The Haptic Body Scale: Designing Imprecision in Times of the Quantified Self

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ABSTRACT
Followers of the *Quantified Self* movement track, analyze and compare vital and environmental data to optimize themselves. It can be stressful to keep all the measured values under control when pursuing this ambitious way of life. Body weight can be an especially emotional issue for many people and slight differences can be perceived as lack of discipline, although little fluctuations are natural. In this paper, we present a tangible display for body weight, based on floor rigidity. It displays body weight without numbers, which makes it less suitable for comparisons, while still giving the user an idea about their weight. We describe the metaphorical foundations of the concept, as well as the development of two prototypes, which implement the envisioned full-body weighing experience. We demonstrate how the design of a display can influence the users' connotation of data.

Author Keywords
Haptic display; tactile feedback; floor; tangible interaction; user experience

ACM Classification Keywords
H.5.2. User Interfaces: Haptic I/O; Prototyping

INTRODUCTION
On the one hand, there are positive consequences of the *Quantified Self* movement. Followers log various inputs, states and performances to gain "self-knowledge through numbers" and choose which need to be adjusted to achieve well-being [34]. Tracking devices, mobile applications and websites can be used as motivational tools and to support, or substitute, a personal trainer.

Body weight is logged by the majority of current self-tracking applications. In most cases, it is displayed as numbers in standardized terms (such as kilograms, pounds, etc.), often with a high accuracy and at short intervals, in order to improve data resolution and give precise results. However, this accuracy may also have disadvantages. Changes in the body weight of an average healthy individual are caused by various factors, many of which are not related to exercising, eating or other behavior [5]. Most of the current body-weight tracking applications do not account for these fluctuations. Therefore, users with a good constitution who are dieting, practicing sports or exercising, can be at risk of becoming frustrated by insignificant weight changes.

The current custom of precision enhancement in self-tracking may have psychological side-effects, from obsession to frustration. Therefore, this work seeks to critically review the current state of self-quantification, and advocate imprecision.

An analysis of the current weight visualization and an analysis of peoples' current weighing experience revealed several design opportunities to improve the weighing experience. Above all we submit the approach to make use of an embodied metaphor in order to encourage users to reflect on data. Although data is supposed to be neutral, it depends a lot on how we display and perceive it. In order to demonstrate this, we want to present the Haptic Body Scale that aims to improve users' experience of weighing themselves or rather receiving the measurements (see Figure 1).

Figure 1. The Haptic Body Scale prototype, displaying weight tendencies through rigidity when stepped upon.

TEI '17, March 20-23, 2017, Yokohama, Japan
© 2017 ACM. ISBN 978-1-4503-4676-4/17/03...$15.00
DOI: http://dx.doi.org/10.1145/3024969.3025003

Metaphorical mappings are an active field of Human-Computer-Interaction (HCI) research [14,15,28]. Interaction models based on embodied knowledge (through embodied metaphors) can support users' experience [2]. This research also follows this path: the Haptic Body Scale is based on an initial survey conducted with a group of weight-conscious students.

RELATED WORK

This project is located at the intersection of different areas of research: critical design, floor-based haptic displays and rigidity-based displays. But first of all, we want to give an overview of how weight is visualized at the moment within the self-tracking community.

Weight visualization within the self-tracking community

By looking at smart phone applications (see Figure 2) for general fitness and weight tracking two conclusions can be drawn.

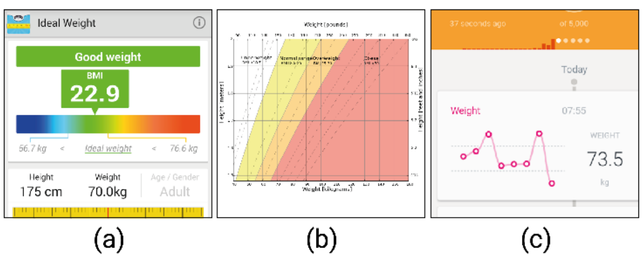

Figure 2. (a) The Application "Ideal Weight" [10] visualizes underweight in blue (b) A Body mass index chart [33] by the World Health Organization (WHO) visualizes underweight in white and seems to be a reference for many applications (c) The Application "Withing's Health Mate" [11], accompanying the Withing's smart scale, visualizes weight development in a way that temporary fluctuations of two kilograms seem to be significant.

First, body weight and its development is usually visualized with a precision that is not in the very nature of body weight. Body weight is often displayed with an accuracy of one or two digits after the decimal point [11]. Furthermore some applications suggest to measure the users' weight multiple times a day. As a healthy adult, variations in body weight are normal and can be as large as 2 kg (4.4 pounds) due to measurement error, clothing, food consumption and fluid balance or for women due to the menstruation cycle [5,17,23,26]. We did not take applications in consideration that are particularly assigned for people with explicit weight problems or chronic diseases. In that case, a high accuracy of measurements may be useful.

And second, underweight is usually visualized in a less alarming way than overweight. In many visualizations, a colored visualization of the body mass index (BMI) is used. The BMI is a value derived from the weight and height of a person [22]. Usually, higher weight is presented in the color red and lower weight in green, blue or white [10,33]. Conventionally in the western world, red in user interfaces is used for alarms and emergencies, green for normal activities and blue and white for neutral states [7]. While overweight is visualized consistently negative, underweight is often visualized in neutral connoted colors which could cause users to underestimate the potential health dangers of being underweight.

Critical Design

Several projects in the field of interaction design research scrutinize and critically reflect self-quantification. Vos investigates the 'quantified brunch' [31], while Broomfield proposes objects for 'data obsessives' [4], which include a tool for the introduction of micro time zones. Dauner's 'disciplinary machine' [6] that converts the step counter data into an overly precise analogue print-out on paper, underlining the potential of compulsiveness in self-tracking. Wang [32] analyzes existing domestic objects in regard to "Asimov's First Law" [1], which postulates that a robot may not harm a human being. Wang claims that weighing scales do harm human beings, albeit psychologically. She proposes different weighing scales, which allow for lying to oneself about the weight and for outsourcing the task of telling the weight to another person, thereby obeying Asimov's law.
We aim to add to this body of research by approaching the topic from a 'haptic display' point of view.

Floor-based haptic displays

Haptic displays often focus on haptic feedback via users' fingers, but also using the floor as a haptic display is being actively researched, often presenting sound feedback for cross-modal effects. Some projects in this area simulate surfaces, e.g. in virtual reality, mixed reality or locomotion interfaces. ALF [27] and EcoTile [30] use shape changing floors, Active Shoes [3] and Frozen Pond [24] use methods of sonification. Another area of floor-based haptic feedback is non-visual navigation. Projects in this area include vibro-tactile [29] and shape changing shoes [8]. A third area of floor-based haptic feedback utilizes simulated floor materials as an awareness tool, as in Fu and Li's "Haptic Shoes" [9] which communicate stock market information through vibration. This work provides insights into how the floor can be used as a display, demonstrating a beneficial approach to displaying 'quantified self' data. As this project is concerned primarily with body weight, actuating the floor's rigidity is proposed as a fitting approach.

Rigidity-based displays

Several HCI projects investigate rigidity as a display. Jansen's Mudpad [16] is a multi-touch input device that uses magnetic liquid to create a surface of variable viscosity. MimicTile [19] is an interface for mobile devices that recognizes gestures and reacts to squeezing. The flexibility can vary through actuation of the shape-memory materials embedded inside. A control device to manipulate objects in virtual environments simulates softness [25]. JamSheets by Ou et al. actuates the deformability of a structure by adding and removing liquids inside [21]. One of several scenarios of the mobile device called SqueezeBlock [12] is to feel the amount of unread e-mails by increasing the rigidity of its case.

These three last areas of research provide valuable insights into critical reflection of societal developments through design, using the floor as a haptic display. Rigidity of the floor material is used as a style of actuation. In this work, we propose to combine the three.

DESIGN OPPORTUNITIES

By taking the related work of weight visualization and weighing procedure into account, we phrased three design opportunities to conceptualize an alternate, less frustrating body scale that encourages body intuition rather than an external valuation:

- The scale may compensate for natural fluctuations as large as two kilograms (which are normal for healthy adults)
- The scale may communicate increasing distance to the users' ideal weight in the same way, no matter if the weight is increasing or decreasing. It should convey the fact that neither extremity carries a risk and requires action. The ideal weight (range) of the user would be set preferably, in consultation with a doctor.
- The scale may make use of an embodied interaction in order to enhance the users' reflection on their body intuition. The implementation of a playful enjoyable interaction metaphor may encourage a less negative perception of measurements away from the ideal weight (range). Therefore, current language can be a source of inspiration.

CONCEPT

The Haptic Body Scale displays changes in the user's weight, by changing the rigidity of an actuated floor surface that they step on. The larger the discrepancy (in either direction) to their subjective ideal weight, the more flexible the floor becomes. If the user is in the range of their ideal weight, they stand on a firm floor. The further away to their supposed ideal weight, the more the floor moves. Comparable to a springboard, they sink in as they step on the scale, but bounce up as they move.

This interaction metaphor originates from the fact, that people are said to be feeling "up" or "low" when they experience positive or negative affects [18]. In fact, one of the definitions for depression indicates, that it is "a depressed or sunken place or part; an area lower than the surrounding surface" [13]. We hope to "uplift" and comfort the users, by connecting undesirable measurements with bouncing interactions.

USER TESTING

For this experimental prototypes we decided to conduct qualitative individual interviews (see table 1) of 30 to 40 minutes, each accompanied by an informal user test of the prototype. We gathered feedback about the user experience of both of the Haptic Body Scale prototypes and their connotations, rather than the technical performance or accuracy of the display. We recorded the users' answers, but also observed their behavior as they tried out the prototypes.

Goal of the interview part	Questions asked
In the first part, we talked about the motivation of the Haptic Body Scale to give an introduction.	• Do you have a personal ideal weight (range)? • Have you ever experienced frustration concerning your weight? • How do you feel about fluctuations in your weight?
In the second part, the participants tried out and described their experience of the three different states of the Haptic Body Scale after they got an explanation of the functionality.	How does it feel… • to be in the range of the ideal weight = rigid ground? • to be slightly out of the range of the ideal weight (2-5 kilograms above or under) = moderately flexible? • to be out of the range of the ideal weight (5-8 kilograms above or under = very flexible? They were asked to describe their experience and how they like the approach and the prototype's implementation of • the replacement of the numerical display by a haptic display • the compensation of fluctuations • communicating underweight and overweight in the same way
In the third part, the participants were asked to compare the experience of the Haptic Body Scale with a regular scale, especially in regards to frustration potential.	• Do you think there are differences in the frustration potential? • What else is different? • What does the Haptic Body Scale do better/worse than a regular scale?

Table 1. Structure of the qualitative user test

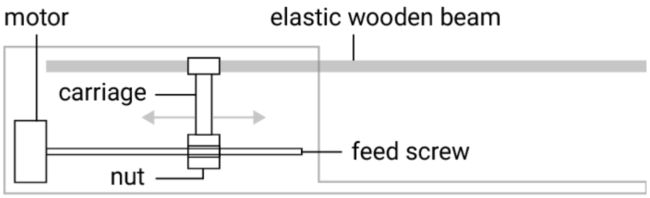

Figure 3. The flexibility of the beam (side view)

Target group

Since we took the self-tracking community as a starting point, we aimed at people without overweight, underweight or chronic disease but technology enthusiasts who are interested in aspects of self-improvement. As the majority of wearables users (which include tracking devices) are between 18 and 34 years old [20] we invited participants of that age group.

PROTOTYPES

An iterative prototyping process allowed us to explore a haptic display that users can step on. Through informal user tests, we wanted to learn about the users' experience of feeling weight through various degrees of floor flexibility. Implementing a numerical and standardized weighing function, or setting an ideal weight was not part of our prototype requirements. Two full-size prototypes and tested with users.

Prototype I: construction

Our first prototype is based on CDLEE (control of deformable length of an elastic element) softness display's construction [25], which we adapted from being small-scale to large-scale so it could be used by users as a full-body scale. The prototype is illustrated in Figure 3. It consists of an elastic wooden beam, a feed screw, a carriage with a nut, and a motor. As shown in Figure 3, the flexibility of the beam corresponds to the position of the carriage and can thus be changed continuously.

Prototype I: user responses

In preparation for an informal user test, we informed seven users (four female, three male, aged 22-34) about the concept of the Haptic Body Scale. They were then asked to try the three states of the system, ranging from rigid over moderately flexible to very flexible. During the accompanying interviews, we asked them about how it felt, what connotations they had and how the haptic display of their

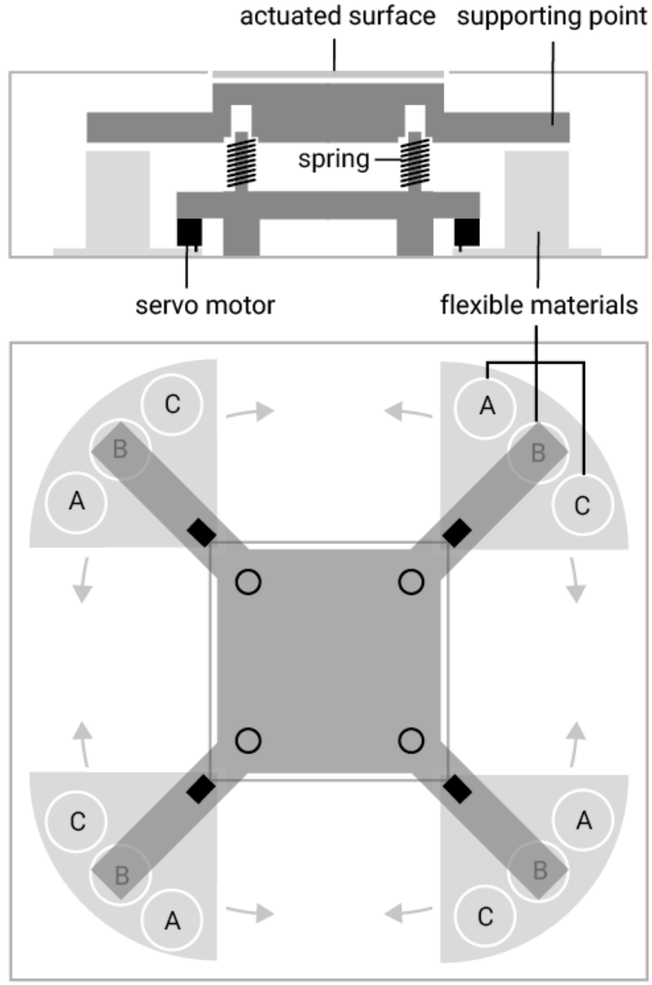

Figure 4. The supporting points of the upper frame can be set to different materials and therefore users can explore three degrees of rigidity

relative weight could influence them emotionally.

All users indicated that they were not in need of a precise number display. Additionally, they also did not always want to know the minor fluctuations of their weight. The users were able to distinguish easily between the three states. Five users mentioned negative connotations when stepping on the prototype.

Key quotes:

- "I feel really heavy because the floor bends as I step on it."

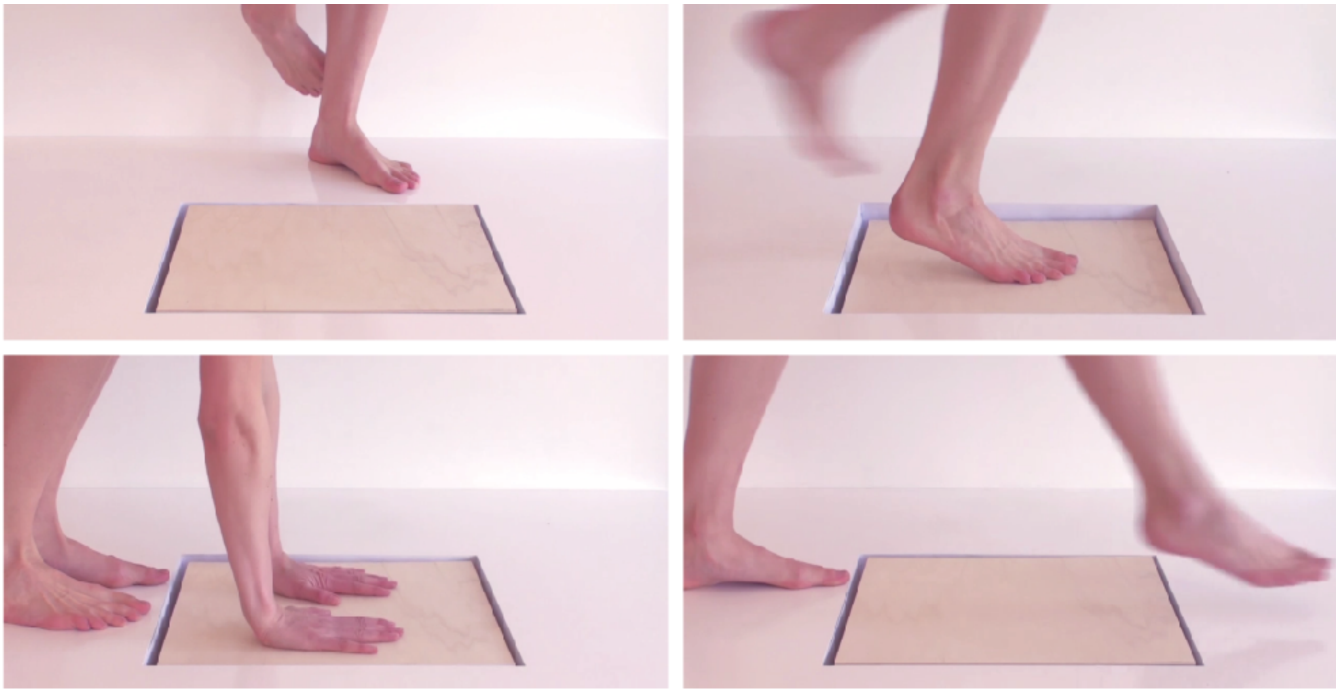

Figure 5. A user enacts different interactions with the Haptic Body Scale (Prototype II)

- “I like the wooden surface, it’s different to a regular scale.”
- “It is a good feeling to step barefoot on it.”
- “It doesn’t feel like I expected it to.”

Key observations:

- Five of the participants stepped very timidly on the scale
- Two tried to move as little as possible when trying out the flexible state of the prototype
- Six users preferred the most rigid state of the prototype

Prototype I: conclusion

After building and testing the first prototype, we concluded that the general idea of a haptic, and therefore imprecise, scale was received positively, but that the haptic experience needed adjustment. States of yielding seemed to be easy to distinguish for the users, so the next iteration should not just yield, but implement a more flexible and “bouncing” character, in order to provide a more positive connotation and a more pleasurable, playful experience.

Prototype II: construction

We built the prototype which is shown in Figure 4 based on the system of a turret head. The lower frame of the construction is floor-mounted and connected to four discs that can be rotated simultaneously using servo motors. On top of every disc, three feet with different material properties are mounted. Depending on the angle, the supporting points of the upper frame that the users are stepping on are laying on top of the feet A, B or C. All feet provide different degrees of rigidity. Setting mode A results in a firm stand since the feet are made out of non-flexible material. For feet B and C, we chose air filled membranes of different volume to achieve more flexible stands. In between the lower and upper frame, the positioning of metal springs as spacers allow free movement of the discs, ensuring that the actuated surface is flush with the scale’s casing.

Prototype II: user responses

In the second informal user test, we presented the prototype to eight users (five female, three male, aged 22-36). Six of the participants tested the first prototype and were asked to compare their experience with the first prototype. Seven out of eight users expressed that they enjoyed the bouncing states.

Key quotes:

- “It feels nice.”
- “If the movement was smoother, it could be really meditative.”
- “It’s actually much more fun to be out of the ideal weight range”
- “I don’t know if I could renounce a traditional numerical scale. There might be situations when I want to know my exact weight.”
- “This one [prototype I] fits better to the concept.”
- "On the other scale [prototype I] I felt heavier, here I feel lighter."

Key observations:

- As we interviewed the participants, they were acting out situations they could imagine if they were using the scale at their home
- Three users “dipped their toe” (see Figure 1) to check the scale’s result, two used their hands before they stepped on it to test the haptic display’s flexibility

- Two ran quickly over the actuated surface to "take a glance in passing" (see Figure 5)

Prototype II: conclusion

Reviewing the users' experience, we concluded that the use of an evolved air suspension system can provide continuously variable flexibility. By involving product designer and mechanical engineers, a smoother bouncing movement would be possible.

Utilizing the two prototypes in initial user tests, we were able to get an initial insight into their experience of weighing, when stepping on a haptic display. We found that our approach to facilitate a "trampoline-like" sensation was received positively. The fact that they invented their own interactions (for example the pre-testing by hand) showed that they adopted the metaphor that the scale uses: movement or backlash for distance (to the ideal weight). The proposals they made should be taken into consideration in further development.

CONCLUSION AND OUTLOOK

We presented the Haptic Body Scale, a rigidity-based haptic display for body weight that users step on. Initial, qualitative user tests indicated that users appreciated a display for their body weight that omits numbers, and rather provides a rather imperfect, and therefore less comparable, type of display.

What we learned from our project is, that using a haptic floor-based display with a playful approach can influence the connotation of data. Data that is generally perceived negatively is reframed in a positive way. Numerous users stated that the use of the Haptic Body Scale is "fun", but only a long-term in-situ study with actual weight data could show how it changes body awareness and self-perception. The approach of translating quantitative data into a haptic experience might be suitable for other areas of application. This may be particularly the case for potentially frustrating data, as is the case of body weight. Here, a playful presentation could help users to keep their motivation if they struggle to keep or reach their ideal weight.

In a lot of cases, precise values are not required, and can be replaced by knowing of whether they are within a certain range. In these cases, haptic ground-based displays could be applied, especially when a close metaphorical connection is implied. The observation that some of the users enacted the checking of their weight in passing, demonstrated, how haptic floor-based actuation could work as an ambient display in other contexts. The actuated surfaces can be integrated in floors, steps of a staircase and doorsteps.

The Haptic Body Scale is not just a tangible display but a visual display too: By standing on it, users can see how much the actuated surface is sinking in. This is another advantage of showing the relative weight instead of the absolute: it leaves room for interpretation. The fact that neither numbers nor other quantifications are used to display the measurement result brings up the question of if and how users would communicate the results. This way users would possibly create alternate descriptions that might influence their relation to their weight.

The principle of actuated ground flexibility as an information display could be transferred to other application contexts. For example, ambient displays in buildings could be achieved by this means, e.g. by displaying inside activity as users step into a house or in front of a door. The Haptic Body Scale has set out to critically review the "Quantified Self" movement's fixation with precision, and to provide a counterweight to its "unforgiving" accuracy.

With data-producing trends like self-tracking and Internet of Things in mind, it will become increasingly important to analyze, display and curate data in a more conscious way in order to comply with human nature. The Haptic Scale shows, how rethinking the display of and interaction with data can influence its perception.

ACKNOWLEDGMENTS

Thanks to the team of the Design Research Lab Berlin, Lisa Weiss, Susann Hamann, Matthias Löwe and Josefine Zeipelt for their help during the project and Marie Beuthel and Berit Greinke for proofreading.

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