Walk After Stroke – Initial development of a Step Counting Game for Stroke Survivors

Charlotte Magnusson
Department of Design Sciences
Lund University
Lund, SE-221 00, Sweden
charlotte@certec.lth.se

Bitte Rydeman
Department of Design Sciences
Lund University
Lund, SE-221 00, Sweden
bitte.rydeman@certec.lth.se

Kirsten Rassmus-Gröhn
Department of Design Sciences
Lund University
Lund, SE-221 00, Sweden
kirre@certec.lth.se

Héctor Caltenco
Department of Design Sciences
Lund University
Lund, SE-221 00, Sweden
hector.caltenco@certec.lth.se

MobileHCI '18 Adjunct, September 3–6, 2018, Barcelona, Spain

ACM ISBN 978-1-4503-5941-2/18/09.
https://doi.org/10.1145/3236112.3236145

Abstract
This paper presents work done within the EU project STARR. Within the framework of the project technologies to empower and support stroke survivors are developed. We report on the iterative development of an outdoor activity game for stroke survivors, and discuss design choices, experiences from the initial testing and outline potential future developments.

Author Keywords
Stroke, activity game, mobile game, co-design.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction
For persons who have survived a stroke, making conscious changes in their life-style becomes important; both to aid recovery and to avoid additional strokes. There are health and fitness related risk factors connected to stroke incidence (c.f. [14]) that have to do with hypertension, blood pressure, diabetes, smoking and cardiovascular disease. Health and fitness apps for the general public is a growing market of great importance. According to [15], there were about 259.000 health and fitness apps available on the major

app stores in 2016. Health and fitness apps are used by 33% of the consumers and wearable technology by 21% of the consumers [12] (2016). Users of health apps and wristbands explicitly state that they use the apps to keep better track of their condition or keep them healthy, and the most used app types relate to fitness and nutrition/diet.

With Pokémon Go, it became apparent that location based games can be powerful tools for encouraging activity [8]. There are many location based games on the market (a recent overview can be found at [6]), but these are designed for the general population and are not tailored for stroke survivors. As stroke survivors are often older (average age 69 in 2005 [7]), and cognitive problems are a common side-effect of a stroke, many mainstream apps can be too hard to use. For example, screens are often filled with content and interaction can be quite complex or stressing. For apps using step goals, pre-set goals for daily steps may not be appropriate. The app has to work even if you are only able to walk shorter distances, since many stroke survivors have partial hemiplegia and balance problems.

While suitably designed video games have been seen to be both useful and beneficial for rehabilitation, eg [3] and there are studies on how mobile devices can support rehabilitation exercises [4] we have not been able to find any studies on mobile mobility games specially designed for our particular user group; stroke survivors. Thus, our work has been exploratory in order to learn more about how an activity game designed for stroke survivors should be designed.

Design process

The initial user studies in the project involved in total 116 stroke survivors (8 persons under the age of 45, 21 persons 45-59, 36 persons 60-69, 34 persons 70-79 and 17 persons 80+), and consisted of a series of interviews and focus groups which were complemented by a co-design workshop carried out together with the Stroke Organization, UK [11]. These initial user studies generated a set of design guidelines for the work in the project. A sub-set of the interviews were done in collaboration with the project STARR, and are published in [9]. To get information on how existing activity bracelets worked for stroke survivors, we followed up on the initial work with a study of commercial bracelets involving 10 stroke survivors (6 men, 4 women), ages: 61-79. In this study we lent bracelets to eight members of the stroke organization in Malmö, Sweden and held qualitative interviews with them about their use, and interviewed four members of the stroke organization who had owned an activity bracelet for at least 3 months (two persons overlapped in these groups, having privately bought an activity bracelet after lending one). In the co-design workshop, one of the suggested design ideas was a mobile treasure hunt game, and in comments in both interviews and focus groups, games have also been generally put forward as an interesting option. Thus, we decided to implement an mobile activity game prototype to explore how such a game could be designed to work well with stroke survivors. Based on our initial studies, the game should be easy to use (but not childish), be possible to use with only one hand, be possible to personalize, be multimodal to support different abilities while at the same time avoid overwhelming the user. Since it was supposed to be a game, while also allowing the user to keep track of their activity, we needed to provide

feedback both on game progress as well as activity (in case these were different). An additional recommendation for our user group is to make use of their language, and also to provide instructions (a manual) on paper.

For the game design, we have been inspired both by Pokémon Go and an inclusive game for visually impaired persons [10] where you catch animals by making gestures with the phone. In a location based game you need to tie content to locations – which either means you have to support location editing for players, or you need to provide location content yourself (automatically or manually). A problem is then that the user may find himself/herself in an area without content (Pokémon Go as one example, works poorly in the countryside where both stops and pokémons are few and far between). Since the game should work "everywhere", and also for persons who are unable to walk very far, we decided to base the game on step counting/distance and not location. As the game is a mobile game, the initial target user group are stroke survivors who are able to move independently and are able to use a smartphone.

A first prototype was implemented, and tested first by members of the team, and then extensively by one beta testing stroke survivor (updates were made iteratively in this process). Once the game worked more reliably, four additional testers were recruited. Based on feedback from these testers, a second version of the game was implemented. This version of the game is currently in the process of being tested.

Design: First prototype

The game is implemented for the iPhone, and is built on a design where you specify both day goals and game goals. The day goals are how much you want to be active over the whole day, while the game goals are how much you want to do in a single game. You can select if you want to track your steps, your distance or your active time. Since the step counting in the iPhone is not real time, a simple step counting algorithm based on peak detection in Kalman filtered accelerometer data was implemented. Although this step counting worked surprisingly well compared to the built in step counting, it cannot be expected to be as good over longer periods of time. Thus, to avoid accumulated errors, the step count is compared to step data from apple health and corrected so that the total step count agrees with apple health. For distance a combination of GPS, and when GPS is poor or unavailable, a distance estimate based on the step count times the average distance per step is used. As for the step count, the total distance is compared to the distance found in apple health and corrected. Active time is measured as the time when the app detects the phone is moving. The active time for when the app isn't active is approximated through step count times average time per step.

In the first prototype of the game, the challenge is to catch stars. These stars appear in a semi-random fashion; after a pre-determined interval there is the potential of triggering a star. The interval is proportional to the step/distance/time goal for the game, but has both a lower and a higher limit in order to avoid too short or too long intervals. Since it is potentially hazardous to walk and look at the screen at the same time, the game is implemented so that sounds and vibrations notify you when the game needs

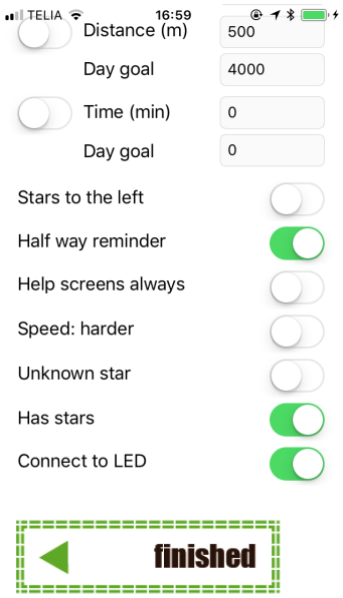

Figure 2. Settings in prototype 1. Stars to the left: you will get the star on the left side of the screen (otherwise it will come at the right side). Half way reminder: get a half way reminder. Help screen always: always show the game help screens. Speed:harder : makes it more difficult to catch the "walk faster" star. Unknown star: All stars have the same colour (otherwise the colour of the star reflects which mini-game it is). Has stars: Mini games are triggered (otherwise there will be no stars and no mini games). Connect to LED: Connect to our feedback lights.

attention, to allow you to keep the phone in the pocket while you are walking. When a star is triggered, there is a sound and a vibration, and the star appears at the top of the screen. The star moves downwards over the screen as you walk - if you stop the star will also stop its progress over the screen. The sounds and vibrations are repeated while the star is visible, to reduce your risk of missing a star.

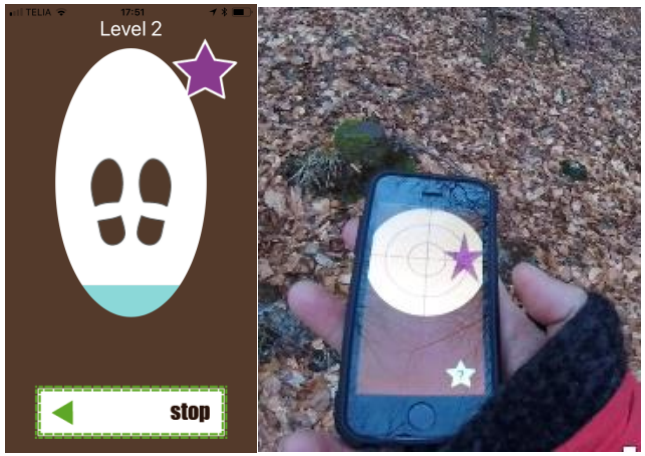

Figure 1. Left: The main game screen. The footsteps will show a walking animation when the app detects that you are walking. The ellipse fills with blue as you progress towards your game goal. Right: The pointing mini game. The blue star in the lower corner is a help button.

To catch the star, you have to succeed in a mini game. To launch the mini game you press the star on the screen (Figure 1: left). Since the game should work equally well for one-handed use, the app has a setting that allows you to select on which side of the screen you want the star to appear.

The star catching mini games were implemented to make use of several modalities. Progress is shown both visually, through sounds and vibration. The first three mini games were: pointing around you to locate the star (the star would be at a specified compass direction, Figure 1: right), catching the star with a fishing line type motion and walking faster. Later a mini game where you throw a "ball" by pushing the phone forwards and two mini games based on tilting the phone were added, one where you need to balance the star in the center of the goal area on the screen, and one where you tilt the phone to avoid obstacles on a "race course". Games get more difficult as you progress to higher levels, and you will also get more games (on the first level you only have three different mini games). The game will remind you when you have reached half-way to your goal. This reminder comes with sounds and vibrations, and you have to manually acknowledge and press a button to stop the notifications.

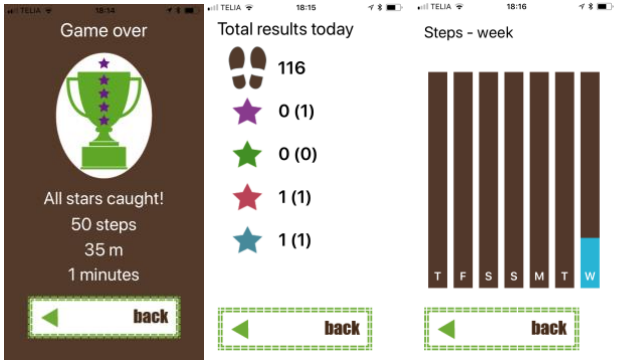

Figure 3. Left: Game over screen. Middle: Day results screen. Right: Week results screen.

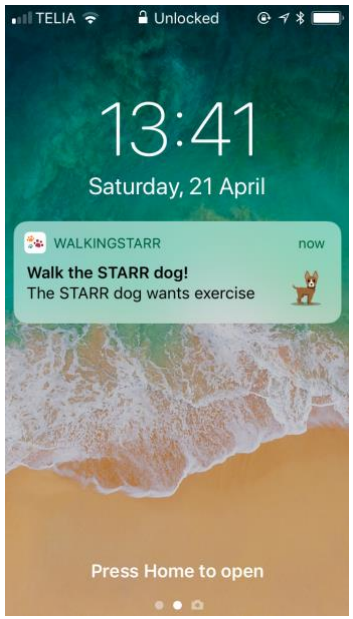

Figure 5. Daily reminder to walk the dog.

Once a game is finished you will come to the game over screen (Figure 3, left). After this you will see your results for the whole day (Figure 3, middle). In the day results screen you can press the different items to see your results for a week (Figure 3, right). The app can also connect to LED feedback lights via Bluetooth LE. The present paper focuses on the game itself, and these lights will not be further discussed.

Design: Second prototype

The second prototype is quite similar to the first "under the hood", but has a different theme: you have a dog that wants to go walking.

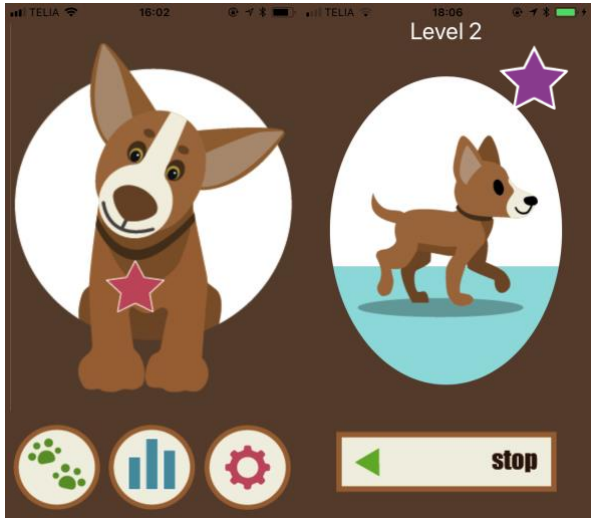

Figure 4. Left: Entry screen. Right: Main game screen.

As you walk the dog, you get different challenges (still indicated by stars on the screen). The challenges have changed to dog related themes: Find a good tree where the dog can pee, stop the dog from barking at a cat, follow the dog as it walks faster, slide a bowl of food to the dog, throw a ball to the dog and guide the dog through a race course. Compared to figure 2, the game has two additional settings: Increase difficulty and Reminder. Increase difficulty allows you to turn on or off the level dependent increase of difficulty in the mini games. Reminder allows you to specify the time for a daily reminder to walk the dog (Figure 5).

Beta testing

The first prototype was beta tested first by the team, to ensure the basic functionality worked. After this we contacted a stroke survivor from the Malmö stroke organization (male, age 62), who was willing to beta test the app. This tester would send almost daily reports with opinions and suggestions which allowed us to improve and further develop the functionality. The "walk faster" star, turned out to be quite unreliable, and we went through a whole series of iterations, ending up relying on a combination of GPS and steps, before this mini game worked well. Another mini-game, the pointing one, was also changed after getting feedback that it was boring – on higher levels the star was made now to move, so that you would need to follow it with the phone.

One thing we learned was how important it was that the progress shown in the app was for the whole day – initially we had limited the results to activity done while the app was active, but our beta tester was very clear on wanting to have "cred" for everything he did (also when not playing the game). It was also interesting to see that given the choice, our tester preferred to track distance instead of counting steps.

For this beta tester, the level progression was an important motivation. Initially the level would not progress unless you had caught all the stars, but this was felt to be unfair, and we changed the requirement to 80% of the stars. It also quickly became clear that more stars were needed, and we added more mini games and more levels to the game.

We also recruited four more beta testers from the stroke organization in Malmö (three men and one woman, ages between 43 and 68). All our test persons from the Malmö stroke organization have had some remaining problems after their stroke, with walking, with balance and with brain fatigue. We visited each of the new testers in their home, installed the app and made initial settings. We also did a demo walk together with the user, to make sure he or she was able to use the app (all of them were).They were also provided with a getting started guide and a manual on paper. Unfortunately, this stage of the testing coincided with the weather turning bad (winter), and it was only our initial beta tester who really kept using the app during the winter. When the weather got better we contacted our testers again, and got comments that led us to believe reminders were needed (one user stated he forgot to use the app) but also a few comments that indicated that the stars were maybe a bit boring and impersonal. This feedback led us to the redesign that resulted in prototype two. Prototype two is currently being tested (we are still recruiting), but the initial response has been positive.

Discussion and Conclusion

In this paper we present the design of an activity game prototype, and describe the iterative development to date. A general difficulty in the game design has been to balance the gaming elements against the activity tracking – how much should this be a game, and how much should it be an activity tracker? This is a difficulty we share with educational serious games [2], however such games have different goals, and are often more content intensive. So far, the one real long term user of the game has found both important; the activity tracking needed to reflect the whole day activity – it wasn't just enough to provide feedback related to the game. Exergames potentially come closer to what we have been attempting to do, although exergames typically involve more focused activity and virtual environments [5]. Thus, we find it appropriate to discuss our design using the "gameflow" model [13], which has the following components:

1. Concentration - games should require concentration, and the player should be able to concentrate on the game.
2. Challenge - games should be sufficiently challenging and match the player's level of skill.
3. Player skills - games must support player skill development and mastery.
4. Control - players should feel a sense of control over their actions in the game.
5. Clear goals games should provide the player with clear goals at appropriate times.
6. Feedback - players must receive appropriate feedback at appropriate times.
7. Immersion - players should experience deep but effortless involvement in the game.
8. Social interaction games should support and create opportunities for social interaction.

For *concentration*, we have tried to separate the gaming elements from the walking. We have one gaming activity

which is to walk faster (similar to Zombies Run! where you also find this type of challenge). This activity was tentatively included initially to see how it worked, and since we got early feedback from our tester that this was one of the more fun challenges, we kept it.

Challenge is still an open question. For our main tester, the challenge level has appeared appropriate. Since our other four testers were able to use the game on the starting level, we believe that at least the initial difficulty is reasonable. For now, we have included an option to turn off the increase in difficulty, but better customization of the challenge is something we want to explore in future versions. Player skill development is currently taken into account through level progression. Players get more and more challenging tasks as they come to higher levels. The responses of our main tester confirms how important this is – and a challenge for the future is to keep this progression during long term use. That *control* is important was seen in the iterations needed to get the walk faster mini game to work as intended. Initially this challenge behaved unpredictably, which caused the tester to be very annoyed. All other challenges appear to have provided appropriate control over the interaction so far. The mini games have on the whole *clear goal*. The one that was problematic in this respect was the fishing line mini game. It was initially hard to explain what the user needed to do, and we didn't really solve this until we changed to the dog (the metaphor of jerking a leash was easier to understand). Judging from the response by our main beta tester, distance is also a more clear game goal than steps.

Feedback is provided in several modalities, and in such a way as to allow the user to keep the phone in the pocket while walking. Still, for this user group the amount of feedback is tricky. One of our users (who had more severe problems with brain fatigue) thought the provided feedback was too much, while others have appreciated the feedback and thought it added to the experience. It is a general problem how much you can remove before the game gets boring – the first prototype with stars was less visually demanding (the dog is animated, and thus there is more movement), but so far it seems the dog is still more appreciated. *Immersion* is more relevant for virtual environments, but we have tried to make the dog more "alive" by adding random barks and breathing sounds at different points in the game. The game does not currently support *social interaction*, but could do so in future versions of the game. Since Pokémon Go apparently is primarily a solitary activity according to [1], a mobile activity game may work well also when played alone. Initially, this was a design choice – we wanted to make daily walking more fun for persons who don't have someone to walk with (persons who have someone to walk with, already has something to encourage their walking). But this is something we need to consider in future versions of the game.

Acknowledgements

We gratefully acknowledge everyone who has tested the game, and in particular Allan Hedlund at the Malmö stroke association. The work has been supported by funding from from NordForsk, project ActivAbles, and the European Union Horizon2020, grant agreement 689947 (the STARR project).

References

1. Burgess, J. and Loveday, P. Flow and Pokémon GO: The Contribution of Game Level, Playing Alone, and Nostalgia to the Flow State. *e-Journal of Social & Behavioural Research in Business 8*, 2

(2017), 16–28.

2. Callaghan, M., Savin-Baden, M., McShane, N., and Gomez Eguiluz, A. Mapping Learning and Game Mechanics for Serious Games Analysis in Engineering Education. *IEEE Transactions on Emerging Topics in Computing 5*, 1 (2017), 77–83.

3. Givon, N., Zeilig, G., Weingarden, H., and Rand, D. Video-games used in a group setting is feasible and effective to improve indicators of physical activity in individuals with chronic stroke: a randomized controlled trial. *Clinical Rehabilitation 30*, 4 (2015), 383–392.

4. Guo, J., Smith, T., Messing, D., Tang, Z., Lawson, S., and Feng, J.H. ARMStrokes: A mobile app for everyday stroke rehabilitation. *ASSETS '15 Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility*, (2014), 429–430.

5. Kappen, D.L., Mirza-Babaei, P., and Nacke, L.E. Older Adults' Physical Activity and Exergames: A Systematic Review. *International Journal of Human–Computer Interaction*, (2018).

6. Karner, J. Most entertaining running and walking apps for Android in 2018. https://www.androidcentral.com/interactive-fitness-apps-worth-checking-out.

7. Kissela, B.M., Khoury, J.C., Alwell, K., et al. Age at stroke: Temporal trends in stroke incidence in a large, biracial population. *Neurology*, (2012).

8. LeBlanc, A.G. and Chaput, J.P. Pokémon Go: A game changer for the physical inactivity crisis? *Preventive Medicine 101*, 2017, 235–237.

9. Magnusson, C., Caltenco, H.A., McGookin, D., et al. Tangible interaction for stroke survivors: Design recommendations. *TEI 2017 - Proceedings of the 11th International Conference on Tangible, Embedded, and Embodied Interaction*, (2017).

10. Magnusson, C., Waern, A., Gröhn, K.R., et al. Navigating the world and learning to like it: Mobility training through a pervasive game. *Mobile HCI 2011 - 13th International Conference on Human-Computer Interaction with Mobile Devices and Services*, (2011).

11. Rassmus-Gröhn, K., Magnusson, C., Rydeman, B., Randall, G., and Belson, S. *Conjuring up New Technology-Using Magic Objects in Co-Ideation with Stroke Survivors*. 2017.

12. Safavi, K., Ratli, R., Webb, K., and MacCracken, L. Patients Want a Heavy Dose of Digital. (2016).

13. Sweetser, P. and Wyeth, P. GameFlow: A Model for Evaluating Player Enjoyment in Games. *Comput. Entertain. 3*, 3 (2005), 3–3.

14. Wolf, P.A., D'Agostino, R.B., Belanger, A.J., and Kannel, W.B. Probability of stroke: a risk profile from the Framingham Study. *Stroke 22*, 3 (1991), 312–318.

15. research2guidance's MHEALTH APP DEVELOPER ECONOMICS 2016. November (2015), 0–4.