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Design requirements for persuasive technologies to motivate physical activity in adolescents: a field study

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Technology probes were used to investigate what adolescents would find persuasive in digital devices supporting opportunistic (unstructured/unplanned) exercise. The probes comprised pedometers, handheld consoles with an exercise game and a customised social website with an exercise focus. Three groups of six adolescents participated in the field study. To contextualise the study their attitudes to exercise, and exercise behaviours, were collected at the start and end of the study. The participants logged their daily exercise and noted any barriers that they encountered over six weeks. They reflected on these experiences and took part in innovation activities to identify requirements for motivational exercise technology. Analysis of the results revealed that they desired individual customisation of devices that can capture a wide range of physical activity data. Moreover, social interaction is expected within digital media and positive messages reinforcing goal attainments are valued, whereas negative feedback demotivates. These findings support those reported in other studies of both children and adults. More specific to this age group was their openness to sharing information beyond their friendship groups, although this was counterbalanced by their lack of autonomy in the physical world. This highlights issues that could constrain the effective design of technology for this age group.

Keywords: field study; opportunistic exercise; adolescent participants; technology probes

1. Introduction

This paper presents a field study, *ehealth*, that used technology probes (Hutchinson *et al.* 2003) to investigate the reactions of adolescents to different sets of exercise-related technologies. The aim was to prompt them to generate ideas about the types of artefacts (both hardware and software) that they and their peer group would be motivated to use. A technology probes approach was adopted since its purpose is to gain an understanding of the users and their contexts, to field test the technology and to elicit new design ideas from the users. The study was conducted at the behest of Sunderland City Council which wanted to determine the effectiveness of using such technologies to enhance the physical activity of its adolescent population. The council wanted to focus on the largest segment of the population to gain the maximum benefit from the findings, that is, the generally healthy (i.e. neither the clinically obese nor the super-fit). The emphasis of the study was also on opportunistic physical activity, which was judged to be the most accessible form of exercise. Opportunistic exercise refers to unplanned activity embedded in everyday activities, for example, walking to school rather than taking the bus and using stairs rather than an escalator. Most attempts to increase opportunistic physical activity through technology have leveraged the ubiquity of mobile devices (such as smart phones) to both collect real-time exercise data and run applications that might persuade users to voluntarily commit to increasing their exercise levels, thus sustaining behavioural change. Persuasion is often delivered in an analogous representation of the user's behaviour, such as the *UbiFit Garden* (Consolvo *et al.* 2008); or it may be delivered through social media where a user's data are shared with a group of peers for social support (Toscos *et al.* 2008).

In the remainder of this section, we review those studies that informed the design of our study. In the following sections of the paper, we present the method adopted within the study, including the procedures for data collection and analysis and the ethical issues considered. The results are reported regarding the attitudes and behaviours of the participants and their design ideas for future persuasive technologies. The emergent themes are discussed in the light of relevant literature and the strengths and limitations of our study area highlighted. We conclude by identifying opportunities for future work.

1.1. *Empirical studies of technology supporting opportunistic exercise*

During the *ehealth* preparation phase, we undertook an extensive literature search to derive a baseline of design elements to include within our study; from this 10 key papers

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Table 1. Key papers: focus and characteristics.

Study	Participants	Paper focus	Study length	Type of application
Arteaga *et al.* (2010)	Adolescents	How design ideas were generated	Survey	Analogous: agent with advice and prompting to do activity
			4 weekends, 1-hour sessions	
Toscos *et al.* (2006)	Adolescents	Participative design	4 days (app) + 2 days	Literal: Chick Clique
Toscos *et al.* (2008)	Adolescents	Design	1-week baseline, 2 weeks study	
Ahtinen *et al.* (2010)	Adults	Presentation of findings	1 week	Analogous: Into
Consolvo *et al.* (2006)	Adults	How study ran	3 weeks	Literal: Houston
Consolvo *et al.* (2008)	Adults	Technology artefacts	3 months (winter)	Analogous: Ubifit garden
Consolvo *et al.* (2009)	Adults	Persuasive technology	End of study feedback	
Fujiki *et al.* (2008)	Adults	Game elements included in prototype	4 × 1 weekday, 1 weekend day (Pilot), 4 weeks (Study)	Analogous: NEAT-o-games (race avatar)
King *et al.* (2008)	Adults	Behavioural impact	8 weeks	Literal: PDA diaries/logs
Lin *et al.* (2006)	Adults	Ubiquitous computing 4 weeks pre-use, 6 weeks of use, 4 week post-use	Analogous: Fish ‘n’ Steps	

Participants’ characteristics

Study	No.	Ages	Gender	Fitness level	Interested in health?
Arteaga *et al.* (2010)	28 (survey) 5 (usage)	12–15, 12–17	– 4F/1M	A mix	–
Toscos *et al.* (2006)	7	13–17	7F	–	–
Toscos *et al.* (2008)	8	13	8F	–	–
Ahtinen *et al.* (2010)	37	20–55	31F, 6M	Generally fit	–
Consolvo *et al.* (2006)	13	28–42	13F	Unfit	Yes
Consolvo *et al.* (2008) Consolvo *et al.* (2009)	28	25–54	15F/13M	Both	Yes
Fujiki *et al.* (2008)	8 (Pilot) 10 (Study)	Av. 28 Av. 38	1F/7M 8F/2M	Mainly overweight Moderately active	–
King *et al.* (2008)	37	50–60	16F/21M	Underactive	Yes
Lin *et al.* (2006)	19	23–63	F/M	A mix	Mixed
Ehealth study	18	11–15	5F/13M	Generally fit	Mixed

were identified that influenced our detailed design (three of which had adolescent participants). Table 1 summarises the characteristics of each (the full literature review is available from Edwards *et al.* 2011). The underlying purpose of these papers was to motivate their technology users to increase their physical activity by providing them with a means to both record their activity and gain advice on behaviour change. However, each study has its own particular nuances as discussed below.

1.1.1. Studies of adolescents

The purpose of Arteaga *et al.*’s (2010) study was to develop an agent (embedded in an iPod touch) that would actively prompt adolescents to do specific physical activities. The intention was for these activities to be specifically linked to the user’s personality traits as measured by the Big Five Inventory (Courneya and Hellsten 1998). The authors surveyed the opinions of 28 adolescents (12–15-year-olds) before conducting focus group sessions with five 12–17-year-olds (four female and one male) to inform their prototype development. This prototype was then trialled by the five focus group participants in four one-hour sessions over four weekends. From the study they concluded that individuals with certain personality traits (such as openness) are more likely to be receptive to the idea of motivational technology. Moreover, games that allow for socialisation and/or competition are more likely to be successful for all participants. However, these conclusions arose from focus group discussions rather than from the evaluation of their application.

In comparison, Toscos *et al.* (2006, 2008) worked with teenage girls to design and test a mobile phone application, *Chick Clique*, that would harness their social networks to motivate their peer group to exercise. The focus was on girls since there is evidence to suggest that they typically become physically less active in adolescence than boys (Sallis and Owen 1999, Kimm *et al.* 2005). Users of *Chick Clique* form social groups (of up to four friends) and each enters their daily step count. Automated text messages are sent to each member to indicate group and individual performance (the messages also offer praise for meeting goals) and a food tips tool provides information on healthy food choices. In the studies reported in 2006 and 2008, the application was tested each time by two small groups of girls for six days (in the first study) and three weeks for the second. The results indicated that the most powerful catalyst of behaviour change was group performance; however, it is difficult to draw firm conclusions from the two studies given their limitations in duration and participant groups.

1.1.2. Studies of adults

Ahtinen *et al.* (2010) involved participants in designing a smartphone application, *Into*, to capture users' daily steps and represent them as pictorial progress on a virtual trip: they also sought to add social sharing and playfulness to the design elements. They expected users to be motivated by the visualisation of their steps as progress on a journey; their participants did find this motivating and they also reported enjoying the social cooperation and competition within their teams. Some were motivated by the rewards sent in response to individual progress. However, they identified the recording of step-based activity only and the need to carry the phone at all times as the major limitations of the approach. Since the study used participant-based design much of the paper focused on this aspect, although a qualitative evaluation of use was also reported.

Consolvo *et al.* (2006) investigated the design requirements for persuasive technologies using a purpose-built application, *Houston*, that enabled users to enter their daily step count taken from a standard pedometer and to make fitness-based diary entries. *Houston* also enabled social competition. Two conditions were studied using a personal and a shared version of the software; the latter allowed users to view group members' data and to message them. Those in the sharing condition were reported as more successful in meeting personal goals. However, across all participants the use of pedometers was only partially successful as they were reported as being inaccurate and inconvenient to wear. However the ability to enter additional activity information into *Houston* was valued by participants, particularly those sharing their data. In a later study, Consolvo *et al.* (2008) developed an analogous application for individuals, *UbiFit Garden*. This harnessed on-body sensing devices that could detect a range of physical activities, record these in real time and automatically transfer the data to a mobile phone for visual display. The display (which could be glanced at, at any time) represented the user's physical activity as a garden: flowers growing in line with activity and butterflies signifying goal attainment (only positive reinforcement was used). The application also allowed users to enter information. The results showed that participants responded well to the *UbiFit Garden* and were motivated by seeing their garden bloom and the appearance of butterflies. The participants also valued the ability to edit their data (to compensate for equipment sensing errors) demonstrating the importance attached to data accuracy.

Fujiki *et al.* (2008) developed an application, *NEAT-o-games*, that operated in the background receiving data from a wearable accelerometer which controlled the animation of an avatar. This avatar competed in a virtual race with other players' avatars over the mobile phone network. Race progress was based on the user's daily movement and the user could choose to view this at any time (or to ignore the application). Winners were rewarded with hints for solving a series of mental games. The results indicated that a 'good percentage' of participants increased their physical activity levels. However, participants wanted the game to provide more encouragement and were affected by technical issues (such as battery charging) and system size.

King *et al.* (2008) investigated whether a personal digital assistant (PDA) could help increase the exercise levels of healthy but underactive middle-aged adults. Daily step data were captured by pedometers and one group entered these into PDA diaries. The PDAs prompted the users to monitor their physical activity levels twice per day and provided daily and weekly individualised feedback, goal setting and support. In comparison a control group received printed physical activity educational materials. Participants using the PDAs self-reported significantly greater mean estimated caloric expenditure levels per week than those in the control group.

Lin *et al.* (2006) aimed to motivate exercise via the *Fish 'n' Steps* software. This linked pedometer use to the care of a virtual pet fish in a tank, its emotion and development being dependent on its owner's activity levels. Two conditions were investigated: an individual fish in a tank and a group of fishes (up to four) in a shared tank where the relative health and happiness were visible. The participants' commitment to behavioural change was measured using the trans-theoretical model (TTM) (Spencer *et al.* 2006) which classifies individuals on a six-stage model, from precontemplative (no recognition of a need to change and have no intention of making change) to termination (where the new behaviour has become so habitual that there is no longer any danger of relapse). The results indicated that the application had only influenced the behaviour of those who were already at the third (preparation) stage of the TTM, regardless of the study condition. The application made those at the lower end of the spectrum aware of the need for action, but did not lead to a change in overt behaviour. An additional finding indicated that the positive visualisation of a growing, happy, fish was appreciated but negative consequences led to avoidance.

1.2. Emergent design considerations

From the detailed analysis of the literature, four areas emerged as important to build into our study design: portability and accuracy of activity-monitoring devices;

social support for users; goal setting; and incentives and rewards.

1.2.1. *Portability and accuracy of activity-monitoring devices*

The findings of Consolvo *et al.* (2006, 2008), Fujiki *et al.* (2008) and Ahtinen *et al.* (2010) suggest that the portability and wearability of any activity-monitoring device would affect product usage; Toscos *et al.* (2006) commented that teenage girls wanted a pedometer that would be considered stylish. Moreover, the accuracy of the devices recording data and the opportunity of participants to correct the data (especially where the information was to be shared with others) emerged as issues in most studies.

1.2.2. *Social support*

Consolvo *et al.* (2006) found that those sharing information were more successful in achieving goals than individuals, and Ahtinen *et al.*'s (2010) participants valued the social element of competition and cooperation; whereas Lin *et al.* (2006) found no differences based on social sharing. Although the evidence for the impact of social support on health-related interventions is inconclusive, Maitland *et al.* (2009) identified two forms of social support: online interactions between people who normally would not meet and (more powerfully) interactions with family and friends. Their analysis suggests that applications should allow for user-controlled selective, partial and incremental disclosure of monitored behaviour.

1.2.3. *Goal setting*

In setting goals for participants, these need to be demanding but still be attainable. Participants in Consolvo *et al.*'s (2009) study, whose baseline was already high, were given goals that they felt were unreasonable. Moreover, as Lin *et al.* (2006) comment, where a goal is too high it will delay, or deny, the participants' rewards. Consolvo *et al.* (2009) explored the issue of how to set goals; three ideas were popular: self-setting, group setting and setting in line with advice from a fitness expert. Participants wanted weekly goals but wanted to be able to declare their own week start and end dates, and wished to retain the record of past achievements (this is also linked to incentives).

1.2.4. *Incentives and rewards*

In each of the studies participants enjoyed receiving rewards and reviewing them. However, in Lin *et al.* (2006), where there were negative consequences to poor performance, they reported some participants as being demotivated by this. In other studies, participants were reported as wanting positive reinforcement only, for instance, Consolvo *et al.* (2008). Therefore, although incentives are seen as beneficial the focus needs to be on positive reinforcement of behaviour.

2. Method

2.1. *Participants*

2.1.1. *Recruitment*

The sponsor's requirements were to recruit adolescents (between the ages of 11 and 14) who were attending and settled in secondary schools (where pupils' ages range from 11 to 16). The sponsor was concerned that, between these ages, physical exercise declined substantially: this view is confirmed in the exercise and health literature, including Troiano *et al.* (2008), Hedley *et al*. (2004) and Sallis and Owen (1999). Moreover, in early teenage years, many adolescents begin to assert their individuality and lay down attitudes and practices that often continue on into later life. Participants were to be allocated to one of three groups; each of which would use a specific set of technology probes (as discussed in Section 2.2). As groups were to be self-contained each needed sufficient members to provide a range of experiences, ideas and interactions. However, we needed to balance this against the ability to manage and resource the groups and ultimately analyse the varied data sets that would be generated. Therefore, groups of six were sought so that, should any participants withdraw before the end of the project (as did happen in one group), we would have interactions between group members and several sets of data for each group condition.

Over 50 voluntary youth organisations in the city were used to cascade information about the project to the target demographic (including the reward of a gift worth £100 for completing the study). Recruitment began in June 2010 but the target figure of 18 participants was not reached until September 2010: this may have been as a result of the school summer holiday. The characteristics of the groups formed are shown in Table 2: gender-balanced groups were sought, however few girls volunteered.

2.1.2. *Ethical issues affecting participants*

A formal ethical framework was used to gain and document the different types of consent needed. These consents were granted by the university's ethics committee, the participants' parents or carers, and the children themselves. In addition, the researchers applied for Enhanced Disclosure from the UK Home Office's Criminal Record Bureau (as part of the application to the university's ethical committee).

2.2. *Materials*

The equipment used for data capture, monitoring and usage is summarised in Table 3.

2.2.1. *Handheld devices*

The project sponsor wanted an evaluation of the impact of handheld digital technologies. Therefore, we examined a number of options (such as mobile phones, PDAs and

Table 2. Participant groups.

	Age range	Gender	Existing social bonds
Group A	14 years	3F, 3M	Yes (members of same youth group and school)
Group B	5 × 13 years, 1 × 15 years	2F, 4M	Yes (each knew at least one member of the group)
Group C	5 × 11 years, 1 × 13 years	0F, 6M	No (individually located)

Table 3. Technologies used.

		Group A	Group B	Group C
Data capture				
Steps	Walk with Me!™ activity meter	✓		✓
	Omron Walking Style II pedometer		✓	
Other activities	Paper-based log book			✓
	ehealth-elgg website	✓	✓	
Barriers to exercise	Paper-based log book			✓
	ehealth-elgg website	✓	✓	
Data monitoring and usage				
Rewards	Paper-based log book			✓
	ehealth-elgg website	✓	✓	
Activities	Walk with Me!™ games using Nintendo DS Lite	✓		✓
	Facilities in ehealth-elgg website	✓	✓	

game consoles) against both the design requirements identified from the literature review and two additional criteria: financial constraints (any device needed to cost less than £100) and availability of age-appropriate exercise applications. Given these constraints Nintendo DS Lite consoles were chosen along with the *Walk with Me!*™ game. The game was chosen after evaluating two potential applications (*My Health Coach* and *Walk with Me!*™) both of which had their own activity meters, enabled users to track their activity and gave supportive feedback. We rejected *My Health Coach* since it emphasised weight loss via burning calories and dieting, supplemented by an exercise theme. We wanted to avoid messages about expected (idealised) body shape and size which might have negative connotations particularly for the female participants. Therefore, we adopted the second option, Nintendo's *Walk with Me!*™ which focused solely on exercise (and came with a pair of activity meters to enable social competition and support).

2.2.2. Social website

Our comparator technology for data monitoring was embedded within a social website environment. In addition to the required features identified from the literature (as identified in Section 1.2), we added the option to allow data to be kept as private or shared as part of the social dimension, in line with Maitland *et al.*'s (2009) recommendations. It was important that any social website should be closed (so that only those invited by the research team could join), not entice participants to navigate elsewhere (to potentially inappropriate internet material), and be monitored to ensure individuals used the site appropriately. These constraints eliminated the popular social websites used by many of the participants and led to the selection of the open-source elgg technology (www.elgg.org) on which to build the *ehealth-elgg* site.

Standard elgg features enabled a personal presence (via members' profiles and blogs) and social interaction (via personal and group messages). To encourage competition we customised the site so that daily and weekly rewards were sent to those who achieved their targets, and these achievements were published in the public area. Other customisations enabled users to log their daily activity, making each entry either private or public. Figure 1 shows an example user profile.

2.2.3. Pedometers

Group B used pedometers and the *ehealth-elgg* site. Omron Walking Style II pedometers (with acceleration sensor technology) were used which had acceptable accuracy for this project. One of the research team carried both a pedometer and an activity meter for a full day to compare their performance: the difference in steps collected by the devices was less than 5%. Had the focus of this project been directed at improving exercise levels then the data capture devices would have needed to be much more accurate and versatile in the type of data collected. However, given their role as technology probes a level of inaccuracy was acceptable.

2.3. Design

The study was designed so that the participants engaged in their everyday activities and recorded their physical activity over seven weeks (a baseline week plus six weeks using the technology probes). Their experiences were used to reflect on the features that they believed persuasive technologies

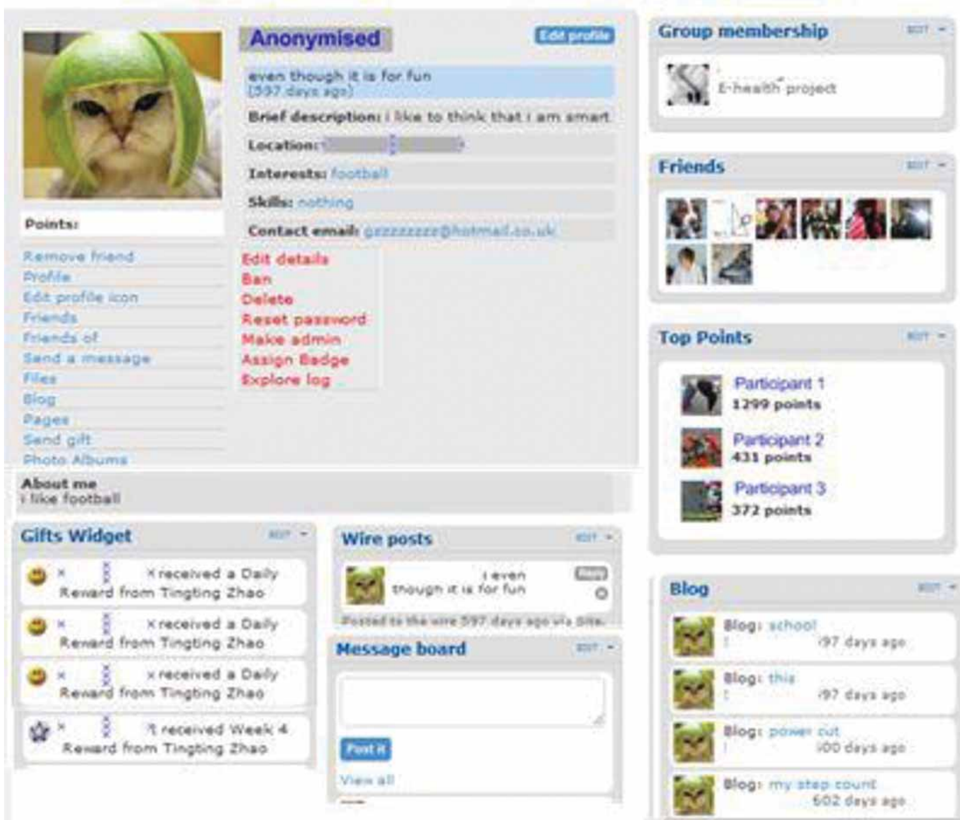


Figure 1. Anonymised personal profile in the ehealth-elgg site.

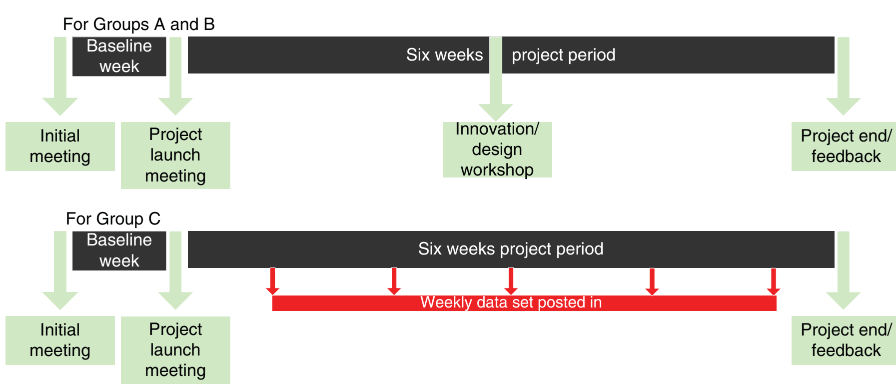


Figure 2. Study overview for the three groups.

would need to contain for their peer group to adopt them. Innovation workshops were also used to see whether further ideas could be stimulated beyond the confines of their experience. Only Groups A and B took part in the workshops since members of Group C were dispersed throughout the city and undertook the study across different time periods. The practical constraints within the project made it impossible to bring them together for such an event.

2.4. Procedure

Figure 2 illustrates the procedural framework for the study.

The procedure followed for each group was similar. Each group had an initial meeting where they met the research team, were given some basic information about the project and were asked to complete a number of questionnaires. These questionnaires assessed each participant's attitudes towards physical exercise and the link with self-image, their technological experience and their views on their current activity. A parents/carers' questionnaire was also used to acquire insight into the family attitudes to exercise. The participants were then provided with a pedometer to use for a baseline week to record their daily steps. These data determined whether the daily target (of 10,000 steps) was reasonable for the main study. It also provided a base from which to track any changes in activity levels as a result of the intervention.

The main study began for each group with a project launch meeting showing the technologies that they were to use (and how to use them) and explaining the study's purpose and their role in it. We reinforced that the aim of the study was not to increase their activity levels per se, but to help us understand what types of technology would be attractive to typical users of their age. For the following six weeks the data were collected and the extent to which Groups A and B used *ehealth-elgg* and its features was monitored. The research team engaged with participants through the website to maintain their interest and let them see that the team were responding to their entries. Group C members recorded their data within their individual consoles and paper-based diaries. To reduce the feeling of isolation, since they were working on an individual basis, they were sent a weekly letter with a log sheet to return after completion (with a stamped-addressed envelope). This established a line of communication and also lets us see the emerging pattern of activity during the project.

At the midpoint separate innovation workshops were held with Groups A and B. Then at the end-of-study meeting interviews were held with participants and the baseline questionnaires were re-administered to identify any changes to attitudes or exercise levels. Finally, the participants were thanked and given their rewards for participating throughout the full study.

2.5. *Data capture and analysis process*

2.5.1. *Attitudes and perceptions*

The pre-study and end of the study data on participants' attitudes and perceptions (collected by questionnaires) were compared at an individual level and statistically analysed. Where there was comparative data from the parents' questionnaire responses these were included in the statistical analysis.

To ensure rigour existing validated questionnaires were used wherever possible. A variant of the Physical Activity Questionnaire for Older Children, PAQ-C (Knowles *et al.* 2009) was used for the self-reports of physical activity. Physical and global self-worth insights were examined via the Physical Self-Perception Profile which has been validated across countries, gender and age profiles (Welk and Eklund 2005). Motivational attitude to change was measured using the TTM (Sarkin *et al.* 2001, Spencer *et al.* 2006). Participants' self-assessed levels of activity were tracked using a variant of Kowalski *et al.*'s (2004) Physical Activity Questionnaire (replacing popular American sports with more common UK sports).

2.5.2. *Physical activity*

Daily steps were logged by each participant over the course of the study then validated by a researcher and transferred to spreadsheets for analysis (as shown in Figure 3).

The accuracy of the participants' logged step data was verified for Groups A and C at the study midpoint and endpoint (this was checked against data stored in the participants' *Walk with Me!*™ game). There was limited validation for Group B's data since their pedometers only stored data for seven days. The step data were analysed for individuals and groups using charting techniques to examine trends.

The participants also logged daily reports about other physical activities and barriers to exercise (these could not be validated). The additional exercise was analysed by simply identifying the types and frequency of activity, and the barriers to exercise were analysed by building an affinity diagram (Beyer and Holtzblatt 1999).

2.5.3. *Reflections*

Participants' reflections on their experiences were elicited using two complementary techniques. Participants commented in their log books (or website) throughout the study on issues that arose 'in the moment'. In addition, we gathered reflective feedback in their final meeting using short

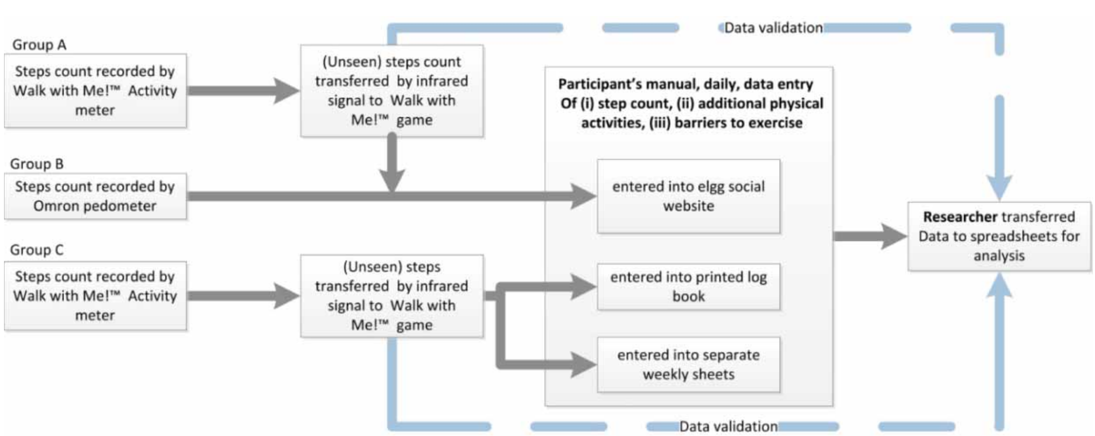


Figure 3. Stages of the data capture process.

questionnaires with Likert-style responses regarding the specific technologies used and their motivational impact. Open questions were used to capture views on what would motivate over the long term. These were supplemented by follow-up discussions. It was possible to hold group meetings with Groups A and B at the end of their study period. At this point the participants completed the questionnaires and then discussed emergent issues (researchers acted as facilitators during this process). However, it proved to be impractical to bring the members of Group C together as they were widely dispersed throughout the city and had started the study at different dates. Therefore, we held individual final meetings with them during which participants were questioned in an informal manner to gather feedback beyond that already captured in their paper-based logbooks. All group and individual discussions were audio recorded (with the participants' permission).

One researcher transcribed and extracted comments from the audio data; thereafter, the full data set of logged comments, verbalisations and questionnaire data was printed as separated comments. The research team used thematic coding to collaboratively develop an affinity diagram: physically grouping-related elements, discussing these and reflecting on the emergent fit, then finalising the diagram and giving names to the themes. This generated a hierarchical understanding of the themes relevant to the participants which was recorded in a spreadsheet.

To elicit imaginative concepts we designed activities to use within a workshop for each of Groups A and B and encouraged them to record subsequent ideas in their *ehealth-elgg* website (which other group members and the research team could view). With Group C members we sought their individual ideas during the final debriefing meetings (along with their reflections).

2.5.4. *Ideas*

Two sets of activities were designed for each innovation workshop: evaluation of visual artefacts and brainstorming (Osborn 1979). Visual stimulants are useful in rapidly generating ideas for debate, but their disadvantage is that they can draw participants into thinking about what has been presented and not what 'could be'; whereas, in brainstorming participants are presented with a blank canvas which can seem daunting. In case there was an order effect involved we changed the order of activities for the two groups, as illustrated in Figure 4 (subsequent data analysis did not show any such evidence).

In both types of activity the participants first captured their ideas pictorially or textually and then discussed them in the group to explore them further (these discussions were audio recorded). A scenario was designed to provide a context within which to brainstorm and four posters were developed as artefacts (with prompts) to stimulate ideas (as illustrated in Figure 5). The posters suggested ways in which daily steps could be used as rewards to enhance three different types of software games:

- social games: with a focus on individual and collaborative activity;
- games that shift the locus of control: exercise benefits a digital character;

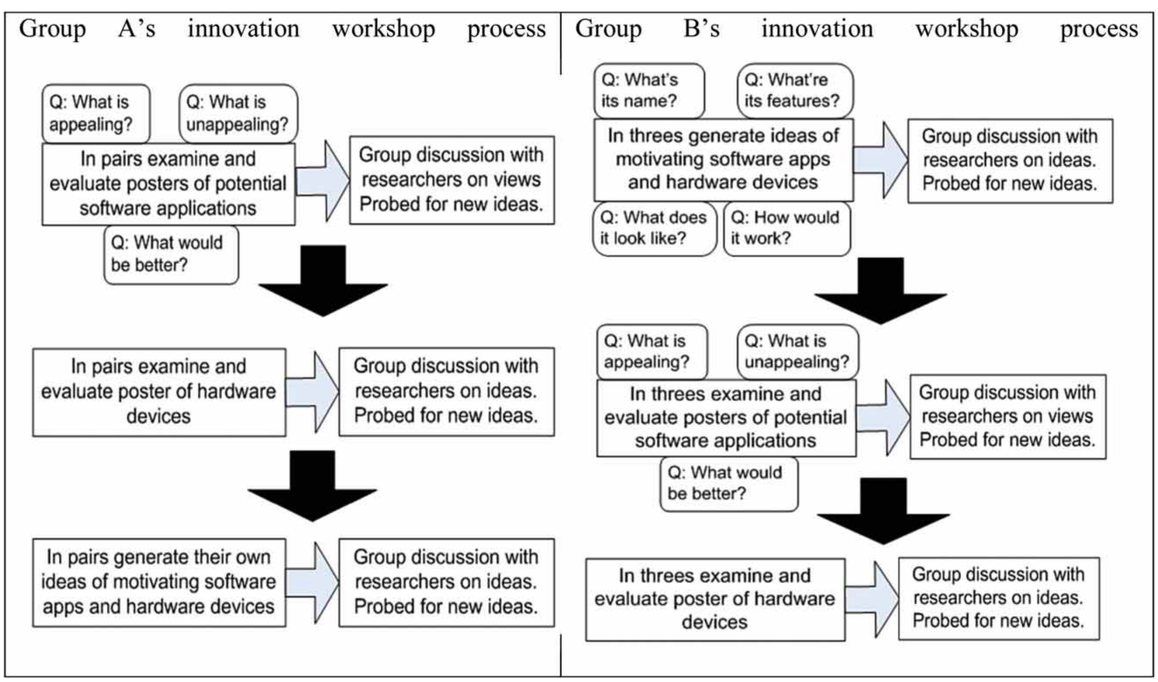


Figure 4. The two innovation workshop processes.

Figure 5. Sample posters and probes used in innovation workshops.

- existing video games: with personal activity enabling enhanced game play.

A hardware poster focused on what activity (beyond steps) might be captured, what the devices might look like and how they might be worn.

The same thematic coding process was used for analysis of ideas as for the reflective data.

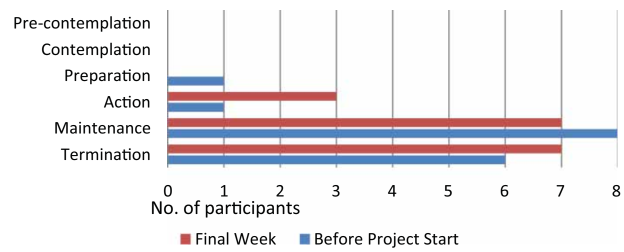


Figure 7. Comparison of self-assessed ratings on the TTM.

3. Results

3.1. *Participants' profiles*

The 18 participants were experienced technology users (as demonstrated in Table 4 and Figure 6) and had no concerns about the use of the equipment we provided.

They were also assessed for their readiness to change their exercise behaviour using the TTM. Figure 7 shows their distribution against this.

The mean placement on the TTM was 5.06 (before project start) and 5.24 (final week) with Wilcoxon signed ranks test $z = 1.13$, $p = 0.257$. Statistical comparison showed no significant change however, the participants rated themselves highly which would imply that any exercise-based behavioural change had already taken place; therefore, it would have been surprising to see much change here.

Table 4. Participants' age when first used computers.

Age	4	5	6	7	8
No. of participants	8			7	2

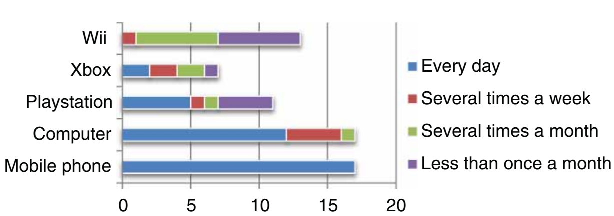


Figure 6. Participants' experience and usage of technology.

3.2. *Behaviour data*

3.2.1. *Attitudes and perceptions*

The attitudinal data focused on motivation to exercise, enjoyment of exercise, perception of sport, physical self-perception and their exercise environment (Likert scale questions were used with the directions of statements varied to avoid leading participants in their responses). Statistical analysis using non-parametric statistical techniques (within SPSS) was undertaken but the results were not statistically significant, Figures 8 and 9 represent their initial views.

Both participants and their parents were asked to indicate the most likely reasons for not engaging in exercise. Figure 10 shows the mean ratings for each of these factors: the higher the rating the more likely the reason is to prevent exercise.

Taking the parents' perceptions first Friedman's Anova revealed a significant difference in the ratings assigned to each of these factors ($c^2(3) = 18.48$, $p < .05$). Wilcoxon tests were used to follow up on this finding. Pairwise comparisons can increase the possibility of a family-wise error; therefore to reduce this possibility we applied a Bonferroni correction meaning that the significance threshold was reduced to 0.008. In making these comparisons, the only significant differences found were school work was rated as a more likely reason not to exercise than the lack of

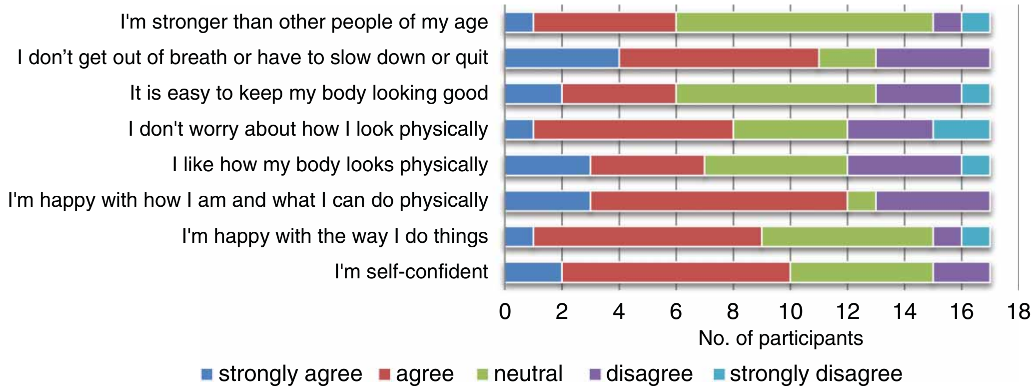


Figure 8. Motivation for exercising and self-perception (start of study).

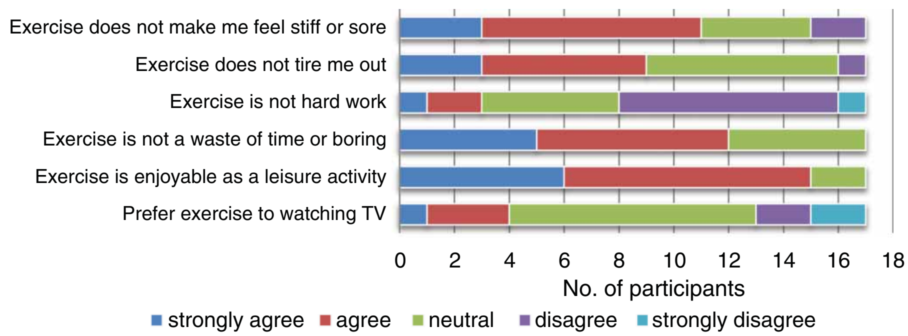


Figure 9. Enjoyment of exercise (start of study).

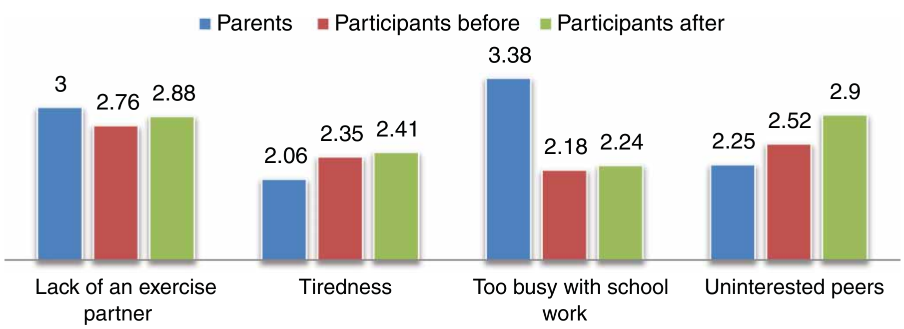


Figure 10. Mean ratings for barriers to exercise (scale: 1 – very unlikely to 5 – very likely).

an exercise partner ($Z = 2.75$, $p < .006$), and the lack of an exercise partner was rated as a more likely reason not to exercise than uninterested peers ($Z = -2.76, p < .006$). This latter finding suggests that parents either felt that their child would exercise alone or that the exercise partner could perhaps come from inside the family unit. Turning to the participants' perceptions of exercise barriers a Friedman Anova test revealed no significant differences in the ratings assigned to the four factors either at the start of the study ($c^2(3) = 4.440, p = .21$) or at the end ($c^2(3) = 6.99$, $p = .07$).

The evidence here is not conclusive but perhaps indicates that personal motivation and use of exercise opportunities may be linked to attitudes and what happens within friendship groups: this is an area warranting further investigation.

3.2.2. *Variety and extent of activity*

Kowalski *et al.*'s (2004) Physical Activity Questionnaire provided a snapshot of participants' activities pre-study and at the end of the study. Statistical analysis of the results showed no significant differences between the two. Figure 11 shows the pre-study results which demonstrate that walking, jogging and football (soccer) were most popular and were undertaken most frequently: these all require little equipment and can be adopted opportunistically.

Data were also captured about their opportunities for exercise within the school day at the individual level: the responses identified that short breaks were rarely used for exercise and even the longer lunch break was, for most participants, a time of little activity. In their free time, where they had more control over their activities, their highest level of activity occurred immediately after school with

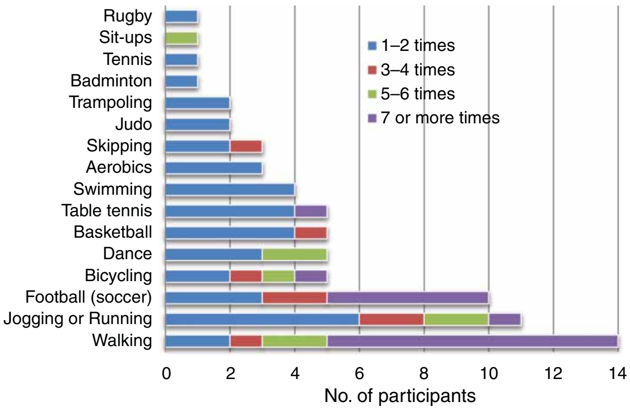


Figure 11. Engagement in specific physical activities (pre-study week).

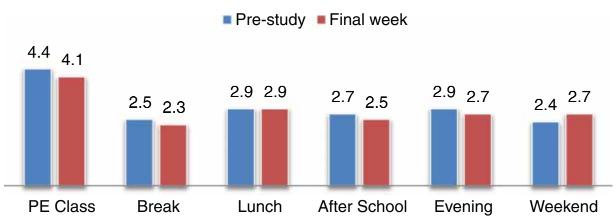


Figure 12. Mean perceptions of physical activity ratings in the pre-study and final study weeks (scale: 1 – inactive to 5 – very active).

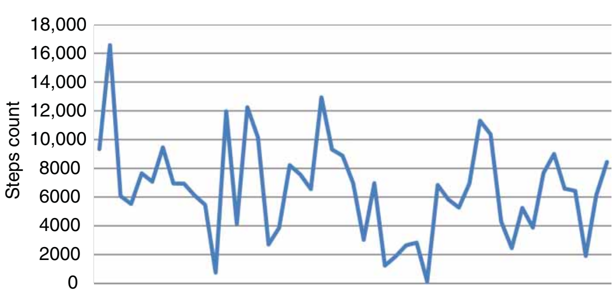


Figure 13. Step counts over the baseline and study period for group member Ag1.

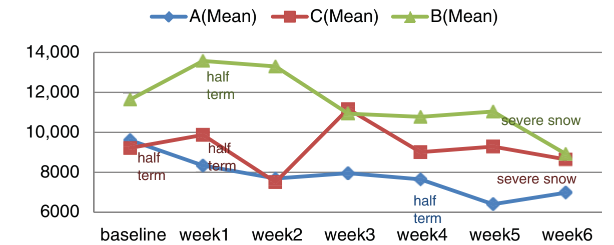
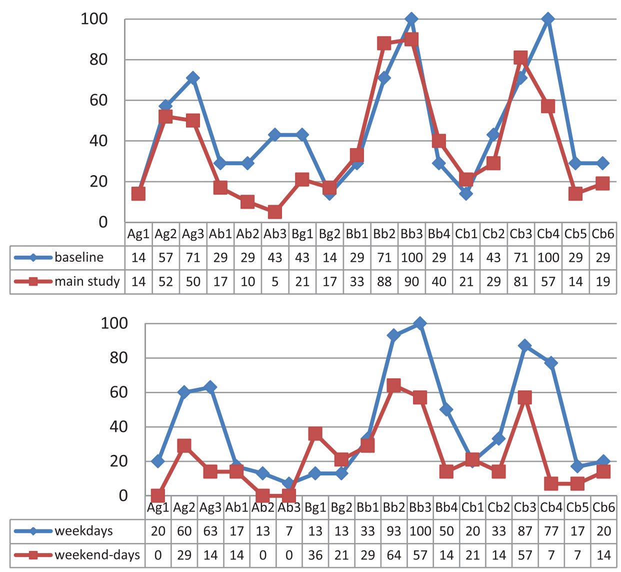


Figure 14. Mean daily step count per week, per group.



	Ag1	Ag2	Ag3	Ab1	Ab2	Ab3	Bg1	Bg2	Bb1	Bb2	Bb3	Bb4	Cb1	Cb2	Cb3	Cb4	Cb5	Cb6
baseline	14	57	71	29	29	43	43	14	29	71	100	29	14	43	71	100	29	29
main study	14	52	50	17	10	5	21	17	33	88	90	40	21	29	81	57	14	19

	Ag1	Ag2	Ag3	Ab1	Ab2	Ab3	Bg1	Bg2	Bb1	Bb2	Bb3	Bb4	Cb1	Cb2	Cb3	Cb4	Cb5	Cb6
weekdays	20	60	63	17	13	7	13	13	33	93	100	50	20	33	87	77	17	20
weekend-days	0	29	14	14	0	0	36	21	29	64	57	14	21	14	57	7	7	14

Figure 15. Percentage of time individuals met 10,000 step target.

Sunday appearing to be their 'day of rest' with least strenuous activity undertaken. A Wilcoxon signed ranks test was used to compare these ratings before and at the end of the study, and no significant differences were found. Figure 12 shows the mean ratings for these.

3.2.3. *Physical activity*

Although the main focus of the study was not on how much exercise was done, we were interested in seeing what transpired over the study. Our supposition was that there would be an increase in activity in the early phase of the study with, perhaps, a settling down period (or tailing off) towards the end of the study, as interest waned. However, the data did not suggest any clear trend. Figures 13 and 14 give examples of the analysis done.

The data had to be interpreted within the study context. For instance, there was a one-week holiday which occurred at different times for the three groups and Group B and C's study period included two weeks of severe snowfalls. Each of these events (as shown in Figure 14) could have affected activity so the data in these time periods were compared against other weeks but no consistent pattern of change was seen. We also examined the data to identify whether there was any (consistent) variation in the extent to which participants achieved their daily targets. The data were sliced into different time frames (baseline week, main study, weekdays and weekends). Figure 15 shows that 12 participants achieved their targets more successfully over the baseline week than over the six weeks of the main study. Perhaps motivation to maintain the step level over six weeks was a much harder challenge. Fifteen participants reached their targets more successfully over weekdays than during weekends, indicating perhaps that their school life keeps them active. This is in line with the self-assessed activity levels which were analysed in their questionnaire responses.

Conclusions drawn from this analysis need to be tempered since participants' comments on 'daily barriers' indicated that the data capture devices were only partially effective and failed to record a number of activities (such as

Table 5. Impact of technology on social support, competition and motivation.

Technology	Aspects	Findings	Commentary
Website	Sharing data	Group A was more interested than Group B in seeing members' data. A Mann–Whitney test revealed that this difference was significant ($Z = -2.068, p < .04$)	There were *both positive and negative comments here:* 'I don't mind who sees the option', 'I'm proud of the steps I did, I want others to see', '. . .depends how many steps I did that day'
		Group A (mean 3) were more interested in seeing each other's data than Group B (mean 2.17)	
	Communication	Group A had a mean of 33.17 website messages (standard deviation 21.65)	This may reflect the stronger friendship ties between Group A members than Group B
		Group B had a mean of 3.83 (standard deviation 6.40)	
	Competition	Group A found the website created competition significantly more (mean rating 3.83) than Group B (mean rating 2). A Mann–Whitney test showed that this difference was significant ($Z = -2.142, p < .032$)	There were no differences between the two groups in terms of the impact of rewards
Console game	Sharing data	58% would share data with their console friend	Of the five mini games 'Walk the world' was highly valued; the others, whether they gave visual (analogous) or literal representations of the data, were not
		33% were against the idea	
	Motivation	50% believed sharing data would be motivating	
		All found the 'walk the world' graphical mini game to be motivational	
		25% thought stamps for achievement motivated, 50% did not	

cycling and swimming). Thus the recorded exercise levels are likely to under-report activity.

3.2.4. *Impact of the technologies used on behaviours*

The data from the three groups were analysed to determine whether the use of the different technology sets had had any impact on them and the barriers that they encountered. Table 5 shows the statistically relevant results determined for the impact of the technologies on social support, competition and motivation.

Affinity diagrams were constructed for the problems related to self-management of exercise which were logged during the study. Table 6 shows their categorisation.

3.3. *Design ideas*

Tables 7–12 show the themes that emerged from the study that would be relevant to the design of motivating technologies for opportunistic exercise. The tables were generated from the synthesis of the different affinity diagrams constructed from the feedback on the technologies' usage and the different strategies for idea generation. In many cases similar themes emerged from different data elicitation mechanisms. This is shown in the tables by codes identifying where the evidence originated, these are daily comments (DC); reflection on use of technologies (R); visual stimulants in innovation workshops (VS); brainstorming in innovation workshops (B) and individual ideas logged in *ehealth-elgg* or logbooks (II).

The ideas about how and where to wear data capture devices (summarised in Table 7) tended to emerge from the participants' experiences. This is generally so even for ideas emerging from the brainstorming sessions where they tended to reflect the limitations they had experienced while using the technology probes.

The key requirements for the data capture devices focused on their accuracy and variety in data types collected, and their appearance and opportunities to integrate with other technologies as shown in Table 8.

In comparing these ideas with the design considerations identified from the literature in Section 1.2 (portability and accuracy of activity-monitoring devices; social support for users; goal setting; incentives and rewards), we can see that ideas summarised in Table 7 tend to focus on the portability aspect of activity-monitoring devices. In Table 8, the ideas focus on the accuracy of activity-monitoring devices and the issue of incentives (via personalisation and external motivation). It could also be argued that data variety and links to purposeful exercise support individuals in achieving goals that are of interest to themselves (although explicit goal setting requirements are not apparent). No evidence emerged to suggest that social support needed to be designed into the data capture devices.

In terms of data usage four themes emerged as shown in Table 9. One was concerned with the individual's immediate

Table 6. Barriers encountered.

Key themes	Issues	Sample comments
External barriers	Illness	'poorly, never went out'
	Weather (snow and rain)	'snow, didn't walk anywhere'
	Homework	'lots of homework'
	Holidays	'packing for Sweden/away in Sweden'
	Long distance journey	'I went on 4 and 1/2 hour car journey'
Inaccurate step recording	Forgot to wear the device	'family emergency, go to hospital and forgot to bring the pedometer'
	Nowhere to keep it during an activity	'I was doing cross country running and had no pockets'
	Ineffective data recording although worn	'did more than recorded! walked a lot today'
	Device lost	'lost pedometer'
	Authority figure prevented use	'couldn't wear from 6:30pm (air cadets)'
Personal decision	Chose inactivity – had a 'lazy day'	'Sunday, relaxed and stay in bed'

Table 7. Data capture devices: how and where to wear the device.

Themes	Sample comments	Where themes emerged			
Invisibility	'Have it on your watch'. 'It could be a belt'. 'my mum likes the idea of it in jewellery'	DC	R	B	II
Ubiquity	'Put it your glasses so you have it on all the time'. 'It could be a belt and the pedometer could be the buckle because you won't forget it or else your trousers will fall down'	DC	R	B	
Flexible location	'It is clip-able to fit around a belt or a watch.' '... I play snooker, I walk around the table, I don't normally have my coat on, so it will be useful to use a bag for one, a pocket bag'			B	II
Support different activities	'Connect it to your BMX, put it on your handle bars for your bicycle, it picked up how many times you paddle, and how long it takes' 'A belt with a pedometer and different sport settings that can be changed'			B	
External visibility	'A robot dog that walks along side of you when you are walking.... It has different types of dogs'			B	

Table 8. Data capture devices: requirements.

Themes	Sample comments	Where themes emerged			
Accuracy of devices	'sometimes the activity meter only picks up steps from one leg!'	DC	R		
Functionality	'the pedometer should have a touch screen'			B	
Data variety	'heart rate', 'calories burned', 'routes', 'distance travelled'		R		
Personalisation	'You should be able to design what your pedometer looks like,.... It has to be colourful'. 'A Tamagotchi like pedometer, with a virtual you on it'			B	II
Persuasive design	'Super cool shoes which glows a different colour for every 1000 steps, you will look so cool'			B	
External motivator	'If you not doing much walking, it [robot dog] talks to you and motivate[s] you to do more'			B	
Connectivity	Devices should integrate with a wider variety of technologies. 'upload it to the wii' 'It also has a USB adaptor so that person can put his/her points into their computer xbox or ps3'		R		
Integration into existing devices	'... built into a phone as well, or Ipod'			B	
Use for purposeful exercise	'A pedometer in headphones so joggers can count their steps with the movement of their head'			B	

access to their data (which was seen as a motivator), and the other three were all linked to the concept of sharing data which maps onto the design concept 'social support for users'.

Persuasion surfaced as a concept that linked with incentivising and rewarding individuals, and three different strategies were identified as shown in Table 10.

Linking activity to games was seen as a motivator as shown in Table 11. These ideas all resulted from evaluation of the researchers' posters. Two ideas (personal focus and character value – negative) also emerged during Group A's brainstorming session; however, this occurred after their evaluation of the posters and thus may have been triggered by the initial activity.

Table 9. Data usage.

Themes	Sample comments	Where themes emerged
Sharing	'. . .when you press button on your DS or computer, you can see yours steps, activities and your friends too if you have special camera codes'	B
Visibility	'You should be able to see straightaway how many steps you did, so you will do more steps'	R B
Real-time sharing	'It should have a camera on, you give your friends, so that you can see where they are, what they are doing. . . .. So if I play football, . . . and my friend could tune in and watch me, . . . and view my acts, like if I scored, he could see it'	B
Focus on 'me' – broadcast to others	'An "invisibubble", a giant transparent see-through hamster ball, with a pedometer to record how many steps you did and how much calories you burned, it is waterproof, with a hidden camera, so that you can upload the video to youtube, so people can watch and laugh'	B

Table 10. Persuasion.

Themes	Sample comments	Where themes emerged
Positive consequence	'A text sent to your phone saying a sports and a length of time, if the people does it, there will be phone credit topped up on the phone'	B II
Negative consequence	'The pedometer could play your ipod music but only when you do activity. Music will stop playing if you stop the exercise.'	B
Kinetic persuasion	'Every 10,000 steps you do, it could power your tv for an hour as well as actual electricity. It saves money, save environment and keep healthy'	B
	'It charges the phone battery. The more steps, the more battery you have for your phone. But the phone also has a small battery so if you haven't done enough steps, it still works'	

Table 11. Game features (linking with steps).

Themes	Sample comments	Where themes emerged
Collaboration	'we more prefer the social games, like the farmville one'	VS
Competition	'I like it that I could compete with friends, and dogs are cute'	VS
Target audience	'It [locus of control game] is only for girls and not for boys. So maybe to make it more manly but still include a girl aspect.'	VS
	'It would be good for young people, but the older you get, the [more] mature you get, you will be less interested in this'	
Social focus	'You could make it more like Habbo hotel so you can talk to friends while looking at activity'	VS
Personal focus	'. . . I am not really bothered about what my friends are doing, as long as I am doing well'	VS B
Content	'If the social game is to build an army or something, we will like that one'	VS
Impact of negative consequences	'My experience . . . is bad as you are expected to be on all the time, otherwise, your plant will die'	VS
Boredom	[for locus of control] 'May get bored of it after a while'	VS
Character value (positive)	'I like that it is like a realistic pet. It encourages you to do more exercises and walking as the fate and happiness of your dog is in your hands, it's fun!'	VS
Character value (negative)	'It would be better if the dogs were hamsters' 'Link to a virtual person, if you didn't walk enough, the person will die'	VS B
Platform	'I don't use facebook, . . . annoying as many people talk about how good it is'	VS

Table 12. Rewards for doing exercise.

Themes	Sample comments	Where concepts emerged		
Points for use in existing games	'This is a very good idea, because it will upgrade you in something you are interested in. It couldn't be better.'	VS	B	II
Reward as cheating (positive)	'I play many games and love puzzle and action games as with this it is like a cheat box because we got help for doing lots of steps'	VS		
Reward as cheating (negative)	'. . . the fact that it is a video game encourages sitting around. But it is cheating'	VS		
Points for use in social games	'It gives you points, could be an online world,. . ., eg. each 10 minutes you do active walking, you get £1, to buy some clothes. More steps you get more points.'	VS		II
Real world 'Freebies'	'Get a free sports equipment if you walked lots of steps, eg. boxercise things, football things' 'If you get enough points, you can get things like, walk around the Newcastle football stadium'	B		II
Real-world discounts	'. . . you can get money off application and songs'			II
Real-world financial rewards	'If you have done 10000 steps plus, you will get £1'	B		II
Rewards within data capture device	'. . . pedometer, with a virtual you on it. More steps you do, you get a bigger gift for your little virtual you, eg. clothes etc. If you don't do many steps you get a tiny/joke gift, but if you do very well you get a bigger prize'			II

In contrast to Table 11 the themes in Table 12 came from a variety of sources and were not linked to the order of activities in the innovation workshop.

From Tables 11 and 12 the features that map onto the literature-based design considerations relate to social support for users and incentives and rewards, with personalisation and contextualisation acting as a means of motivation.

4. Discussion

At the outset of the study we selected technology probes that would ensure that the participants encountered the four literature-based design principles: portability and accuracy of activity-monitoring devices; social support for users; goal setting; and incentives and rewards. Section 4.1 reflects on what we learnt about these. We also explicitly engaged the participants in idea generation via technology probes and innovation workshop sessions, and the new themes that emerged are discussed in Section 4.2. The focus of technology probes is as a research tool for requirements elicitation and therefore in Section 4.3 we reflect on its effectiveness in this study before evaluating the limitations of our work and posit future directions in Section 4.4.

4.1. *Reflection on the design concepts and constraints identified in the literature*

4.1.1. *Portability and accuracy of activity-monitoring devices*

The importance of portable and accurate devices was supported by comments made in daily logs about the barriers to exercise, participants' reflections and their ideas. In line with the earlier literature (e.g. Consolvo *et al.* 2008, Ahtinen *et al.* 2010) participants want devices to reliably record all their activity, not just steps. This need can be satisfied with existing devices that use a wider variety of measures to estimate activity but they tend to have limitations in terms of portability. Such an example is *bodybugg*® (www.bodybugg.com) as discussed in Gil-Castiñeira *et al.* (2011), although it is more versatile than a pedometer it cannot be worn in water. The issue of a device's appearance and who sees it was important to our participants and generated a number of differing suggestions. Some wanted their device to be visible to both themselves and others, particularly to highlight when they were doing well. Others wanted discreet devices. Some wanted data visible at all times, others only when they were interested. Some suggested non-literal displays to represent the data (such as embedding colour change in jewellery-based devices or shoes). Many of these concerns and ideas reinforce those reported elsewhere, such as discreet devices (Toscos *et al.* 2006, 2008), thermochromatic devices for children (Ananthanarayan and Siek 2010) and shoe-based pedometers (Poole *et al.* 2011). What emerged overall from our participants were two key requirements: the ability to personalise devices (a new insight) and the ability of users to control the visibility of their data.

4.1.2. *Social support for users*

The literature analysed indicated strongly that social support was a key element in maintaining the individual's motivation (e.g. Ahtinen *et al.* 2010). The analysis of our participants' comments generally supports this. However, there was a gap between what was said and what was practised. There was little use made of the *ehealth-elgg* website by Groups A and B; most of the users simply recorded their daily data and checked for their daily or weekly rewards. The researchers posted comments and messages to try to engender more social interaction but this had little effect. In discussion with the participants it was clear that all but one were frequent users of Facebook, perhaps they did not see any advantage in committing their time to yet another social website. The data showed greater website interaction between Group A members than Group B members (Table 5), this may reflect their pre-existing real-world friendships which would support Maitland *et al*'s. (2009) differentiation between types of social support: online interactions between people who normally would not meet and (more powerfully) interactions with family and friends. The *Walk with Me!*™ console game allowed two people to record their data and use its mini-games; so there was the opportunity for members of Groups A and C to compete with a friend of their choice using the activity meters provided. There was evidence of some Group A members comparing and competing with each other across the consoles. However, only one individual provided direct evidence of using *Walk with Me!*™ for social support: in his case he competed with, and encouraged, his mother. Verbal feedback from her confirmed the positive effect of this competition on both of them, this again supports the findings of Maitland *et al.* (2009) and Colineau and Paris (2011) about the value of family support.

4.1.3. *Goal setting*

Daily steps of 10,000 is seen as the standard target for the general population although analysis of youth pedometer studies by Tudor-Locke *et al.* (2009) indicates that higher values are the norm for this age group (10,000–11,000 steps for girls and 12,000–15,000 for boys). We considered these factors in deciding the daily target, and we also considered whether to set individual targets. Since the study was aimed at participants identifying design requirements rather motivating or improving physical activity per se, we decided to set a standard tariff of 10,000 steps per day and to evaluate the participants' response to this to see what it revealed in terms of the importance of goals. The data that were logged during the study showed significant variation in achievement, for instance: two boys in Group B commonly exceeded 15,000 steps (and often recorded more than 30,000 steps); whereas in Group A one boy only achieved his target on 9 of his 49 days. The literature on goal setting suggests that having achievable but demanding targets is important (Consolvo *et al.* 2009). For our participants it would seem that for some the target was not achievable, while for others it was not demanding. However, the comments made informally to the researchers at meetings suggest that the Group A and B high achievers were motivated by the promise of rewards but also enjoyed greatly exceeding the target, knowing that their group members were aware of their achievements. In contrast, one Group A participant found that for part of the study her pedometer failed to record all her steps which prevented her from reaching her target, she found this to be frustrating. The study did not provide very much evidence about the importance of goal setting for the participants although some of the design ideas did reveal that there was some interest in letting others know of achievements (for instance by shoes changing colour). There were no comments made in the different data sets about who should set goals, at what levels, nor how frequently they should be changed. Goal setting does not seem to have been a concept of interest, despite being secondary school pupils who were used to having targets set for them in their academic and personal lives. The only directly relevant comment was made by a girl in Group B who said 'if you just tell me what to do I'll do it', although that statement was not matched by her practice.

4.1.4. *Incentives and rewards*

Our initial literature review highlighted that incentives and rewards were important motivators and participants were reported as enjoying receiving rewards. Such daily and weekly rewards were built into our study and for Groups A and B these were shared within their *ehealth-elgg* communities. The console game used by Groups A and C gave stamps of achievement when targets were reached. The feedback confirmed that participants believed that incentives and rewards were motivational; elements in Tables 9–11 show the range of ideas they proposed for this area. During their discussions all participants were enthused by the idea of being rewarded, particularly materially or financially. The innovation data showed that they valued the idea of positive rewards and typically disliked the concept of negative consequences to behaviour, which was in line with Lin *et al.*'s (2006) findings. However, their use of the technologies did not demonstrate this passion for rewards. This links with the earlier discussion of goals, where only some participants exhibited a clear desire to achieve goals and gain rewards. This is an issue noted by Xu *et al.* (2012) who identified five different types of child participants with different reactions to issues such as rewards and incentives.

4.2. *Emergent design concepts*

Our study identified two new themes that emerged from the data which we characterised as openness to sharing and lack of autonomy. We discuss these and identify some recent literature that offers confirmatory support for the concepts.

4.2.1. *Openness to sharing*

The data reported in Tables 5 and 9 in Section 3.3 indicate the extent to which participants are prepared to share the minutiae of their lives, although there were some reservations expressed about always making data public, for instance '. . .depends how many steps I did that day'. Overall the facility to publish what they did, not only to friends but also to the wider world, was seen as acceptable and fanciful ideas for making it happen were suggested. This is perhaps an indication of how embedded social media such as Facebook and YouTube have become in their lives, eroding the concept of privacy for many in this age group. It was clear; however, they expected to control such broadcasting (whether of step counts or real-time video streaming). Xu *et al.* (2012) also detected such openness to sharing, but only among a subset of child–participant types. Such openness to sharing is likely to have a significant impact on how adolescents use and report personal data, and thus needs to be considered in designing appropriate exercise-supporting technologies.

4.2.2. *Lack of autonomy*

An unanticipated issue was the lack of autonomy of the adolescents in the physical world, where they are required to obey rules and authority figures in their everyday activities. For instance, permission was needed from some head teachers to ensure that participants could use their pedometers at school. Even away from school participants could be constrained by those in authority, for instance, one boy complained '... couldn't wear [the pedometer] from 6:30 pm (air cadets)'. Moreover, although in conversation they talked about 'always having their phones' with them, they made conflicting comments indicating that during school time phones had to be out of reach. This constraint affecting school children was recently reported by Miller *et al.* (2012). Such restrictions would impact on the types of technologies that could be used effectively for capturing exercise data. Thus undermining the participants' suggestions for embedding data capture in other digital artefacts (particularly mobile phones) and calling into question some proposed technological solutions (for example, Bielik *et al.* 2012). However, if the emphasis is on supporting structured exercise, as in Arteaga *et al.* (2010), such embedding could be appropriate since the time of use would be under the adolescents' control.

4.3. *The value of technology probes as a research tool in requirements elicitation*

The use of technology probes (Hutchinson *et al.* 2003) encourages interaction between artefacts and users thus enabling us, through the generation and analysis of rich data, to understand users and contexts; field-test technology and inspire design ideas. These goals, which matched the purpose of our study, are often addressed using separate techniques at different phases of a design activity. However, the advantage in considering the goals within one overarching approach is that none dominates. We report technology probes usage in this study so that other researchers can reflect on their relevance to design-focused field studies.

4.3.1. *Understanding users and contexts*

Through embedding the technologies in the users' everyday lives we identified issues that otherwise would have been missed, for example, 'lack of autonomy' which is a significant constraint. Moreover, it alerted us to mismatches between articulated opinions and the lived experience recorded in the data: for instance, claims of rewards being motivational versus the reaction to them in practice. The recent paper by Klasnja *et al.* (2011) argues that using technology *in situ* is an important strategy if the human–computer interaction field is to make a contribution to research in health behaviour changes.

4.3.2. *Field-testing technology*

As a result of field-testing the technologies with each participant for six weeks, we could evaluate in practice the four literature-based design features and scrutinise how the changing environment impacted on them. For instance, the study period included school weeks, weekends, school holidays and (unexpected) periods of severe snowfall. These all had the potential to affect how the technologies were used and our data analysis did identify such differences (as reported in Section 3.2.3). Similarly Consolvo *et al.* (2008) also considered the impact of the season in their study (which included Thanksgiving, Christmas and New Year, poor weather and dark nights); they found that their participants' use of *UbiFit Garden* motivated them to overcome seasonal inertia. This was counter to their expectations and would have been unlikely to be detected by other forms of enquiry.

4.3.3. *Inspiring design ideas*

The participants' experiences with the technology probes also provided an experiential baseline from which to propose new design ideas (as summarised in Section 3.3). These ideas often resulted from a reaction to limitations that they experienced with the devices. However, their experience informed the ideas generated in the innovation workshops where more positive concepts were proposed. The extent to which the new ideas were stimulated by the probes cannot be determined since there was no control group (participants without technology probes).

4.3.4. *The benefits of low-technology artefacts*

We used low-technology artefacts in this study to examine the design needs of participants. In contrast, many studies in this field (such as Lin *et al.* 2006, Consolvo *et al.* 2008, Fujiki *et al.* 2008) develop hardware/software solutions of varying levels of complexity and sophistication before testing and evaluating them for effectiveness, thus focusing on evaluation of technologies rather than needs. Our approach kept the spotlight on requirements elicitation and gave the participants freedom to incorporate the technology into their lives and thus reflect upon the fit to their needs, and their desired user experience. Since we used existing technologies we had no proprietary attitude towards them and the participants knowing this were comfortable in critiquing and making suggestions about the artefacts. This freedom to use and comment on the probes led to the emergence of the unanticipated issues discussed in Section 4.2. This experience mirrors that of Markopoulos *et al.* (2006) who commented on the emergence of surprising results from their use of technology probes.

4.4. Limitations and future work

A key limitation of any field study is duration. Each of our participants engaged for seven weeks which, although longer than many previous studies, is still limited and falls short of Klasnja *et al.*'s (2011) gold standard of long-term (24 months) randomised controlled experiments. However, it did map onto some of the features that they have proposed as requirements for valuable studies of behaviour change intervention strategies, in particular developing a deep understanding of people's experiences with technology *in situ*.

Field studies need to be appropriately resourced. For the *ehealth* study levels of access to participants and physical resources were constraints that impacted on the scope of the study. Researchers need robust strategies to enable recruitment and retention of committed volunteers. It took three months to recruit sufficient volunteers to participate in what they saw as a long-term project: during the project one participant withdrew and could not be replaced within the study's time frame. However, we believe our recruitment strategy (working via youth groups in the city) aided participant retention since we established rapport with youth workers who were trusted by the participants. Another retention strategy was to offer an end-of-study reward to each participant. Such a strategy could be problematic in a study focused on behavioural change, since a promised reward could itself change behaviour. However, in our study the focus was on design ideas and the technologies used were merely probes.

During the study there were some problems with physical resources, two participants lost pedometers and three had intermittent internet access (despite pre-study checks of availability). These problems caused loss of step data for some of the study period, until replacement devices were sourced and locations for internet access identified. Meeting locations were chosen for the participants' convenience to minimise their disruption during the study. Group A were met at their youth group and Group B at university premises (since it was a central location for all). Group C members were met individually at different venues around the city to accommodate individuals' needs. We had planned to hold meetings with parents, but these could not be arranged at times that were suitable to all. Therefore, a postal survey was used to capture their views of their children's level of physical activity and attitude towards it. Although many of these problems were of a short-term impact and solutions could be found, it meant that some expected data were unavailable, both in daily logs and in the richer data that could have been gathered from parents in meetings.

5. Conclusion

The *ehealth* study has confirmed that motivational exercise technologies need portable and accurate activity-monitoring devices and that social support is seen as important by adolescents, as is the concept of incentives and rewards. However, there was little evidence to support the importance of goal setting. Two features that would affect technology design were identified, those of openness to sharing and lack of autonomy. In addition to these main themes, more specific issues were identified that provide areas for future work. In particular, the desire for devices, goals, rewards and incentives all to be to customised to the specific adolescent highlights a need for investigations into individual differences to develop more nuanced approaches to persuasive technologies. Some work has begun in this area. For instance, Bielik *et al.*'s (2012) proposed avatar-based system for children includes many of the key design features highlighted in this study and specifically the personalisation of goals. In working with teenagers, Arteaga *et al.* (2010) have adopted the Five Factor Model of personality to underpin the design of games. Courneya and Hellsten (1998) previously found that this model was a useful framework for understanding how much exercise people (adults) performed and also their motives, barriers and preferences. Xu *et al.*'s (2012) analysis of the American Horsepower Challenge has identified five distinctive child participant types to consider against the dimensions of motivation, behaviour and influence on others. These are all useful contributions to the area but more remains to be done.

Finally, in this study the participants were all quite active and in good health (which matched the sponsor's requirements): this meant that there was no investigation of what might motivate unfit or inactive adolescents. This is an area that still needs to be effectively investigated.

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