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CASE REPORT

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Design of the user interface for "Stappy", a sensor-feedback system to facilitate walking in people after stroke: a user-centred approach

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ABSTRACT

Introduction: Sensor-feedback systems can be used to support people after stroke during independent practice of gait. The main aim of the study was to describe the user-centred approach to (re)design the user interface of the sensor feedback system "Stappy" for people after stroke, and share the deliverables and key observations from this process.

Methods: The user-centred approach was structured around four phases (the discovery, definition, development and delivery phase) which were fundamental to the design process. Fifteen participants with cognitive and/or physical limitations participated (10 women, 2/3 older than 65). Prototypes were evaluated in multiple test rounds, consisting of 2–7 individual test sessions.

Results: Seven deliverables were created: a list of design requirements, a personae, a user flow, a low-, medium- and high-fidelity prototype and the character "*Stappy*". The first six deliverables were necessary tools to design the user interface, whereas the character was a solution resulting from this design process. Key observations related to "readability and contrast of visual information", "understanding and remembering information", "physical limitations" were confirmed by and "empathy" was additionally derived from the design process.

Conclusions: The study offers a structured methodology resulting in deliverables and key observations, which can be used to (re)design meaningful user interfaces for people after stroke. Additionally, the study provides a technique that may promote "empathy" through the creation of the character Stappy. The description may provide guidance for health care professionals, researchers or designers in future user interface design projects in which existing products are redesigned for people after stroke.

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➤ IMPLICATIONS FOR REHABILITATION

- The case study provides a structured methodology and seven deliverables that may contribute to the (re)design of interfaces of existing supportive technologies for stroke rehabilitation.
- For supportive technologies in stroke rehabilitation important aspects to consider are the provision or presence of "feedback" (sensor-feedback system), "readability and contrast of visual information", "understanding and remembering information", "physical limitations" and "empathy".
- Apart from functional requirements and an understandable user interface, i.e., good usability, our case study demonstrates that the inclusion of a (fictional) character like "Stappy" may lead to a more meaningful and enjoyable user experience.

Introduction

The number of people affected by stroke continues to rise throughout the world due to an ageing population [1]. About two-thirds of stroke survivors experience difficulties in walking [2]. It is known that frequency and intensity within a functional approach are essential prerequisites for effective rehabilitation [3,4]. However, in the first stages after discharge from hospital or inpatient rehabilitation facilities, therapy time is often limited, whereas at the same time stroke survivors still feel they would benefit from more therapy [5]. Effective and efficient therapy is essential to cope with the increased numbers of incidence and prevalence of stroke survivors.

To meet the required training intensity, which is needed for optimal recovery, patients are encouraged to practice independently at

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home. Unguided practice may not only contribute to physical recovery but may also improve feelings of autonomy. However, the actual compliance by patients at home to therapist-prescribed activities seems poor [6,7]. The presence of cognitive impairments, which is commonly seen in people after stroke [8], may be one of the explanations. People can forget to exercise (e.g., due to memory deficits), find it hard to monitor own performance (e.g., due to attentional deficits) or may not be motivated enough to practice. Affordable and simple solutions, such as smart devices could support people after stroke during unguided practice.

Smart devices with sensor-feedback have the potential to stimulate and motivate users to practice. Moreover, they allow practice without therapy supervision at convenient times in the preferred (home) environment of the patient. An example of an easy to use sensor-feedback system is the CuPiD-system [9]. Casamassima et al. [9] developed this wearable gait training system (Figure 1) for people with Parkinson, which was later adapted by Ferrari et al. [10]. The functionalities of the technology also seem compatible for gait rehabilitation in people after stroke. However, next to functionalities, designing a meaningful user interface for this target population may optimize the user experience and therefore the actual use of the system. We therefore wanted to examine whether the CuPiD-system could be altered for use within this new target population. The current study describes a user centred approach that was used to (re)design the user interface of this existing sensor-feedback system for people after stroke.

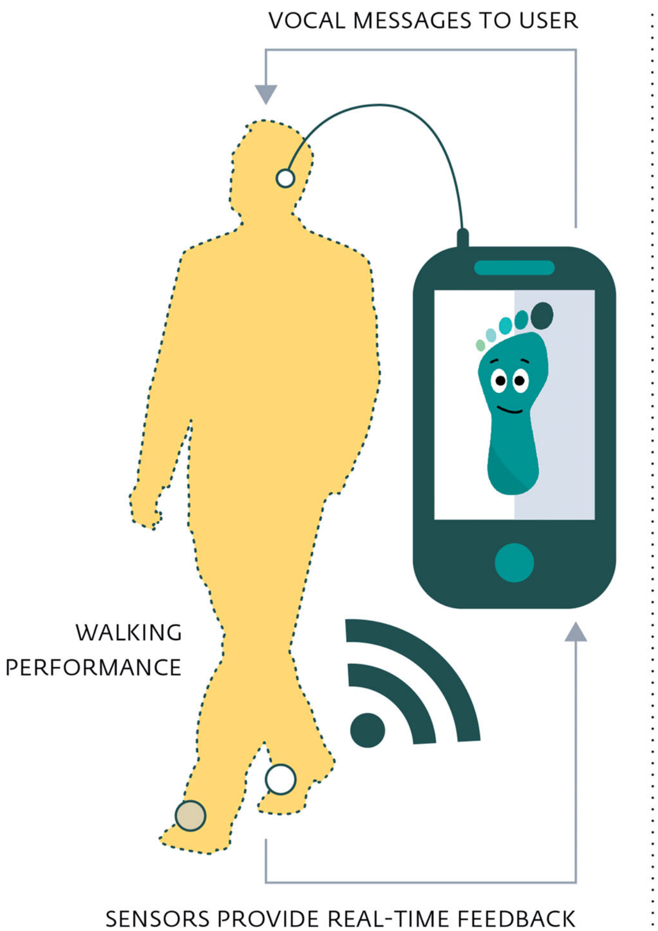

Figure 1. Overview of the sensor-feedback system, with sensors on the shoes, smartphone and auditory feedback through speakers.

As input for the (re)design process, the designers needed a thorough understanding of the needs and preferences of the new target population to ensure a meaningful and comprehensible user interface. Therefore, as a first step of the design process (so called "discovery phase"), three main characteristics of the stroke population were identified from literature [8,11–13] and user interfaces of related projects (Quick Board [14], Med App [15], Oefen App beroerte [16]). The characteristics include "the older population (65+)", "cognitive" and "motor impairments". For the user interface, these characteristics imply that the design should consider aspects related to readability [12], reduced cognition (e.g., minimize task complexity) [8] and motor impairments [11,13]. Also, preferably, traditional and intuitive colours are used, e.g., "green" (good) and "red" (wrong) to match the mental model of the target population [17,18]. Based on the stroke specific characteristics and literature, design requirements for the sensor-feedback system were established (Table 1). Design requirements were discussed and confirmed with potential future users in informal conversations.

The main characteristics and design requirements formed the departure point for the design process. In order to develop a meaningful and intuitive user interface, users were intensively involved throughout the entire design process.

The current study was conducted to finetune and optimize the sensor-feedback system that is part of a larger usability study. The overall goal was to create a meaningful user experience for people after stroke through designing a usable and enjoyable interface of the sensor-feedback system. The second aim was to provide a systematic description of the user-centred approach with its associated deliverables. The identification of key observations may support the (re)design of existing and future products or user interfaces for the stroke population. The final result was a high-fidelity prototype of the sensor-feedback system, called "*Stappy*" (see Box 1 for description).

Box 1 . About *"Stappy"*

- *Stappy* (Figure 1), is a spinoff of an existing sensor-feedback system originally developed for people with Parkinson's [9].
- The system provides real-time feedback to users while walking.
- The overall concept and hardware-software architecture of the system is described in detail by Casamassima et al. [9].
- The current study describes continued developments on the user interface of *Stappy* for the target population "stroke".
- The sensor-feedback system is named after the character *Stappy*, which was designed by Kate Smit. The character *Stappy* guides users through the steps in the smartphone application.

Method

The user-centred approach was structured around four phases, the discovery, definition, development and delivery phase (see top layer, Figure 2) [21]. The first (discovery) phase established the characteristics (translated into user requirements) of the target population. The discovery, definition, development and delivery phase are outlined below. Within each phase several deliverables were produced (see middle layer, Figure 2). To uncover as many issues as possible, small rounds of test sessions took place until all major usability problems were resolved. The duration of the entire design process took place over a one-year period. This study is part of a larger usability study that was approved by the local ethics committee with reference number METC Z 17-T-06. All ethical principles, e.g., voluntary participation, privacy, confidentiality, were considered during the design process of the user interface.

Participants

Test rounds took place within the development phase in which participants evaluated the prototypes in individual test sessions. Participants were recruited from a local rehabilitation centre (Limburg, The Netherlands) and via client representatives of the project team. As cognitive impairments are a main characteristic of the

Table 1. List of user requirements.

Stroke specific characteristics	Design requirements for user interface	References
	Feedback = basis (general principle and function of sensor-feedback system)	
Older population: readability and contrast of information	Large font size	[12,18]
	Clear call to action[a] in page	[14,15]
	High contrast use of colours	[18]
	No hidden information (fold-outs, scrolling)	[16]
	Use of relevant pictures to complement the text	[12]
	Intuitive use of colours	[14,17]
Cognitive impairments: understanding and remembering information	Use of simple language (no jargon) and simple instructions	[12,14,19,20]
	Limited amount of text	[18,20]
	Avoid complex interactions	[19]
Motor impairments: physical limitations	No (fast) moving or animated elements	[19]
	Relatively large buttons	[14,16,18,19]
	Avoid holding a device during exercise	Clinical expertise
	Easily secured sensors	Clinical expertise

[a]Call to action (CTA): a key element on a webpage, acting as a signpost that lets the user know what to do next.

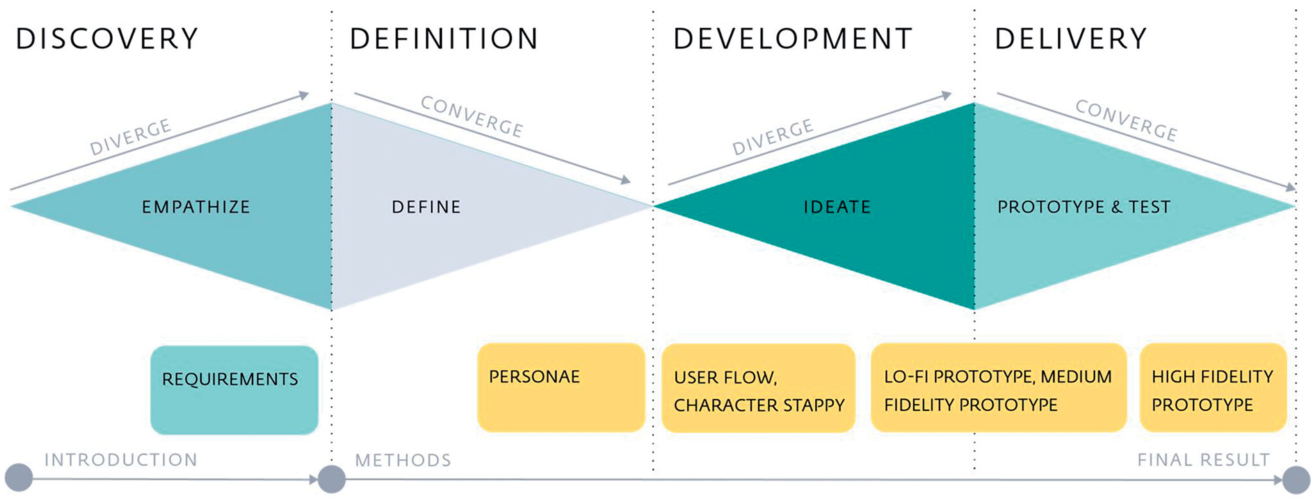

Figure 2. Schematic overview of the design process structured around four phases of the so called double diamond model [21]. The top layer represents the double diamond, below (middle layer) the different deliverables derived from the design process are described. The bottom layer represents the timeline of our design process.

Table 2. Participant characteristics.

Part	Age	Sex	Condition	Design phase	Previous experience with Smartphone	Previous experience with Tablet
1	65+	F	Stroke	Discovery phase	Yes	No
2	63	F	Acquired Brain Injury	Discovery phase	Yes	Yes
3	54	F	Multiple Sclerosis	Discovery phase	Yes	Yes
4	65+	F	Dementia	Development phase: test round 1	No	No
5	65+	M	Dementia	Development phase: test round 1	Yes	No
6	65+	F	Alzheimer	Development phase: test round 1	Yes	Yes
7	65+	F	Stroke	Development phase: test round 2	No	No
8	60+	M	Stroke	Development phase: test round 2	No	No
9	65+	M	Stroke	Development phase: test round 2	No	Yes
10	60+	F	Stroke	Development phase: test round 2	Yes	No
11	65+	F	Stroke	Development phase: test round 2	No	No
12	65	M	Stroke	Development phase: test round 2	No	No
13	65+	F	Stroke	Development phase: test round 2	No	Yes
14	65+	F	Stroke	Development phase: test round 3	Yes	No
15	65+	M	Stroke	Development phase: test round 3	Yes	Yes

F: female; M: male; Part: participant; Age in years.

target population (Table 1), for the first test round only people who experienced cognitive limitations in daily life were included. Furthermore, people were included in the test sessions if they were open towards use of technologies and had the goal to improve gait function. Each test round consisted of 2–7 individual test sessions. In total 15 participants (10 female and 5 male) of which 10 people with stroke took part in the study: the majority was older than 65 years (10/15) and all had cognitive and/or physical limitations. About half of the participants were familiar with smart devices, e.g., had previous smartphone or tablet experience. Demographic data of the included participants are presented in Table 2.

Definition phase

Based on literature and related projects (discovery phase), user requirements were gathered (Table 1). The list of user requirements was evaluated and if applicable extended during the design process, e.g., when new information derived from the test sessions. Knowledge derived from the discovery phase was synthesized into a persona. A persona can be defined as "an archetype of a user that is given a name and a face, and it is carefully described in terms of needs, goals and tasks" and is used by the design team to satisfy the user needs and goals [22].

Procedure and analyses

In the current study, the persona was based on the main characteristics and design requirements as identified from the discovery phase. This persona is a visual representation of the application's intended user.

Development phase

Test sessions with the deliverables, i.e., designed prototypes, began in the development phase. Based on the persona and design requirements (discovery and definition phase), the following deliverables were designed: a user flow[1] and low to high fidelity prototypes. In test sessions with potential future users, the user flow, low and medium fidelity prototypes were evaluated, the high fidelity prototype is evaluated in the delivery phase.

Procedure and analyses

The test sessions involved the evaluation of different components. In the first test round, with regard to the user flow participants were asked to evaluate (1) whether steps were placed in a logical order, (2) whether text was clear and (3) whether provision of information was complete or what was missing. With regard to the prototypes they were asked to evaluate which they preferred (and why) and what they (dis)liked (and why). After test round one, all feedback was considered and processed in the design. In the consecutive test, round participants were asked to provide feedback on each component of the application. These included the homepage, the walking exercise and stopping the training. In test sessions, users reported what they (dis)liked about the following items: use of colours, readability, instructions, language and feedback. Test sessions took place until no major usability problems occurred. Key observations were summarized at the end of each test round. Examples of the designed prototypes along the design process were displayed in figures and clarifying quotes were reported.

Delivery phase

The delivery phase presents the results of the last round of test sessions, i.e., when no major usability issues were reported by the users. A high-fidelity prototype formed the starting point for the delivery phase. Test sessions were similar to the development phase, hereby users were asked to evaluate components related to use of colours, readability, instructions, language and feedback. Next to these components, if applicable, users could report other usability issues that were not listed. Together with engineers of the project team, the high fidelity prototype "Stappy" was implemented in the existing smartphone application of the sensor-feedback system.

Results

Within each phase, different deliverables (persona, list of user requirements, and prototypes) were created (Figure 2). In total three rounds of test sessions (iterations) were needed to develop a low, medium and high fidelity prototype. The first two rounds are described in the development phase and evaluation of the high-fidelity prototype (third test round) is described in the delivery phase.

Definition phase

The definition phase resulted in a persona that is presented in Figure 3.

Development phase

The development phase presents the prototype, key observations and evaluation by the users of each test round. Results of each test round are described as follows: first the deliverables are presented, then the evaluation of the deliverable are described and finally the key observations from the test round are summarized.

Test round 1: user flow and low fidelity prototype

The discovery phase delivered input for the design of the user flow (Figure 4) and low fidelity prototype (Figure 5).

Three users evaluated the user flow, and low fidelity prototype of the user interface (Table 2). All three people understood and agreed with the user flow. They emphasized that the option to receive extra information if needed is nice. People were positive about the extra reminder at the end of practice to charge the system. Based on responses of the users in the first test round, no further changes were made in the user flow. All three people preferred the sketch that included a fictional character (Figure 5, right). People mentioned that the character made the design cheerful and personalized. Importantly, the character was not perceived as "childish" but users found the character suitable for the application. Users reported that the text "connect with the sensors" was not clear and reacted to the text with "*but how do I do this?*" (participants 4 and 5). The feedback from test round one and the remaining design requirements that could not yet be implemented in the low fidelity prototype (Table 2) were integrated in the medium fidelity prototype (Figure 6). Two versions (Figure 6) of the medium fidelity prototype with different colour options were evaluated in the following test round (Box 2).

Box 2. Key observations: user flow and low fidelity prototype

Known from literature and confirmed in study

- *Understanding and remembering information:* Cognitive limitations are common within the target population, therefore, an extra reminder function to charge the sensors after practice was added in the user flow. Second, an optional step was included with extra instructions on how to use the sensor-feedback system.

- *Readability and contrast of visual information:* Based on the earlier defined user requirements, the low-fidelity prototype aimed for a clear and simple presentation of the functionalities and provision of information. To emphasize the user experience, part of the sketches in this prototype included a fictional character.

Test round 2: medium fidelity prototype and character Stappy

The first test round revealed that the user flow was clear, therefore, no other changes were made in the user flow. Furthermore, feedback from the low-fidelity prototype was processed in the design of the medium fidelity prototype (Figure 6) and the inclusion of a fictional character was further explored (Figure 7).

In total, seven people evaluated the medium fidelity prototype of the user interface. People had a strong preference (six out of seven) for the version with a light background and letters displayed in black (Figure 6, left). Font and button sizes were found to be clear but some instructions were not. The screen with text "press to connect" (to turn on the sensors on shoes) brought some confusion. Text was intended to press on the button of the actual sensors but instead users pressed on a button of the user interface. For clarity some people proposed changes in the supporting image "*the image should be more three-dimensional*" (participant 9). Two users mentioned that it would be nice if the system would refer to their personal names. Users mentioned that they liked to receive feedback at the end of the training for example people reported "*Even a low percentage would motivate me to do better next time*" (participant 7) and "*It would be motivational to have both the duration of practice as the success percentage as feedback*" (participant 13). They reported that it would motivate them to keep on training. All seven people were positive about the character *Stappy*. Users stated "*It's a funny foot, I like that it's there*" (participant 13) and "*Stappy makes it inviting to start training*" (participant 10). The character was seen as a positive, enjoyable element of the interface that evoked sympathy "*Stappy has a sympathetic look*" (participant 9) (Box 3).

Box 3 . Key observations: medium fidelity prototype and character *Stappy* (test round 2)

Known from literature and confirmed in study

- *Readability and contrast of information:* To optimize readability for the target population text was supported by illustrations.

NEW:

- *Character Stappy:* There was a strong preference for including a fictional character (test round one). Therefore, the addition of character *Stappy* was further explored (Figure 7). *Stappy* was shaped as a foot so that people would associate character with the activity "walking".
- *Empathy and feedback:* The character *Stappy* can empathize with the users through displaying different emotions, e.g., happy face when an action goes well. Through different emotions (empathy) the character *Stappy* also forwards some level of feedback. For example, when the user is waiting for the sensors to connect, the face expression of *Stappy* is waiting (Figure 7(B)) until the connection is established. Then the character transforms into a happy emotion (Figure 7(A)), connection succeeded.

Delivery phase

With input from the development phase a high-fidelity prototype was designed. In the delivery phase, this prototype is evaluated. First, the high-fidelity prototype is presented, then the evaluation by the users and final key observations are described.

Test round 3: high-fidelity prototype

In the high-fidelity prototype, feedback from the second test round related to readability and the character Stappy were integrated (Figure 8).

Two users evaluated the high-fidelity prototype and both mentioned that they were able to walk through the application easily. They reported to perceive the graphics as enjoyable "*I like that Stappy's expression changes during the instructions*" (participant 14) and "*the instructions are clear and the images are a nice addition*" (participant 15). The users confirmed that feedback at the end of practice and the built-in reminders were nice "*I like the positive message about the score at the end of practice*" (participant 14). Despite impaired motor skills (trembling hand) by one of the participants the buttons were big enough to "tap". One of the participants mentioned that she would like to see the battery status at the beginning of practice, while the other participant did not find this necessary. No other, major usability problems were experienced by the users and therefore this test round was determined as the end of the test sessions. Based on these results, no further changes were integrated in the user interface (Box 4).

Box 4 . Key observations: high-fidelity prototype

Known from literature and confirmed in study

- *Readability and contrast of information:* The image of sensors was not clear. The graphic of the sensors was therefore transformed into a three-dimensional image and the associated text was adjusted to clarify that users should press the button of the sensors on the shoes (not the user interface itself).
- *Readability and contrast of information:* To keep provision of information to a minimum and avoid distractions from the actual task, battery status is only visible in the most relevant places (not on every slide).
- *Feedback:* Test round two pointed out the importance of feedback about performance. Therefore, at the end of practice the success rate of practice (percentage of correct performance) is shown in a pie-diagram.

Discussion

The main aim of the study was to describe the user-centred approach used to (re)design a user interface from an existing sensor-feedback system for people after stroke, and share the key observations from this process. Within this approach, seven different deliverables derived: a list of design requirements, a persona, a user flow, a low-, medium- and a high-fidelity prototype and the character *Stappy*. The iterative nature of the user-centred approach enabled us to gain a deeper level of user understanding and thereby design an interface that may lower the threshold for people after stroke to actually use the sensor-feedback system. Furthermore, the expressive personality of the designed character *Stappy* may contribute to a more enjoyable interaction with the product. Through the development of the interface,

Figure 3. Persona of the application's intended user.

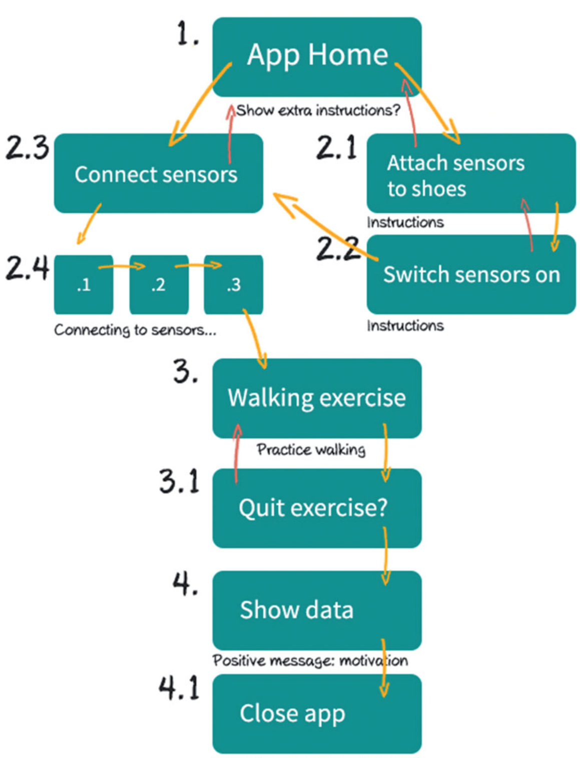

Figure 4. User flow of the mobile application.

more general key observations could be obtained. Key observations covered aspects concerning "feedback" (sensor-feedback system), "readability and contrast of visual information" (older population), "understanding and remembering information" (cognition), "physical limitations" (motor impairments) and "empathy (character)". The first four listed domains of design requirements as reported in literature and observed in related projects (Table 1) were confirmed. "Empathy" was an additional domain derived from this specific design process. Feedback and empathy seem important motivational factors in general [23,24], and of course also for people after stroke [25,26]. Hopefully, the description of the user-centred approach and associated key observations will contribute to the (re)design of existing and future products and interfaces for the stroke population.

Comparison with other studies

To improve designs of assistive technologies within the stroke population scientific literature advocates patient involvement throughout the entire design cycle [26,27]. Comparable studies [27,28] that described the design process using a user-centred approach demonstrate similar design cycles. Starting with "getting to know" the users (e.g., through defining user requirements) after which products are developed and evaluated in an iterative manner with the users (e.g., through focus groups). This general design cycle could be placed in the double diamond model (see top layer, Figure 2) [21]. The double diamond model offers structure and was

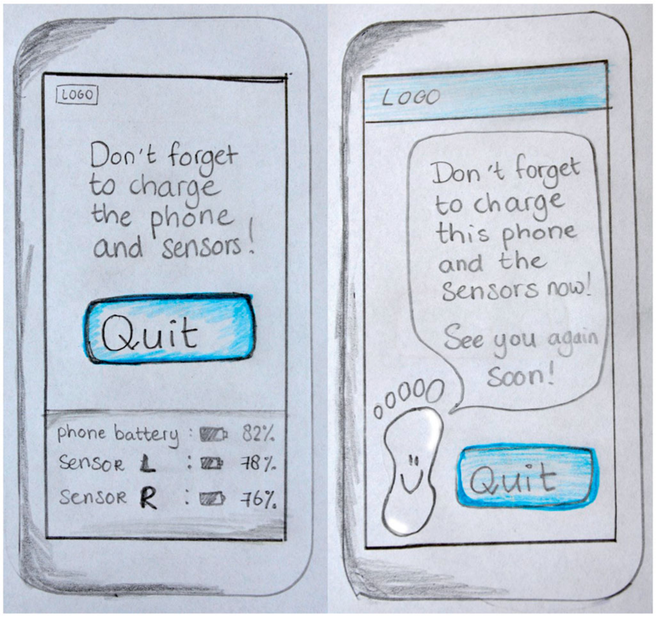

Figure 5. Low fidelity prototype.

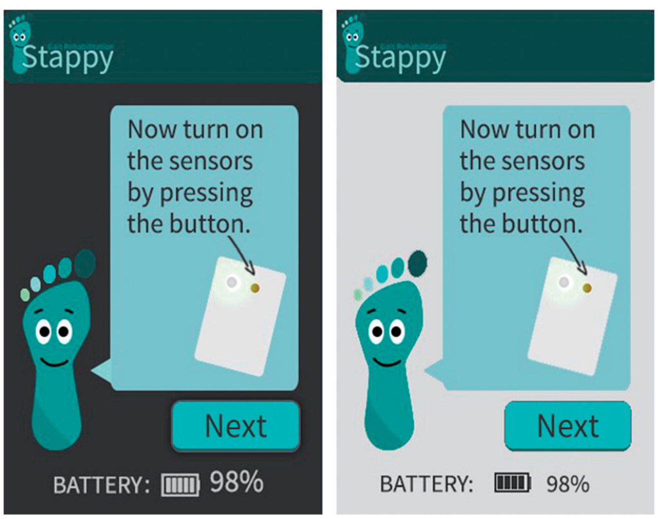

Figure 6. Medium fidelity prototype. Version 1 (dark background); version 2 (light background).

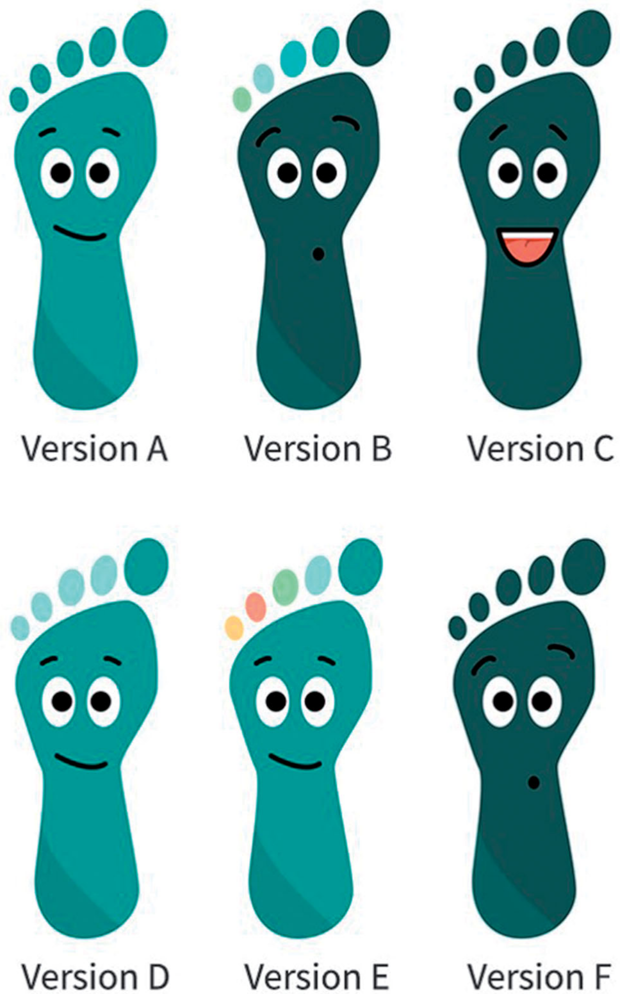

Figure 7. Exploration of the character "*Stappy*".

therefore used in the current study as a guidance to organize the design process. Below the double diamond in Figure 2, the deliverables created are presented, these may be different and specific for each design project. The choice of co-design techniques and deliverables may depend on various factors such as the expertise of the team, timeline, costs and main aim of the product.

Interface characters are a familiar concept within software technology [29]; however, the design process of a character is not often explicitly described. Also, as far as we know, no other studies designing user interfaces for people after stroke have described and evaluated the application of an interface character like *Stappy*. Within the current study, the character *Stappy* seemed meaningful to users as it evoked feelings of sympathy and joy. *Stappy* was found to motivate people to practice, this is important as it may contribute to the overall goal of the system which is to optimize intensity and quality of independent practice of gait.

Methodological quality

There are some strengths and weaknesses in this study that need to be addressed. A strength of the study is that the design cycle as presented in Figure 2 does not describe a linear process and moreover there seems no golden recipe on how to proceed. The process requires flexibility and resilience of the design team. Following an iterative approach, structured around four phases (double diamond model [21]), helped the design team to keep focus firmly on the user and make informed choices regarding methods and techniques. Truly understanding the user proved to be key in order to design a meaningful user experience.

A broad range of inclusion criteria was set in which cognitive limitations played a central role. Findings of the current study may therefore also be generalizable to other populations with similar characteristics for example older people and/or people that may experience cognitive limitations, e.g., people with Parkinson. Lastly, today there is a strong increase within current health care when it comes to the development of technologies [30]. Sometimes there seems to be an overkill in similar products, instead of improving or altering existing ones. This study describes the changes made on a promising existing system [10] rather than focussing the developments of new technologies per population, which seems inefficient.

A weak point of the study might be the confirmation of the characteristics of the participants. The inclusion criteria stated that

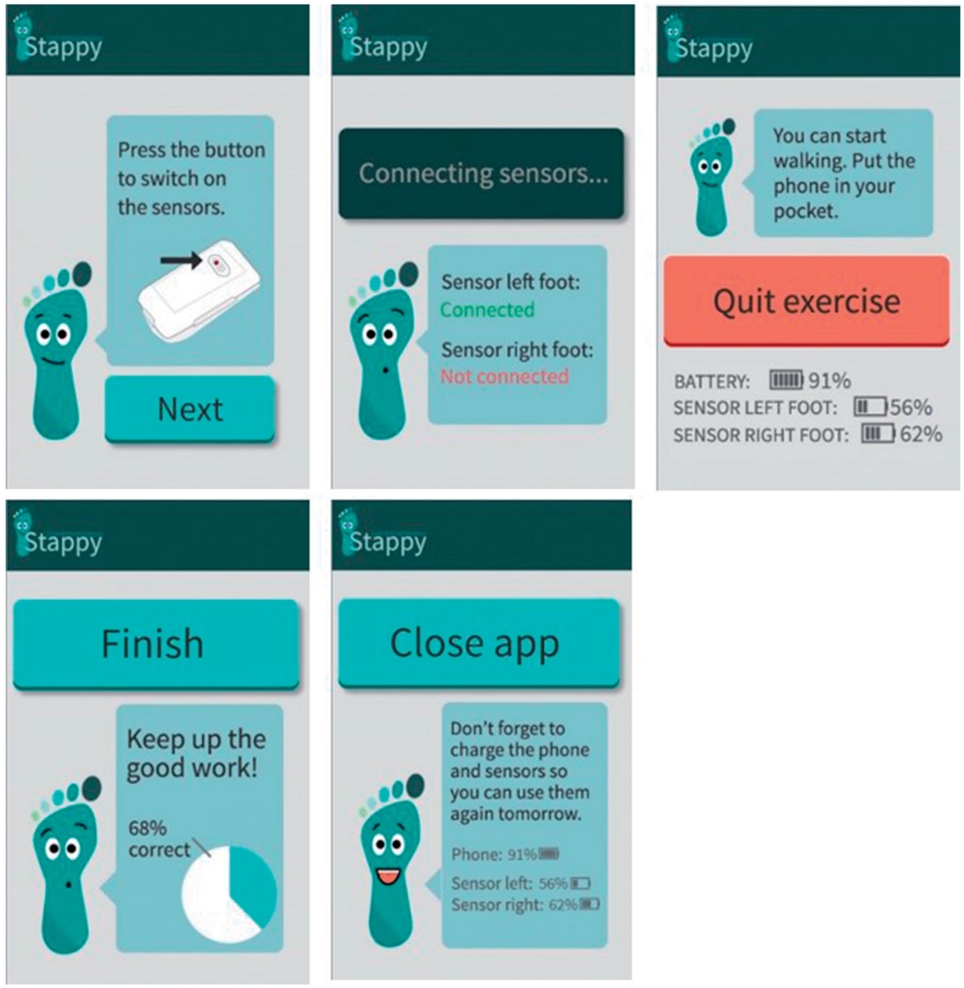

Figure 8. The final implemented user interface for the sensor-feedback system.

only people who experienced cognitive impairments could be included. Although all participants reported cognitive limitations in daily life, no cognitive tests were performed to confirm this. It is therefore not clear what range and severity of cognitive impairments in the current sample size was.

Implications for research

The (re)designed user interface should contribute to a positive and meaningful user experience. People should feel encouraged to practice their gait with the sensor-feedback system on a regular basis. Future research should assess the impact of the (re)designed user interface on the actual use sensor-feedback system. Furthermore, as the system is able to register frequency and duration of practice, it would be interesting to explore whether perceived usability can be linked to actual use of the sensory-feedback system. In other words, are people that evaluate the usability the highest, also the people that use the system the most (and vice versa).

Within this preliminary study, we observed that users were very positive about the potential use of Stappy. We believe that in some patients, the sensor-feedback system could really contribute to rehabilitation and unguided practice. In reality however, many technologies are not always used as regular as intended and the level of use is determined by various factors [31]. To gain a better understanding of who to offer the technology (and who not) to, it would be interesting to explore which aspects motivate users the most to engage with the sensor-feedback system "*Stappy*" (compliance).

Conclusions

The study offers a structured methodology and seven deliverables with associated key observations that can be used for designing meaningful user interfaces for people after stroke. Furthermore, the study provides a technique that may promote "empathy" through the creation of the character *Stappy*. The description will hopefully provide guidance to health care professionals, researchers or designers that (are planning to) design meaningful and intuitive user interfaces for this target population. Future studies are needed to assess the actual impact of the (re)designed interface of this study on the usability of sensor-feedback system "*Stappy*" on walking performance of the users.

Note

1. The user flow is a requirement for designing the user interface of the application and depicts the path that a user follows through to complete a certain task, e.g., connecting the sensors to the phone.

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Disclosure statement

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