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Paidi O'Raghallaigh
Infant Research Centre, University College Cork, p.oreilly@ucc.ie

Frederic Adam
University College Cork, Cork, Ireland, FAdam@ucc.ie

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A Framework for Designing Digital Health Interventions

Paidi O'Raghallaigh

INFANT Research Centre, University College Cork, p.oreilly@ucc.ie

Frederic Adam

Cork University Business School, University College Cork
and
INFANT Research Centre, University College Cork FAdam@ucc.ie

Abstract

The only sustainable way to provide more effective healthcare and at the same time to reduce soaring healthcare costs is by keeping people healthier. Digitally Based Change Interventions (DBCI) are interventions that utilise digital technologies to promote and maintain health and wellbeing through monitoring, managing and preventing personal health problems. DBCIs are typically automated, interactive, and personalized 'just-in-time' adaptive interventions (JITAIs) that provide real time support to individuals especially during moments when they have the greatest opportunity to engage in a healthier behaviour (or are most vulnerable to engaging in a negative behaviour). To date, the potential of DBCIs has scarcely been realized, partly because of difficulties in generating an accumulating knowledge base for guiding their design. As a result, most designers do not use theory as a basis for developing new interventions or for analysing why some interventions fail and others succeed. In this paper, we bring together insights from a number of theories in order to bridge this gap and to produce a "theory-based" framework for assisting with their design. In turn, we demonstrate the power of this framework by using it to review the design of a digital programme previously described in a well cited paper.

Keywords: Digital health, digital wellness, digitally based behavior change, digital therapeutics, connected health.

1. Introduction

While life expectancy in many countries has increased over recent decades, there is increasing evidence that healthy life expectancy is not keeping up. As well as being responsible for a significant reduction in wellness, chronic conditions, such as obesity, type 2 diabetes, and high blood pressure, are responsible for a high proportion of early deaths. It seems certain that as we continue to live longer, we will also experience more episodes of illness caused by these chronic conditions. The combination of chronic conditions and multiple comorbidities are contributing to a *global crisis in health*. The ability of our health systems to deal with this crisis is complicated by a number of factors. First, the conditions operate in stealth mode in that they are largely symptomless and cause their harm silently over time. For example, high blood pressure is commonly referred to as the '*silent killer*' because unless individuals make a habit of checking their blood pressure, it is virtually undetectable until it reaches acute levels. Second, the conditions are often directly related to the unhealthy lifestyles of individuals and they cannot be adequately managed through medical intervention alone. Instead, they require sustained changes in the individuals' lifestyles and behaviours to address sedentariness, poor diets, poor sleep habits, and the like. Third, the attitude of many individuals towards their own health is 'reactive' in that they only seek treatment when the conditions reach acute levels. By this stage much of the damage has already been done.

At the same time as the number of people requiring care for chronic conditions is increasing, there is a growing shortage of healthcare professionals in both primary and secondary care. The demand for services is growing at such a rate that if we continue to insist on face-to-face reactive interactions as the only way to deliver care, we will not have the health professionals to keep pace with the demand. Removing the barrier requiring individuals and doctors to be in the same place at the same time and at all times when care is required must be investigated. In addition, the focus, which traditionally has been on treating individuals once they develop chronic conditions, must switch to keeping these individuals well during their lifetimes. The new reality is that the only sustainable way to provide more effective healthcare and at the same time to reduce soaring healthcare costs is by keeping people healthier. Digital approaches, enabled by emerging technologies, are beginning to offer some promise by allowing individuals to become more aware of the state of their health, to encourage them to take greater responsibility for their lifestyles, to make knowledgeable decisions about their behaviours, and to act on these decisions. However, getting individuals to change their everyday behaviours is challenging, can be difficult to achieve, and the impacts are often short-lived (Cugelman 2013; Kvedar, Colman, & Cella, 2015).

In response some companies are developing digital health technologies that focus primarily on helping individuals to change their everyday behaviours in support of healthier lifestyles (Consolvo, McDonald, & Landay, 2009). The market is responding and the demand for apps is growing rapidly and it is estimated that 1.7 billion smartphone users worldwide will have downloaded a healthcare app by 2018 (Patrick et al., 2016). However, to date most healthcare apps offer little or no evidence of their long-term efficacy in changing behaviours (Patrick et al., 2016). In addition, reviews of healthcare apps commonly note their lack of adherence to theory, evidence, and best practice (Patrick et al., 2016). Yet the field of psychology offers a growing body of knowledge regarding behaviour and behaviour change. Over the past decades psychology has accumulated an extensive toolbox of behaviour change techniques and it has built evidence of their effectiveness (Abraham & Michie, 2008; Michie, van Stralen, & West, 2011; Peters, de Bruin, & Crutzen, 2015). This knowledge base has received little or no attention in the extant Information Systems (IS) literature, not to mind the IS literature dedicated to the design of digital healthcare interventions to change human behaviour. This paper seeks to go some way towards bridging this gap.

In this paper, we therefore draw on literature *to create a theoretically based framework aimed at assisting those designing digital health interventions in delivering greater and sustained health and wellness benefits by supporting individuals in maintaining long term behaviour change.* We demonstrate the power of this framework by using it to

review the design of a digital programme previously described in a well cited paper. The remainder of this paper is structured as follows. In the next section we examine the state of the art in digital health. This is followed by an exploration of the key theoretical underpinnings of behaviour change. The next section builds on these underpinnings to build a theoretical framework for designing digital behaviour change interventions. This is followed by the use of the framework to evaluate a case study of a digital programme designed to increase exercise. We finish with a brief discussion and a set of concluding remarks.

2. State of the Art in Digital Health

The long held assumption that face-to-face engagements between health professionals and patients are best for delivering positive healthcare outcomes is being increasingly questioned. For example, an individual that is a regular visitor to her doctor is unlikely to get more than one to two hours of face time in total with her doctor annually (Kvedar et al., 2015). We need to focus more attention on the other 99% of time when she is not with her doctor. But health professionals cannot follow each of their patients around every minute of each day (Kvedar et al., 2015). Sensors are one way in which healthcare can move beyond the need for face-to-face engagements. For instance, individuals at risk of chronic conditions could be provided with a remote monitoring system that consists of a blood pressure monitor and a weighing scale that can provide nurses with automatic alerts whenever a patient has abnormal blood pressure, has sudden weight changes, or has worsening symptoms that might point to an impending crisis. The nurses could review the data daily and proactively contact those patients at the highest risk. This '*management by exception*' approach enables far more productive use of resources (for example allowing a nurse to effectively manage over 300 patients simultaneously (Kvedar et al., 2015)) and assists people with self-managing their own wellness. At the same time the approach does not have the elevated costs associated with face-to-face care.

The term *Digitally Based Change Interventions* (DBCI) is used to refer to these types of interventions that utilise digital technologies to promote and maintain health and wellbeing through monitoring, managing and preventing health problems (Hekler et al., 2016; Yardley et al., 2016). DBCIs are typically automated, interactive, and personalized. They employ user input or sensor data to tailor interventions while requiring less direct health professional input (Yardley, Choudhury, Patrick, & Michie, 2016). Through the provision of 'just-in-time' adaptive interventions (JITAIs) they provide real time support to individuals when they have the greatest opportunity to engage in a healthier behaviour (or are most vulnerable to engaging in a negative behaviour) (Hekler et al., 2016). JITAIs attempt to ensure that the correct support is there for the person at the correct time and is delivered in the correct way. The interventions can include activities focused on testing, monitoring, diagnosing, and treating. In this way the DBCIs can complement and at times reduce the need for traditional healthcare professional involvement.

2.1 Challenges for Digital Health Technologies

According to a PwC (2016) 'connected living' survey, 26% of 18–34 year olds are already using technology such as wearables to monitor their health. They predict that the connected health market will be worth almost 61 billion USD globally by 2020. However, the evolution of the market is not without its challenges – especially around persuading somewhat reluctant consumers to change their behaviours and to increase the stickiness of health offerings. For example, a 2007 review of literature by researchers at the Stanford University School of Medicine found that the use of a pedometer was associated with significant increases in physical activity, reductions in weight, and improvements in blood pressure (Bravata et al., 2007). A total of 2,767 people participated in the various studies; most participants were female, overweight and relatively inactive before they started their exercise programmes. The pedometers were shown to increase physical activity by over 2,000 steps, or about 1 mile of walking, per day - a 27% increase in physical activity. The study followed patients for an average of 18 weeks, but not long term. The authors concluded that: "*The results suggest that the use of a pedometer is associated with significant increases in physical activity and significant decreases in body mass index and blood pressure. Whether these changes are durable over the long term is undetermined*" (p. 2296). However, a more recent study by researchers at the Duke NUS Medical School in Singapore, found that although Fitbit fitness trackers might help to increase daily steps, at least for a short time, they do not make

their users any healthier in the long run (Finkelstein et al., 2016). The study followed 800 adults for a year, and randomly assigned participants into different groups, some using the devices and some not. After six months, the only people to actually exercise more than usual were those who were offered a cash incentive of up to 22 USD per week if they walked at least 50,000 steps per week. However, even they did not lose weight, lower their blood pressure, or improve their heart rate. A deeper review of the literature uncovers only limited evidence of the effectiveness of these technologies in changing actual behaviour and in providing longer term health and wellness benefits.

At the same time there are an increasing number of reports suggesting a noticeable decline in consumer interest in the fitness wearables market. Although as many as one out of five people over the age of 18 owns a fitness tracker (Juntti, 2016), studies have shown that 32% of users give up on their devices after three months and 50% abandon them after a year (Barker, 2016). The picture for mobile health apps is similar. While market analysts predict that 1.7 billion people will have downloaded a mobile health app by 2017 (PWC, 2016), there is scepticism as to how many of these apps will be put to sustained use. Just 12% of apps account for 90% of consumer downloads, and 36 apps generate nearly half of all downloads (Terry, 2015). The vast majority of downloaded apps are likely to be deserted within two weeks (Kvedar et al., 2015). It appears that getting individuals to try something new is the easier part, but getting them to continue engaging is the harder part. Indeed those that work with patients often report how they see many individuals who are rather ambivalent towards their own behaviour even when it is damaging to their health (Kvedar et al., 2015). In other cases individuals want to do what is best for their health, but they struggle to make the jump from good intentions to good behaviour. Gamification may hold some promise in this regard.

2.2 Role of Gamification in Digital Health

Gamification has been a predominant focus of the health app industry in recent years (Lister, West, Sax, & Brodegard, 2014). The term gamification was originally coined in 2008 and is defined as the use of game design elements in non-game contexts, such as health and wellness (Cugelman, 2013; Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011; Hamari, Koivisto, & Sarsa, 2014; Lister et al., 2014). The idea being that those ingredients that make games effective, may also be used by developers to make digital health interventions more effective in shifting beliefs, attitudes, and actions (Cugelman, 2013). Organisations have widely adopted gamification as a means of initiating and sustaining desired behaviours (Lister et al., 2014). For example, it has been estimated that 60% of health initiatives in workplaces now include gamification elements (Lister et al., 2014). Hamari at al. (2014) reviewed peer-reviewed empirical studies on gamification and they found evidence that gamification does provide some positive effects, however, these effects greatly depend on the context in which the gamification is applied, as well as the individuals on which it is used.

Gamification as an academic topic of study is still relatively young, and there are few well-established theoretical frameworks underpinning it (Hamari et al., 2014). In order to move the agenda forward, Cugelman (2013) explores the relation between gamification and the behaviour change frameworks used in the health sciences and shows how gamification principles are closely (and perhaps unsurprisingly) related to principles that have been proven to work in health behaviour change interventions – see Table 1. There is some justification for exploring the use of gamification for moving healthcare from a reactive care model towards proactive wellness and preventive care. However, to date there has yet to be an extensive review of the effectiveness of gamification elements in health interventions. Very few health interventions demonstrate the required deep understanding of the lives of individuals. In addition, they lack the behavioural hooks required to maintain the individual's interest and adherence.

Gamification Element[1]	***Description***	***Example***
Goal Setting	The individual commits to achieving a clear and measurable goal.	Goals, such as a target weight loss, are set and the individual commits to the required behaviour change.
Capacity Building	The individual grows, learns, and develops in order to overcome challenges.	A path, such as increased exercise, is created that provides opportunities for acquiring new knowledge, mastering new skills, and ultimately achieving positive and sustainable weight loss.
Feedback Provision	The individual receives regular feedback on her performance.	Feedback loops, such as from a wirelessly connected weighing scales, are provided to the individual in order to provide her with timely and transparent feedback on her weight loss performance.
Reinforcement	The individual gains rewards for appropriate actions and penalties for inappropriate actions.	Appropriate actions, effort, focus, perseverance, and improvement in her weight loss are rewarded and inappropriateness is penalised.
Progress Comparison	The individual's performance is compared with that of others.	The weight loss performance of the individual is assessed in real-time and her progress is compared to her target weight and also to the progress of others.
Social Connectivity	The individual is provided with opportunities for interacting with others.	The weight loss actions of the individual are embedded within a social network that promotes support, learning, recognition, comparison, and peer pressure.
Playfulness	The initiative plays out in an alternative reality.	Weight loss is embedded in a fun or competitive narrative (e.g. an adventure setting, a disaster scenario, etc.) that piques the interest and motivation of the individual.

Table 1. Use of Gamification Elements in Health Interventions

The popular interest in gamification in academia is reflected by a growing number of papers published on the topic (Hamari et al., 2014). However, as already stated there are few well-established theoretical frameworks underpinning it. We now turn our attention to identifying some of the more common theories relevant to this space.

3. Theoretical Underpinnings of Behaviour Change

Improving the design and implementation of health interventions requires evidence-based practice that drives successful behaviour change (Michie et al., 2011). Interventions to change health-related behaviours typically have modest effects but are likely to be more effective if grounded in appropriate theory (Davis, Campbell, Hildon, Hobbs, & Michie, 2015). Yet, health interventions continue to be designed without reference to theory (Davies, Walker, & Grimshaw, 2010; Davis et al., 2015; Prestwich et al., 2014). Choosing a relevant theory is a challenging task for intervention designers, especially given the large number of theories to choose from (Davis et al., 2015; Michie et al., 2005). There is a lack of guidance on how to select an appropriate theory for a particular intervention (Davis et al., 2015; Michie et al., 2011). Where theory is used, it is often only loosely referred to rather than rigorously applied to the intervention design (Davis et al., 2015; Painter, Borba, Hynes, Mays, & Glanz, 2008; Prestwich et al., 2014). In addition, some of these interventions use a 'common' or 'favourite' theory, rather than one that may be better suited to the particular context in which the intervention is to take place (Davis et al., 2015).

Here we draw on a number of theories identified in a literature review of behaviour change. The theories allow us to extract some theoretical pillars that can increase our understanding of how we ought to go about designing digital health interventions to support behaviour change. Two of these theories - *Goal-Setting Theory* and the *Transtheoretical Model of Behavior Change* – are two theories that are often used in persuasive technology and health intervention

[1] after: Cugelman, 2013

research (Consolvo et al., 2009). We focus explicitly on those elements of both theories that prove useful in building the framework that we present in this paper.

3.1 Goal-Setting Theory (GST)

The Goal-Setting Theory describes how goals can be used to motivate individuals to achieve new or increased levels of behaviour. In 1990, Locke and Latham published their seminal work, "A Theory of Goal Setting and Task Performance" and they provided five principles guiding how to set goals to increase motivation (c.f. Locke and Latham 1990). These principles are: clarity, challenge, commitment, feedback, and task complexity. The first principle focuses on *clarity* and suggests that goals ought to be clear about which behaviour is desired and how it is to be measured and rewarded. The second principle is focused on *challenge* and suggests that goals ought to be challenging but also achievable. The third principle focuses on *commitment* and suggests that goals need to be understood, agreed upon, and committed to. The fourth principle focuses on *feedback* and suggests that feedback on progress toward goals ought to be provided in order to provide the opportunity to adjust the level of challenge, adjust expectations, and provide recognition. The fifth principle is *task complexity* and focuses on ensuring that the challenge remains appropriate and is within reach. These principles can be combined when designing health interventions. For example, the individual must understand and accept that a particular goal is important to her. The goal needs to be challenging but always within reach of her capabilities. It should be easy to gauge her progress and to identify how close she is to achieving her goal. As can be seen these overlap with the elements of gamification presented in Table 1. Perhaps areas that receive less attention in Goal-Setting Theory are the gamification elements of Progress Comparison, Social Connectivity, and Playfulness. This in of itself is interesting.

3.2 Transtheoretical Model (TTM)

The Transtheoretical Model (TTM) (c.f. Prochaska & DiClemente, 1986; Prochaska et al., 1992) is one of the most widely accepted theoretical models that conceptualizes the process of intentional behaviour change. Whereas other models of behaviour change often present behaviour change as an event, the TTM includes stages that represent the temporal dimension of change. TTM, therefore, recognizes that individuals change their behaviour gradually, by advancing along a series of five key stages – precontemplation, contemplation, preparation, action, and maintenance. The *precontemplation (or 'not ready') stage* is when individuals do not intend to take action in the foreseeable future (sometimes measured as the next six months). Being uninformed or poorly informed about the consequences of one's behaviour may cause a person to remain in this stage for an indefinite period. The *contemplation (or 'getting ready') stage* is when individuals intend to change in the next six months but are as of yet not fully committed or ready to take action. They have become more aware of the benefits of changing, but may also be aware of the sacrifices of changing. The lack of a clear differential between benefits and sacrifices can result in individuals remaining in this stage for long periods. The *preparation (or 'ready') stage* is when individuals have decided to take action in the immediate future (sometimes measured as the next month). Typically they have a clear plan of action. The *action stage* is when individuals are making specific and often measurable changes in their lifestyles. The *maintenance stage* is when individuals have made specific changes to their lifestyles, but they are now making fewer changes than when in the action stage. They may need to work to prevent relapse. While progression through each stage can occur in a linear fashion, a nonlinear progression is also common and this often sees individuals recycling through the stages or switching back to earlier stages from later ones. As can be seen the elements of gamification presented in Table 1 pay little or no attention to the temporal aspects of behaviour change that are at the core of TTM. Again this in of itself is interesting.

3.3 Behaviour Change Techniques (BCT)

It is not always clear from the literature which behaviour change techniques can be used to nudge individuals forward through the stages of change. Here we turn our attention to this aspect of behaviour change. Michie et al.

(2011) leverages the extant literature and expert opinion to develop their COM-B framework as a 'behaviour system' providing clear links to overarching theoretical models of behaviour change. At the centre of their framework are three essential generators of behaviour: capability, opportunity, and motivation. *Capability* is defined as the individual's psychological and physical capacity to engage in the change activity concerned. *Motivation* is defined as all those internal processes that energize and direct behaviour, not just goals and conscious decision-making. *Opportunity* is defined as all the factors that lie outside the individual that make the behaviour possible or indeed trigger it. In turn they subdivide each of these three components in order to capture further distinctions noted in the research literature. With regard to capability, they distinguish between physical and psychological capability. For opportunity, they distinguish between physical opportunity afforded by the environment and social opportunity afforded by the social milieu. With regard to motivation, they distinguish between reflective processes (involving evaluations and plans) and automatic processes (involving emotions and impulses). Thus, they identify six components that form the hub of a 'behaviour change wheel' (BCW) around which they further position a taxonomy of nine behaviour change techniques aimed at addressing deficits in one or more of these conditions. We present these techniques in Table 2.

Technique[2]	***Description***	***Relationship to Gamification Elements***
Education	Increasing knowledge, awareness or understanding to build capability.	Related to Capacity Building
Persuasion	Using communication to induce positive or negative attitudes or stimulate actions.	Related to Feedback and Progress Comparison
Incentivisation	Creating an expectation of a reward for positive actions.	Related to Reinforcement
Coercion	Creating an expectation of a cost for negative actions.	Related to Reinforcement
Training	Imparting skills to build capability.	Related to Capacity Building
Restriction	Using rules to reduce the ability to engage in inappropriate behaviour.	
Environmental Restructuring	Restructuring the physical and social environment to promote appropriate actions and limit inappropriate actions.	
Modelling	Providing examples and role models to inspire behaviour change.	Related to Social Connectivity
Enablement	Increasing the means and reducing the barriers to increase capability and opportunity.	

Table 2. Use of Behaviour Change Techniques in Health

While BCW is a model of behaviour, it also provides a basis for designing interventions aimed at behaviour change (Michie et al., 2011). Applying this to intervention design, the first task is to consider what the target behaviour should be, and then to identify which components of the behaviour system would need to change to facilitate the target behaviour. A designed intervention might change one or more of the components in the behaviour system. As can be seen in Table 2, not all change techniques used in health and wellness map neatly to gamification elements as presented in Table 1. Cugelman (2013) identified seven core ingredients of gamification, of which six have clear linkages to proven behaviour change strategies. The exception is Playfulness, which has perhaps, not received much attention in the health behaviour change literature. On the other hand change techniques such as Restriction, Environmental Structuring, and Enablement have no counterparts in gamification. This exploratory mapping demonstrates that there are some promising links between gamification principles and digital behaviour change science, but also that there are some interesting unexplored or missing links between the two. Although gamification shows some clear links to health behaviour change strategies and tactics, the technical mechanics used in health behaviour change interventions can be radically different to those used in gamified technologies, even though they may appeal to similar psychological faculties (Cugelman, 2013).

[2] after: Michie et al. (2011)

4. A Theoretical Framework for Designing DBCIs (TFDD)

As we have already discussed, most intervention designers do not use existing frameworks as a basis for developing new interventions or for analysing why some interventions fail and others succeed (Michie et al., 2011). Interventions ought to be configured to the needs of the individual and the context in which the intervention must take place. For example, TTM suggests that an intervention design to target precontemplation stagers might focus on education in order to change people's awareness of a problem, whereas for action stagers the design might focus on keeping track of progress to maintain consistency and possibly incorporate elements of social influence (Consolvo et al., 2009). However, outside of such broad suggestions, the extant literature provides little guidance to the interaction designer as to which behaviour change techniques should be used when. Neither GST nor TTM on their own or together consider in detail the specific techniques required to exact behaviour change. Therefore, in this section we bring together insights from each of these two theories as well as BCT in order to bridge this gap and to produce a framework for assisting with the design of DBCIs. A review of the literature on behaviour change literature has informed the development of the framework presented below in Figures 1, 2, and 3.

Figure 1 focuses on those behaviour change interventions that are found in the literature to be successful in *increasing the capacity of an individual for changing their behaviour towards some desired target behaviour*. The figure lists interventions focused on both physical and psychological capability building. Here the focus is initially on increasing the awareness of the issues caused by inappropriate behaviour (Precontemplation Stage) before building understanding of the behaviour change required to improve the situation (Contemplation Stage). Next focus moves to equipping the individual with the physical and cognitive skills to make the change and to build social support for the change (Preparation and Action Stages). Finally focus shifts towards providing just-in-time feedback on the performance in order to support decision making to maintain appropriate behaviour change (Action and Maintenance Stages).

Figure 1 –Capability Building for Behaviour Change

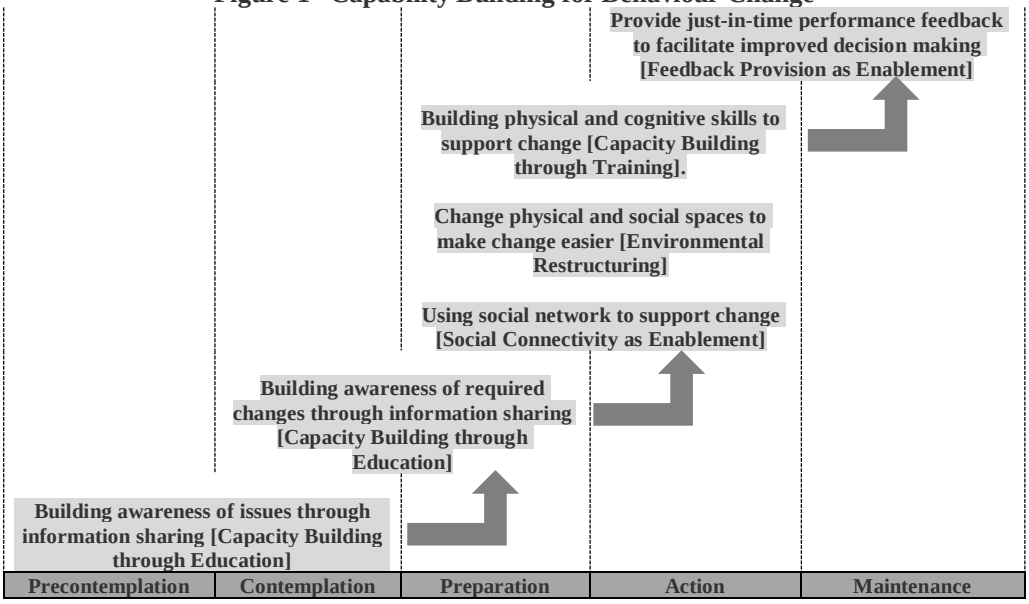


Figure 2 focuses on those behaviour change interventions that are found to be successful in *increasing the motivation of an individual to change their behaviour towards some desired target behaviour*. The figure lists interventions focused on both reflective and automatic motivation building. The focus is initially on increasing motivation through sharing information about the issues caused by inappropriate behaviour (Precontemplation Stage),

before building motivation through feeding back performance information about current behaviour (Contemplation Stage). Next focus moves to strengthening motivation through setting appropriate goals, offering examples of model behaviour, and comparing performance with that of oneself and others (Preparation and Action Stages). Finally focus shifts towards reducing the barriers to performing appropriate behaviours (Action and Maintenance Stages).

Figure 2 –Motivation Building for Behaviour Change

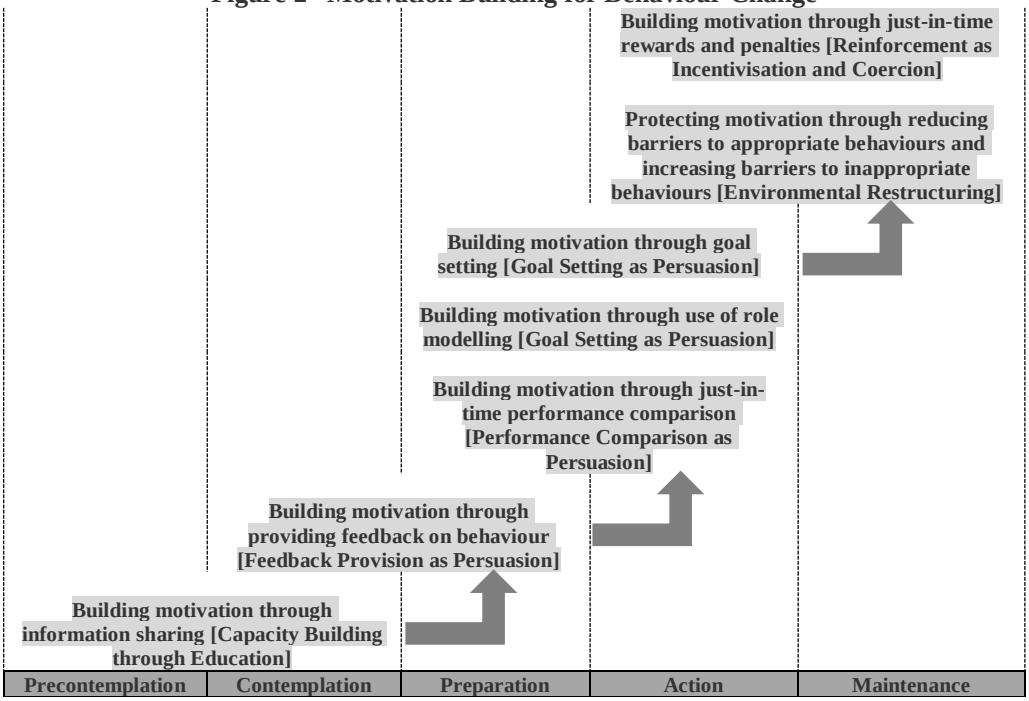
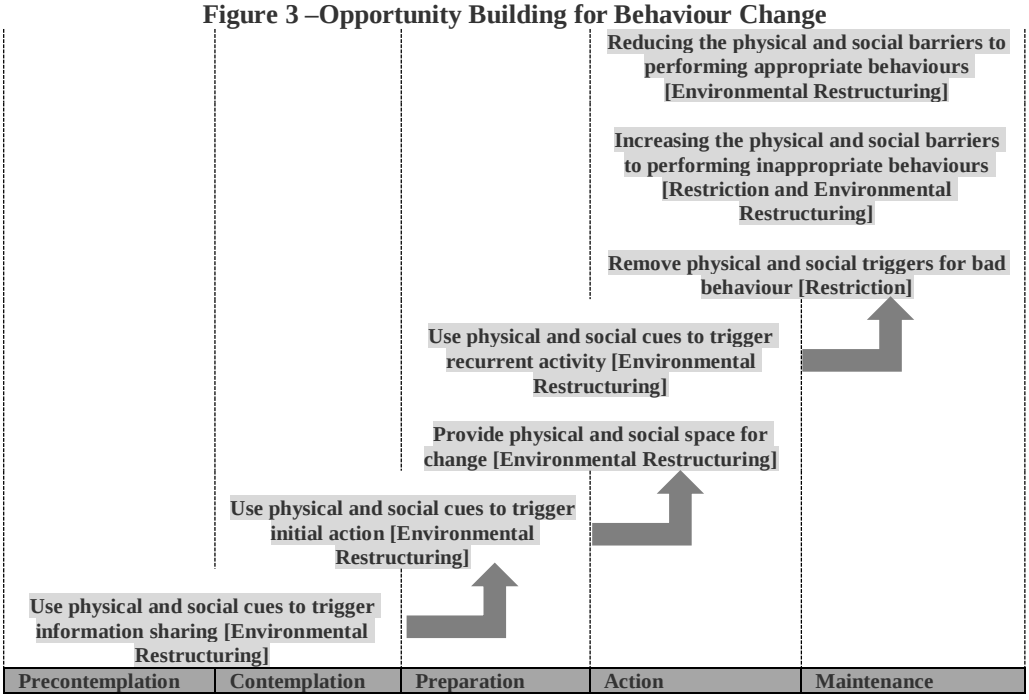


Figure 3 focuses on those behaviour change interventions that are found to be successful in *increasing the opportunities for an individual to change their behaviour towards some desired target behaviour*. The table lists interventions focused on both physical and social opportunity building.

Figure 3 –Opportunity Building for Behaviour Change



Here the focus is initially on using physical and social triggers to promote the sharing of information about the issues caused by inappropriate behaviour (Precontemplation Stage), before encouraging some early sporadic actions (Contemplation Stage). Next focus moves to providing the physical and social space in which recurrent actions can take place (Preparation and Action Stages). Finally, focus shifts towards reducing the barriers to maintaining and extending recurrent actions and increasing the barriers for inappropriate actions (Action and Maintenance Stages).

In the next section we evaluate the power of TFDD by examining how it could be used in analysing a case study of a previously designed digital wellness programme focused on increasing the exercise activity of a group of people with jobs of a sedentary nature. The purpose of the analysis is not to denigrate the design of the programme but to show how TFDD could be used to explain why some design features of the game did and did not work as planned. We posit that many of the issues encountered by the programme could have been pre-empted through the use of TFDD. In particular, TFDD could have assisted in improving the design of the programme by focusing explicitly on the use of specific techniques targeted at changing behaviour through capability building, motivation building, and opportunity building.

5. Case Study Analysis – Fish 'n' Steps

The Fish'n'Steps programme, as described by Lin, Mamykina, Lindtner, Delajoux, and Strub (2006), is a social computer game designed to encourage players to increase their daily physical activity. The programme is chosen mainly for the reason that it is well known and it is described effectively in a well cited academic paper. Detailed descriptions are, unfortunately, not the norm for papers describing DBCIs. The player's daily step count is measured using a pedometer and the number of steps taken each day is mapped to the growth, activity and emotional state of an animated fish 'belonging' to each player and displayed in a virtual fish tank. Progress toward the player's step count goal affects the growth of her fish (whereby the higher her step count, the larger the fish becomes) and the fish's facial expression (whereby the closer to her target step count, the happier the fish's facial expression). As further encouragement, some virtual fish tanks are visible in a common area of an office and include fish belonging to other players, thereby creating an environment of both cooperation and competition. Insufficient progress from the players may result in murky water and the removal of decorations from the virtual tank in which the fish swim.

To evaluate the programme, 19 players (11 females and 8 males, aged from 23 to 63) with jobs that did not require physical activity were recruited to participate in a 14-week study. The players were a relatively homogeneous group in terms of education (in that all had a graduate degree), working environment (in that all were staff of Siemens Corporate Research), and living environment (in that all were living in suburban New Jersey). However, there were large variations in their lifestyles and particularly in their attitudes towards physical exercise, with some players neither having nor wanting an exercise routine, and other players exercising regularly. The average daily step count collected during a pre-study reflected these differences, and ranged from 3,700 to over 11,000. After this pre-study, the players were encouraged to increase their daily step count to achieve a goal derived after taking their baselines (determined during the pre-study) into account.

In assessing the impact of the programme, it was found that the programme was a catalyst for a positive change for 14 out of the 19 players. This effect was evident in either an increase in their daily step count (for 4 players), a change in their attitudes towards physical activity (for 3 players) or a combination of the two (for 7 players). However, we found a number of limitations in the design of the programme that we believe restricted the positive behaviour changes of some individuals. Next we will discuss some of these main issues.

5.1 Appropriate Interventions for each Stage

The Fish'n'Steps study results shows how the performance of players varied depending on the stage of change that they occupied prior to their commencement on the programme. The programme was designed so that all players, regardless of their initial stage of behaviour change, were exposed to the same behaviour change techniques throughout the game. On the other hand, the TFDD posits that different interventions should have been used for each different stage of behaviour change. TFDD advocates that precontemplator and contemplator stagers should be targeted through education in order to create awareness of issues associated with their existing behaviour, build understanding of the required behaviour changes, and nurture their fragile motivation. There is little evidence that this took place in the game and indeed the results for precomtemplator and contemplator stagers were as a result disappointing. Prior to the game, the 4 pre-contemplator stagers had not established exercise routines, nor had they intended establishing them in the near future. Providing them with goals and with animated fish had little impact on their actual behaviour and indeed if anything may have had a negative impact. They were found to be less likely to engage with the game. They were further discouraged by the very visual negative appearance of their fish. One player stated that: "*The game and fish made me realize that I am walking so little. It made me conscious*" (p. 271). So while the game may have increased their awareness of their low levels of exercise, this newly gained awareness rarely led to any significant change in the level of their daily steps. They needed to achieve a significant shift in motivation *before* the goals (as they were implemented in the game design) could have had a positive impact. *As postulated by TFDD, the effectiveness of behaviour change techniques depends on the stage of behaviour change of an individual player.* For example, the use of motivation building techniques (see Figure 2), such as education, may have been a more effective strategy for moving the less motivated precontemplator and contemplator stagers forward.

5.2 Portfolio of Dynamic Interventions

In the game, preparation stagers, action stagers, and maintenance stagers demonstrated the highest level of engagement with the game. Players in these stages were already motivated to change their behaviour and indeed in many cases had already taken some sporadic actions (e.g. joining a gym, establishing an exercise routine, etc.) to change their behaviour. For these players the game provided enough motivation to translate mental readiness into physical action. The game design with its strong focus on goal setting, feedback, and comparison seems to have been well suited to the needs of these players and as a result they demonstrated the greatest change in their daily number of steps. For example, of the 6 preparation stagers, the game seems to have provided four of them with the kind of additional motivation that they needed and all of these players increased the number of steps to varying degrees (from 36 steps to over 5,000 steps daily). Even more importantly, many of them indicated their commitment to sustaining their increases after the game had finished. One player stated: "*The game had impact on my activity … I am walking everyday now; this game gave me more incentive to walk more each day, because I wanted to be competitive. I walked for about 45 minutes each day. I am at the point now where I will just walk anyways; I don't need the contest anymore. It motivated me to continue with this speed*" (p. 272). The other two players who did not demonstrate improvement attributed their lack of progress to their unusually heavy workload rather than any issue with the game per se. These findings are well aligned with TFDD, which posits the need for building motivation through goal setting, performance comparison, and triggering action using physical and social cues. However, these same behaviour change techniques may be inappropriate for those at different stages of change and on their own are unlikely to be sufficient for any one player. *As postulated by the TFDD, a portfolio of behaviour change techniques is required to dynamically match to the needs of an individual player.* For example, in addition to the use of goal setting, the game designers ought to have considered capability building (see Figure 1) and opportunity building (see Figure 3) techniques in the design of the game.

5.3 Appropriate Use of Rewarding and Penalising

Another insight of interest from the game is the need for appropriate rewarding and penalising. 14 out of the 19 players developed an emotional attachment to their animated fish and they mentioned feelings of guilt or happiness when their fish were sad or happy. For example, one player stated how: "*I was really happy when I saw my fish grow. I*

tried to motivate myself to walk more to make it grow. I have even increased my regular walking activities; when I saw that the fish had grown I felt very happy" (p. 273). Unfortunately, this emotional attachment could also backfire. A finding of particular interest is that some players chose not to look at their fish when their fish were not growing or were not happy. For example, one player stated: "*I didn't want to check on it, because I knew it was going to be sad*" (p. 274). Punishment seemed to result in at least some players avoiding the game rather than motivating them to reach their target behaviour. This caused the game designers to rethink their use of punishment in that *"… the game highlighted the importance of careful selection of incentives: unachievable or not challenging goals can fail to inspire the desired change"* (p. 263). While the animated fish was intended to provide positive reinforcement of appropriate behaviour and negative reinforcement of inappropriate behaviour, this did not always work as expected. While many players felt a level of responsibility towards their fish and tried to prevent it from being sad, some reduced their interactions with the game rather than observing a sad fish. In line with the Goal Setting Theory, TFDD advocates that individuals should be demonstrating signs of commitment and control before goals and rewards are used to reinforce their efforts. In the absence of commitment and appropriate task complexity, goals and rewards can have a negative impact. *TFDD advocates a mix of just-in-time behaviour change techniques matched to the disposition of the player towards change.* For example, role modelling could instead be used to instil in the player an image of a role model (demonstrating model behaviour) that they could aspire to.

5.4 Competition, Playfulness and Stickiness

The game was not intended as a sustainable intervention, but as a temporary means of assisting the players in advancing along the behaviour change stages towards greater levels of physical activity. Despite the initial excitement, the game was perceived by players as being increasingly repetitive. While 10 of the 19 players continued to have daily interactions, others limited their interactions to a few occasions a week. One player summed up the felling: *"It was exciting at the beginning but then it turned into a nuisance; you would forget to put [the pedometer] on, or you would forget to log [the steps counts] and stuff like that… I have to remember a lot of things during the day and that is on top of that…"* (p. 275). The initial interest in the game subsided after the first two weeks. Perhaps one limitation of TFDD is that it does not spell out the importance of creating a space that not only allows and supports the desired behaviour but does so in a fun and engaging manner that is sufficient to hold the attention of players. The gamification element of playfulness seems to be critical in this regard and is not explicit in TFDD.

Additional motivation was provided for players by placing some of them in a team situation that encouraged competition between members of a team and also between teams. Announcements were made of winning teams and also comparing the fish belonging to different members of the same team. The competitive aspect of the game elicited mixed reactions in the players. For some of them competitiveness was a more enduring motivation than the virtual fish. One player stated that *"… the fact that I was in the first place it's all I need; it means that I was competitive so the fish didn't have much of an effect"* (p. 274). But for a majority of players, having the fish of other players in the virtual tank presented both a stimulating challenge and a benchmarking mechanism. Another player stated: *"I was wondering who the other people behind the fishes were, the other fishes in my team were always crying, so I was wondering if my team members were working on it.", "...one fish in my team was really small the whole time, the others also got pretty big in the end. I was wondering, why the person with the small fish was not working"* (p. 274). However, it was found that the difference in performance between those who shared virtual tanks and those that did not, was not significant.

6. Conclusion

While there will always be 'Quantified Selfers', who are interested in tracking multiple aspects of their own fitness and wellbeing, these are the minority (Kvedar et al., 2015). Real socio-economic impact can only be achieved through focusing on those other people who may care about their health but who do not necessarily have the motivation or know-how as to what it takes to change their behaviours and to remain well. Putting new health technologies into the

hands of these individuals is unlikely to be enough unless they also enable them to change these behaviours. Joseph Kvedar MD (2015) suggests that: "*We need to put just as much effort into trying to break the code of human behaviour*" (p. 40) as we do into the design of these new technologies. However, this is not straightforward as many individuals do not find the promise of some far off healthier future enough of a reason to alter unhealthy day-to-day activities. It takes a good deal more to inspire them to change deep-rooted behaviours, even when they express their intent on turning their behaviour around and even when they understand their risk factors. Cugelman (2013) suggests that gamification can influence behaviour change, meaning gamification can make health interventions more engaging and in some cases more fun. In addition, we have seen how the likes of the Fish'n'Steps game (c.f. Lin et al., 2006) is claimed to demonstrate the value of games to foster long-term behavioural change.

There is a wide scale emergence of new apps, wearables, and devices that target behaviours to support health and wellness. Though great in numbers, the quality and evidence base for these are noticeably lacking. There is a lack of adherence to theory, evidence, and best practice (Patrick et al., 2016). Intervention designers are often faced by a bewildering range of behaviour change techniques that could be used, with no clear evidence on which to base the selection of particular combinations (Yardley, Morrison, Bradbury, & Muller, 2015). For example, elements of gamification on their own are unlikely to be sufficient to nudge behaviour change. There is a strong need for a more systematic theoretical foundation and evidence base supporting intervention design and particularly regarding which behaviour change techniques work and under which conditions (Peters et al., 2015). The theoretical framework offered in this paper offers a "theory-based" and "evidence-based" approach to incorporating behavioural science into digital behaviour change intervention (DBCI) development. To date, the potential of DBCIs has scarcely been realized, partly because of difficulties in generating an accumulating knowledge base for guiding design decisions (Murray et al., 2016). We hope and expect that this article goes some way towards addressing this gap and to opening up the enormous potential for DBCIs to deliver effective, economic, safe, and scalable interventions to improve health and wellness of individuals. We hope that the theoretically based framework will assist those designing digital health interventions in delivering greater and sustained health and wellness benefits by supporting individuals in maintaining long term behaviour change.

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References

Abraham, C., and Michie, S. 2008. "A Taxonomy of Behavior Change Techniques Used in Interventions," *Health psychology* (27:3), p. 379.

Barker, J. 2016. "Fitness: Activity Trackers – Essential Gear, or Gimmicks?" *Special to Montreal Gazette* Retrieved 20/02/2017, 2017, from http://montrealgazette.com/health/diet-fitness/fitness-activity-trackers-essential-gear-or-gimmicks

Bravata, D. M., Smith-Spangler, C., Sundaram, V., Gienger, A. L., Lin, N., Lewis, R., Stave, C. D., Olkin, I., and Sirard, J. R. 2007. "Using Pedometers to Increase Physical Activity and Improve Health: A Systematic Review," *Jama* (298:19), pp. 2296-2304.

Consolvo, S., McDonald, D. W., and Landay, J. A. 2009. "Theory-Driven Design Strategies for Technologies That Support Behavior Change in Everyday Life," *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*: ACM, pp. 405-414.

Cugelman, B. 2013. "Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers," *JMIR Serious Games* (1:1), p. e3.

Davies, P., Walker, A. E., and Grimshaw, J. M. 2010. "A Systematic Review of the Use of Theory in the Design of Guideline Dissemination and Implementation Strategies and Interpretation of the Results of Rigorous Evaluations," *Implementation science* (5:1), p. 14.

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., and Michie, S. 2015. "Theories of Behaviour and Behaviour Change across the Social and Behavioural Sciences: A Scoping Review," *Health Psychology Review* (9:3), pp. 323-344.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., and Dixon, D. 2011. "Gamification. Using Game-Design Elements in Non-Gaming Contexts," *CHI'11 Extended Abstracts on Human Factors in Computing Systems*: ACM, pp. 2425-2428.

Finkelstein, E. A., Haaland, B. A., Bilger, M., Sahasranaman, A., Sloan, R. A., Nang, E. E. K., and Evenson, K. R. 2016. "Effectiveness of Activity Trackers with and without Incentives to Increase Physical Activity (Trippa): A Randomised Controlled Trial," *The Lancet Diabetes & Endocrinology* (4:12), pp. 983-995.

Gartner. 2013. "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units by 2020." Retrieved 20/02/2017, 2017, from http://www.gartner.com/newsroom/id/2636073

Hamari, J., Koivisto, J., and Sarsa, H. 2014. "Does Gamification Work?--a Literature Review of Empirical Studies on Gamification," *System Sciences (HICSS), 2014 47th Hawaii International Conference on*: IEEE, pp. 3025-3034.

Hekler, E. B., Michie, S., Pavel, M., Rivera, D. E., Collins, L. M., Jimison, H. B., Garnett, C., Parral, S., and Spruijt-Metz, D. 2016. "Advancing Models and Theories for Digital Behavior Change Interventions," *American Journal of Preventive Medicine* (51:5), pp. 825-832.

Juntti, M. 2016. "Do Fitness Trackers Actually Help You Get Fit? What the Science Says." Retrieved 20/02/2017, 2017, from http://www.mensjournal.com/health-fitness/articles/do-fitness-trackers-actually-help-you-get-fit-what-the-science-says-w445205

Kvedar, J. C., Colman, C., and Cella, G. 2015. *The Internet of Healthy Things*. Boston (MA): Partners Connected Health.

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. B. 2006. "Fish'n'steps: Encouraging Physical Activity with an Interactive Computer Game," *International Conference on Ubiquitous Computing*: Springer, pp. 261-278.

Lister, C., West, J. H., Cannon, B., Sax, T., and Brodegard, D. 2014. "Just a Fad? Gamification in Health and Fitness Apps," *JMIR Serious Games* (2:2), p. e9.

Locke, E. A., and Latham, G. P. 1990. *A Theory of Goal Setting & Task Performance*. Prentice-Hall, Inc.

Michie, S., and Abraham, C. 2004. "Interventions to Change Health Behaviours: Evidence-Based or Evidence-Inspired?," *Psychology & Health* (19:1), pp. 29-49.

Michie, S., Johnston, M., Abraham, C., Lawton, R., Parker, D., and Walker, A. 2005. "Making Psychological Theory Useful for Implementing Evidence Based Practice: A Consensus Approach," *Quality and safety in health care* (14:1), pp. 26-33.

Michie, S., van Stralen, M. M., and West, R. 2011. "The Behaviour Change Wheel: A New Method for Characterising and Designing Behaviour Change Interventions," *Implementation science* (6:1), p. 42.

Murray, E., Hekler, E. B., Andersson, G., Collins, L. M., Doherty, A., Hollis, C., Rivera, D. E., West, R., and Wyatt, J. C. 2016. "Evaluating Digital Health Interventions: Key Questions and Approaches." Elsevier.

Painter, J. E., Borba, C. P., Hynes, M., Mays, D., and Glanz, K. 2008. "The Use of Theory in Health Behavior Research from 2000 to 2005: A Systematic Review," *Annals of Behavioral Medicine* (35:3), p. 358.

Patrick, K., Hekler, E. B., Estrin, D., Mohr, D. C., Riper, H., Crane, D., Godino, J., and Riley, W. T. 2016. "The Pace of Technologic Change: Implications for Digital Health Behavior Intervention Research." Elsevier.

Peters, G.-J. Y., de Bruin, M., and Crutzen, R. 2015. "Everything Should Be as Simple as Possible, but No Simpler: Towards a Protocol for Accumulating Evidence Regarding the Active Content of Health Behaviour Change Interventions," *Health Psychology Review* (9:1), pp. 1-14.

Prestwich, A., Sniehotta, F. F., Whittington, C., Dombrowski, S. U., Rogers, L., and Michie, S. 2014. "Does Theory Influence the Effectiveness of Health Behavior Interventions? Meta-Analysis." American Psychological Association.

Prochaska, J. O., and DiClemente, C. C. 1986. "Toward a Comprehensive Model of Change," in *Treating Addictive Behaviors*. Springer, pp. 3-27.

Prochaska, J. O., DiClemente, C. C., and Norcross, J. C. 1992. "In Search of How People Change: Applications to Addictive Behaviors," *American psychologist* (47:9), p. 1102.

PWC. 2016. "Megatrends - My Life Connected."

Terry, K. 2015. "Number of Health Apps Soars, but Use Does Not Always Follow." Retrieved 20/02/2017, 2017, from http://www.medscape.com/viewarticle/851226

Yardley, L., Choudhury, T., Patrick, K., and Michie, S. 2016. "Current Issues and Future Directions for Research into Digital Behavior Change Interventions," *Am J Prev Med* (51:5), pp. 814-815.

Yardley, L., Morrison, L., Bradbury, K., and Muller, I. 2015. "The Person-Based Approach to Intervention Development: Application to Digital Health-Related Behavior Change Interventions," *Journal of medical Internet research* (17:1), p. e30.

Author Biographies

Paidi O'Raghallaigh is an Innovation Research Fellow at the Science Foundation Ireland (SFI)-funded INFANT Research Centre at University College Cork (UCC), Ireland. He is on the global lecturing panel at the Irish Management Institute and is an adjunct innovation lecturer at UCC. Dr. O'Raghallaigh specializes in the areas of innovation and entrepreneurship and is a regular speaker at national events. He collaborates with local and global organizations by facilitating design thinking workshops and providing training for their teams. Previously, Dr. O'Raghallaigh was Director of Innovation & Research with a UK technology company. He was awarded a PhD for his contribution in the area of innovation models and innovation strategies. Dr. O'Raghallaigh has over 20 years' experience in planning, managing, and implementing a diverse range of innovation projects.

Frédéric Adam is a Professor in Business Information Systems in Cork University Business School (CUBS) at University College Cork (UCC), Ireland. He is also a Principal Investigator in two research centres, the INFANT research centre where he leads the Connected Health Stream and the Financial Services Innovation Centre (FSIC). His research interests include data analytics, decision making, decision support, and enterprise resource planning systems. Prof. Adam has authored and edited seven books and has more than 30 papers published in international journals, including the Journal of IT, Information and Management, Decision Support Systems, the Journal of Strategic Information Systems and the International Journal of Operations and Production Management. He is Chair of the Working Group 8.3 on DSS of the International Federation for Information Processing (IFIP). Prof. Adam holds a PhD from the National University of Ireland and a Habilitation qualification (Habilitation à Diriger des Recherches) from Université Paris VI (France).