

Encouraging Physical Activity and Self-Enhancement in Women with Breast Cancer Through a Smart Bra

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Physical activity (PA) can have a substantial benefit in the prevention, treatment and rehabilitation of (breast) cancer. Wearable devices offer possibilities to monitor PA, to provide feedback and to set targets. Although the market for PA related wearable devices is booming, the impact of these wearables is questionable. One of the main concerns is the limitations to address individual needs of users, among which specific groups such as women with breast cancer. Through design, we see opportunities to stimulate for self-enhancement while encouraging PA after cancer treatment. Following a constructive design research approach, Aymée was designed. Aymée is a smart bra that changes its pattern based on the amount of PA. Through this interaction, Aymée aims to reinforce women recovering from breast cancer to feel good about themselves and to be (more) active. In this paper, we describe both the design approach in co-creation with former breast-cancer patients, as well as first results. We also discuss implications for designing intelligent systems that address PA encouragement.

physical activity; breast cancer; constructive design research; self-enhancement

1 Introduction

1.1 Breast cancer, body changes and PA

Worldwide, one of the most common cancers among women is breast cancer (Ma & Jemal, 2013). This cataclysmic event not only affects the health of the woman but also disrupts her daily life significantly. Bodily self-perceptions often deteriorate due to body changes (e.g., weight-gain, mastectomy, lumpectomy, hair loss) (Brunet, Sabiston & Burke, 2013), and physical activity (PA) levels may change due to physical barriers (e.g. mobility restrictions, lack of energy, fatigue, pain) (Brunet, Taran, Burke, & Sabiston, 2013).

Weight gain is a common disadvantageous effect of breast cancer treatment (Demark-Wahnefried et al., 2001; Demark-Wahnefried, Winer & Rimer, 1993; Goodwin et al., 1999) and is related to poorer



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survival in many studies (Holmes, Chen, Feskanich, Kroenke & Colditz, 2005). Even though this is an effect due to treatment, in general women are tended to feel a personal responsibility for their weight gain (Tiggemann & Rothblum, 1997) as a result of control failure. This might be reinforcement as women in treatment may struggle with feeling less in control over their bodies (Hefferon, Grealy, & Mutrie, 2010) due to other changes in their body, such as mastectomy, lumpectomy, hair loss. Additionally, research suggests that for a significant portion of women, in the early months after being diagnosed with breast cancer, these body changes negatively affect body-image (Fobair et al., 2006). Even long after the mastectomy operation, self-image is still often influenced negatively (Polivy, 1977). Due to the effects these body changes have on breast cancer patients, Brunet et al. (2013) state how important it is to be aware of these negative body-related emotional experiences, which even continue when cancer treatment is finished.

By use of make-up and the wearing of scarves, prosthetics, clothes, and wigs, women indicated that they were able to camouflage visible changes to their body affected by breast cancer (Brunet et al. 2013). Not only did these strategies camouflage the visible changes, but they also helped with self-enhancement and dealing with the negative emotions towards their changed body (Brunet et al. 2013). These strategies even persevered a long time after the end of the treatment. This suggests that the negative feelings towards body changes due to the cancer treatment are not erased for a long time.

Physical inactivity is a growing public health concern (World Health Organization, 2016) and it leads to a rise in non-communicable diseases (Blair, 2009; Blair et al., 1989; Chakravarty et al., 2012). Even though there are more physical barriers to be physically active for cancer patients, a growing number of studies provide evidence for the benefits of PA in cancer prevention, treatment and rehabilitation (McNeely et al., 2006; Monninkhof et al., 2007; Speck, Courneya, Måsse, Duval & Schmitz, 2010). One of the most important benefits is reducing the risk of death from this disease (Demark-Wahnefried et al., 2001). Moreover, a relation between lack of PA after diagnosis and weight gain has been found (Demark-Wahnefried et al., 2001) which in many studies is also related to poorer survival (Holmes et al., 2005). The positive effects of PA are not only influenced by strength and conditioning training, but also by daily activities such as walking (Holmes et al., 2005; McNeely et al., 2006).

1.2 Monitoring PA through wearable technology

In recent years, the consumer market for PA related monitoring devices has exponentially grown (Vos, Janssen, Goudsmit, Lauwerijssen & Brombacher, 2016). This increase in low-cost technology related to PA is consistent with more general trends such as the use of mobile computing and communication technologies in health care and public health (Fiordelli, Diviani & Schulz, 2013), and the self-monitoring of health outcomes (Swan, 2012). Wearable technologies have the potential to improve personal health outcomes and offer possibilities for early detection and monitoring of (chronic) diseases, remote care and self-management (Vos et al., 2016; Vos, 2016).

Well-known wearables brands such as Jawbone, Fitbit, Misfit, and Garmin have raised the public awareness of PA. Their wearable devices track daily activity on a 24/7 basis and provide feedback through accompanying smartphone apps. Nutrition, as well as sleep quality, are sometimes even included to sketch a complete picture of one's state of well-being. By creating cognitive awareness about the current lifestyle of the users, they try to persuade people to adopt a more active and healthy lifestyle (Shih, Han, Poole, Rosson & Carroll, 2015).

These innovations in smart wearable body sensors have created possibilities for people to become 'experts' in self-monitoring of PA on a 24/7 basis (Vos et al., 2016). Notwithstanding the above-mentioned opportunities for the domain of PA, many challenges need to be overcome. Although there is a general acceptance that people are different, most of these available consumer devices are still mainly based on underlying data models and design propositions following a 'one size fits all' approach in which, generic, standardized solutions will successfully address the needs of individual

users (Vos et al., 2016). Furthermore, they seem to apply that ‘the numbers will tell the tale’. However, most people are not good at thinking statistically (i.e., quantitatively) but are good at thinking in stories (i.e., qualitatively) (Swan, 2014; Peeters & Megens, 2014). Moreover, standard approaches will not likely increase people’s motivation to be physically active. For example, studies have shown that people’s intrinsic motivation to exercise was not higher while training with a virtual coach, compared to people training without a coach (IJsselsteijn, de Kort, Bonants, de Jager & Westerink, 2004; Westerink et al., 2005). Hence, the impact of these wearables is questionable.

1.3 Design Opportunity

As current wearables do not address the needs of individual users, we aim to investigate whether it might be desired to design a more personalized approach of giving meaningful feedback about the PA level for former breast cancer patients. Brunet et al. (2013) have shown that wearables, such as clothes and scarves, provide strategies to feel better about body changes and to support self-enhancement. Hence, a design opportunity would be to create a wearable that, through self-enhancement of a garment, encourages PA. In this paper, we describe a constructive design research process that focusses on self-enhancement through a wearable that monitors PA. Within the discussion, we elaborate on opportunities to increase PA.

2 Design Process

In the next sections of this paper, the different steps of the constructive design research (Koskinen, Zimmerman, Binder, Redstrom & Wensveen, 2011) process are elaborated, explaining the different decisions that were made. First, a design exploration was made supported by a review of literature and an ideation session. Second, interviews were held with three former breast cancer patients and one breast cancer patient to learn about their experiences with breast cancer and being physically active. Third, a second design exploration was made to be tested in real life by one of the authors. Fourth, a co-creation session with three former breast cancer patients was held to indicate what preferences the final prototype should have. Fifth, the final design, Aymée, was realized and finally, Aymée was tested by two former breast cancer patients.

2.1 First Design Exploration

The start of the design process was to ideate different possibilities that aim to both encourage physical activity and positively the way the woman feels about herself and her body. Supported by a review of literature, different ideas were generated, such as an intelligent prosthesis that reassured the wearer that she can move without moving the prosthesis, or a bra whose strap would enlarge when there is no activity measured for a long period. However, neither ideas could contribute to positively influencing the way the wearer feels about herself. These iterations did include the use of a bra, probably due to its direct relation with the changed body affected by mastectomy or lumpectomy. As previous research indicates this relation to body changes is important to be aware of, the use of a bra seemed a suitable garment to design for. Previous work by Almeida et al. (2016) shows promising results in how the use of underwear can be an opportunity for intimate body-worn interactions.

The final chosen concept was a bra that changes its pattern based on the PA level, where a high activity level represents a more detailed and/or colourful pattern. This concept was further elaborated by doing several explorations on how to realize a changing pattern with the use of diffused LED, feathers, fabric movements and thermochromic inks. To avoid designing a bra with a high-tech feeling, it was essential to search for a pattern change that can be realized in a subtle and refined way. This was best realized with the use of thermochromic ink, a material that when applied to fabric becomes, becomes transparent if heated to a specific temperature. By mixing thermochromic ink with textile ink, it becomes possible to let the colour of the textile ink appear slowly by heating the fabric. Thermochromic ink can also be applied on fabric that already has a pattern; this makes it possible to hide the pattern but revealing it when heating the fabric. The tipping point of the thermochromic ink determines when the ink will become transparent. When

using different thermochromic inks with different tipping points, the possibility arises to let colours and/or patterns appear one by one on a piece of fabric.

To realize a bra with a controllable changing pattern, a first design exploration was made (Figure 1). The elements that needed to be integrated within the bra, besides applying the pattern with use of thermochromic and textile ink, were a battery pack and a heating element to heat the fabric. Making this design exploration made it possible to communicate the final concept through a prototype.



Figure 1 First demo of Aymée. Left: cup before change of pattern, right: cup after change of pattern.

2.2 Interviews

Interviews were conducted with four respondents: three former breast cancer patients and one woman who has breast cancer. A semi-structured format with an interview guide was used. All interviews were recorded and transcribed verbatim. The interview guide consisted of open-ended questions regarding the respondents' personal experiences with breast cancer and their perceptions about PA and wearables. The transcriptions of the interviews were manually coded based on a coding framework that was developed inductively. The coding frame and the content analyses were checked by the different members of the research team.

In the interviews, the personal impact of breast cancer was addressed. The interviewees emphasized that cancer did not only affect their physical well-being (lower energy level, weight-gain, mastectomy, hair loss), but also it affected their emotional well-being. The struggles of feeling like a patient instead of feeling like oneself were mentioned. One of the respondents stated:

I didn't feel like myself anymore. I'm not [interviewee name], I am a patient. That was the worst part...I'm not myself anymore, I had to give up my identity. (P1)

Next, respondents indicated they used strategies, such as make-up, clothing, perfume, and lingerie, to feel feminine and beautiful, more after their experience with breast cancer. Why feeling feminine and beautiful became more important was explained by one of the respondents:

I have accepted it (about mastectomy), but I don't think it's pretty, I believe pretty is something different. (P1).

One of the other respondents mentioned:

Mainly because your body is damaged, your body has changed, that is why it is even more important for me to look good. (P2)

During the interviews, the importance of emotional well-being was confirmed, which is in line with previous research by Brunet et al. (2013), in which the importance of strategies that deal with negative emotions and that are used for self-enhancement are indicated.

At the end of the interviews, a demo of the first design exploration was presented to evaluate the first thoughts about a bra whose patterns transform based on the PA level. The concept to additionally encourage self-enhancement was not elaborated to avoid influencing the participants in

the evaluation process. Based on the demo, the participants found it very hard to imagine what such a bra could mean to them as they were not able to wear the bra. Therefore, the decision was made to concretize the concept, so the participants were able to experience the bra.

2.3 Testing and Exploring

In the first design exploration, a bra was designed with a controllable pattern. However, this pattern was only controllable by turning it on/off via connection to the battery pack. A second design exploration had to be developed to make the pattern controllable based on the PA level. Because our aim is to stimulate daily PA, the bra should be able to measure the amount of PA throughout the day. Hence, a small microcontroller with an integrated accelerometer, Light Blue Bean, was implemented.

During the second design exploration, the limitations of small usage of thermochromic ink became evident. In theory, it is possible to create many variations in patterns when using thermochromic ink as it is possible to vary in different tipping points and control the heating elements to specific temperatures. However, due to the available variety of thermochromic ink tipping points (27°C, 31°C, and 47°C), real-life testing was necessary to experience which thermochromic ink already became transparent due to the effect body temperature has on the bra. The only ink that did not become transparent due to body temperature had a tipping point of 47°C. So by adding additional warmth (next to body temperature) with use of heating elements, the thermochromic ink became controllable. Unfortunately, this limited the possibilities in the variations of patterns and/or colours to only one change. Therefore, the bra will only change its pattern when the number of steps during the day is higher than the goal that was set up front.

The bra was tested in real-life conditions by one of the authors of this paper to calibrate the electronics (translating the data of accelerometer in a number of steps), and experience whether the heating elements are still comfortable when heated to 47°C. Furthermore, to enable the wearer to be in control of the heating elements, an interaction needed to be implemented so the wearer could indicate when she wants to see whether the goal is achieved or not. So even when the wearer already achieved her goal during the middle of the day, the pattern should not appear until the wearer indicates she wants to see it. During this first test in real-life conditions, different interactions with the bra were explored that considered several practicalities, such as accessibility and ease of use.

Integrating all these elements within a bra made it possible to monitor PA. The wearer of the bra could see whether her PA goal is achieved, by pushing a button which let the microcontroller turn on (or stay off, depending on whether the goal is achieved) the heating elements. As a consequence, the thermochromic ink becomes transparent, and the pattern and/or colour on the bra will appear.

2.4 Co-creation

In co-creation sessions with the three former breast cancer patients, user requirements were defined (Figure 2). The participants were presented with three different design sketches that vary in garment (bra, sports bra, and tank top), pattern (lace, animal print, and geometrical print) and the way the patterns transitioned (new print, asymmetrical, and filling in the pattern). The three sketches were discussed, to gain insights into the individual designs. While comparing the different designs, the participants immediately began to talk in terms of 'preferences'. Different combinations of design and shape were thought of as the 'ideal' wearable that represented their PA level. Evidence for the importance of using this technique, before realizing the prototypes, was found when the three participants indicated different preferable combinations in design, shape, and transition. Two of the participants indicated a preference for a bra; the third preferred a tank top. It was decided to design two different bras due to practicalities of integrating technology and heating elements.



Figure 2 co-creation session with former breast cancer patient.

2.5 Aymée

The final design was Aymée, a personalized bra that encourages former breast cancer patients to be more physically active by additionally stimulating the wearer to feel good about herself (Figure 3). When the wearer reaches her desired PA level and wants to reflect upon this, Aymée will change from a 'normal' dark bra to a bra that reveals a beautiful pattern.

The transformation within Aymée aims to stimulate reflection moments on the daily PA level. However, by linking the PA level with a pattern on a bra, which is directly associated with the place of the cancer, a psychological effect is pursued: Aymée aims to complement the overall appearance of the wearer and stimulates the feeling of self-enhancement by encouraging her to feel proud of her achievement.

As the Light Blue Bean was a valuable approach to measure PA during the real-life testing, this microcontroller was also implemented in Aymée. For the pattern change, two black thermochromic inks were used with two different tipping points. The first tipping point was at 31°C and the second at 47°C. Before wearing the bra, the bra appears to be entirely dark. After wearing it for the entire day, the parts that are covered with the thermochromic ink with the tipping point at 31°C would already reveal a part of the pattern. When the wearer wants to see whether she achieved her daily PA goal, she pushes a button in the centre of the bra and the microcontroller will turn on the heating elements (if the PA goal is reached). By doing this, the thermochromic ink with the tipping point of 47°C will become transparent and reveal the last parts of the pattern.



Figure 3 two variations of Aymée worn by former breast cancer patients; P1 on the left, P2 on the right.

2.6 User Evaluation

To evaluate whether the transformation of Aymée contributes to how the wearer sees herself and how this affected her PA level, Aymée was worn for five days in a row by the two former breast cancer patients (Figure 3) with a preference for a bra. One of the participants (patient 1 –P1) was 57 years old, survived from breast cancer twice and wears a prosthesis due to a mastectomy. The other participant (patient 2 –P2) was 50 years old, recently survived breast cancer and had a reconstruction. To compare the monitoring of and feedback on the PA-levels by Aymée with a traditional wearable providing feedback through numbers and graphs on a smartphone, the patients also wore a Jawbone Up2. The patients were told this wearable was used to calibrate the electronics of Aymée to avoid influencing the participants up front.

Interviews were conducted with the two participants. A semi-structured format with an interview guide was used. All interviews were recorded and transcribed verbatim. The interview guide consisted of open-ended questions regarding the respondent's experiences with Jawbone Up2 and Aymée. The transcriptions of the interviews were manually coded based on a coding framework that was developed inductively. The coding frame and the content analyses were checked by the different members of the research team.

2.6.1 Pride

One of the first aspects addressed in the interviews was pride. Both participants were very positive about the use of the bra to receive feedback about the level of PA. Their feeling of pride was reinforced due to the change of pattern on the bra. A possible explanation for this can be found in the intuitive connection between the goal (being active) and why it is so important (prognosis cancer). The respondents stated:

If I hadn't been sick and I would have only worn a wrist wearable, I still would have been proud. Yet, I believe proud in a different way and fulfilled as how I felt with the bra. Because this is linked to my illness. (P2)

It is nearby because it is on your body, it's more like: that's something I did ... you feel like: I was able to make it (Aymée) change its colour (P1)

This intuitive connection contributed the wearer in accepting her new body but also in converting this feeling into pride. Feeling proud to conquer cancer and being able to be active again. The following extract describes this view:

I don't have to be embarrassed about anything. I've been through something hard, so I can be so proud of myself that I look the way I do. (P2)

2.6.2 Shift of Goal

The respondents indicated that they checked the application on the smartphone (connected to the Jawbone Up2) during the day to see if they had reached their activity goal. Within this application, a graph of the PA level is presented. This helped the participants reflect upon their PA level but when they saw they reached their goal, 'nothing' additional happened. The participants mentioned making Aymée change its pattern was considered as a goal itself. So there was a shift of goal: from trying to be active, to being active to change the pattern. One of the respondents explained:

Look, this graph says nothing to me. I mean look, you only check whether you have reached your goal or not. But this (Aymée) is a goal on its own, that it will change of colour. (P1)

As this shift of goal was achieved, Aymée had an influence on the participant's mood. The feeling of joy and disappointment was considered bigger when (not) reaching the daily activity goal, as appears from the following extracts:

This (Aymée) had an impact on my entire mood. Primarily feeling proud and fulfilled...This is more personal than something on your wrist. Because this is really addressing femininity. This has way more impact when it doesn't work (change of colour) than Jawbone has. (P2)

2.6.3 Personal

Jawbone Up2 was considered stand-off and generic. Moreover, due to its visibility, it raised questions from people around the participants about the function of the product. The participants continuously referred to Jawbone Up2 as a 'pedometer'. The interviewees expressed it as follows:

With such a wearable (Jawbone) everybody thinks, o yes that's a pedometer. But this (Aymée), nobody will, this is just for me. (P1)

This is more personal (Aymée), that is more distant (Jawbone). The bra is more intimate. (P2)

These extracts also indicate the increased intimacy level of Aymée. The participants had a feeling it was closer to their body than Jawbone Up2. This is probably again related to the placing of the product and Aymée's connection with the illness itself (i.e., bra and breast cancer). The following extract describes these perceptions:

Actually, I feel it is a really beautiful way to show how important being active is. And precisely because it's a bra, I was maybe even more conscious of this. A wrist-wearable, for me this (Aymée) feels more special to achieve that goal. (P2)

3 Discussion

The aim of the study was to investigate if self-enhancement can be achieved among former breast cancer patients by use of a more personalized approach to giving meaningful feedback through a wearable that monitors PA. As previous research has indicated current wearables that monitor PA lack personalization (Vos et al., 2016). Thus, addressing individual needs of former breast cancer patients should be considered important due to the awareness of negative body-related emotional

experiences (Brunet et al., 2013). In this study, we have seen that by addressing these individual needs it is possible to design interactions in a different and distinctive way, and a wearable that takes that into consideration has promising results for self-enhancement.

Providing feedback on PA level through a pattern change on the bra resulted in a goal shift among the participants in the study. Instead of the familiar way of using numbers and graphs as feedback on PA level, the pattern change of Aymée, based on PA level, allowed the wearer to experience this kind of feedback differently. Where PA monitors ask you to interpret graphs and statistics, Aymée asks the wearer to look in the mirror and see the result of that day, both on the bra but also on your body. This shows the potential and importance of context related wearables that combines feedback with the individual needs of the users, where being physically active becomes a means to an end.

By giving the feedback on the PA level on a bra, Aymée also increased the intimacy level in its interaction with the wearer. The feedback of Aymée is, therefore, more personal and intimate, and only available to the wearer. This affected their mood and how they felt about their PA level more directly. For example, they felt a great sense of achievement when their daily goal was reached. On the other hand, this could also result in a greater disappointment when the goal was not achieved during that day, as the first test also showed. Both are a result of the interactions in such a personal and intimate way.

In this study, a constructive design research approach was used. Typical for this kind of design research is that the prototype (or a different construction) is the centre and starting point of constructing knowledge (Koskinen et al., 2011). By doing this, it was possible to communicate the final concept better and therefore enabled the possibility of co-creation. With this approach, the individual needs of the users could be addressed and implemented in the final designs of Aymée.

Some limitations and questions for further research can be highlighted. The user testing of Aymée was limited to two former breast cancer patients based on which we cannot generalize our results. However, for both women in our study, several themes appeared to be of importance, which might indicate promising results. Another limitation was the use of semi-structured interviews to gain more insight into the influence of breast cancer on the women's self-esteem. A validated instrument, such as The Rosenberg Self-Esteem Scale (Rosenberg, 1965), could have provided more detailed information. However, due to the vulnerability and sensitiveness of the subject, we decided to use interviews (Baumeister, Campbell, Krueger & Vohs, 2003).

Changes of the bra are dependent on the taste of the wearer. If a wearer already dislikes the pattern, it is hard to reach a positive effect on self-enhancement and eventually on the PA level. In this study, the main goal was not to seek for a pattern that suits most people but to examine the effect of such a pattern change, based on PA level, can mean on the wearer. By use of co-creation sessions, their preferences became clear. When designing for a larger group of participants, it will be more difficult to implement all these preferences. However, it shows the potential of the use of this kind of products for PA wearables as they can be just as diverse as current bras. This is contrary to the 'one size fits all' principle used within the current consumer wearables.

In the current design of Aymée, one reflection moment about the PA level is stimulated at the end of the day whereas, for most wearables that monitor PA level, it is possible to reflect upon the PA level every moment of the day due to the accessibility of looking at the application. Aymée, therefore, limits the wearer to only one reflection moment and affects whether the wearer can already anticipate on her PA level throughout the day. Further research should be conducted to provide more reflection moments to the wearer.

Our design showed a promise for designing interactions and feedback of daily activity in a different and distinctive way compared to most consumer available wearables. The user evaluation also provided evidence for a more personal interaction with its users. The question that arises is whether this first step can lead towards (sustainable) behaviour change related to physical activity. In this

paper, we described a constructive design research approach of a wearable aimed at self-enhancement. The assumption that is in question here is whether this self-enhancement leads to physical activity over time. To investigate this assumption, a longitudinal study with a baseline measurement is required to measure whether this effect will arise. This asks for a more robust prototype that can be used autonomously for a longer period. We see opportunities to develop these kinds of prototypes and evaluate them in such a longitudinal study through living labs or experiential design landscapes approaches (Peeters, Megens, Hummels, Brombacher & IJsselsteijn, 2013).

Furthermore, although within this study we only focused on former breast cancer patients, we do also see the promises of self-enhancement through PA for other groups of people, as this type of feedback proves to be more personal and motivational than the current standards. New studies and design processes are needed to develop these new kinds of design proposals.

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