F1, M4, M5, F7).

Although the **ten-week quest** design scored neutral, participants expressed it was *"useful that you can see I have so many things to do and all yes, so many days to go."* (P6). All participants indicated they did like to see the progress made so far. They also liked that it gave *"a good overview when you have to bring it back, and how many days you*

have to do; and how much you have already done." (P1). However, this should just be an option, not the first thing you see when you open the platform.

Closely related to other motivation/adherence research [62], P7 also reported a decrease of interest over time: *"In the beginning, I would look at this and then less and less."*

2) *Medical insight*: The second most important theme was the need for more comprehensive medical insights. One of the main questions participants had, both patients and their parents, was whether they were doing OK, whether their values were within a healthy range.

The current mobile application only reported the meta data, i.e., only the number of measurements, but not the actual measurement values themselves. Although it was technically possible to see all measurements by logging in to the web client, participants were sometimes not aware of this functionality or found this too much effort. Furthermore, only the blood pressure and SpO2 sensor have an LCD that shows the values before transmission.

Three designs were praised by their ability to provide medical insights. Of course, the **medical insight** design is able to show the values and patterns directly. But also the **authority** reminder served as a confirmation the doctors were indeed checking the medical status. Participants (correctly) argued that everything is probably OK, otherwise doctors would have informed them. Finally, the **info** of the day design was appreciated, if it would provide timely and relevant information on the progress of the healing process.

As is clear from the ratings for the **medical insights** design, as shown in Fig. 3, parents were more interested in the actual values than their children. *"As parents, you want as much information as possible on those things."* (F1) But they also inquired about the reliability of the devices: *"Then I think like, how reliable are those things?"* (M8) In contrast, patients indicated they did not know enough to care.

P1: *"Nice to see, how you progress, but for children, it is sometimes difficult, what does it mean?"*

P3: *"No, this does not mean anything to me."*

P4: *"I do not understand that."*

The **info** designs mainly scored neutral. Six patients (P1, P2, P3, P4, P5, P7) reported they did not like to read too much text. Patients argued that *"if it is serious, then I will certainly hear it."* (P8) Although the design should not be prominent, it definitely has its added value. It could inform users about what is to come and their path towards full recovery and in this manner provide patients with reassurance.

P3: *"Now it is about blood pressure, but with me, they planted a rod inside my body, but then maybe what about the wound, did not get all the information from the doctor, but just nice text, maybe less text."*

F7: *"But before the operation, it would be much more interesting than after the operation, because you know what is going to come."*

P5: “So I did that once, no twice, went to the hospital because I had too much pain, so, if it would be added that now you could walk as many miles or something, or now you should already be able to start doing that, that would be useful, also because you then dare to do more than now.”

3) *Technical support*: Related to will to be adherent, was the need to know whether all measurements were received and all technical devices were working well. Participants wanted to be aware of both technical issues, such as failing connections, or receive technical feedback, did the measurement arrive at the hospital?

The strengths of the **progress**, **points**, and **ten-week quest** designs, as perceived by the participants, were primarily the possibility to see their progress, but also to get immediate feedback whether all measurements were correctly received by the hospital.

P2: “Then you also see what the doctors see and possibly miss.”

P5: “For example, the activity tracker, you can think, what is actually there, and then you realize ah yes, the battery might be empty.”

M1: “Because I think it is important to know if it ends up with the doctors.”

M8: “Except for when it does not come through, that I can ask you, have you already done that? That he says yes, that it has not been submitted or something.”

This study also exposed some minor technical issues. However, these issues were related to specific situations and hardware and are already addressed with upcoming updates of the platform. Patients reported their will to adhere, but that this was sometimes hindered: “because when I fill it in, I immediately fill in everything - IF it works.” (P2) Unfortunately, occasional connection issues might also have negatively influenced participants’ confidence whether all measurements arrive at the hospital: “at least then I’m sure that message has arrived, right?” (P8)

4) *Private life*: Participants indicated that their surgery and postoperative telemonitoring follow-up belonged to their private life (M2). They indicated they had no interest in other patients: “yes I know that I am not alone, so it does not matter” (P1)

P3: “because I personally would not be interested in how many other people should do that, but other people might think differently about this.”

As shown in Figure 3, the **social** design was, therefore, perceived as negative by the majority of participants.

P2: “I certainly would not use that, that share function, I think no one will use that, but I would not know. I would not want to share medical affairs on Facebook.”

P5: “Not everyone should know that I have been treated in the hospital. Yes, many friends know, but

to put this for everyone on Facebook... yeah, I do not like that, I do not think so, I also do not know if that complies with privacy regulations and so.”

P8: “I would absolutely not want this.”

However, in contrast, the **progress** and **consensus** design enabled participants to compare themselves with other patients in an anonymous manner. Four patients explicitly mentioned they liked this feature. These designs did not disclose any personal information, but only allowed participants to compare their relative performance to other similar patients.

P4: “I would add that, because when you do, you can continue to strive to be the best.”

P6: “That too, but perhaps better than the best. That you can say so, I want to be the best. A kind of race.”

P2: “I have already done this, and others have not done that yet, that is also something competitive.”

P8: “Gives me a feeling of, yes I am among the best.”

5) *Means-to-an-end*: The final theme is means-to-an-end. The goal of the telemonitoring platform is to support patients to submit telemonitoring data towards the hospital for further follow-up: “especially to me this is mainly about medical issues and I do not see that as a game.” (P8)

Patients favored techniques that empowered them to control **notifications** and set their own **goals**. Designs that were too game-like such as the **avatar** and the **theme** scored lower. This may also explain the lower rating of the **easter egg**.

P5: “yeah, this is not the app where you go, keep on searching. So to say, you will not be using this app for your pleasure I think so; no, it’s about those measurements, right?”

Finally, the **time pressure** design scored neutral. Participants expected they will be informed about the remaining time. This feature should just be present, but not necessarily on the home screen.

P6: “That is also useful that you know that I still have so much time to do that.

P8: “Then you really have a timer, then it is clearer how much time you have, because I do all my measurements on time, but suppose someone does that in the evening, suppose you have a busy day, then you will see clearly how time you have left.

V. DISCUSSION

A. Understanding pectus patients

Overall, pectus patients perceived the integration of motivational design techniques as useful. Patients foremost expected a platform that always worked and supported them in their telemonitoring therapy. They welcomed motivational design techniques that showed them how they were doing, empowered them to set their own goals and reminders, and kept high standards towards the confidentiality of the data.

Patients articulated the intention to adhere to their telemonitoring therapy and certainly for a limited period of time, such as the ten weeks required after pectus surgery. Designs that support patients in showing their progress were

perceived well. Similarly, patients appreciated designs that showed them how they were performing. Frequent questions asked were: did the hospital receive all data, did we forget a measurement, and can we do better? Reasons for the will to be adherent are threefold: 1) the main reason was to allow their care team to provide more adequate care; 2) once committed, they felt motivated to finish the follow-up period; and 3) they also indicated they were potentially helping future patients by providing their care team with more data.

The use of a telemonitoring platform may facilitate biopsychosocial, postoperative follow-up, especially in the long term after hospital discharge [40]. However, the captured data is currently mainly used by the professional care team. Parents often expressed that they would also appreciate additional insights on how their children are recovering. After all, unnecessarily avoiding activities to avoid pain, might have an adverse effect on the recovery [52], [63]. More medical insights might empower both patients and parents.

Young adolescents in this sample were particularly motivated by helping other people. The philanthropist design was perceived as one of the best designs. In close relation to McGonigal's [64] epic scale, patients felt they were part of something bigger, that their actions were contributing to something. Although this might be considered as shifting patients' motivation to an external motivator, patients cited this as an *additional* motivator. After all, their main interest was to recover. Moreover, not only charity motivated the adolescents, but also knowing that their data could help the care team to improve future treatment plans. One participant (P1) even recommended changing the theme design to videos of past patients. The fully recovered patients could provide motivational messages to future pectus patients, similar to the professional actors in Pain Squad [58].

Finally, in contrast to other related research [30], [44], we found that pectus patients and their parents strongly disliked direct social contact in their medical telemonitoring platform. This is in line with Geuens et al. [65] who also found that *"every patient hurts in his own way."* We subscribe to this finding: also young pectus patients consider health issues as private. The context should thus always be studied before integrating social features.

B. Implications for design

Gamified applications are perceived as 'gestalts' by their users, they are perceived as one meaningful whole, rather than a mere atomistic addition of gamification elements [66]. We want to postulate that it is less relevant to choose one specific design to embed in a telemonitoring application. The implementation of the points design, for example, can be framed from a behaviorist perspective (a reward), as well as from self-determination (promoting a sense of competence), or the trait perspective (promoting status) [67]. More important is to study how the various motivational design techniques are operationalized and perceived by its users in the design. In this study, for instance, pectus patients primarily valued the points

design thanks to its ability to show progress, not because it could show competence or status.

We, therefore, do not argue to pick one or two designs to be integrated into a telemonitoring application targeting young adolescents, but argue to understand the motivation and incentives of the target group first. We also recommend to involve parents in the design process, as they are an important stakeholder in the healing process of the patient. Our results show that pectus patients were particularly motivated by helping other patients. Finally, we showed that a robust platform and a flawless user experience are an important prerequisite before integrating motivational design techniques into a telemonitoring application.

C. Limitations and future work

This study has a few limitations that affect the contribution. First, the sample sizes are too small for meaningful statistics. However, like Sonne et al. [68], we argue *"that it is more important to first uncover potential problems and understand the use of the technology, than to conduct longer and larger efficacy studies."* Furthermore, UZA is one of the five biggest hospitals in the country and is specialized in pectus surgery. All pectus patients were informed and invited.

Second, with this study, we cannot recommend one best design. Often motivational design techniques are considered modular elements, which are simply added to the application. This reflects an additive-deterministic notion of gamification [66]. According to such a simplistic reasoning follows then the more gamification, the better. In such studies, neither the quality of the gamification nor the coherence with other components is examined, nor how these elements can be operationalized for a specific user group or context.

Notwithstanding these limitations, we were able to provide a deeper understanding of pectus patients in the context of telemonitoring and demonstrate the perceived usefulness of alternative designs. Next, we will integrate these lessons learned in a new telemonitoring platform and scientifically monitor whether we can indeed impact patients' adherence.

VI. CONCLUSION

In this paper, we provided a deeper understanding of young adolescents when they are asked to use a telemonitoring platform for their postoperative follow-up. In total, 17 alternative designs that integrated various motivational design techniques were carefully designed with all stakeholders.

A mixed methods study with eight pectus patients and nine parents revealed that adolescent pectus patients had the will to be adherent, were invested in their own well-being, appreciated technical feedback, valued their privacy, and requested a professional platform to support them in their daily telemonitoring activities.

Quantitative analysis revealed that patients perceived the configuration designs as very useful. Finally, pectus patients, and in general young adolescents, were particularly motivated by *philanthropic* reasons.

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