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Increasing physical activity in older adults using STARFISH, an interactive smartphone application (app); a pilot study

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Abstract

Background: Increasing physical activity in older adults has preventative and therapeutic health benefits. We have developed STARFISH, a smartphone application, to increase physical activity. This paper describes the features of STARFISH, presents the views of older users on the acceptability and usability of the app and reports the results of a six week pilot study of the STARFISH app in older adults.

Methods: The operationalisation of the behaviour change techniques (BCTs) within the STARFISH app was mapped against the BCT Taxonomy of Michie et al. Sixteen healthy older adults (eight women and eight men; age 71.1 ± 5.2 years) used the app, in groups of four, for six weeks. Focus groups explored the user experience and objective measure of steps per day recorded.

Results: Participants were very positive about using the STARFISH app, in particular the embedded BCTs of self-monitoring, feedback and social support (in the form of group rewards). Objective step data, available for eight participants, showed that step counts increased by an average of 14% ($p = 0.077$, $d = 0.56$).

Conclusion: The STARFISH app was acceptable and straightforward to use for older adults. STARFISH has potential to increase physical activity in older adults; however, a fully powered randomised controlled trial is required.

Keywords

Telehealth, patient behaviour monitoring devices, design requirements, assistive technology, ageing

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Introduction

Older adults are the least physically active members of society¹ although physical activity is effective in promoting health and improving quality of life in this population.² Older adults who take part in regular physical activity have fewer falls, lower levels of depression^{2,3} and, like the rest of the population, are less likely to develop chronic diseases such as cardiac disease, stroke, type II diabetes, osteoporosis, osteoarthritis, colon and breast cancer.^{4,5} For optimal health, the evidence suggests that older adults should undertake at least 150 minutes of moderate intensity physical activity per week;⁶ however, there is a continuous dose–response relationship between physical activity

and health benefits, such that any increase in physical activity is beneficial.⁷

While the benefits of being physically active in later life are clear, motivating people to take part in physical

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activity is challenging. To maximise effectiveness, interventions to increase physical activity should incorporate behaviour change techniques (BCTs).⁸ Goal setting, self-monitoring, action planning and feedback have been shown to help facilitate long-term increases in physical activity.^{9,10} In addition, engaging social support also improves the effectiveness of physical activity interventions.⁹

Smartphone technology provides an accessible and low cost approach to support behaviour change using evidence-based BCTs which may help motivate people to undertake physical activity. Muller and Khoo recently suggested that, as older adults become more skilled with technology, physical activity interventions using smartphones should be explored.²

A number of previous studies have used web-based platforms or smartphone technology to facilitate users to increase their physical activity.¹¹⁻¹⁵ Although generally successful these previous studies have required the user to wear an additional activity monitor to sense steps taken. Smartphones have inbuilt accelerometers that track movement and can provide convenient, real-time monitoring and feedback on physical activity to users without the need for any additional device.^{14,16} In addition, the connectivity available via smartphones provides the opportunity for users to share or observe each other's physical activity achievements, thus providing a form of social support which has been shown to increase individual motivation and can lead to improved goal attainment.^{9,17}

Overall, previous studies using technologies to support physical activity interventions have lacked the explicit inclusion of some evidence-based behaviour change techniques such as real time feedback to participants^{15,17,18} and social support,¹⁹ have involved wearing an additional device^{11,15,18} and have focused on healthy younger adults.^{14,15}

The STARFISH app

We have developed a smartphone-based application (app) called STARFISH from previous work by research team members²⁰ to allow users to accurately self-monitor their physical activity as measured by daily step counts. We also incorporated goal setting, action planning, feedback and social support to encourage users to be more physically active.

STARFISH is designed to be used by groups of four people to facilitate social support, with each group member represented by a different coloured fish avatar. Each user sees all four fish avatars in a fish tank on the wallpaper of their smartphone home screen. The inbuilt smartphone accelerometer records steps taken by the user, which are fed back in real time, both numerically and through the movement

and appearance of each user's fish avatar (i.e. when users walk, their fish blows bubbles and swims in the tank). Therefore no additional device is required. Each group member receives an individualised daily step count target, and the fins and tail of their fish avatar grow as the user approaches their target (Figure 1). Changes in the movement and appearance of each user's fish avatar can be seen by the whole group. If all four members reach their daily step count target on at least five days of the week, the group is rewarded by the addition of a sea creature (e.g. an octopus or a crab) to their fish tank (Figure 1). STARFISH also contains a personal planner that prompts users to make specific plans on how they are going to reach their step count target each day.

The aims of this feasibility study were: a) to map and describe the operationalisation of BCTs within the STARFISH app, b) to explore user experience in terms of the acceptability and usability of the STARFISH app and c) to demonstrate the app's potential to support older adults in increasing their daily step counts over a six week period.

Methods

Phase 1: BCT mapping

In order to describe the operationalisation of BCTs within the STARFISH app, three authors (LP, SW and CMG) mapped the key features of the app against the BCT Taxonomy (v1) of Michie et al.²¹

Phase 2: Pilot study

A mixed methods pilot study used focus groups to explore the views of older adults around the acceptability and usability of the STARFISH app, and objective pre- and post-intervention outcome measures to assess the potential of STARFISH to support older adults to be more physically active over a six week period.

Participants

Convenience sampling was used to recruit 16 people aged over 65 years from the University of the Third Age ($n=4$), Glasgow Seniors Forum ($n=1$), the University of Glasgow ($n=4$) and family/friends of the research team ($n=7$). The sample consisted of eight women and eight men (mean age 71.1 years, SD 5.2) who were assigned to groups of four in the order they were recruited. Ethical approval was granted by the Ethics Committee of the College of Medical, Veterinary & Life Sciences, University of Glasgow. All participants gave written, informed consent.

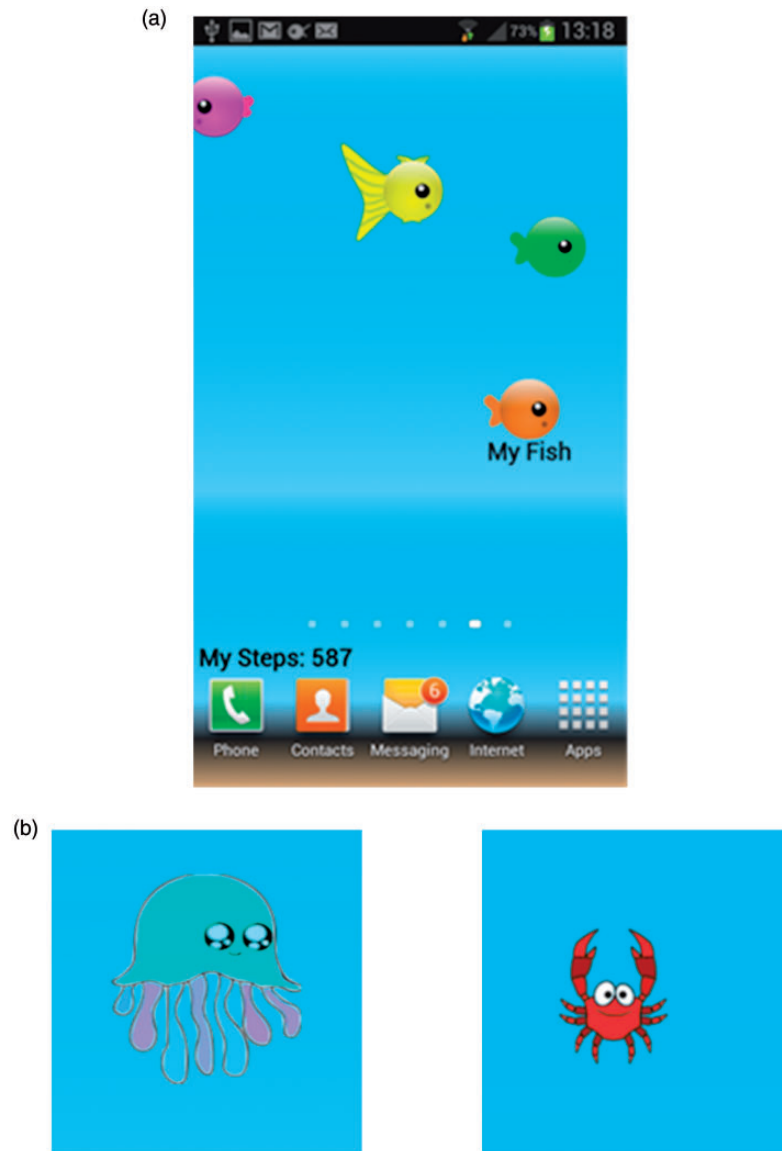


Figure 1. (a) STARFISH wallpaper. (b) Examples of group goal rewards.

Procedures

The intervention involved the use of the STARFISH app for six weeks, during which step counts were monitored and fed back in real-time to participants. Participants attended the Clinical Research Facility (CRF) at the University of Glasgow in their STARFISH group, that is, in groups of four. At the first visit, participants were given a brief explanation of the study and provided written informed consent. Each participant was given a smartphone (Samsung Galaxy SII) and asked to carry it for seven days while performing their usual activities. Although no feedback was given to the participant on their physical activity during this period, the data recorded from the

phone's accelerometer was used to determine their baseline daily step count. Participants were asked to keep the phone in their trouser pocket or were given a case for the phone which could be threaded through a belt. The data was stored on a secure server which was only accessible by the research team.

At the end of the week, participants returned to the CRF, when the STARFISH app was then activated on the participants' phones, and demonstration and instructions provided on how to use the different features of the app. Each participant's individual daily step count target was set for the first week of the intervention by adding 10% to their baseline step count. At the end of each week thereafter, step counts on the server were reviewed by the research assistant (AD)

and, if users had achieved their daily step count target on five of seven days, their target for the following week was increased by 10%. If the target was not reached, it remained unchanged for the following week. The goal was updated in the STARFISH app remotely and the new step count target displayed on each user's STARFISH home screen. The size of the fish fins and tail were reset each week, but any sea creature rewards the group had received remained in the tank for the duration of the intervention. Daily step counts were recorded directly from step count data on the phone but also on the secure server.

At the end of the six week intervention, each group returned to the CRF and took part in a focus group discussion which was facilitated by one of the research team (LP). A semi-structured topic guide was used to explore participants' views of the acceptability and usability of the STARFISH app, and their experiences of using the integral behaviour change features. Outcome measures were also repeated.

Data analysis

The focus group discussions ($n=4$) were audio recorded and transcribed verbatim, and transcripts analysed thematically (by CMG) using a Framework Approach.²² NVivo 10 software was used to assist data coding and organisation. The transcripts were read line by line to identify occasions where participants spoke about: 1) the acceptability, usability and effectiveness of the STARFISH app itself; and 2) the behavioural change features that were integral to STARFISH. These broad themes were then examined in detail using the OSOP analysis technique²³ to identify different perspectives, noting both anticipated and unanticipated issues. Careful attention was taken to identify any 'deviant cases' to ensure that all perspectives were captured.²⁴ Extracts are labelled with participant ID (SF01–SF16) and group membership (Groups 1–4).

Descriptive statistics were used to summarise daily step counts, paired *t*-tests were used to investigate any changes over time and effect sizes were calculated. Analysis was performed on IBM SPSS v.22 using a 5% level of significance.

Results

Phase 1: BCT mapping

Three researchers used the Michie et al. taxonomy²¹ to map the BCTs present in STARFISH and to describe how these were operationalised within the app. Consensus was achieved through discussion. In addition

to self-monitoring, goal setting, action planning, feedback and social support, the mapping exercise demonstrated that a number of other BCTs were integral to the STARFISH intervention. These included adding objects (a mobile-phone based app) to the environment, graded tasks, social comparison, rewards and incentives (Table 1).

Phase 2: Pilot study

The 16 participants formed four STARFISH groups. Participants in three of the groups did not know each other, with the exception of one married couple in Group 2. The participants in Group 3 were relatives or friends and knew each other before starting the study.

One woman suffered a serious adverse event, a broken leg, which was not related to participation in the study, and was unable to continue the intervention. Thus 15 people completed the study.

Views and experiences of using STARFISH

Acceptability and usability

Although some (but not all) of the participants had previous experience of smartphones, none appeared to be fully confident in their use (SF13: 'I had used one of these, I didn't bother to use any other facilities on it'; Group 4). Nevertheless, once initial technical problems with the app, which prevented collection of step count data from two of the groups, had been overcome, the general consensus was that the STARFISH app itself was 'pretty straightforward' (SF13) to use. A few minor problems were identified. These included the small size of some of the textual information:

SF10: *I think...the step count...I wear glasses for reading...and if I am out so I had to stop put my glasses on and read it on again.* (Group 3)

Some participants commented on the size of the smartphone itself, and felt it was easier to carry using the case provided than trying to keep it in a pocket:

SF14: *Only one thing maybe about the size and whatever, you know normally during the day it could sit in my pocket, but when you are in joggies and a T-shirt, I started to look for a T-shirt with a pocket. If it would be on a belt it would be a lot easier you know because I tended to leave it somewhere else.*

Interviewer (Int.): You have to find something else that had a pocket.

SF14: *Exactly, I had to buy new pyjamas with pockets.*

Table 1. Description of the behavioural change techniques operationalised within STARFISH using the Taxonomy of Michie et al.¹⁸

Label	Definition	An example of how the technique is operationalised in STARFISH
Feedback and monitoring Self-monitoring of behaviour	Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy	Step count monitoring is integral to the STARFISH application and visible to the user as real-time step counts. Users can also view their daily step count history both numerically and graphically to monitor change in activity over time.
Feedback on behaviour	Monitor and provide informative or evaluative feedback on performance of the behaviour	The fins and tail of users' fish grow as they progress towards their weekly step count target.
Monitoring of behaviour by others without feedback	Observe or record behaviour with the person's knowledge as part of a behaviour change strategy	Users can see other group members' fish moving and blowing bubbles as they walk.
Goals and planning Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved	The baseline step count is determined by monitoring usual activity for a week. Thereafter, an algorithm is applied at the end of each week so: a) those who achieve their step count target on five of seven days that week have their target increased by 10% for the following week; b) those who do not achieve their step count target continue with the same target the following week.
Discrepancy between current behaviour and goal	Draw attention to discrepancies between a person's current behaviour and the person's previously set outcome goals, behavioural goals or action plans	Each morning a comparison of the user's previous day's step count against their daily step count target is displayed. If the user achieved their target the previous day, a 'happy Starfish' congratulates them on achieving their target. If there is a shortfall (discrepancy), a 'quizzical Starfish' points out that the target was not achieved.
Action planning	Prompt detailed planning of performance of the behaviour	Each day users are prompted to consider how they will achieve their step count target that day, and a diary is incorporated to allow them to plan their walking throughout the day.
Social support Social support	Advise on, arrange or provide social support or non-contingent praise or reward for performance of the behaviour	Achieving the weekly reward (additional creature in the fish tank) is contingent on all group members achieving their daily step count target on five of seven days.
Comparison of behaviour Social comparison	Draw attention to others' performance to allow comparison with the person's own performance	Users can observe the growth of the fins and tails of other group members' fish as they progress towards their weekly target.
Repetition and substitution Graded tasks	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behaviour is performed	The individualised step count targets are reviewed each week and increased by 10% when users have successfully achieved their target on five of seven days the previous week.

(continued)

Table 1. Continued

Label	Definition	An example of how the technique is operationalised in STARFISH
Reward and threat		
Non-specific reward	Arrange delivery of a reward if and only if there has been effort and/or progress in performing the behaviour	The fins and tail of each user's fish <i>only</i> grow as their step count increases towards their weekly target. The weekly group reward (a sea creature swimming in the group tank) is contingent on all group members achieving their daily step count targets.
Social reward	Arrange verbal or non-verbal reward if and only if there has been effort and/or progress in performing the behaviour	A 'happy Starfish' congratulates users <i>only if</i> they have achieved their step count target the previous day.
Non-specific incentive	Inform that reward will be delivered if and only if there has been effort and/or progress in performing the behaviour	Users are made aware that rewards are contingent on progress in achieving their daily step count targets.
Antecedents		
Adding objects to the environment	Add objects to the environment in order to facilitate performance of the behaviour	The STARFISH smartphone application is added to the physical environment.

Participants in one focus group agreed that more information on how to use the app could have been provided initially:

SF01: *Maybe a wee bit of explanation would be helpful.*

Int.: So maybe a wee bit more explanation on the beginning on how to navigate the phone, would that be helpful?

SF01: *Yes.*

SF02: *It wouldn't have done any harm.* (Group 1)

However, most of the participants felt the benefits of using the app outweighed any difficulties they encountered. In addition to increased general fitness levels, participants reported sitting less, that their 'spirits were lifted', and one person who was asthmatic reported that their breathing had improved. Some also said that being part of the STARFISH study had motivated them to lose weight:

SF03: *I cut down the intake [food] as well; it was something I needed to do, so I thought just to put things together.* (Group 1)

Therefore, despite being an older age group with limited experience of using smartphones and mobile apps, participants generally found STARFISH easy to use and appreciated the benefits of doing so.

Experiences of using BCTs

The STARFISH app was designed to include BCTs (self-monitoring, goal setting, action planning and feedback) that have been shown in traditional (not mobile phone-based) interventions to be effective in increasing physical activity.⁹ The focus group discussions provided an opportunity to explore older adults' experiences and responses to these BCTs on a mobile app-based platform.

Many participants described how being able to monitor their step count in real time had raised their awareness of how active or inactive they were in everyday life:

SF15: *What surprised me was a sheer number of steps at normal day...and I haven't done anything and I've done four thousand of steps, and I thought how come?*

SF13: *Yes.*

SF15: *Today if you would ask me how many steps I've taken today, I would have said probably couple of hundred, but it turned out to be four thousand. You are doing more than you think you are.* (Group 4)

SF12: *I think you sort of realise as well, how little you do some days. Before we had those phones I could do nothing sitting on the couch all the afternoon before, whereas after I felt I need to get up from here and actually do something.* (Group 3)

Many also reported using the step count history feature. However, as time went on, some said they became more instinctively aware of the number of steps they were doing and tended to reduce the frequency with which they consulted their STARFISH step count display:

SF01: *But you know the number of steps, you go the local shop – 500 steps.* (Group 1)

SF10: *After a while I didn't even bother doing that 'cos I knew if I walked for 20 minutes at a normal pace I get 2000 steps.* (Group 3)

Some expressed frustration that the STARFISH app only counted certain activities towards the daily step count target:

SF15: *...while the treadmill walking registered steps but when I am on the cycle machine the cycling didn't register.* (Group 4)

Users agreed that their individualised daily step count target was important in motivating them to be more active:

SF16: *I went out for a walk specifically or walk long enough to make sure to get my target. I did that pretty well just about every day which is a big step forward.*

SF13: *I remember one day I was at 11,500 [steps], at ten or half past ten to walk up to the dining room upstairs three, four times to get my five hundred steps, I wouldn't lose my 500 steps.* (Group 4)

Only one participant described using the personal planner within the STARFISH app to help them make specific plans about how to achieve their daily step count target. Nevertheless, simply using the app itself seemed to encourage some users to think ahead about how to overcome challenges to being active:

SF03: *I planned I'd do such and such and get it. If the weather was too bad we would go to the gym and use the treadmill. You would make a plan that you would walk somewhere...or walk in the house, you know, if the weather was too bad.* (Group 1)

Opinion was mixed on the utility of the visual feedback on target achievement (tail and fins growing). Whilst some people found it motivated them to walk more, others found monitoring their step counts more motivational. However, being able to see all group members' fish avatars promoted social comparison, and a couple of people admitted that this had introduced an element of competition, which they had enjoyed:

SF05: *I was looking at the tails, to see if I can get a bigger tail.*

SF06: *He was just trying to have the biggest tail.* (Group 2)

The visual feedback and step counts therefore seemed to encourage individual, rather than group, achievement. The weekly group-based reward (a different sea creature appearing in the group fish tank) appeared to be more effective in promoting team spirit, particularly in the group who knew each other beforehand:

SF12: *[...] Yeah, we are disappointed [...] We never got the diver.*

SF11: *We've got seahorse and a crab and...*

SF12: *Jelly fish and octopus and the...*

SF09: *Sea lion [...]*

SF12: *On a Thursday, initially it was on Thursday, then it moved to a Friday, you did look at your phone more often to see if your creatures come on, you know.*

SF11: *You started that...'We haven't got it. We haven't got the creature yet'.* (Group 3)

One participant suggested that provision of more information (e.g. other group members' step counts) might have made being part of a group more salient:

SF14: *I would like to see the other numbers to be honest with you...because at one point I don't know whose fish was it but it was dead.*

[Laugh]

SF15: *That was that day I left it at home.*

[Laugh]

SF14: *I think you know if I see that were get...that would give me the initiative to do a bit more.* (Group 4)

Outcome measures

Physical activity was assessed objectively via the daily step count recorded from the smartphone's inbuilt accelerometer. Initial technical problems with the STARFISH app affected the first two groups and resulted in missing step count data from these participants. Therefore only step count data from the last two groups ($n=8$) was analysed and, due to the small sample, considered as one group. The average age of these participants was 67.6 years (SD 2.4 years) and there were six men and two women.

The mean daily step count increased from 9443 steps (SD 3952) before the intervention to 10,773 steps (SD 2659) after the intervention, a mean increase of 14%. The effect size was moderate ($d=0.56$), but was not statistically significant ($p=0.077$). Generally, participants with lower baseline step counts showed larger increases than those with relatively higher baseline step counts. This data suggested that any subsequent

randomised controlled trial (RCT) would need 58 subjects in each group to detect a 30% increase in step count, at $p < 0.05$ with 80% power for the interaction effect.

Discussion

Many participants reported positive health benefits both physically and psychologically (e.g. improvements in general fitness, lifted spirits) from using the STARFISH app. It was recently proposed that as older adults become more skilled in using technology, smartphones may provide a suitable platform for physical activity interventions for this group.² All participants managed to use the app, and most reported finding it straightforward, thus confirming that the use of smartphone-supported interventions for physical activity interventions is acceptable and feasible for some older adults. Participants also made some suggestions for further development of the intervention, including the provision of more information about the app initially.

The real-time self-monitoring and goal setting features of the STARFISH app were useful in increasing users' awareness of their levels of activity or inactivity, and this encouraged them to alter their behaviour. Previous studies using web platforms or mobile phone apps also reported that providing real time feedback to participants raised awareness of the individual's level of physical activity and thus facilitated behaviour change.^{13,15} Some participants reported their self-monitoring behaviour changed as the intervention progressed. Initially they consulted their step counts on the phone frequently; however, as time progressed they became aware of how many steps they would take on regular walking routes (e.g. 500 steps to the shops) and therefore used this feature less. Visual feedback on the number of steps taken was provided in two ways; numerically and by the changing shape of the fish avatar. There was no consensus on which method people preferred, with different users motivated by different forms of feedback on their behaviour.

Although the personal planner within the STARFISH app was rarely used (except by one user), participants described their own strategies for planning their day to ensure they achieved their step targets. It is possible that participants did not receive adequate information about how to use the personal planner, or that the method chosen to operationalise action planning within STARFISH was ineffective. Further research is needed to explore how to optimise older users' engagement with features designed to promote action planning within smartphone apps.

Finally, the weekly group reward of a creature added to the tank when the group achieved their step target on

five of seven days appeared to be a very positive feature of the STARFISH app, and this provided a strong motivational component. Consolvo and colleagues reported that people working in groups were more likely to meet their physical activity goal than those working on their own.¹⁷ However, being part of a group is only effective if the members of the group are known to each other¹⁵ and indeed STARFISH was more beneficial in increasing physical activity where group members knew each other previously.

Step count data was only available for two groups (i.e. eight participants); however, using the STARFISH app for six weeks increased the average daily step count of participants by 14%. This increase was not statistically significant ($p = 0.077$); however, there was a moderate effect size ($d = 0.56$). Although the sample size was small the results demonstrated the potential for the STARFISH app to increase levels of physical activity in older adults and the power calculation suggested that any subsequent RCT would need 58 subjects in each group.

Participants with lower baseline step counts showed the greatest improvement. One participant with a very high baseline step count showed a decrease (from 15,611 steps to 14,772 steps) over the intervention period, which, given the small sample size, may have skewed the overall results.

In terms of limitations, although the STARFISH app and underlying step count algorithms had undergone considerable development and validation within the laboratory setting,²⁰ deployment of the app into the 'real world' resulted in a number of technical problems. Klasnja et al. recognised that complex technical interventions are rarely deployed without initial problems, and recommend the conduct of pilot studies such as this to identify and overcome technical difficulties.²⁵ A previous pilot study which aimed to increase physical activity in people with chronic obstructive pulmonary disease involved a smart phone app and accelerometer and similarly reported a number of technical issues when the system was deployed.¹³ The authors reported that the technical problems were frustrating for participants and staff, which we also found. However, in addition we lost reliable step count data for the first two groups. The technical difficulties were resolved for the next two groups, and the STARFISH intervention has since been implemented in stroke survivors,²⁶ with no technical problems.

The accelerometers on the phone were only calibrated to collect step count data, thus other activities such as cycling were not accurately reflected as physical activity. This limitation has been recognised in previous studies.^{11,13} The Ubitfit intervention is a good example of different forms of activity (strength, flexibility,

walking) being visually represented by different flowers in a garden. In Ubifit the additional fitness device senses some activities, for example, walking and cycling, and users can input additional data on other forms of activity.¹⁴ Further work is required to validate the accelerometers within mobile phones in terms of sensing activities other than walking, to prevent additional burdensome hardware being required.

As a pilot study, the results of this study are limited due to the small sample size. The study was also limited due to the lack of a control group, the non-blinded nature of the study and the lack of longer term follow up data. Currently STARFISH is not connected with the participants' clinical records; however, the data might be useful for health care providers.

Conclusion

STARFISH is relatively unique in that the phones' accelerometers detect physical activity, meaning the user is not required to wear any additional devices. Another positive feature is that the intervention is undertaken in groups with group targets and rewards being dependent on individuals' achieving their targets. The STARFISH app was acceptable to users and showed potential to increase physical activity. The results of this study therefore support the conduct of a fully powered RCT to evaluate the effectiveness of STARFISH in increasing physical activity in older adults. Smartphones are now a ubiquitous aspect of society and may provide an ideal platform from which to deliver behavioural change programmes. However, further research is required to improve understanding of how to design and implement features within smartphone apps to encourage older adults to engage more fully with the BCTs (e.g. action planning) that are effective in increasing physical activity.

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