Failing to encourage physical activity with wearable technology: what next?

Short title: Failures within wearable technology interventions

David A. Ellis PhD

Lancaster University

Lukasz Piwek PhD

University of Bath

Authors Note

David A. Ellis, Department of Psychology, Lancaster University, Bailrigg, Lancaster, United Kingdom.

Lukasz Piwek, School of Management, University of Bath, Bath, United Kingdom.

Corresponding author: David Ellis, Department of Psychology, Lancaster University, Bailrigg, LA1 4YW, Lancaster, United Kingdom. E-mail: d.a.ellis@lancaster.ac.uk

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Abstract

Wearable devices and associated systems that provide real-time feedback aim to encourage healthy behaviours. However, while the research base has grown considerably, results continue to paint a mixed picture when demonstrating wearables' ability to increase levels of physical activity. Given these recent developments, this commentary explores the key reasons why wearable devices and other mobile technologies often fail to change behaviour. We also provide several suggestions that could feed into future research designs and maximise the success of subsequent interventions. These recommendations aim to stimulate interdisciplinary discussions by encouraging clinicians and researchers to consider how these technological advances can be effectively leveraged, and become a core component of preventative medicine in the 21st century.

The Importance of Failure

Modern wearables can characterise health-related behaviours and assist with a variety of behaviour change interventions that aim to encourage physical activity [1]. The latter proposition is particularly pertinent given that even small changes in behaviour could have far reaching consequences for society as a whole. For example, if physical inactivity decreased by only 10% more than 533,000 deaths could be averted every year [2]. A typical intervention provides participants with a device in isolation or as a supplement to an existing behavioural intervention. In the previous decade, some research has supported the notion that simply helping people to quantify their activity levels can change their behaviour [3]. However, wearable technology and the research methodology that underpins related interventions has a considerable distance to cover if it is to become a standardised intervention that can help people become more active, healthier, and happier. Results from small pilots have often failed to replicate across larger samples that employ longitudinal designs. For example, one trial conducted over several years demonstrated a negative effect when patients were provided with a wearable intervention to help them lose weight [4]. In addition to causing harm (e.g., reduced well-being), other negative effects in this context would include wearables that provide no added benefit when compared to standard interventions or result in poor retention rates. Similarly, an effect that dissipates over time would also be classed as an overall negative outcome. This mirrors similar issues witnessed during the development of home telemonitoring interventions [5]. For example, several trials in this domain have reported no benefit when patients were able to self-monitor blood glucose, with others demonstrating that these interventions led to increased levels of depression [6].

Nevertheless, these outcomes remain a key cornerstone in the literature because they emphasise the importance of understanding failures or unexpected results in order to capture the ideal functioning of a future device or intervention. Only then will it be possible to predict what novel interventions are more likely to show larger benefits at a population level.

In this context, we propose and discuss a set of interdisciplinary guidelines that could assist in the development of future interventions that encourage physical activity with wearable technology (Figure 1). While current research is at a relatively early stage, the consideration of recent failures warrants a full discussion regarding future directions, which this think piece aims to stimulate. It is also important to ensure that new research is mindful of current pitfalls, and develops new paradigms accordingly.

[Figure 1: An infographic illustrating key issues in research that aims to encourage physical activity with wearable interventions. These guidelines were developed following a review of papers that document failures in wearable interventions, which aim to encourage physical activity. This illustrates key limitations with devices themselves and the methods used to measure and evaluate the impact of current interventions. While not exhaustive, these two key points of failure provide an avenue to develop future research priorities. (A) Outcomes from interventions may be set up to fail from the start, but subtle benefits (or harms) are likely to remain invisible with existing measures (human computer interaction). (B) Many interventions are theoretically uninformed and mechanisms of action remain hidden (theoretical rigour).]

Human Computer Interaction: falling at the first hurdle

Wearables' design can often have an early negative impact to the point where a potential treatment effect may be thwarted from the outset. For example, one large clinical trial that provided wearable technology as part of a weight loss intervention observed that, over a 2-year period, only 10% of patients reported wearing a daily performance feedback device [4]. Many patients continue to report that devices are unpleasant to wear and can make them feel uncomfortable around other people. Poor design that leads to low levels of comfort and social acceptability could reduce the impact of any similar intervention by limiting potential exercise opportunities [7].

Understanding the design issues that lead to high attrition rates within patients and consumers remains a key priority for future research. Where they are worn and how people engage with them on a daily basis is also likely to be fundamental to their success or failure. The wrist and upper arm have proven problematic despite their popularity and convenience [8]. In addition, research concerning digital health interventions has failed to include a measurement of behaviour that accurately quantifies how a participant interacts with their device [4]. Subtle interactions with digital technology remain difficult to capture with self-report measures alone and are often inaccurate when it comes to health-related metrics [9,10]. Device usage, while straightforward to collect, has to-date only been recorded in small samples of patients with pre-existing health conditions (e.g., hypertension) and not for devices used as part of a behaviour change intervention [11]. Therefore, while hardware development will continue to adapt and innovate, researchers are already in a position to capitalise on the quality and variety of data that can be captured from existing devices.

Theoretical Rigour: understanding mechanisms of action

Technologies evolve more rapidly than traditional research models can evaluate them [e.g., 4]. While wearable technology itself has made great advances, their theoretical contribution towards behaviour modification has been considerably smaller [12]. Wearable systems could help to improve, and develop new, behavioural change techniques as part of a subsequent intervention [13]. It may however, be more valuable to deliberately limit and control these techniques in order to test specific mechanisms of action, but this has also been slow to materialise. Randomised trials are likely to remain the gold standard when it comes to demonstrating the effectiveness of any intervention, but the mechanisms that underpin a specific change in behaviour are largely hidden. Even in larger research designs, there is frequently no control group [4]. In contrast, trials within the life sciences that administer a new drug have well-established action pathways long before an intervention takes place.

Several theoretical avenues are worthy of further investigation. One causal pathway may involve the use of a device to make self-monitoring easier, which increases the frequency of self-monitoring over time. An alternative is that active self-monitoring increases the salience of behavioural choices more than passive self-monitoring, although a lack of engagement (e.g., not wearing a device) across many interventions suggests that this is unlikely [13]. Powerful research designs could manipulate the specific techniques deployed as part of an intervention and record a participant's interaction with a device to understand which specific methods are more effective. A complimentary approach could manipulate when feedback is provided, which may challenge the widely held assumption that real-time feedback will always produce a larger effect.

Moving Forward

Research programmes should aim to strike a balance between controlled trials, with input from those working in applied contexts, and basic 'blue-sky' research. Without this equivalence, it will remain increasingly difficult to dismantle which elements of an intervention are driving or hindering an effect. A more extreme view would argue that it is too early for large-scale trials when it comes to testing if wearable interventions can help increase physical activity levels, particularly when the vast majority of applied research struggles to change how decisions are made within public health [14]. One solution here may simply involve bringing public healthcare professionals together with technology designers at the earliest opportunity.

On the other hand, it would also be naive to assume that wearable devices will be the silver bullet solution. Current devices, interventions, and research only reach a small part of the population that is interested in health or personal data capture [15]. While the line between assessment and intervention has blurred, the digital divide still exists, and we would question how these interventions can reach people who are most in need, especially children, older adults, and low-SES populations. Considerable interdisciplinary progress is required if such interventions are to become commonplace, regardless of ability or personal goals. Even within the context of existing trials, the variation in patients' experience and behaviour is largely ignored. While many will abandon their new device within a couple of months, others will persevere with these devices and will continue to track specific activities for several years. However, in the context of long-term behaviour change, strong evidence has yet to appear that supports these anecdotal observations within wearable interventions and beyond [16].

Wearable interventions are perhaps more likely to become part of a larger set of patient monitoring systems within digital health. Interventions may need to include other linked devices that further monitor behaviour directly or act passively to support and motivate individuals and groups [17]. Nevertheless, we remain optimistic that wearable interventions alone can increase levels of physical activity in large groups of individuals and sections of society as a whole, provided the research base adequately acknowledges failures as well as successes.

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References

[1] Piwek L, Ellis DA, Andrews S, Joinson A. The rise of consumer health wearables: promises and barriers. *PLoS Med*. 2016;13(2):e1001953. https://doi.org/10.1371/journal.pmed.1001953

[2] Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, Lancet Physical Activity Series Working Group. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219-29. https://doi.org/10.1016/S0140-6736(12)61031-9

[3] Lyons EJ, Swartz MC, Lewis ZH, Martinez E, Jennings K. Feasibility and acceptability of a wearable technology physical activity intervention with telephone counseling for mid-aged and older adults: a randomized controlled pilot trial. *JMIR Mhealth Uhealth*. 2017;5(3):e28. https://doi.org/10.2196/mhealth.6967

[4] Jakicic JM, Davis KK, Rogers RJ, King WC, Marcus MD, Helsel D, Rickman AD, Wahed AS, Belle SH. Effect of wearable technology combined with a lifestyle intervention on long-term weight loss: the IDEA randomized clinical trial. *JAMA*. 2016;316(11):1161-71. https://doi.org/10.1001/jama.2016.12858

[5] Kitsiou S, Paré G, Jaana M. Systematic reviews and meta-analyses of home telemonitoring interventions for patients with chronic diseases: a critical assessment of their methodological quality. *J. Med. Internet Res*. 2013;15(7):e150 https://doi.org/10.2196/jmir.2770

[6] O'Kane MJ, Bunting B, Copeland M, Coates VE. Efficacy of self monitoring of blood glucose in patients with newly diagnosed type 2 diabetes (ESMON study): randomised controlled trial. BMJ. 2008;336(7654),1174-1177. https://doi.org/10.1136/bmj.39534.571644.BE

[7] Patel MS, Asch DA, Volpp KG. Wearable devices as facilitators, not drivers, of health behavior change. *JAMA*. 2015;313(5):459-60. https://doi.org/10.1001/jama.2014.14781

[8] Finkelstein EA, Haaland BA, Bilger M, Sahasranaman A, Sloan RA, Nang EE, Evenson KR. Effectiveness of activity trackers with and without incentives to increase physical activity (TRIPPA): a randomised controlled trial. *Lancet Diabetes Endocrinol*. 2016;4(12):983-95. https://doi.org/10.1016/S2213-8587(16)30284-4

[9] Lichtman SW, Pisarska K, Berman ER, Pestone M, Dowling H, Offenbacher E, Weisel H, Heshka S, Matthews DE, Heymsfield SB. Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. *N. Engl. J. Med.* 1992;327(27):1893-8. https://doi.org/10.1056/NEJM199212313272701

[10] Ellis DA, Kaye LK, Wilcockson TD, Ryding FC. Digital Traces of behavior within addiction: Response to Griffiths (2017). *Int J Ment Health Addict*. 2018;16(1):240-245. https://doi.org/10.1007/s11469-017-9855-7

[11] Bloss CS, Wineinger NE, Peters M, Boeldt DL, Ariniello L, Kim JY, Sheard J, Komatireddy R, Barrett P, Topol EJ. A prospective randomized trial examining health care utilization in individuals using multiple smartphone-enabled biosensors. *PeerJ*. 2016;4:e1554. https://doi.org/10.7717/peerj.1554

[12] Ogilvie D, Foster CE, Rothnie H, Cavill N, Hamilton V, Fitzsimons CF, Mutrie N. Scottish Physical Activity Research Collaboration. Interventions to promote walking: systematic review. *BMJ*. 2007;334:1204. https://doi.org/10.1136/bmj.39198.722720.BE

[13] Mercer K, Li M, Giangregorio L, Burns C, Grindrod K. Behavior change techniques present in wearable activity trackers: a critical analysis. *JMIR Mhealth Uhealth*. 2016;4(2):e40. https://doi.org/10.2196/mhealth.4461

[14] Ioannidis JP. Why most clinical research is not useful. *PLoS Med*. 2016;13(6):e1002049. https://doi.org/10.1371/journal.pmed.1002049

[15] Sullivan AN, Lachman ME. Behavior change with fitness technology in sedentary adults: a review of the evidence for increasing physical activity. *Front Public Health* 2017;4:289. https://doi.org/10.3389/fpubh.2016.00289

[16] Dunton GF (2018). Sustaining Health-Protective Behaviors Such as Physical Activity and Healthy Eating. *JAMA* Published online May 31, 2018. https://doi:10.1001/jama.2018.6621

[17] Muse ED, Barrett PM, Steinhubl SR, Topol EJ. Towards a smart medical home. *Lancet*. 2017;389(10067):358. https://doi.org/10.1016/S0140-6736(17)30154-X