The understanding and interpretation of innovative technology-enabled multidimensional physical activity feedback in patients at risk of future chronic disease

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Abstract

Background

Innovative physical activity monitoring technology can be used to depict rich visual feedback that encompasses the various aspects of physical activity known to be important for health. However, it is unknown whether patients who are at risk of chronic disease would understand such sophisticated personalised feedback or whether they would find it useful and motivating. The purpose of the present study was to determine whether technology-enabled multidimensional physical activity graphics and visualisations are comprehensible and usable for patients at risk of chronic disease.

Method

We developed several iterations of graphics depicting minute-by-minute activity patterns and integrated physical activity health targets. Subsequently, patients at moderate/high risk of chronic disease (n=29) and healthcare practitioners (n=15) from South West England underwent full 7-days activity monitoring followed by individual semi-structured interviews in which they were asked to comment on their own personalised visual feedback Framework analysis was used to gauge their interpretation and of personalised feedback, graphics and visualisations.

Results

We identified two main components focussing on (a) the interpretation of feedback designs and data and (b) the impact of personalised visual physical activity feedback on facilitation of health behaviour change. Participants demonstrated a clear ability to

understand the sophisticated personal information plus an enhanced physical activity knowledge. They reported that receiving multidimensional feedback was motivating and could be usefully applied to facilitate their efforts in becoming more physically active.

Conclusion

Multidimensional physical activity feedback can be made comprehensible, informative and motivational by using appropriate graphics and visualisations. There is an opportunity to exploit the full potential created by technological innovation and provide sophisticated personalised physical activity feedback as an adjunct to support behaviour change.

Keywords

Physical activity; sedentary time; public health; accelerometry; feedback; at-risk patients; healthcare professionals; qualitative research.

Background

Physical inactivity has a powerful effect on global health and an increase in activity would have an enormous impact on the burden of chronic disease [1]. Of all the strategies implemented to positively change an individual's behaviour, self-monitoring is one of the most effective [2,3]. In the past few years, technological innovation has transformed the landscape and a plethora of instruments are now commercially available for the self-monitoring of physical activity. These include devices produced by major international companies such as Fitbit, Jawbone UP,

GENEActive, Philips DirectLife and Nike+ Fuelband. Large manufacturers such as Samsung and Apple are reportedly about to enter the market [4]. Some of these devices have only limited published validity to date but it is noteworthy that one commercially available multi-sensor instrument from Bodymedia is already classified by the US Food and Drug Administration (FDA) as a Class II medical device. Thus, as instruments become more accurate, affordable, comfortable and discrete [5] millions of people around the world are beginning to use physical activity monitoring technologies and such self-monitoring will become increasingly common in the future.

We recently demonstrated that using the data collected from even the most sophisticated physical activity monitors provides erroneous information about an individual's physical activity unless this includes a multidimensional profile constructed across the key physical activity dimensions [6]. It is quite possible for a given person to score highly in one physical activity dimension but low in another (e.g. one could engage in substantial vigorous intensity activity but still spend over 80% of their day sedentary) [6]. This is a problem because people sometimes focus on just certain physical activity behaviours without taking into account other dimensions and this could lead to misguided perceptions and expectations. For example, an individual with a weight-loss goal who substantially increases their vigorous intensity structured physical activity might only see a relatively modest impact on overall energy expenditure [7]. Knowledge of all the important physical activity dimensions would remove the potential ambiguity in understanding how their behaviour relates to their goals as well as providing more behavioural options that align to their needs and preferences and offer sustainable solutions [8].

Although we now have the technology to provide feedback that integrates the important multidimensional health-harnessing aspects of physical activity this potentially introduces new risks and challenges. An understanding of personal physical activity is integral to various models of behaviour change and regulation [9,10]. In this context, sophisticated multidimensional physical activity feedback could be seen as more confusing and/or difficult to interpret than simple unidimensional messages. Before we can capitalise on technological innovation, it is important to establish that people can understand multidimensional physical activity feedback in terms of what the feedback represents, the concept of different physical activity dimensions, and the overall meaning of personalised data [8]. There is good evidence that people and patients prefer visual and meaningful images rather than numerical scores and these can be used to increase attention and comprehension of health education information [11,12]. Clearly, the design of the graphical images and representation of multidimensional physical activity feedback will be important for optimising its usefulness as a tool for behaviour change.

To date, there has been very little attempt to determine whether people can understand the information that is available and provided with the advent of increasingly sophisticated physical activity monitors. In particular, there has been no attempt to establish that people can handle potentially complex and conflicting information across the biologically healthful physical activity dimensions. This is especially important in clinical populations who would benefit most from a change in physical activity behaviour (e.g., as a route to manage their risk of chronic disease) [13]. Thus, the purpose of this study is two-fold (i) to develop innovative ways to present

multidimensional and sophisticated physical activity feedback to enable self-monitoring and (ii) to explore the understanding, interpretation and potential utility of personalised physical activity feedback amongst patients at future risk of chronic disease and corresponding healthcare practitioners.

Methods

Experimental design

We worked with professional infographics specialists to develop multidimensional physical activity visualisations and then evaluated whether patients and healthcare professionals could comprehend these designs and personal feedback on their physical activity and whether they subsequently found this information useful.

Ethics Statement

Ethical approval for the study was obtained from the National Research Ethics Service Committee South West (REC reference 12/SW/0374).

Multidimensional visualisations

The infographics we used to depict the physical activity data were created in collaboration with Information is Beautiful and aligned to a design process model [14]. An iterative process was used to develop three sections of information: activity patterns over a day or week, summary graphics of time and energy spent in varying activity intensities, and depictions of performance in relation to multidimensional health targets. Following a phase of piloting and refining initial designs with health professionals (n=2) and members of the general public (n=2), a final booklet

containing three distinct visualisations for each section of information was developed and shown to participants at interview with their personalised data (an example of this booklet for one participant can be found in S1 Fig.). Fig. 1 provides two extracts and examples of the multidimensional physical activity profiles.

Participants

Patients (n=30) from two general practices were invited to take part if they had been identified as being at moderate (10-19.9%) or high (>20%) risk of cardiovascular disease and/or type 2 diabetes (http://qintervention.org/). Purposive sampling was used to recruit 15 healthcare professionals (HCPs) including 3 general practitioners, 3 nurses/healthcare assistants, 3 research nurses, and 6 physical activity healthcare trainers from two regions in the UK (Bath and North East Somerset and Wiltshire). HCPs were included because of their unique understanding developed over years of working with a wide range of patients. All participants provided written informed consent.

Procedure

Participants were provided with an arm-mounted Bodymedia Armband (SenseWear Pro 8.0, Pittsburgh, USA), which accurately estimates energy expenditure [15-17]. Participants were instructed to wear the device for seven consecutive days commencing at midnight and asked to only remove the device for showering or water-based activities[18]. Minutes spent in the distinct intensity thresholds based on metabolic equivalent cut points (METs) and multidimensional health target attainment were calculated[6]. Intensity thresholds were set using ubiquitous cut-points as follows (where 1 MET is equivalent to the basal metabolic rate (BMR) for each

participant as calculated using the age and sex-matched Schofield equation [19]): Sedentary activity = <1.5 METs; Light activity = 1.5-2.9 METs; Moderate intensity activity = 3.0-5.9 METs; Vigorous intensity activity = 6.0-10.1 METs and Very vigorous intensity activity = ≥10.2 METs [6]. In order to complete the 7-day, 24-hour record, each minute of missing data where participants had removed the device as instructed was assigned that individual's BMR [19].

Participants were invited to a digitally-recorded two-hour one-to-one interview conducted by the lead researcher (MW). Interviews primarily took place at the University of Bath (patients) or their place of work (HCPs). Participants were typically interviewed within 2-3 weeks of their physical activity monitoring period. The interview topic guides for HCPs and patients were compiled with input from an expert panel of academics and health professionals including 3 senior health psychologists, 2 senior health physiologists, 2 social marketers, a general practitioner and a research nurse. They included questions to capture interviewees' views on physical activity and the importance they place on it (prior to seeing feedback), the preferences and comprehension towards the various feedback designs and the impact of receiving personalised physical activity feedback in terms of its motivational properties and practical application. Aside from the interpretation of their own feedback, HCPs were questioned about anticipated understanding from their patient's perspectives (rather than themselves). Participants were shown the designs in a random order so that preferences were not influenced by exposure order. Each section of graphics and individual designs was given a brief verbal introduction by the interviewer.

Analysis

Audio recordings were transcribed verbatim in Microsoft Word and then uploaded to NVivo (Version 9.0, QSR, Southport, UK) for coding and data organisation. The principles of Framework Analysis were used to analyse the data[20]. A period of familiarisation with the dataset by the lead researcher was followed by a process of coding whereby *a priori* themes directed by the interview topic guide, unexpected emergent themes and recurring viewpoints were identified. The accuracy of the initial themes, derived from a subset of the data, was confirmed by other members of the research team, and then used to guide the indexing of the remaining transcripts. The coding process enabled the development of lower order themes to be charted and organised into salient higher order themes that manifest within the whole dataset. At the final stage of data analysis, the derived themes for both groups were compared and similarities and differences were identified.

Results

Participants

We successfully recruited 30 patients and 15 HCPs who showed a diverse range of physical activity status. Of patients, 34% would have been considered sedentary, 45% moderately active and 21% highly active based on their total daily energy expenditure (based on a PAL of 1.40-1.69, 1.70-1.99 and 2.00-2.40, respectively). Similarly, 34% of HCPs would have been classified as sedentary, 53% moderately active and 13% highly active. One patient failed to complete the activity monitoring leaving 29 for analysis in that group. All other demographic and anthropometric characteristics of the study participants can be found in Table 1.

Higher and lower order themes

The analytical framework included two key components, the interpretation of the physical activity feedback designs and data (Fig. 2), and the impact of personalised visual physical activity feedback on facilitation of health behaviour change (Fig. 3). Indexing of lower order themes (peripheral circles) led to the emergence of two congruent higher order themes (inner circle) within each component of the framework. The lower order themes identified in the data that support these interpretations are quantified according to the number of respondents who shared that particular view. Lower order themes included in Figs. 2 and 3 represent those that were identified in both patients and HCP groups. Additional lower order themes that were solely represented in one of the participant groups and example quotation extracts of the raw transcripts can be found in the supporting table (S1 Table). Where views within a group are contrasting, the opposing perspective was presented as a distinct theme (e.g. 'handle and use technology' and 'dislikes technology').

Component 1 - Interpretation of the personalised feedback designs and data

The higher order themes identified within the data included the ability of HCPs and patients to understand the comprehensive multidimensional feedback and the enhancement of their physical activity knowledge (Component 1, Fig. 2). Similar proportions of HCPs (93%) and patients (100%) championed the clarity of certain visual images and were unified in their views on some of the more specific features such as the colours and simplicity of the designs. Only a very few participants felt that the images were not sufficiently detailed and 83% and 88% of patients and HCPs were able to easily relate the feedback to their behaviour in a meaningful way. Within

the second higher order theme, a greater proportion of patients (72% vs. 20% for HCPs) felt that the data provided them with new information whilst more than 65% of both groups were able to recognise and accept the multidimensional nature of physical activity. Both groups were able to identify the times during their monitored week in which they were active at certain intensities and a large proportion of participants found aspects of their own personal feedback surprising, revealing or misaligned to their initial perception.

Component 2 - The impact of personalised visual physical activity feedback on facilitation of health behaviour change

The two higher order themes characterised by the analysis within the second component included the motivation to change physical activity behaviour and the usefulness of the personalised visual feedback to support health behaviour change (Component 2, Fig. 3). Many of the lower order themes alluding to the positive motivational properties of the personalised feedback were evident in similar relative proportions of patients and HCPs. For example, 83% and 73% respectively found the feedback inspiring compared to only 7% of each group who demonstrated apathy towards the information. The health target data and the use of traffic light colours were acknowledged as key factors motivating individuals to want to increase their physical activity. A key discrepancy between the HCP and patient groups was their belief on the ability of patients to self-monitor their behaviour using the personalised feedback (13% vs. 55%) and on the need for additional support and guidance (80% vs. 28%). The two user groups were, however, more unified in their views on the utility of using technology to manage the feedback, plan and set goals, and the need to ensure the data was available longitudinally rather than as a simple snapshot.

Discussion

We developed a promising and innovative way to present sophisticated physical activity profiles and feedback across key biologically healthful physical activity dimensions. Patients at risk of chronic disease and healthcare professionals who work with such patients expressed a clear ability to interpret the information and it was not perceived to be complex or confusing. The personalised feedback enhanced physical activity knowledge, was motivating and was reported to be a potential aide to the self-management of physical activity.

Physical activity has a critical role in the prevention of non-communicable disease[1] but translating this evidence into action has been challenging[21]. We have previously proposed that traditional conceptually-narrow approaches to physical activity do not provide individuals with sufficient information about the important aspects of behaviour, nor do they necessarily enable an individual to find tailored physical solutions that align with their interests and needs and are sustainable [6]. With technological innovation now already widespread, we are no longer constrained and can provide a much richer, more sophisticated and personalised profile regarding physical activity. In the present study, we demonstrate that patients value technology-enabled feedback about their activity and can grasp the innovative multidimensional portrayal of their physical activity. This gives encouragement that this sophisticated format of feedback is conceptually attainable for this population and that healthcare providers can trust individuals to handle more comprehensive physical activity information as this becomes increasingly accessible.

Participants in the present study also acknowledged an enhanced understanding of their own physical activity in response to receiving personalised feedback. Overall, a large proportion of participants found aspects of their own feedback surprising or revealing and demonstrated a misalignment between their perceptions and the objective data. A better understanding of their current physical activity could help individuals identify their relative strengths and shortcomings, make more informed decisions on how they might improve and set realistic goals [22]. For many participants the detailed minute-by-minute physical activity patterns helped them identify their activity and inactivity time, which could usefully be applied as a tool to communicate how even small changes can be important for reducing health risk [23]. Encouragement can also be taken from the recognition of the options and choices in their multidimensional profiles, which, as an approach to the presentation of meaningful feedback, would offer patients the chance to find sustainable solutions aligned to their personal preferences and needs.

The provision of bespoke options and heightened awareness may provide individuals with a sense of attainable and volitional solutions rather than prescribed choice which, in turn, is likely to improve the quality of their motivation and prolonged engagement in physical activity [24]. A large proportion of individuals in the present study highlighted the multidimensional health targets, the use of a comparative discrepancy between target and performance and the traffic light colours as factors that inspired them to contemplate change. This alleviates fears that multidimensional feedback might be complex and/or confusing and, whilst the assertions made by the patients

and HCPs about their desire to change are prospective, our results suggest that this approach may be a useful motivational resource if applied appropriately.

Many theoretical frameworks applaud the role of feedback, self-monitoring and goal-setting as key constituents for successful and sustained lifestyle modifications [2,3,25]. However the challenge to date has been finding the most effective way of implementing such strategies [26]. Interestingly, in the present study, a large proportion of patients felt that they could effectively self-monitor their own physical activity behaviour without additional support using the presented feedback and expressed confidence in using technological platforms to do so. HCPs on the other hand were somewhat sceptical of patients' ability to self-monitor in the absence of any support and guidance. Speculatively, this contrasting view may be reflective of a greater wealth of experience that HCPs have with patients acting on their advice and/or the challenges associated with setting realistic goals, adhering to lifestyle modifications and sustaining behaviour change. Nonetheless, the optimism and enthusiasm of patients to use the feedback presented here suggests that this offers a promising strategy for supporting behaviour change. These findings are useful to researchers who are interested in capitalising on technological innovation to provide physical activity feedback across various biologically important and healthful physical activity dimensions. Prior research indicates that the effectiveness of technology-enabled health behaviour interventions is likely to be enhanced when the patient is involved in its development [27,28] and particularly in the application of physical activity feedback [29,30]. In this regard, we have used these results to inform a randomised controlled trial (Mi-PACT, ISRCTN18008011) that is currently underway and that will determine whether the provision of multidimensional personalised

feedback helps patients to change their physical activity and reduce risk of chronic disease.

Conclusions

In conclusion, using appropriate graphics and visualisations, multidimensional and sophisticated physical activity feedback can be presented to patients in a way that is informative and understandable rather than complex and confusing. For the first time, we show that a targeted clinical population can accurately interpret comprehensive multidimensional physical activity information and that this information is potentially motivating for this population. As technology for monitoring physical activity becomes more accurate and affordable, we can move beyond simple physical activity messages and there is an exciting opportunity to generate an integrated and holistic picture of physical activity that is more informative and tailored to an individual's needs, preferences and abilities.

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References

1. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT (2012) Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 380: 219-229.
2. Michie S, Abraham C, Whittington C, McAteer J, Gupta S (2009) Effective techniques in healthy eating and physical activity interventions: a meta-regression. Health Psychol 28: 690-701.
3. Dombrowski SU, Sniehotta FF, Avenell A, Johnston M, MacLennan G, Araújo-Soares V (2012) Identifying active ingredients in complex behavioural interventions for obese adults with obesity-related co-morbidities or additional risk factors for co-morbidities: a systematic review. Health Psychol Rev 6: 7-32.
4. Chu S (2014) Samsung Galaxy Gear Fit Is An Apple iWatch Concept Come To Life, Features Stylish Curved LED Screen. International Digital Times.
5. Chen KY, Janz KF, Zhu W, Brychta RJ (2012) Redefining the roles of sensors in objective physical activity monitoring. Med Sci Sports Exerc 44: S13-23.
6. Thompson D, Batterham AM (2013) Towards integrated physical activity profiling. PLoS One 8: e56427.
7. Turner JE, Markovitch D, Betts JA, Thompson D (2010) Nonprescribed physical activity energy expenditure is maintained with structured exercise and implicates a compensatory increase in energy intake. Am J Clin Nutr 92: 1009-1016.
8. Thompson D, Peacock O, Western MJ, Batterham AM (2015) Multidimensional physical activity profiling: An opportunity not a problem. Exercise and Sport Sciences Reviews.
9. Kirschenbaum DS (1987) Self-Regulatory Failure - a Review with Clinical Implications. Clin Psychol Rev 7: 77-104.
10. Weinstein ND, Rothman AJ, Sutton SR (1998) Stage theories of health behavior: conceptual and methodological issues. Health Psychol 17: 290-299.
11. Edwards A, Elwyn G, Mulley A (2002) Explaining risks: turning numerical data into meaningful pictures. Br Med J 324: 827-830.
12. Houts PS, Doak CC, Doak LG, Loscalzo MJ (2006) The role of pictures in improving health communication: a review of research on attention, comprehension, recall, and adherence. Patient Educ Couns 61: 173-190.
13. Patel MS, Asch DA, Volpp KG (2015) WEarable devices as facilitators, not drivers, of health behavior change. JAMA 313: 459-460.
14. Design Council T (2007) Eleven lessons: managing design in eleven global companies.
15. Johannsen DL, Calabro MA, Stewart J, Franke W, Rood JC, Welk GJ (2010) Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. Med Sci Sports Exerc 42: 2134-2140.
16. Lee JM, Kim Y, Welk GJ (2014) Validity of Consumer-Based Physical Activity Monitors. Med Sci Sports Exerc.
17. Fruin ML, Rankin JW (2004) Validity of a multi-sensor armband in estimating rest and exercise energy expenditure. Med Sci Sports Exerc 36: 1063-1069.
18. Scheers T, Philippaerts R, Lefevre J (2012) Variability in physical activity patterns as measured by the SenseWear Armband: how many days are needed? Eur J Appl Physiol 112: 1653-1662.
19. Schofield WN (1985) Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr 39 Suppl 1: 5-41.
20. Ritchie J, Spencer L (1994) Qualitative data analysis for applied policy research. In: Bryman A, Burgess R, editors. Analysing qualitative data. London: Routledge. pp. 173–194.

21. Kohl HW, 3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, et al. (2012) The pandemic of physical inactivity: global action for public health. Lancet 380: 294-305.
22. DiClemente CC, Marinilli AS, Singh M, Bellino LE (2001) The role of feedback in the process of health behavior change. American Journal of Health Behavior 25: 217-227.
23. Erikssen G (2001) Physical fitness and changes in mortality: the survival of the fittest. Sports Med 31: 571-576.
24. Standage M, Ryan RM (2012) Self-determination theory and exercise motivation: Facilitating self-regulatory processes to support and maintain health and well-being. In: Roberts GC, Treasure DC, editors. Advances in motivation in sport and exercise. 3rd ed. Champaign, IL: Human Kinetics. pp. 233-270.
25. Greaves CJ, Sheppard KE, Abraham C, Hardeman W, Roden M, Evans PH, et al. (2011) Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. BMC Public Health 11: 119.
26. Michie S, West R, Spring B (2013) Moving from theory to practice and back in social and health psychology. Health Psychol 32: 581-585.
27. Yardley L, Morrison L, Bradbury K, Muller I (2015) The Person-Based Approach to Intervention Development: Application to Digital Health-Related Behavior Change Interventions. Journal of medical Internet research 17: e30.
28. van Gemert-Pijnen JE, Nijland N, van Limburg M, Ossebaard HC, Kelders SM, Eysenbach G, et al. (2011) A holistic framework to improve the uptake and impact of eHealth technologies. Journal of medical Internet research 13.
29. Consolvo S, McDonald DW, Landay JA. Theory-driven design strategies for technologies that support behavior change in everyday life; 2009. ACM. pp. 405-414.
30. Consolvo S, Klasnja P, McDonald DW, Avrahami D, Froehlich J, LeGrand L, et al. Flowers or a robot army?: encouraging awareness & activity with personal, mobile displays; 2008. ACM. pp. 54-63.

Figures

Fig. 1 - Two examples of the 3 variants of infographics depicting the multidimensional physical activity behavioural recommendations

Green represents a 'hit' target, amber a 'near' target (within 25%) and red a 'missed' target (>25% away). Graphic i) is a simple colour coded wheel format where each segment represents each dimension but has no magnitude; ii) uses a reference target bar to compare a coloured bar scaled to the relative value attained within each dimension; and graphic iii) places the individuals performance for each guideline as a bubble on a sliding scale relative to the target value represented by the central line. The varied nature of physical activity 'status' is highlighted by the data from the two participants where A is an individual who has hit their vigorous activity target and is short on the other four dimensions and B is a participant who has a high PAL and considerable moderate intensity activity but is still quite sedentary and has very little vigorous intensity activity.

Fig. 2 – Component 1: Interpretation of the personalised feedback designs and data

Two higher order themes, represented by the large central circles, included the ability to accurately understand the visual physical activity data (A) and the enhancement of physical activity knowledge (B). The magnitude of the peripheral circles representing the lower order themes supporting the central theme, relate to the proportion of participants within each group identifying with each theme as indicated by the key at the foot of the figure.

Fig. 3 – Component 2: The impact of personalised visual physical activity feedback on facilitation of health behaviour change

Two higher order themes (inner circles) included the motivation to change physical activity behaviour (A) and the usefulness of the personalised visual feedback to support health behaviour change (B). The magnitude of the peripheral circles representing the lower order themes supporting the central theme, relate to the proportion of participants identifying with each theme as shown by the key at the foot of the figure.

Tables

Table 1 – Demographic characteristics of all participants included in the analyses

Characteristic	Patient (n = 29)	HCP (n = 15)
Sex		
Male	21 (72%)	6 (40%)
Female	8 (28%)	9 (60%)
Age[a]	63 (7)	48 (10)
<45	1 (3%)	4 (27%)
45 – 54	2 (7%)	6 (40%)
55 – 64	9 (31%)	4 (27%)
65 – 74	17 (59%)	1 (7%)
Marital status		
Single	2 (7%)	3 (20%)
Married/ Civil partnership/ Cohabiting	22 (76%)	7 (47%)
Divorced/ Separated/ Widowed	5 (17%)	5 (33%)
Highest educational attainment		
None	2 (7%)	0 (0%)
GCSE or equivalent	7 (24%)	3 (20%)
A-Level or equivalent	3 (10%)	3 (20%)
1st Degree or equivalent	12 (41%)	5 (33%)
Higher degree	5 (17%)	4 (27%)
Smoker		

Yes	2 (7%)	0 (0%)
No	27 (93%)	15 (100%)
Height (m)[a]	1.74 (0.10)	1.73 (0.09)
Weight (kg)[a]	82.0 (16.7)	76.7 (10.4)
BMI (kg/m^2)[a]	26.9 (4.3)	25.7 (3.5)
Waist circumference (cm)[a]	95.0 (12.6)	84.5 (10.4)
Physical activity dimensions[b]		
Physical activity level[a]	1.83 (0.31)	1.72 (0.21)
Daily sedentary time (% waking day)[a]	68 (11)	69 (11)
Daily moderate activity (min/day)[a]	134 (75)	107 (45)
Weekly moderate-vigorous bouts (min/week)[a]	479 (361)	341 (208)
Weekly vigorous activity (min/week)[a]	100 (147)	125 (128)

a= Values reported as mean (standard deviation)

b= Physical activity dimensions that were presented in the 'health target' section of the feedback were as follows:

- Physical activity level (PAL) was the average total daily energy expenditure/basal metabolic rate (Kcal/day);
- Daily sedentary time was the percentage of a 16 hour waking day (8 hours of sleep was assumed and subtracted from the total sedentary time) spent sedentary (<1.5 METs);
- Daily moderate activity was the average number of single minutes of moderate activity (≥3 METs, <6 METs);
- Weekly moderate-vigorous bouts included all activity greater than 3 METs sustained for at least a period of 10 minutes;
- Weekly vigorous activity combined all the minutes of vigorous activity (>6 METs) accumulated over the monitored week.

Supporting information

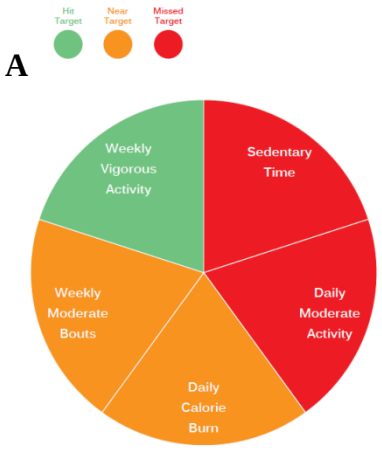
S1 Fig. - Example physical activity profile portfolio for an individual including all nine feedback graphics shown to participants

Participants were given a short introduction to each section within the interview and then shown and asked to comment on each depiction of their feedback in turn. Graphics were shown in a random order per section and participants were given the key to intensity thresholds on page 4 for reference whilst interpreting graphs A to F.

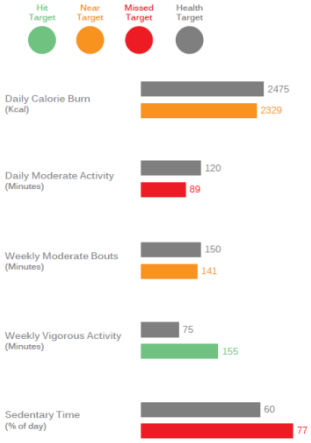
S1 Table - Extracts of raw data sources used to exemplify lower themes identified under the two components of the Framework analysis

Identified themes are in a clockwise order that they appear in Figs. 2 and 3 within the main text and are accompanied by a quote and the percentage (%) of participants in which the theme was identified. Lower order themes under the dotted lines represent single items not included in the figures and represent those lower order themes that were solely identified in one of the participant groups (i.e. only patients or healthcare professionals) for each higher order theme.

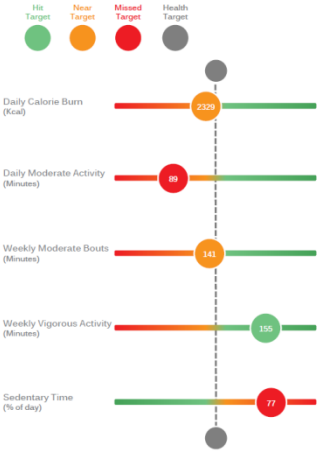
A



i)

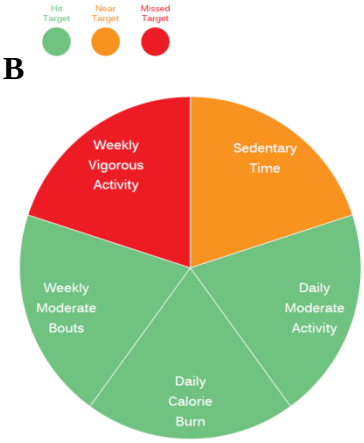


ii)

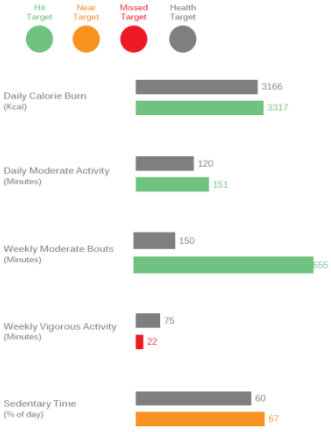


iii)

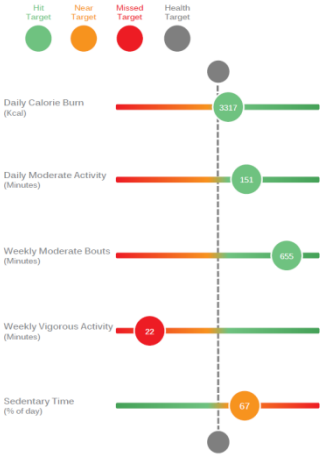
B



i)

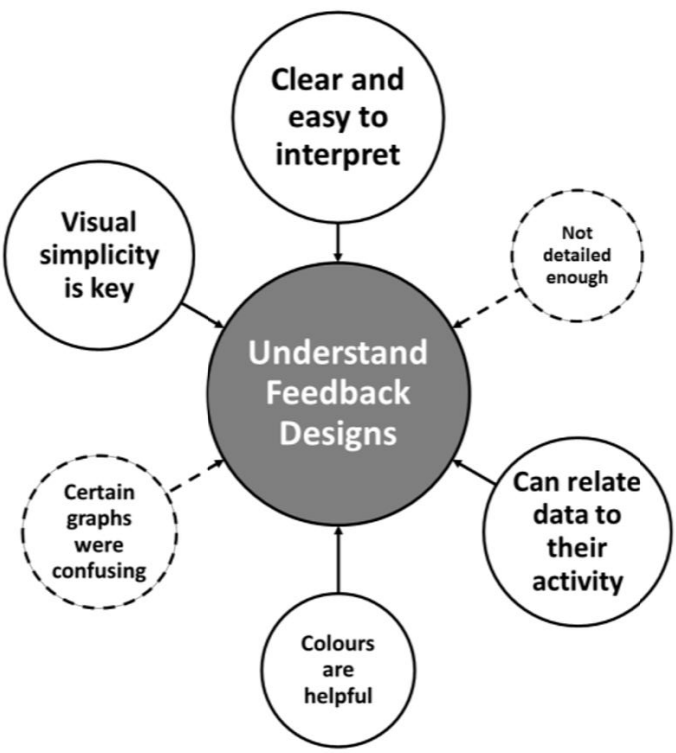


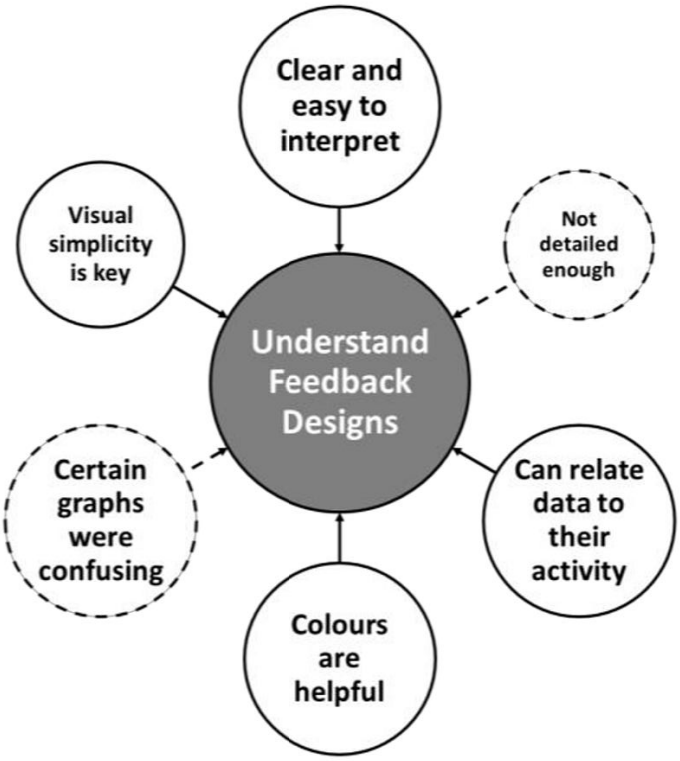
ii)



iii)

A





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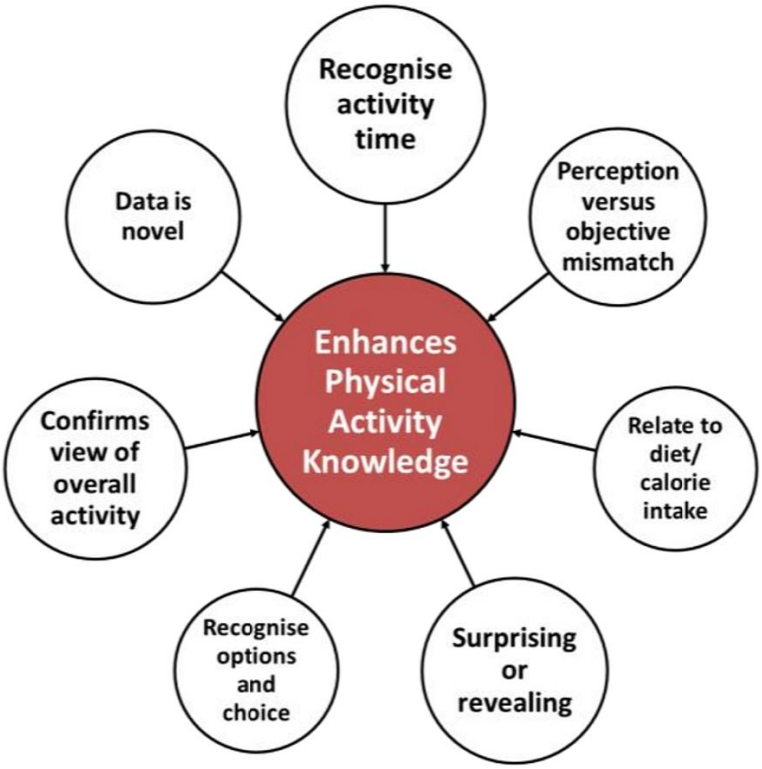
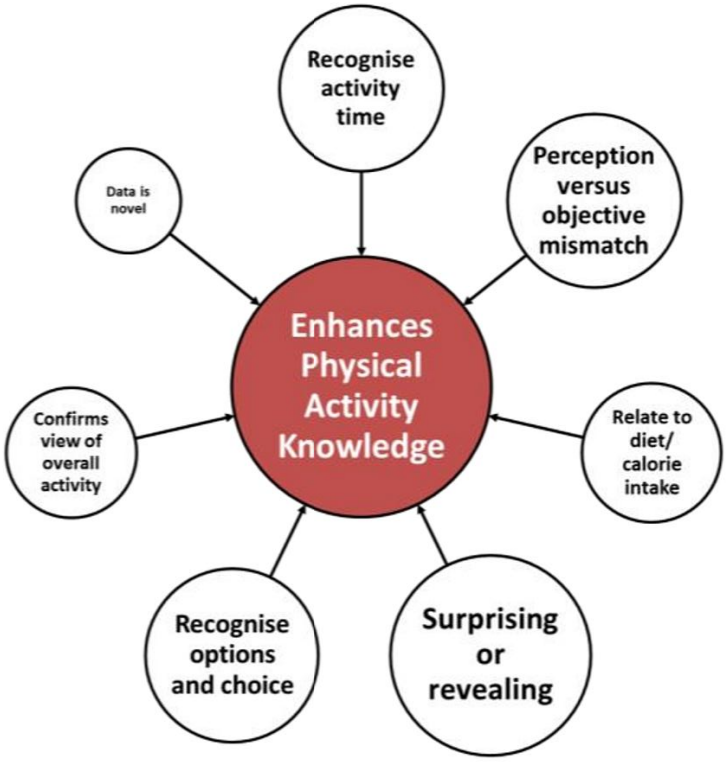
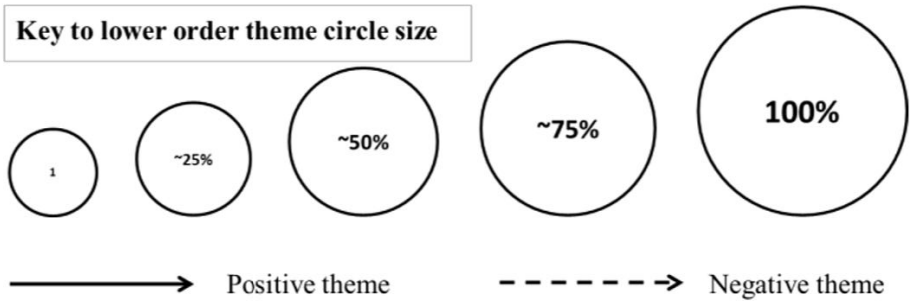


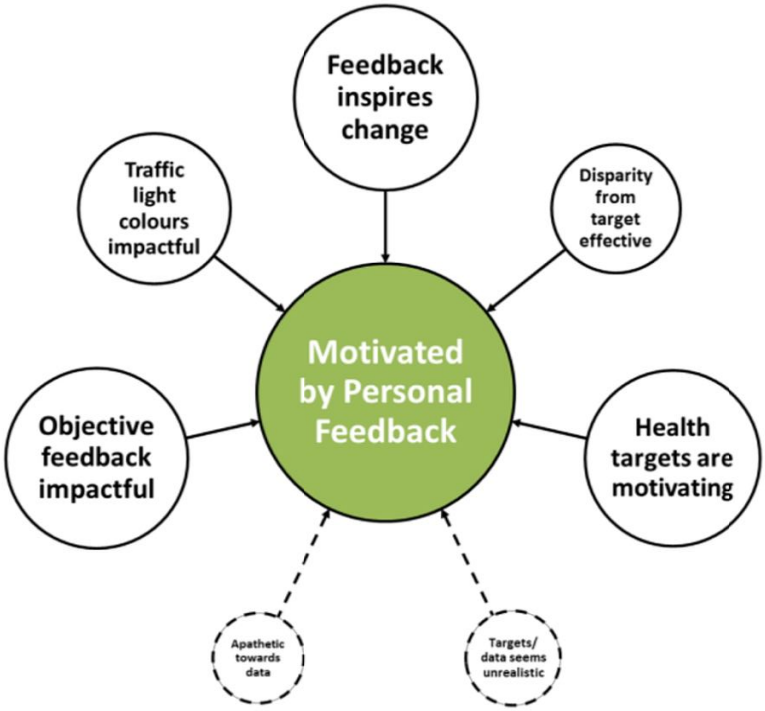


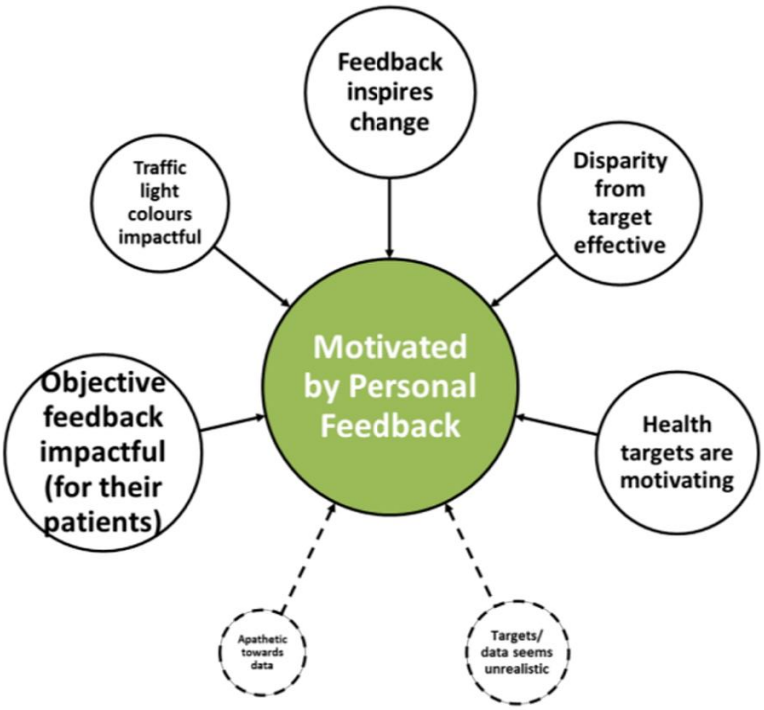
Patients

Healthcare Professionals



A





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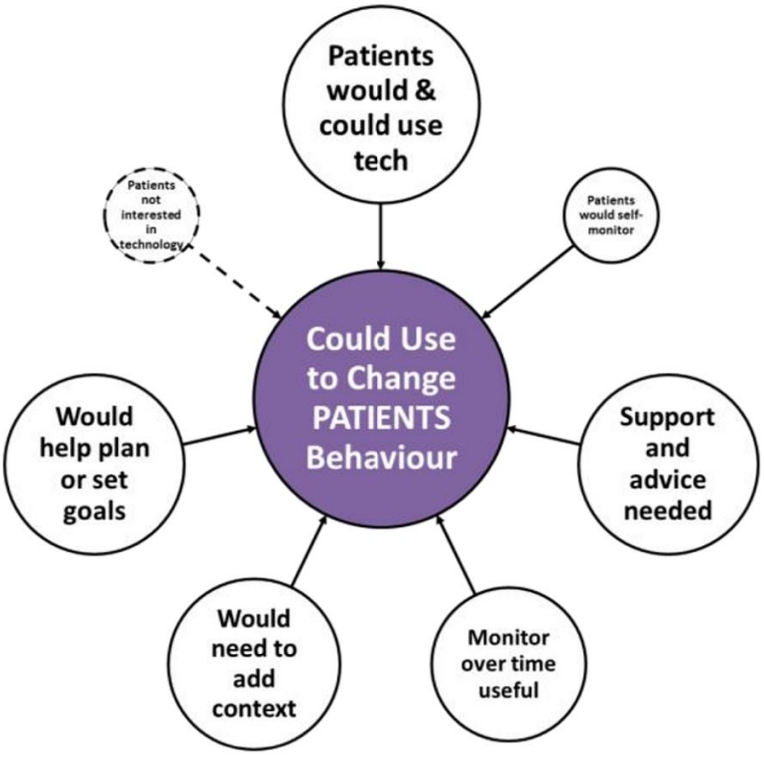
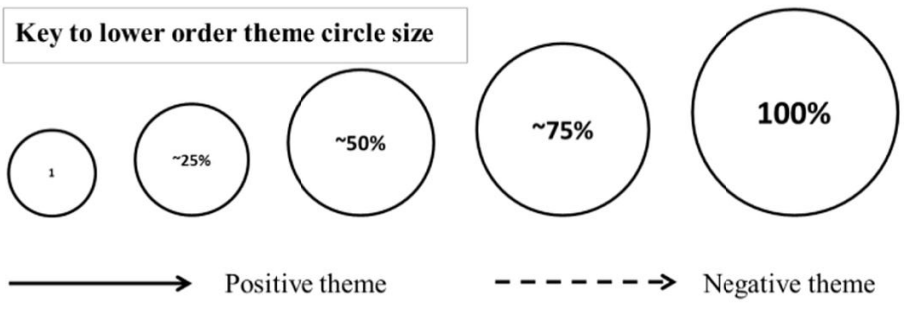


Patients

Healthcare Professionals



Department for Health

MiPACT PROJECT

Physical Activity Profile Portfolio

Table of Contents

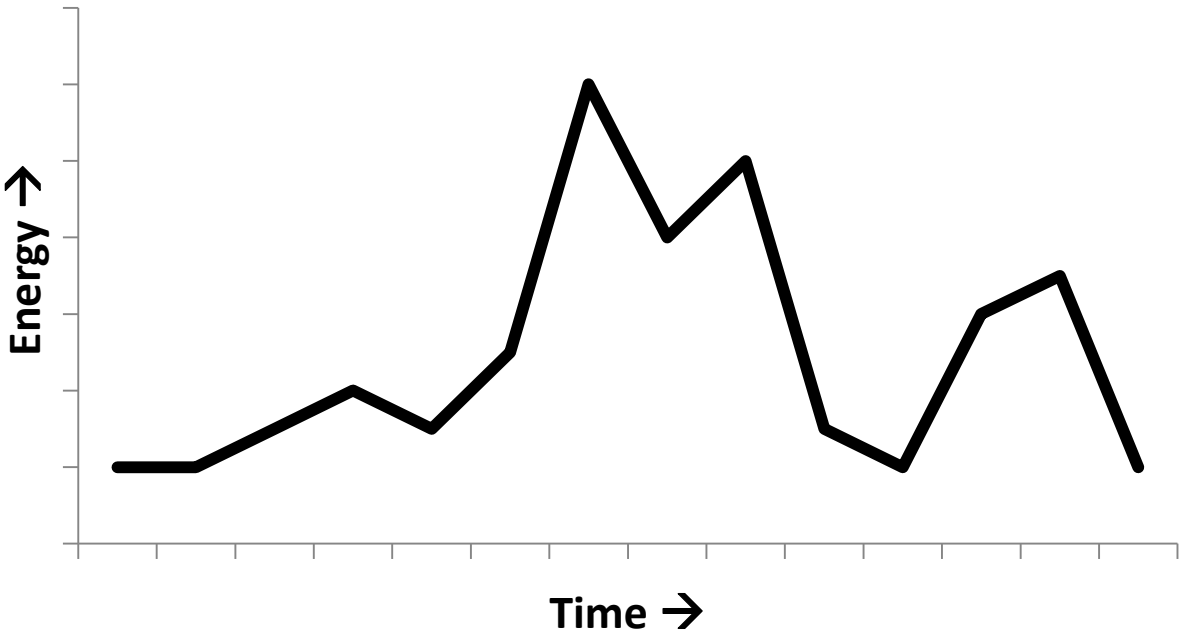
We have measured your 24-h daily energy expenditure (i.e. the number of calories you burn per day)

For each day we have collected 1440 minutes of data!

There are a variety of ways of presenting such a large amount of information.

In this section, we will present your individual data (for one 24-h day) in a number of different ways.

After a brief introduction to each graphic we will ask you a few questions regarding your thoughts, opinions and preferences.



Key to Intensity Thresholds

Sedentary

Sitting and/or lying (reading, TV, video games, talking), computer work (desk based or seated)

Light

Light home-based activities (food preparation, washing dishes, ironing, light cleaning)

Moderate

Walking (with dog, shopping), golf, moderate intensity home and garden (hoovering, sweeping, mowing lawn)

Vigorous

Brisk walking (flat or uphill), cycling, swimming and jogging

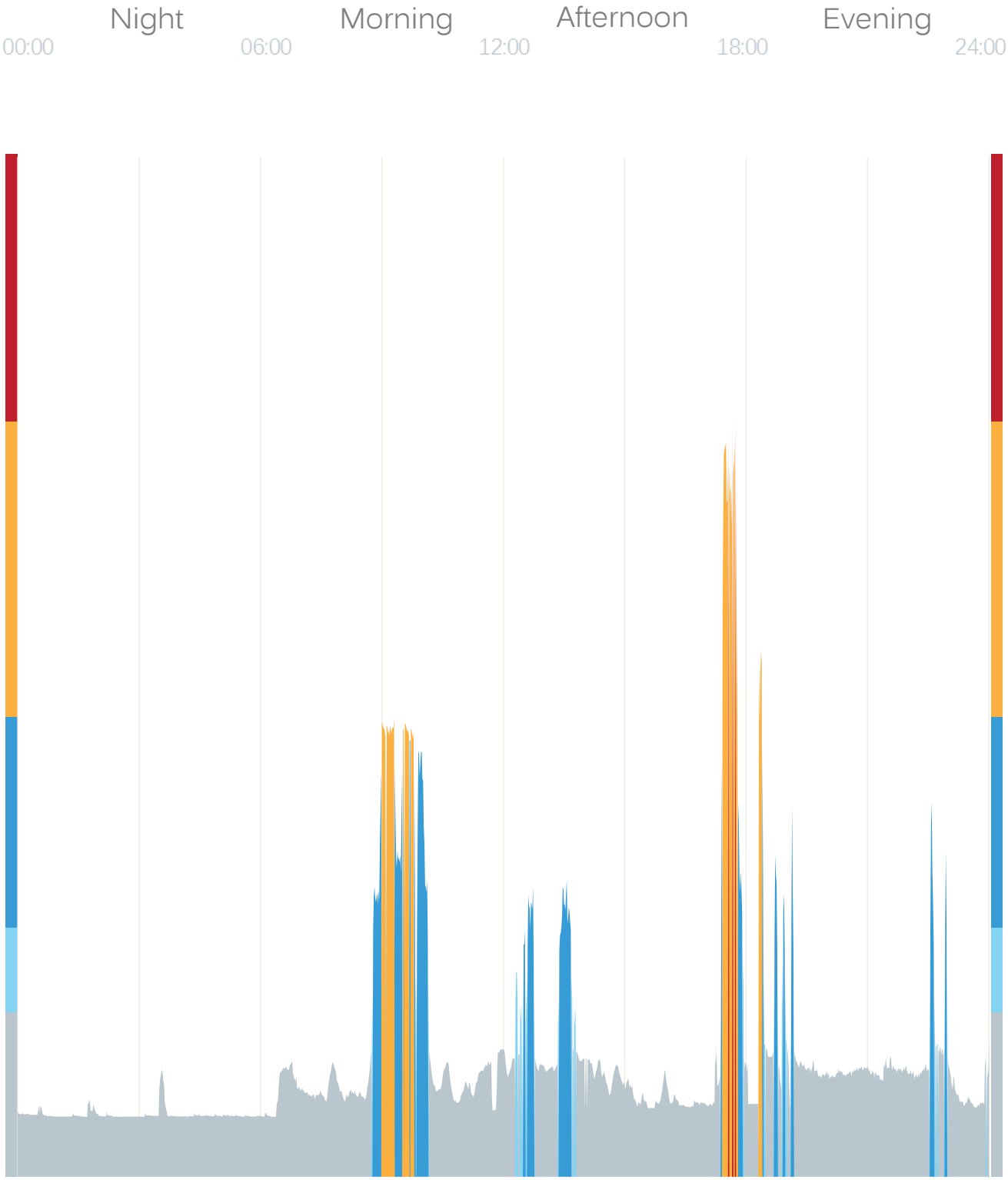
Very vigorous

High intensity competitive sports, running, squash and basketball

A – 24 Hour Bar

Sedentary
Light
Moderate
Vigorous
Very Vigorous

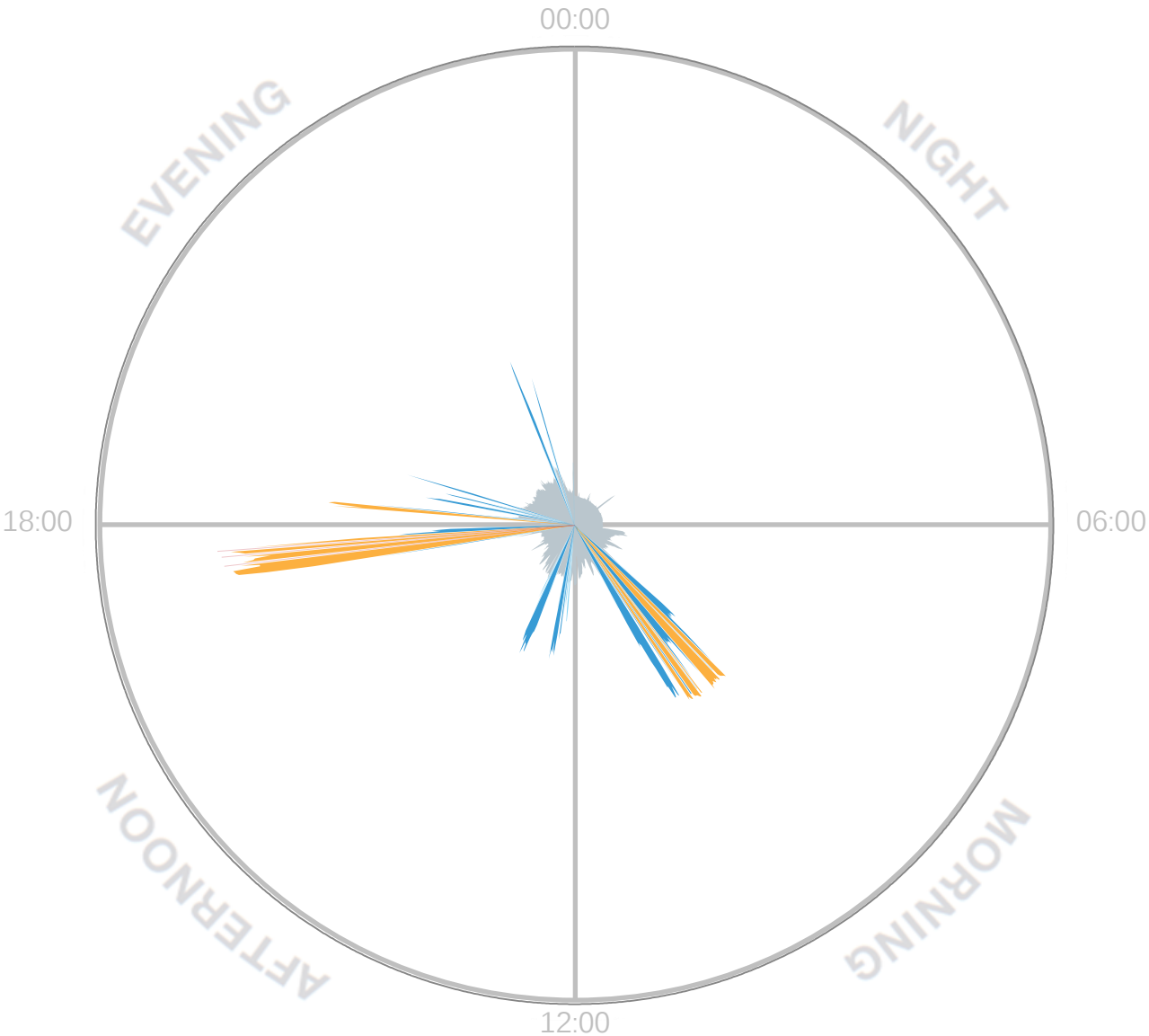
Saturday 23/03/2013
Total Calories: 2614



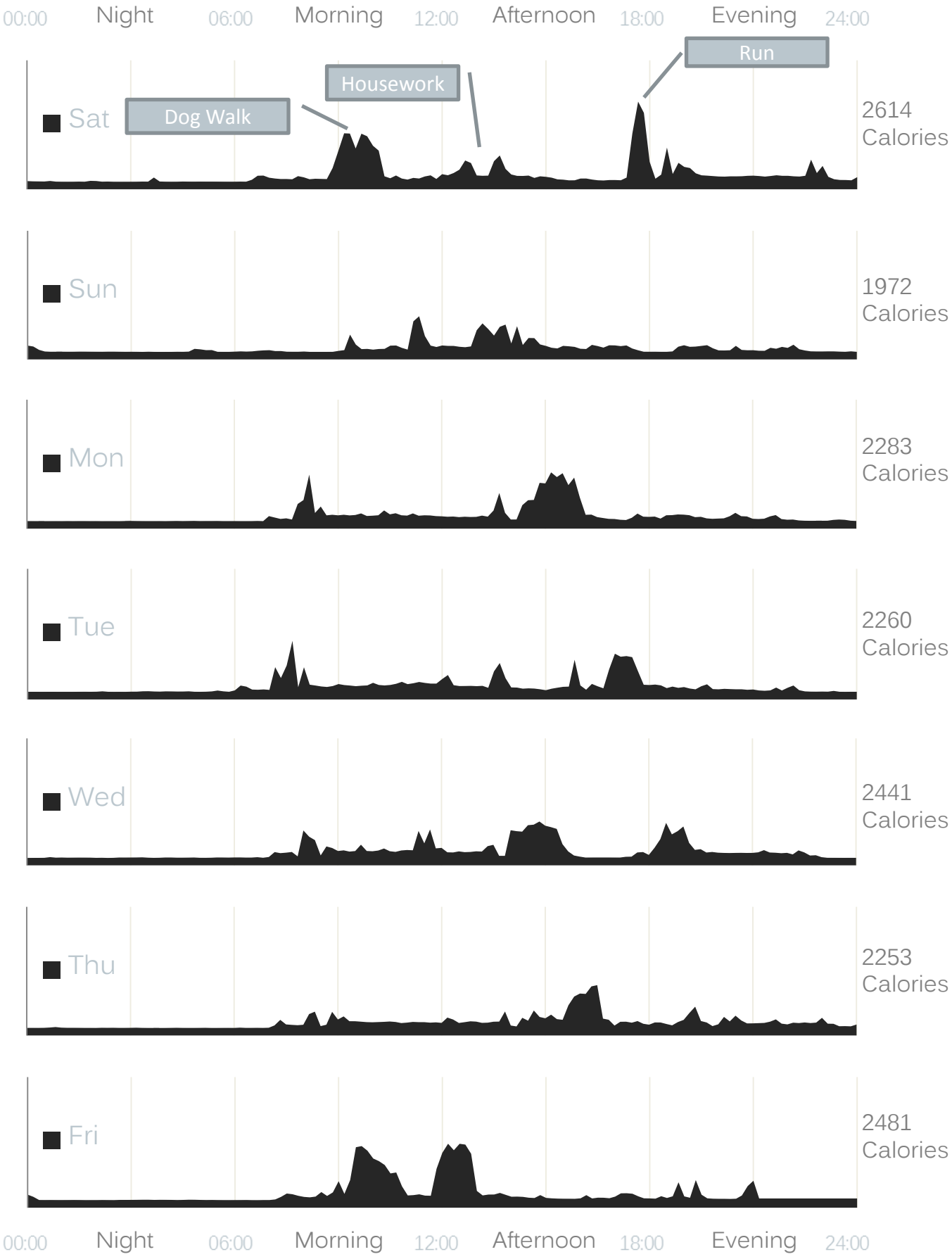
B – 24 hour Radial

Sedentary
Light
Moderate
Vigorous
Very Vigorous

Saturday 23/03/2013
Total Calories: 2614



C – 7 Day Data


00:00
Night
06:00
Morning
12:00
Afternoon
18:00
Evening
24:00
Sat
Dog Walk
Housework
Run
2614 Calories
Sun
1972 Calories
Mon
2283 Calories
Tue
2260 Calories
Wed
2441 Calories
Thu
2253 Calories
Fri
2481 Calories
00:00
Night
06:00
Morning
12:00
Afternoon
18:00
Evening
24:00

We have shown you various ways of displaying your daily or weekly activity patterns, we can now pick out key summary information.

For example we can display the average and total time spent in each activity intensity threshold during your week.

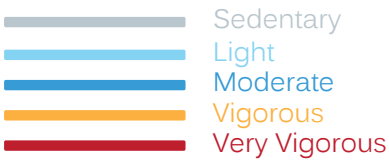
We can also summarise the amount of calories expended at each of these intensity thresholds.

The table below is used to describe the relationship between time and energy within each activity threshold.

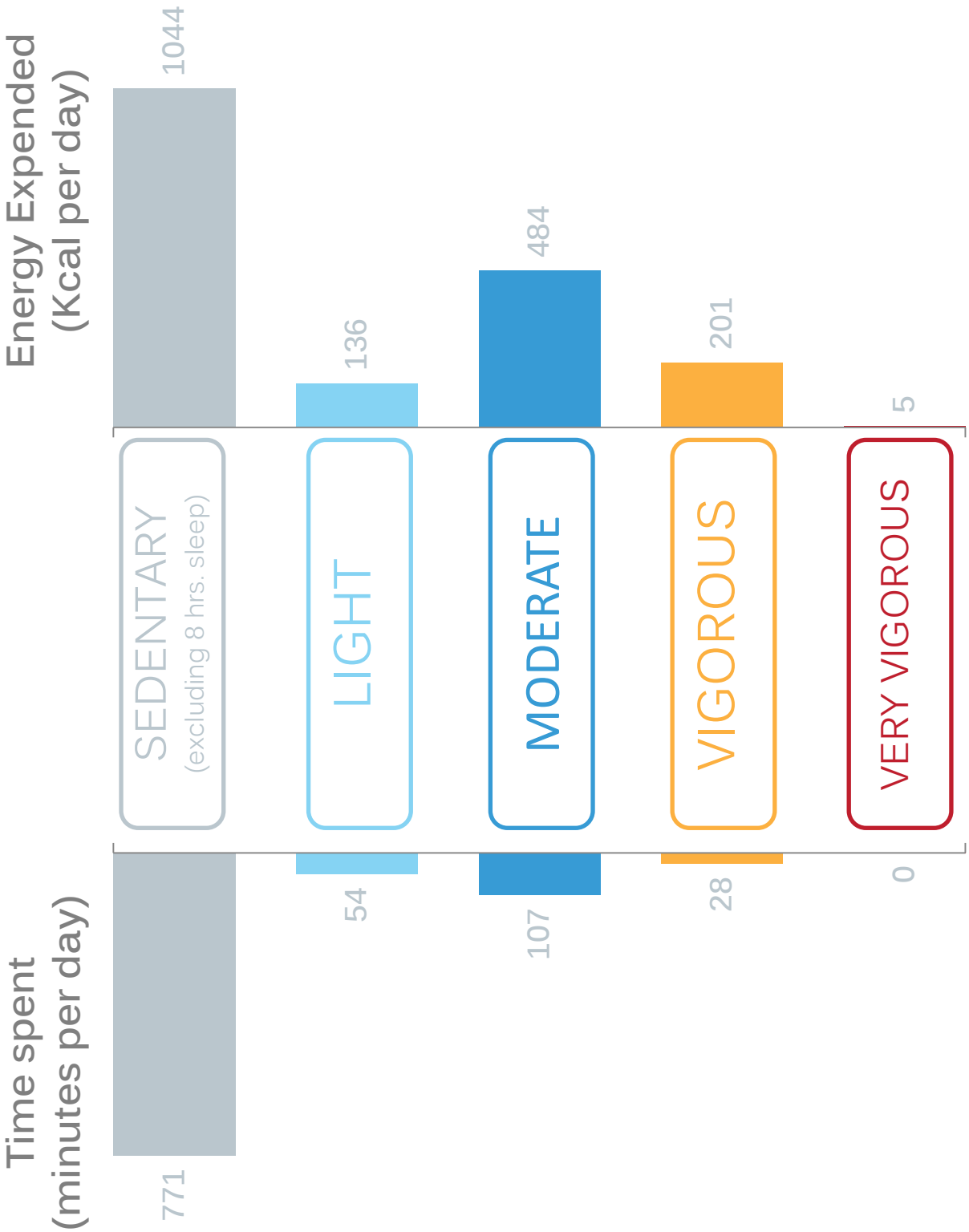
You will now be shown some visual images of your summary data.

Activity Intensity	Time (Minutes)	Calories	Calories	Time (Minutes)
Sleep	30	35	500	400
Sedentary	30	50	500	275
Light	30	100	500	150
Moderate	30	180	500	80
Vigorous	30	300	500	50
Very Vigorous	30	425	500	35

D – Bubble



Time spent (hh:mm)	Energy spent (Kcal per day)
12:50	1044
00:54	136
01:46	484
00:27	201
00:01	5


Energy Expended
(Kcal per day)
Time spent
(minutes per day)
1044
136
484
201
5
771
54
107
28
0
SEDENTARY
(excluding 8 hrs. sleep)
LIGHT
MODERATE
VIGOROUS
VERY VIGOROUS

SEDENTARY
(excluding 8 hrs. sleep)

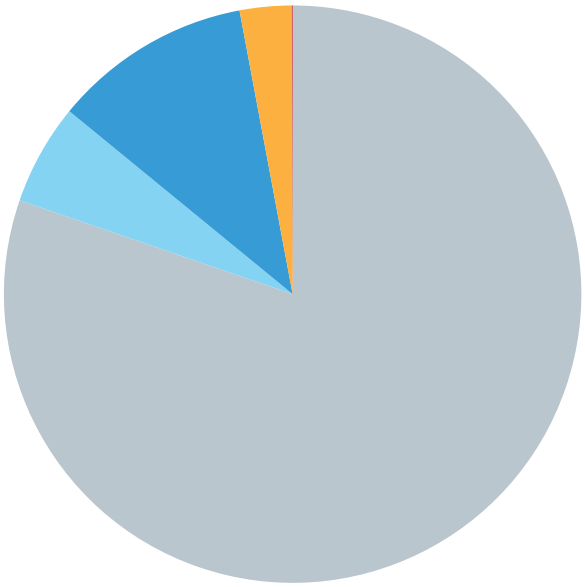
LIGHT

MODERATE

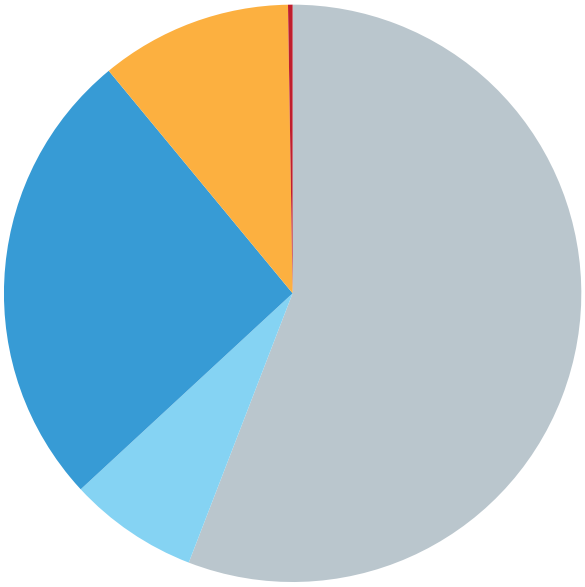
VIGOROUS

VERY VIGOROUS

Time (% of day)



Calories (% of day)



Further to summarising your activity data, we can now show how this sits with current health recommendations.

These recommendations are set based on levels of activity associated with risk for a variety of health problems.

Here we present 5 physical activity targets which have independent effects on your health risk.

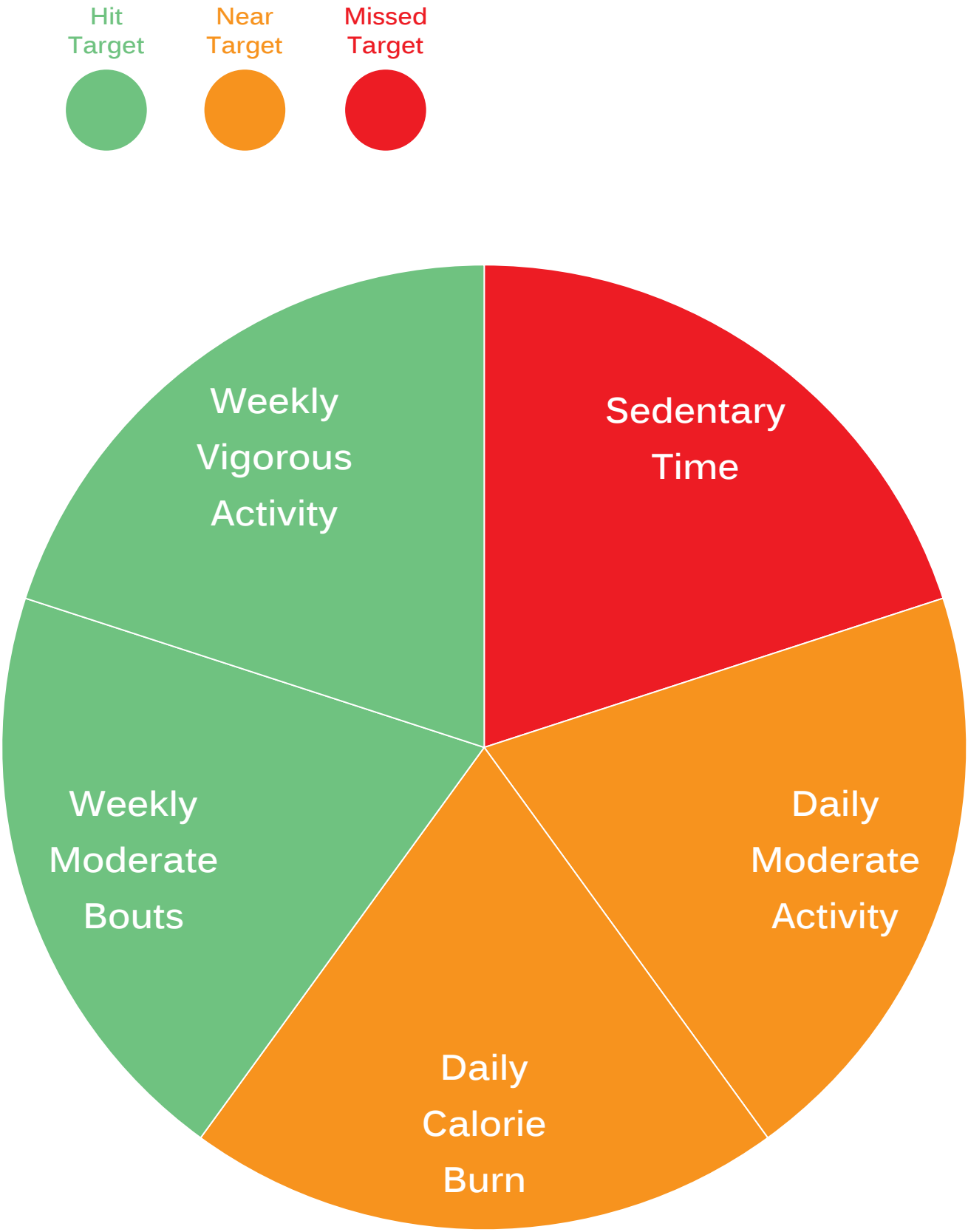
There are therefore various aspects of your physical activity profile that can be altered to improve your health.

The 5 dimensions are:

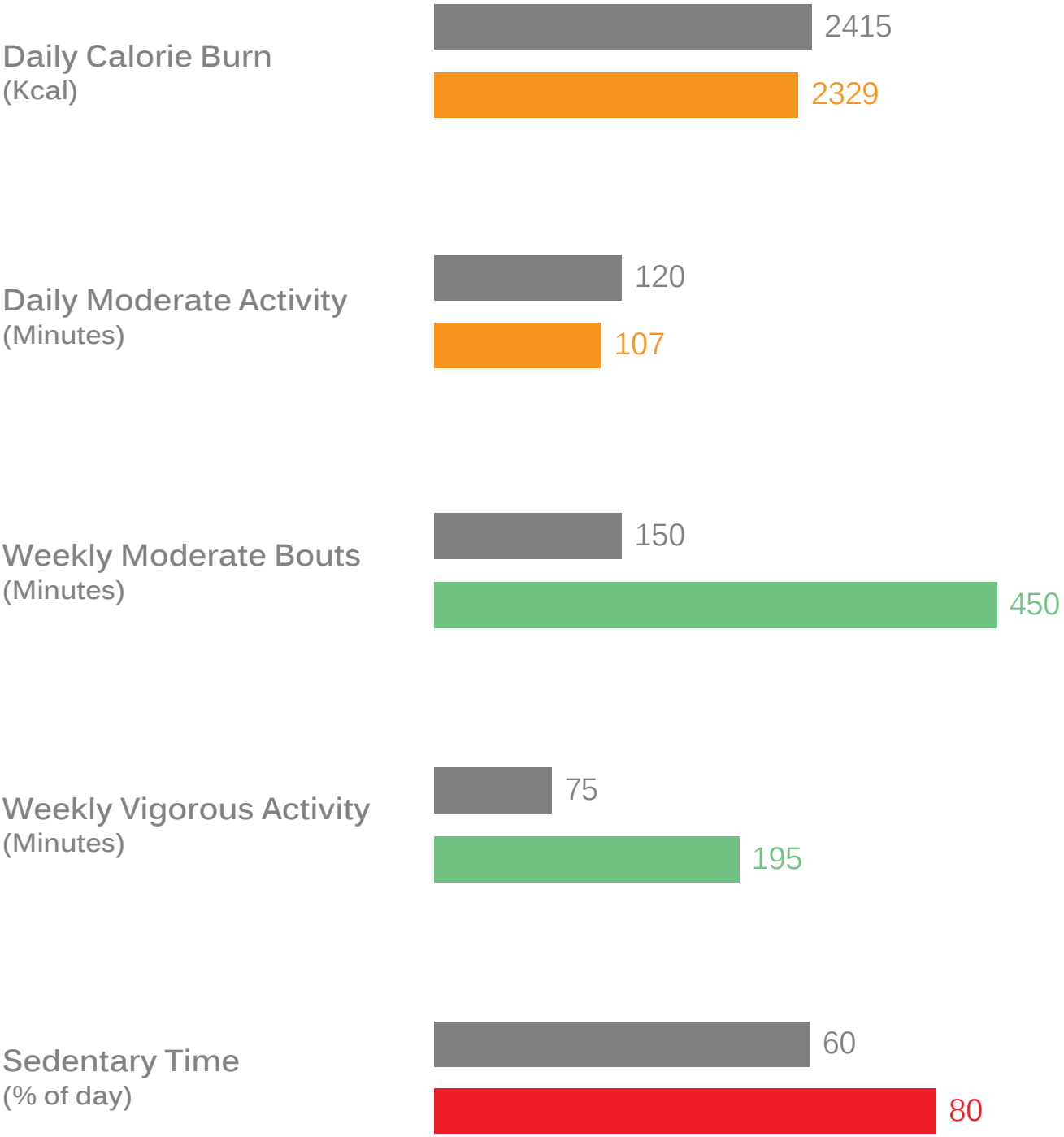
- **Daily calorie burn**: PAL ≥ 1.75
- **Weekly moderate activity**: 120 accumulated minutes
- **Moderate 10 minute bouts**: 150 minutes per week
- **Vigorous activity minutes**: 75 minutes per week
- **Sedentary time**: < 60% of waking day

This section will use a traffic light colour system to indicate whether you are under, near or over the target.

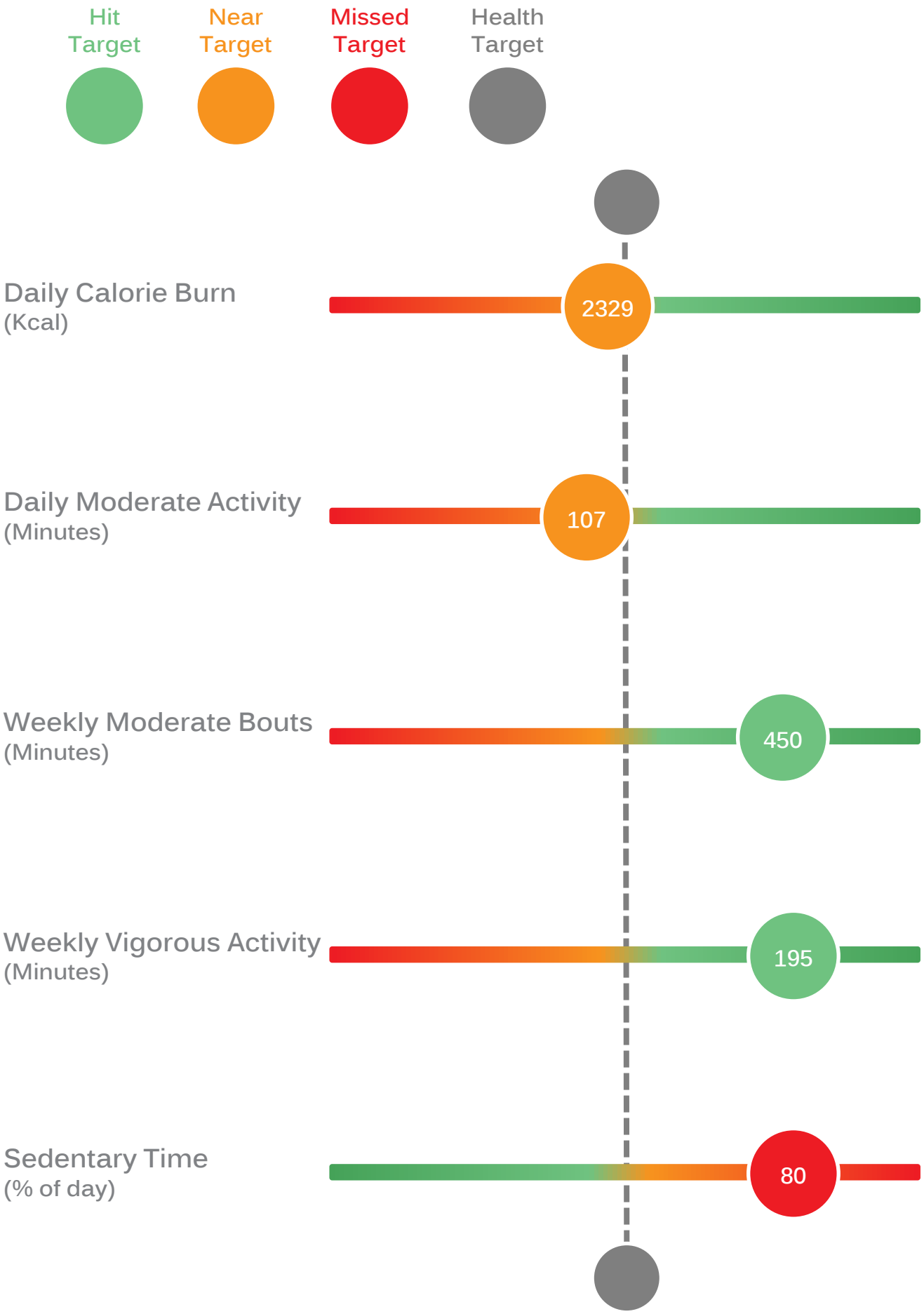
G – Wheel of Activity



H – Target Bars



I – Sliding Targets



Lower Order Theme	Evidence (Quotations)			
	Patient (29)	**%**	**Healthcare Professional (15)**	**%**
Component 1: Interpretation of the feedback designs and data				
Higher Order Theme: Understand Feedback Designs				
Clear and easy to interpret	*…Yeah well that's quite interesting just...I can clearly see which days I do activity, that's obviously more activity throughout the day…*	100	*…Yeah I think for someone who is um, not doing any exercise at all that would be enough really, yeah definitely, that to me would be very simple for them to see. It's very clear….*	93
Not detailed enough	*…No I don't find that particularly helpful um, once you've analysed this one and this one that doesn't really add anything to it, not to my mind…*	38	*…Um I guess the problem with that is it just shows me bad, but it doesn't really tell me how much I need to change to make better….*	53
Can relate data to their activity	*… Remember that day yes I was playing in Bristol, kind of a long day. Gardening. That would probably have been travelling back from golf I suppose. It's interesting that Pilates doesn't spike up more…*	83	*…that's why the temperatures and the calorie expenditure would be high in the evening. So it's gym there and then, running classes there… and similarly here…Thursday with the circus as well…*	87
Colours are helpful	*…Well again I think the uh…the colour is going through all this you get to know what the colours represent so it makes it easier to read together…*	66	*…Right that's really interesting and that is clear now because the colours the colours make that clear…*	87
Certain graphics were confusing	*…there's a slight confusion in my mind I suppose because that is… but that is calories, you know the units change that's minutes that's percentage...but you only have to read it to understand it…*	55	*… The 'E' bar…it's not clear…without spending time looking at it and analysing it. Whereas that, that's quite clear isn't it? Just by looking at it simply…*	87
Visual simplicity is key	*…It's just simpler it tells me exactly the same I can see my performance against the recommending one and it's an easy comparison there, each of the categories and it's nice and simple…*	83	*…I just like this one here because I think it's very clear very visual very simple, and it's straight to the point…*	67
Used to Seeing Graphics	*…Keep it as plain as you possibly can and as simple as you can. I used to do lots of presentations with charts and things and I know simple, people understand…*	48	-	-
Confused by multiple targets	-	-	*…But maybe these targets, when you start presenting them together, it's almost like there's inconsistency between them. Yeah, so that's the first impression…*	20

Higher Order Theme: Enhances Physical Activity Knowledge				
Recognise activity time	*…Yeah yes. Especially when you can identify the exact time that that represents, as I say you can actually break it down into what it was that caused that spike. Excellent…*	93	*..Moderate mostly in the morning, lunchtime, and then….I don't know it sort of fades out, very little in the evening. Very little vigorous exercise in the evening. Mainly moderate. And good night's sleep...*	67
Perception versus objective mismatch	*…Yeah I am surprised that that to be honest with you the sedentary yeah, there is more there than, than I thought to be honest…*	76	*…yeah so I thought it'd be a lot higher than that. From what I think is vigorous activity I thought it'd been...but like you said it's all right isn't it…*	73
Relate to diet/ calorie intake	*…how you fill in that calorie gap with food. That's the next part of it really I suppose. Presumable if you're filling yourself up with food the balance would change wouldn't it…*	66	*interesting to see how many calories you've used each day... in comparison to, well I know what sort of food intake I consume,*	47
Surprising or revealing	*…I'm sort of, I'm surprised by the results really because although I feel healthy, and I eat well, I'm surprised that I'm not sort of just this side of the line. I would imagine that I am a bit too sedentary really for, for health but hey…*	83	*…I'm surprised I haven't ever reached the category of very vigorous because sometimes when I've done a hard step class or something I think I've worked really hard, I'm quite…that surprised me, has surprised me…*	93
Recognise options and choice	*…Yeah it does. Because doing one would sort these two so...um, that would be my aim is to work on those two really. By the nature of it that would bring that one down wouldn't it…?*	66	*…I like this idea that you say that you target one section, one segment, and um…and I think it's a really good way of letting them work on something…*	73
Confirms view of overall activity	*…Yes in that it confirms what I already knew to a point. Yeah it's just nice to see it in front of you what your average week is like. So yeah I'm fine with that…*	79	*…again it confirms the picture of an overall sedentary life with big bursts of energy here and there basically. Thank goodness I cycle, if I didn't cycle id just become flat lined wouldn't it…*	40
Data is novel	*…Very interesting yes. I wondered what it was all doing, I must say it is interesting…*	21	*…Well I'll I don't know how to respond really, I've never seen anything like it before, I've never seen my days portrayed like that…*	3

Component 2: The impact of personalised visual physical activity feedback on facilitation of health behaviour change

Higher Order Theme: Motivated by Personal Feedback				
Feedback inspires change	*…seeing the data laid out makes me think I'm not as active as I should be and that I have to do more to maintain my health or to improve it if I possibly can…*	83	*…it makes me feel that I must try harder. Room for improvement, but, then that's all of us…*	73

Discrepancy from target effective	*...I think that it's the length of the bar; you know you can graphically say 'hey look you know my target is only there and I'm just short of it…*	38	*...It'd be nice to do that whole test again but this time...but then I suppose you'd try and achieve something more and see what you do but um, no it's good…*	67
Health targets are motivating	*…the targets I think. Um, that I think has got me going more than any of the data. The others you can see where you are and what's expected, when you see the targets it gives you incentive if I see I missed those targets how to meet them…*	76	*…I think it's just encouraging to have it all in front of you, and then go through it, and um….it makes me want to do more, so I think it would make other people want to do more…*	67
Targets /data seems unrealistic	*…That's quite a lot actually as a target I'm comfortably achieving that at the moment but for somebody in a full-time job with commuting at either end of the day that's going to be really hard…*	10	*...it's encouragement that matters I think. Rather than showing people how inactive they are. That's not going to help them to do anything about it…*	20
Apathetic towards data	*…I think that's the problem because mine's all green obviously those don't mean much…*	7	*…But, and that hasn't, I'm not sure this will prompt me to do anything about it actually, uh because I thought I would be prompted to do more when I was wearing the monitors actually but it didn't…*	7
Objective feedback is impactful (for patients)	*I think just seeing your actual results is good… anything preventative for national health has got to be good so if this is going to...I know it's not a preventative thing but it's to help me keep my health so it's a way forward isn't it? It's showing me on my own things what I should be doing. Yeah no it's been very helpful.*	79	*…but I think it really could make someone sit back and realize wow, just maybe an extra 10 minutes here or doing something like that. Not a massive change, but could really have a dramatic change on an overall week of what they do so yeah…*	93
Traffic light colours impactful	*…I'm concerned but clearly if one was orange or one was red it would stand out as an area I needed to do something about be it not sitting around so much or a bit more short bursts and things…*	55	*…Yeah I'm uh, a little bit disappointed. There's such a big red 'miss target', um…but, I think if, well, I have seen it so, I will try and do something about it because it makes me feel bad…*	47
May put patients off	-	-	*…And its encouragement that matters I think. Rather than showing people how inactive they are. That's not going to help them to do anything about it I don't think…*	20
Higher Order Theme: Could use to change own (patients) behaviour				
(Patients) would and could use tech	*…I'd love to and as I've said to you I'm sort of a silver surfer and modern technology is something that um, I don't find easy but I keep sort of having battles with it and hoping I win. So I'd be happy to...I would be very interested…*	66	*…even though some of our older people might not have the technology – even though the ones I tend to deal with in our specialist groups all seem to have computers – all the family have them, or they've got smart phones…*	93

(Patients) would self-monitor	*...I'd want to have the monitor but then also have some way...what I'd like to do is have the monitor, and download the info onto my PC, I'd be able to take the monitor off, download the data at the end of the day, or at the end...do it myself, and I'd probably want to do it on a daily basis...*	55	*...I think most people would be able to manage it, yeah. Yeah, definitely you might get the odd one two perhaps, you know…but I think most people would…*	13
Support and advice needed	*...So um, that sort of information is what you would need to have available to support or whoever's going to be their follow-up support would need that sort of information…*	28	*...I think in people who aren't already exercising I think they would need on-going support or prompting to continue doing something….*	80
Monitor over time useful	*...No absolutely. Yes it'd be interesting if you could know it every and compare every week as I say one month to another and one season to another...as a relatively short period of time it wasn't necessarily a normal week …*	62	*...I'd want to say right okay give me 6 months to get my act together and let me come back again and see if I've actually improved and I think that would be of benefit…*	60
Would need to add context	*…could give a quick suggestion on ways you could change that pattern to your benefit and that would be easy to use as a basis I would've thought. You spend an extra 20 minutes a day on vigorous exercise you're going to increase that a lot more than if you're a sedentary person…*	59	*...I think your challenge would be just – or the challenge of the health care professional using your data – would be to turn that into alter their thoughts to if they're doing well – so tell them what they're doing well…*	73
Would help plan or set goals	*… or you can tell it, well I've got free evening there or a free afternoon there and it can suggest an activity that you can do that would get you up to the target. Yes I like that! Yeah something proactive yeah…*	52	*I think it would do because you know you're asking somebody, 'what are your goals' …and if they've got nothing coming up, whereas here it could be 'well actually yeah I would like to increase my calories a bit more so how are we going to do that?*	80
(Patients) Not interested in technology	*...No I'm one of the few I don't go on the computer a lot, no actually…*	10	*...I'm still amazed at what high percentages do not use the internet. And they're scared of it and um, even if they do use it, there are an awful lot of people that are very limited in what they use it as…*	13
Feedback needs to be tailored	-	-	*...I mean it's...everyone's different isn't it, how they portray something how they perceive it and how they understand it, everyone's going to be different I think so, what I might suggest I mean I like that but some other person might come in and go 'it doesn't mean anything to me'…*	87