Designing activity games for stroke survivors

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In this paper we present work carried out in the EU project STARR and the NordForsk project ActivAbles. We report on the design and iterative development of an outdoor activity game for stroke survivors, and discuss design choices, experiences from the iterative testing and outline potential future developments.

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. [1]) 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 [2], 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 [3] (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 [4]. There are many location based games on the market (a recent overview can be found at [5]), 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 [6]), 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 [7] and there are studies on how mobile devices can support rehabilitation exercises [8] 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. A first report on our design was published in [9], the present paper focuses on the design of the audio and haptic/gesture interaction.

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 [10]. 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 [11]. 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 [12] 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 (male, age 62). Updates were made iteratively during the beta testing. Once the game worked more reliably, four additional Swedish testers were recruited (three men and one woman, ages between 43 and 68). Based on feedback from these testers, a second version of the game was implemented. This version of the game was tested by 4 stroke survivors (one woman, three men, ages 63-79) on Iceland during 3-4 weeks. All the testers both in Sweden and on Iceland were able to

walk, but had difficulties with balance/walking after their stroke. The feedback from these test users prompted the design of two new game versions, which will be tested in the spring of 2019.

DESIGN

An overall description of the game can be found in [9], the main points are repeated in the following. The game is a step counting game 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.

The game challenge is to succeed at a series of mini games that appear in a semi random fashion. The first version of the game had a star theme, while the second version had a dog theme. The underlying mechanics of the mini games were the same, but the sounds and graphics were different in the two versions. As the player progresses to higher levels, new challenges are unlocked. The app has settings that allow you to customize game difficulty (the default setting is that the difficulty of the challenges increase at higher levels), but it also allows the complete removal of the mini games so that the app becomes an activity monitoring app instead of a game.

Figure 1. Left: Entry screen (dog theme). Right: Main game screen when a game challenge (a star) has appeared.

THE MINI GAMES

The mini games make use of different gestures with the whole phone – pointing, tilting, shaking – but also walking faster.

THE POINTING MINI GAME

The first mini game to be implemented was a pointing game. The challenge of this game is to find a specific compass direction, and keep the phone pointing in this direction for a specified time duration (compass jitter makes it a challenge to keep the direction fixed). In the first version of the game, the objective was to point to a star that was located at a compass direction (eg north), and by keeping the phone pointed at the star, it is caught. The pointing gesture is accompanied by sounds – higher frequencies means you are closer to the right direction. When catching is initiated, a tingling sound is heard, and there is a failure sound if the star moves out of range.

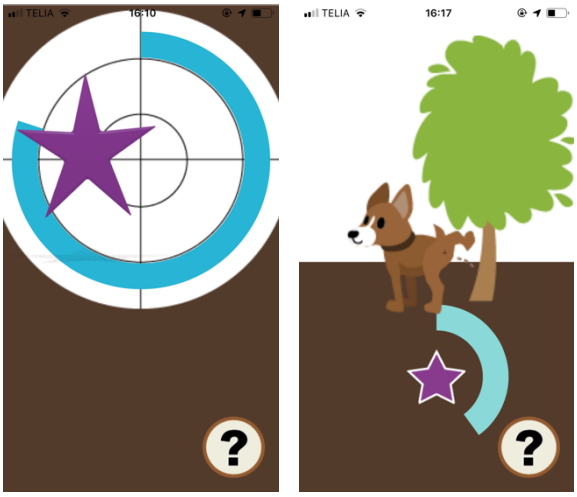

Figure 2. Left: Catching a star. Right: Helping the dog pee.

In the second version (dog theme), the objective is instead to help the dog find a good « peeing-tree ». In this case the pointing gesture is accompanied by dog barks, which get louder the closer the phone is to the right direction.

WALKING FASTER MINI GAME

The second mini game to be implemented, was one which requires the user to increase their walking pace a short distance. The implementation is basically the same in both versions of the game; in the star theme you have to walk faster to catch up with and catch the star, in the dog theme the dog wants to walk faster and you need to keep up. Technically this turned out to be quite difficult to implement, since the simple step counting algorithm was not reliable enough (although it worked reasonably well on the average there were both occasional extra steps and steps missing that made the signal noisy), and the gps speed was slow to update. In the final version, a combination of both signals was used in an algorithm that erred on the generous side (it assumes the user will try to walk faster, and thus reduces the difficulty if the target isn't met). The sound feedback is musical notes that get higher in frequency the closer you get to the goal.

GESTURE MINI GAME

In this game, the user should make a throwing/jerking gesture with the phone. In the star theme, this is explained as throwing a virtual fishing line to catch the star, while in the dog theme you jerk the leash to stop the dog from barking at a cat (to loose there is no effect, and

too hard makes the dog annoyed – you need to get it right). The sounds in this game are currently only success and failure feedback – you get information if you jerked too little, too much or just right.

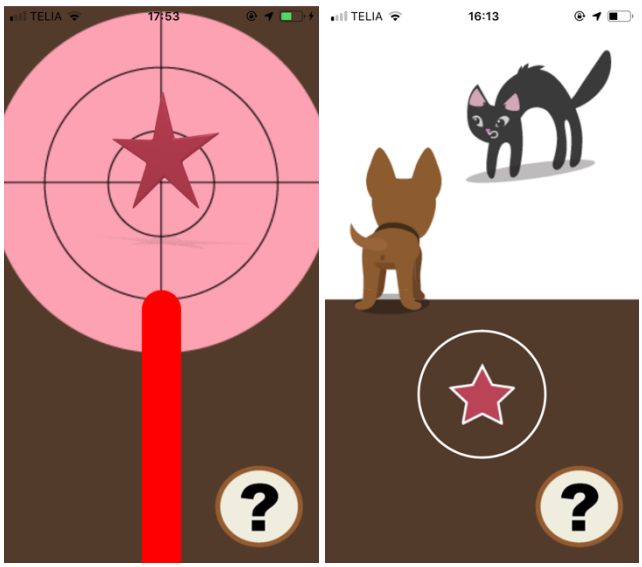

Figure 3. Left : Throw the fishing line (red, together with a fail sound indicates failure) Right : Stop the dog from barking (dog theme).

Balancing mini game

In this game, the goal is to get an object to balance in a specific location. Tilting the phone in the x direction (sideways) moves the object along the x-axis, and tilting in the y direction (forwards or backwards) moves the object in the y direction. In the star theme the object is a star, while in the dog theme the object is a bowl of dog food. In the star theme, musical notes indicate how close you are to the target (higher frequency means closer), while in the dog theme the dog barks louder the closer the food gets.

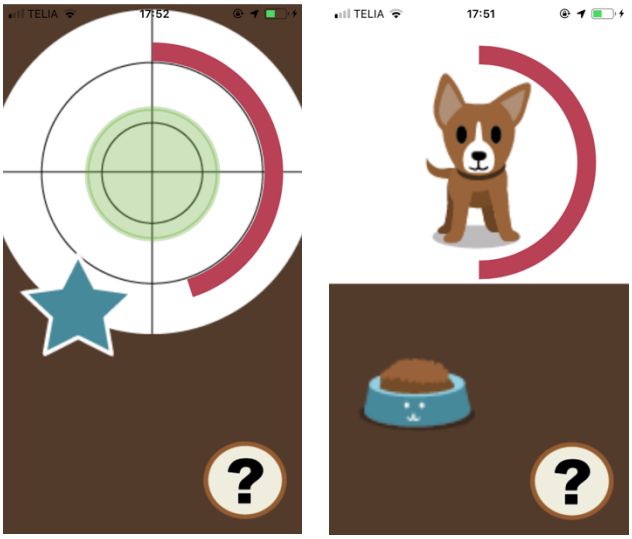

Figure 4. Left : Balance the star in the green area. Right : Get the food to the dog.

Tilt sideways mini game

This game is more of a traditional mobile game where the goal is to help a star or a dog to pass obstacles along a race course. The main functionality is that the star/dog moves sideways as you tilt the phone, but it is also possible to get the star/dog to move faster by tilting the phone forwards. This game has success and fail sounds – success as you complete the course, and fail when you hit an obstacle.

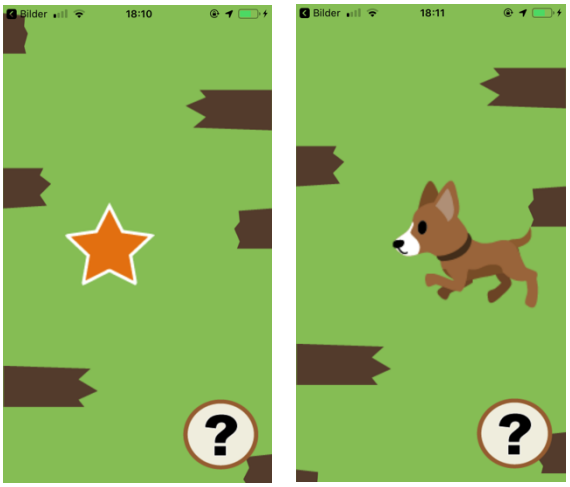

Figure 5. Left : Help the star avoid the obstacles.. Right : Help the dog avoid the obstacles.

Tilt and shoot game

The final game combines tilting with a quick forwards gesture to launch an object. Tilting positions the object ("bullet" or bone) along the x-axis, and when the user is happy with the position, it can be launched by moving the phone rapidly in the forwards direction. For the star theme musical notes reflect the position of the object you try to hit with your bullet, while currently the dog just barks.

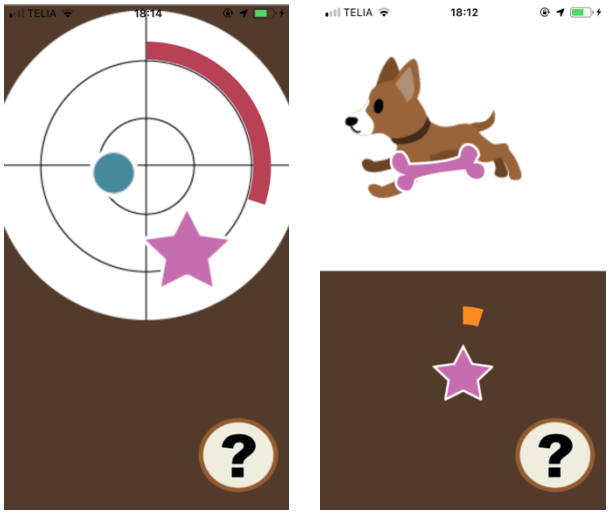

Figure 6. Left : Hit the star with the ball.. Right : Throw the bone so the dog can catch it.

Additional feedback

The game notifies the user of the presence of a star through repeated sounds and vibrations. The star moves over the screen as the user walks, and stops if he/she stops. Thus there is no time pressure in the process of launching a mini game. The game can give a notification when the user is half-way to their goal, and also gives a

notification once the goal is reached. These notifications are given through on screen information as well as repeated vibrations and sounds. The game will also give sound and vibration feedback and ask for confirmation when the user is about to exit the game.

USER FEEDBACK

The initial user kept using the game and thought it was fun, while later test persons have been more sceptical. One person, who had not previously played mobile games, felt stupid doing the mini games in public. Two users also report the game element being "too much", while still potentially finding games like this interesting. At the tests on Iceland, only one of the testers actually used the mini games, but thought they were difficult and also thought the dog design may be better suited to children. The other test users used the app as a step counter, and appreciated this function, but the games were again thought to be too difficult. An interesting observation was that three of the users used the app mostly indoors – they followed the step counts and the animation of the walking dog but didn't play the mini games.

DISCUSSION

The varying feedback reflect a wide variation of both user abilities (our initial test user had walking difficulties, but not major) and preferences. All the Swedish test users were able to play the games during the introductory demo that was given at the start of the test period, although two users thought it was "too much" to use during a longer period. Generally, the mini games appears to have been too demanding for the Icelandic test users. One of our Icelandic test users also experienced the games as childish. As was stated in [9], the reason for introducing the dog theme, was feedback that said the original star theme was boring, but this change was made without actual comparisons of the two designs – and we have brought the (potentially less childish) star theme back as a possible selection in our new version of the app. Taken together the feedback we have indicates that either the mini games need to be re-designed, or more alternative game designs are needed. Since we have users who think the mini-games are fun (especially our first test user used the app extensively), we have decided to start with the second alternative and have implemented a version of the app which includes two completely new games: one game where you don't have to do anything actively while you are walking – you automatically pick up keys and chests with treasure which can later be unlocked; and one version which is less of a game – each completed exercise moves you forward in a journey through a landscape. This new version of the app will be tested during 2019.

Looking more at the audio-haptic design, a challenge in these mini games has been to reflect the effects of gesture interaction in audio. While this could potentially have been done with musical mappings, we had design requirements pointing to a need for simplicity [11]. Thus we tried to keep our feedback simple and limited it to distance mappings combined with success and failure information. Following [13], distance or closeness to a goal was mapped either to pitch or to volume. Although not formally tested, it is our impression is that in our designs pitch generally worked better – although the volume mapping is quite intuitive since things in the real world tend to get louder as they are closer, you don't get much information when the distance is longer and the volume thus very low. An observation based on the received feedback, is that even the limited multimodal feedback used, appears to have been too much for some of our test users.

Another specific design challenge has been that persons with walking difficulties need to focus on the environment and not on the screen. Not looking at the screen is important for many users in many situations [14], but for our user group it is crucial. Thus the app needs to be designed so that it can be kept in the pocket, or in the hand without the user looking at it, for all use that involves walking. All our mini-games except one, are designed to be played while standing still. Even so, the rotation involved in the pointing turned out to be challenging for a person with balance problems. This could be beneficial since it implies playing the game will train your balance, but it could also be a problem for persons with significant balance difficulties. The walking faster game, the game which involves walking, is designed so that all information needed to play the game is presented through sound and vibration.

A specific problem with pocket use, is accidental touch events (particularly in damp weather). Since the app relies mostly on gestures, and less on touch, the main effect of this has been that the app sometimes can turn off in the pocket without the user realising this has happened. To prevent such accidental closing of the game, the app currently notifies the user through sound and vibration and also requests extra confirmation before exiting.

An interesting observation from the design process, is that while one can come up with a wide range of gesture based challenges, it can be a pedagogical challenge to come up with an explanation of what the user needs to do in order to succeed in the game. As an example: While the jerking gesture in itself is not complicated, providing appropriate feedback supporting the learning of the gesture, together with an appropriate mental model for the user of what you should do, required several iterations in the early game versions.

CONCLUSION

In this paper we report on design explorations in the process of developing an activity game for stroke survivors. Our results so far confirm that this kind of games can be useful and appreciated, while at the same time indicating the need for further development in order to reach more persons from our target user group.

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REFERENCES

[1] P.A. Wolf, R.B. D'Agostino, A.J. Belanger, and W.B. Kannel, Probability of stroke: a risk profile from the Framingham Study, *Stroke*. **22** (1991) 312–318. doi:10.1161/01.STR.22.3.312.

[2] research2guidance's MHEALTH APP DEVELOPER ECONOMICS 2016, (2015) 0–4.

[3] K. Safavi, R. Ratli, K. Webb, and L. MacCracken, Patients Want a Heavy Dose of Digital, (2016). https://www.accenture.com/_acnmedia/PDF-8/Accenture-Patients-Want-A-Heavy-Dose-of-Digital-Infographic-v2.pdf.

[4] A.G. LeBlanc, and J.P. Chaput, Pokémon Go: A game changer for the physical inactivity crisis?, *Prev. Med. (Baltim).* **101** (2017) 235–237. doi:10.1016/j.ypmed.2016.11.012.

[5] J. Karner, Most entertaining running and walking apps for Android in 2018, (n.d.). https://www.androidcentral.com/interactive-fitness-apps-

worth-checking-out (accessed April 25, 2018).

[6] B.M. Kissela, J.C. Khoury, K. Alwell, C.J. Moomaw, D. Woo, O. Adeoye, M.L. Flaherty, P. Khatri, S. Ferioli, F. De Los Rios La Rosa, J.P. Broderick, and D.O. Kleindorfer, Age at stroke: Temporal trends in stroke incidence in a large, biracial population, *Neurology*. (2012). doi:10.1212/WNL.0b013e318270401d.

[7] N. Givon, G. Zeilig, H. Weingarden, and D. Rand, 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, *Clin. Rehabil.* **30** (2015) 383–392.

[8] J. Guo, T. Smith, D. Messing, Z. Tang, S. Lawson, and J.H. Feng, ARMStrokes: A mobile app for everyday stroke rehabilitation, in: ASSETS '15 Proc. 17th Int. ACM SIGACCESS Conf. Comput. Access., 2014: pp. 429–430. doi:10.1145/2700648.2811337.

[9] C. Magnusson, K. Rassmus-gröhn, B. Rydeman, and H. Caltenco, Walk after stroke: initial development of a step counting game for stroke survivors, in: MobileHCI '18 Proc. 20th Int. Conf. Human-Computer Interact. with Mob. Devices Serv. Adjun., ACM, Barcelona, 2018: pp. 237–244. doi:10.1145/3236112.3236145.

[10] K. Rassmus-Gröhn, C. Magnusson, B. Rydeman, G. Randall, and S. Belson, Conjuring up New Technology-Using Magic Objects in Co-Ideation with Stroke Survivors, 2017. doi:10.3233/978-1-61499-798-6-429.

[11] C. Magnusson, H.A. Caltenco, D. McGookin, M. Kytö, I. Hjaltadóttir, T.B. Hafsteinsdóttir, H. Jónsdóttir, and I. Bjartmarz, Tangible interaction for stroke survivors: Design recommendations, in: TEI 2017 - Proc. 11th Int. Conf. Tangible, Embed. Embodied Interact., 2017. doi:10.1145/3024969.3025073.

[12] C. Magnusson, A. Waern, K.R. Gröhn, Å. Bjernryd, H. Bernhardsson, A. Jakobsson, J. Salo, M. Wallon, and P.-O. Hedvall, Navigating the world and learning to like it: Mobility training through a pervasive game, in: Mob. HCI 2011 - 13th Int. Conf. Human-Computer Interact. with Mob. Devices Serv., 2011. doi:10.1145/2037373.2037416.

[13] G. Dubus, and R. Bresin, A systematic review of mapping strategies for the sonification of physical quantities, *PLoS One*. (2013). doi:10.1371/journal.pone.0082491.

[14] C. Magnusson, A. Larsson, A. Warell, H. Eftring, and P.-O. Hedvall, Bringing the mobile context into industrial design and development, in: Nord. 2012 Mak. Sense Through Des. - Proc. 7th Nord. Conf. Human-Computer Interact., 2012. doi:10.1145/2399016.2399039.