An Ontology of Psychological Barriers to Support Behaviour Change

Yousef Alfaifi
Computer Science department,
Liverpool University, UK
Y.Alfaifi@liverpool.ac.uk

Floriana Grasso
Computer Science department,
Liverpool University, UK
Floriana@liverpool.ac.uk

Valentina Tamma
Computer Science department,
Liverpool University, UK
V.Tamma@liverpool.ac.uk

ABSTRACT

Helping people adopt and maintain healthier lifestyles is a primary goal of behaviour change interventions. Successful interventions need to account for different barriers (informational, environmental, or psychological) that prevent people from engaging in healthy behaviours. Computational approaches to modelling these interventions focus primarily on informational needs, or on persuasive techniques. The study presented in this paper is specifically aimed at creating a formal conceptual model of the *psychological* notion of *barriers* to healthy behaviour, by means of an *ontology*, i.e. an explicit and machine readable specification of a conceptualisation shared by all the stakeholders [34]. The model accounts for other related patient concepts to understand patient behaviour better. This machine-readable knowledge can function as a background to finding the right interventions for behaviour change. Whilst the model is generic and expandable to include other diseases and behaviours, our study uses *type 2 diabetes* to contextualise the problem of behaviour change.

KEYWORDS

Behaviour Ontology, Behaviour change Ontology, Physical Activity Behaviour, Type 2 Diabetes

ACM Reference Format:
Yousef Alfaifi, Floriana Grasso, and Valentina Tamma. 2018. An Ontology of Psychological Barriers to Support Behaviour Change. In *Proceedings of Eighth International Digital Health Conference (DH'18).* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/XXXXXX.XXXXXX

1 INTRODUCTION AND MOTIVATION

Comprehensive e-health interventions provide mechanisms that deal not only with the symptoms of a condition but also with the psychological health of the patient [24]. Behavioural medicine aims to provide interventions to address *unhealthy behaviour* through *behaviour change* [18, 19]. Watching TV instead of engaging in physical activity and eating unhealthy food on a daily basis are examples of unhealthy behaviour [19]. Interaction between individuals and contextual factors influence this behaviour [18], making interventions a complex psychological problem [19]. Matching these two levels (behaviour and behaviour change) requires organising the knowledge scientifically to enable data aggregation and result comparison across behavioural studies [9, 35]. In addition, the lack of shared terms and labels (including uncertain and mixed ones) is common across related studies, therefore making it difficult to devise a comprehensive framework to compare different approaches. In behavioural studies, the lack of shared labels and the uncertainty about the meaning of labels, and behavioural factors hinder the aggregation of knowledge based on these studies. Clearly, knowledge aggregation is an essential step in understanding and studying human behaviour [19].

Ontology is an explicit and machine readable specification of a conceptualization [34] that effectively supports knowledge sharing and aggregation. For example, the Gene Ontology[1] [10] derives from over 100,000 peer-reviewed scientific studies, which allows for integration of different data sources [19].

In the behavioural medicine field, early efforts sought to create ontologies (hierarchical taxonomies) for behaviour and behaviour change interventions, however not many have attempted to translate these conceptual models and shared vocabularies into machine readable ontologies. Where these ontologies are defined in terms of the entities used to label behavioural medicine phenomena, but more importantly the relationships existing between these entities. For example, a behaviour ontology taxonomy from the World Health Organization (WHO) classified some human behaviour (e.g. self-care) based on the International Classification of Functioning, Disability and Health (ICF) [27]. Modelling behaviour (e.g. via domain determining, controlled vocabularies) supports deciding the proper strategies for behaviour change [19, 21–23]. Thus, a preliminary version of a hierarchical taxonomy of *behaviour change techniques (BCTs)* was proposed by Michie and colleagues. BCTs include 93 techniques with clear and distinct labels, definitions and examples [21].

To contextualise the problem of behaviour change, we want to focus on a specific scenario and have thus selected physical activity behaviour for type 2 diabetes (T2D). Diabetes is one of the most prevalent diseases worldwide [4, 28]. More than 422 million patients suffer from diabetes [28], with T2D affecting at least 90% of diabetic patients [4]. T2D, also known as 'non-insulin-dependent' diabetes, happens when the body cannot use insulin effectively [4, 28]. This means the pancreas works properly to produce insulin, but the body's cells do not absorb it. Medications and healthy behaviour (e.g. regular physical activity) can help manage the disease [28]. Thus, promoting healthy behaviour to diabetic patients will help the body control blood sugar levels by stimulating muscles to use glucose without using insulin. Unfortunately, different

[1] http://geneontology.org/

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
DH'18, April 23–26, 2018, Lyon, France
© 2018 Association for Computing Machinery.
ACM ISBN 978-1-4503-6493-5/18/04…$15.00
https://doi.org/10.1145/XXXXXX.XXXXXX

barriers prevent patients from performing healthy physical activity. These barriers usually pertain to both diabetic patients and the general population. There are few attempts to classify barriers, which is an initial step to model the knowledge formally. These barriers include *psychological* [26] and *physical* barriers such as *environmental, health, social and personal* ones [31]. Psychological barriers can include, for example, a lack of knowledge and low self-efficacy [26]. In addition, physical barriers affect psychological barriers either partially or wholly [7, 32]. For instance, a health barrier, such as diabetes, can prevent a patient from performing some physical activities or priorities constituting a psychological barrier [7]. In another example, a lack of motivation or enjoyment (*psychological barriers*) can result from a lack of support or a partner (social barriers). This study focuses on *psychological barriers,* taking into consideration other related barriers in order to provide a comprehensive picture of the interactions existing between them. Our assumption is that psychological barriers prevent patients from progressing or transitioning from one stage to another (Section 3.3) in changing their physical activity behaviour. In other words, promoting healthy physical activity through behaviour change requires accounting for the barriers [3]. A review of the existing ontologies (e.g. BioPorta Ontologies[2]) and studies indicates there is no barrier ontology, or taxonomy, to import or reuse. Nevertheless, studies for more than a decade have highlighted the term *'barrier identification'* as crucial in interventions, especially for T2D [30].

This study is an extension of previous studies on barriers and their impact on behaviour and behaviour change, especially physical activity [2, 3]. This paper focuses more on modelling the psychosocial barriers yet also considers other related patient concepts to better understand the patient's physical activity behaviour. This conceptual modelling (ontology's machine-readable format) of behaviour supports the ability to computationally determine the most appropriate type of intervention to overcome these barriers.

The rest of this paper is organised as follows: Section 2 presents related studies and how this study differs from them. Section 3 discusses the conceptual model components of the patient's physical activity behaviour, including barrier modelling. Finally, Section 4 provides a brief conclusion and suggested future works.

2 RELATED STUDIES

Behavioural medicine and health professionals manage diseases through behaviour change interventions. Behaviour change includes regular physical activity, taking medications, healthy eating, etc. A better understanding of the patient's behaviour (e.g. physical activity) helps determine the proper behaviour change interventions [19, 21–23]. Different behavioural studies focus on interventions to stimulate healthy behaviours. Some of these studies are summarized below.

The argument approach, proposed by Hunter [17], is a framework to support a specific type of intervention (an argument) for behaviour change. This approach derives from computational persuasion or persuasion technology, which [14] defines as 'learning to automate behaviour change'. Some examples of these persuasion technologies are reminder messages and recording the user's ongoing behaviour. Persuasion technology not only positively influences argument intervention for behaviour change, but also allows users to explore their behaviour themselves. This argument-based persuasion technology supports a progression throughout the stage of change (Section 3.3).

Another study [19] is a cooperative work between behaviour medicine and information science experts. This study reviews the current efforts to create ontologies of behaviour and behaviour change. Our discussion of the ontology presents some of these efforts, such as BCTs [21] and the taxonomy of disability behaviour [27]. The study describes the efforts in this area that are in the early stages and still need much work.

Many different studies strive to model behaviour and behaviour change. The contribution of our study comes as we combine a new machine-readable format for physiological barriers that will enhance behaviour modelling (to understand the behaviour better) and help decide the best interventions for behaviour change.

3 CONCEPTUAL MODEL COMPONENTS

The integrated conceptual model of the patient's physical activity behaviour not only supports a better understanding of the behaviour but also helps a software application select the best intervention (e.g. feedback) to influence this behaviour. Thus, the behaviour model, which includes barrier modelling, links to the behaviour change intervention (e.g. BCTs [21]), based on a related study [22], via the barrier concept in two different directions (Figure 1). The behaviour model describes all informational needs, namely all concepts used to describe the patient's physical activity behaviour. Furthermore, the model specifies the relationships associating these concepts with their respective individuals. Therefore, we decided to subdivide the conceptual model into self-contained modules or theories that detail specific aspects of this context model (e.g. Section 3.3). This means we can further detail each concept represented as an individual module. For example, the patient concept extends to all attributes and features such as the patient's condition and diseases. Using the ontology development process [16, 25] helps create each of these modules. These processes or steps require the following tasks:
(i) determine the domain and scope of the ontology
(ii) enumerate important terms in the ontology
(iii) develop relations or hierarchical taxonomies among these concepts or terms, respectively
(iv) reuse existing ontologies as much as possible
(v) translate the conceptual model into the web ontology language (OWL), which could be a future work

This work aims to create the barrier concept (conceptual model) from scratch (Section 1). During this process, we will discuss all of these steps except the last step (codifying the model into OWL format), which is beyond the scope of this paper. Reusing existing flexible ontologies, instead of creating one from scratch, is a good practice and a powerful process in ontology development [16, 25]. General User Model Ontology (GUMO) is an one of the existing ontology that supports the modeling of the conceptual model [15]. GUMO derives from situational statements divided into three parts:

[2]BioPortal, http://bioportal.bioontology.org/ontologies/

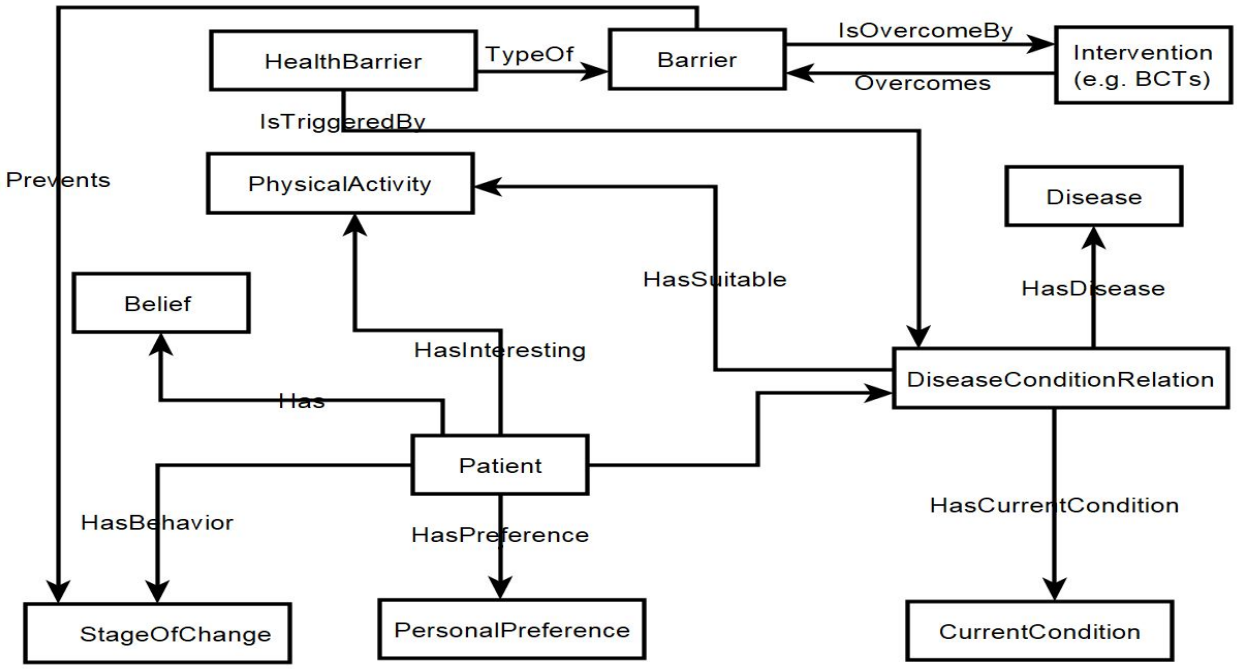

Figure 1: High-level model of the physical activity behaviour

auxiliary, predicate and range [12, 15]. For example, if a patient shows an interest in cycling, in GUMO, *'HasInteresting'* is the auxiliary, *'cycling'* is the predicate and *'low, medium, high'* is the range (probability). GUMO includes about 1000 groups of these components, such as *HasPreferences* and *HasBelief*, to support especially the modeling of the patient components (e.g *PersonalPreferences*). Figure 1 shows a high-level model of the physical activity behaviour. We will now describe the most important components of the behaviour model.

3.1 Barrier Component

One of the main goals of this study is to formalise the model of barriers and the underlying assumptions in a machine-readable format. As mentioned earlier (Section 1), there is no existing barrier ontology or hierarchical taxonomy to reuse or to extend. Therefore, and based on ontology development methodology [16, 25], we decided to create a barrier ontology from scratch as follows:

Steps 1 and 2 determine the scope and enumerate the vocabularies or terms, respectively, of the barriers domain. These two steps constitute 'acquired knowledge'. Our previous work discussed these in further detail [3]. Moreover, our hypothesis to capture the specified barriers based on their signs derives from research in [2].

Step 3 develops the hierarchical relationships among the barrier concepts. The type of hierarchical taxonomy among the concepts is *(SubClassOf)*. This step aims to classify the barriers into five categories: health, environmental, psychological, personal and social barriers (Figure 2). For example, we could represent an environmental barrier (e.g. a weather condition such as rain) in a hierarchical taxonomy as follows:

- *Barrier*
  - *Health*
  - *Psychological*
  - *Personal*
  - *Social*
  - *Environmental*
    - *HeavyTraffic*
    - *ClimaticCondition*
    - *DifficultParking*
    - *PoorAccess*
    - *LackOfSafety*
    - *LackOFFacility*
    - *EquipmentCost*
    - *WeatherCondition*
      - ***Raining***
      - *Cold*
      - *Hot*

Step 4 involves extending the domain to include related existing ontologies. Disease Ontology (DO)[3] is the only ontology reused in the barrier domain, but not in behaviour ontology. It includes 8,043 hierarchical relationships (`Is_A`) to identify the health barriers [33]. Figure 2 shows how the DO identifies T2D as a disease (health barrier), under the health barrier concept.

3.2 Patient Component

The patient profile is the central of the physical activity behaviour and relates to most concepts in the behaviour ontology (Figure 1). The patient concept identifies necessary information or properties

[3] http://disease-ontology.org

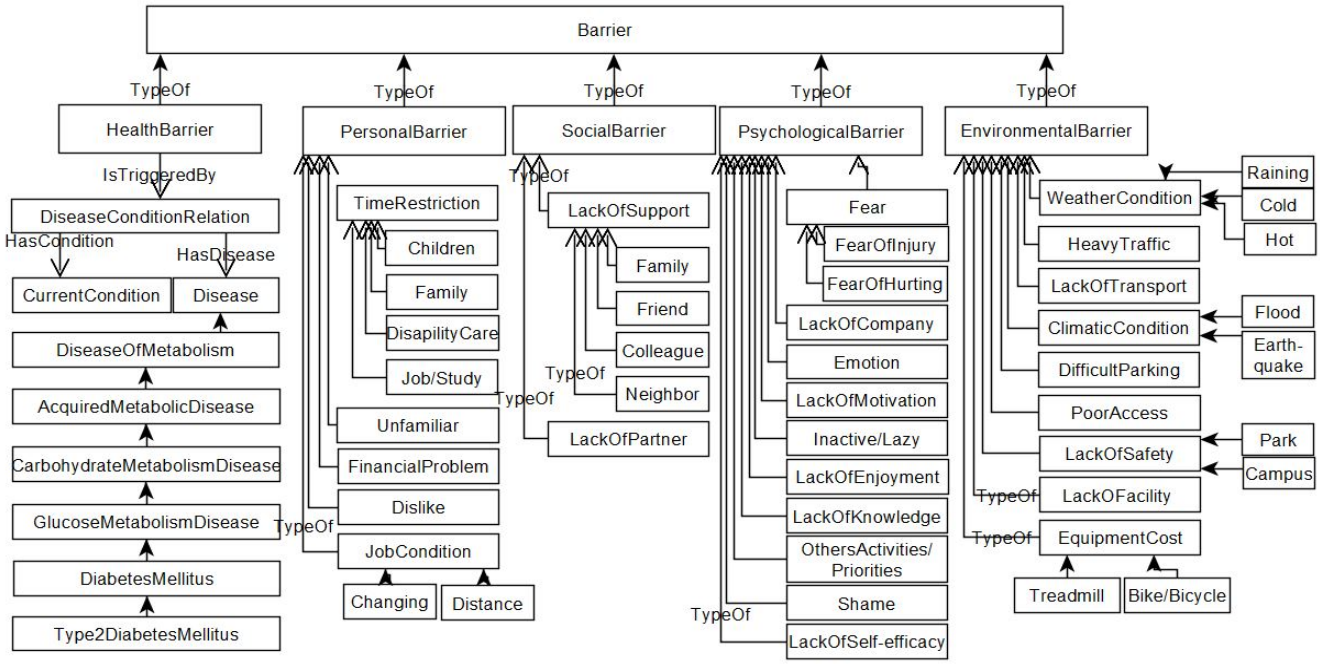

Figure 2: Barriers ontology's taxonomy (partial view)

about the patient such as patient ID, name and date of birth. In addition, this concept supports applying of GUMO (Section 3)

3.3 Stage of Change Component

The stage of change is an attitude of change in a specific behaviour or action [29]. This concept aims to determine the current patient's behaviour of physical activity [8]. Identifying the current patient behaviour helps to decide the best intervention techniques [21] to overcome this behaviour (e.g. walking activity). The stage of change [29] extends to include four properties: the `short-term activity level`, the `long-term activity level`, knowledge about intending to perform a physical activity (`Knowledge`) and the behaviour requiring change (`Goal`). Therefore, the patient will have one of the stage of change values: pre-contemplation, contemplation, preparation, action or maintenance [5, 11]. In addition, the stage of change is responsible for assessing the patient transition through these stages of change. Influencing patient behaviour (intervention) will take place stage by stage to avoid any negative reflections or risks. For example, patients with no intention of physical activity behaviour (the pre-contemplation stage) can take action towards intending to alter their behaviour within the next six months (the contemplation stage). So, the intervention does not mean to motivate a person who initially does not think about physical activity to go and run a marathon, for example.

3.4 Belief Component

This concept relates to the patient's beliefs, which have a high priority in the patient's life. The patient belief concept is useful in identifying the type of influence or emphasis that can affect intervention, especially in the argument technique [17]. Possible values of the belief concept include: health, work, social relations and self-efficacy [20]. The probabilities of these values are high, medium or low. Thus, the behaviour change strategies (e.g. argument) will focus primarily on beliefs with high probabilities.

3.5 Physical Activity Component

The physical activity concept includes different types of physical activities (e.g. athletic sports). The model reuses existing physical activity ontology[4] from Open BioPorta Ontologies.[5] The activity ontology extends to include some required properties such as the level of physical activity *(intensity)*, *frequency* and *place* (activity place) [1]. The intensity property helps link the barriers (e.g. the health barriers) to the type of activity. Therefore, the restricted values will be in the disease definition rather than the physical activity properties *(intensity)*. Similarly, an 'indoor' value of the 'place' property *(place=indoor)* can overcome environmental barriers (e.g. bad weather, an unsafe area or a lack of transportation). Thus, the value restriction is on the environmental barrier instead of the activity property *(place)*.

4 CONCLUSION AND FUTURE WORK

Managing and preventing disease complications via behaviour changes are the central goals of e-health and behavioural medicine.

[4]Physical activity ontology
[5]https://bioportal.bioontology.org

Engaging in regular physical activity is an important lifestyle modification. Psychological barriers can prevent patients from performing regular physical activity. A comprehensive conceptual model of patient physical activity behaviour, including barriers, supports selection of proper motivational interventions to promote behavioural changes in patients.

Some of the proposed works are as follows: i) convert barriers and behaviour models to the OWL, ii) build a computer-readable format of behaviour change to determine the right interventions (e.g. suggestion and argument) to overcome the physiological barriers and iii) extend the behaviour model to include other general medical user models, such as electronic health records (EHR) [13], or the Unified Medical Language System (UMLS) [6].

The model of behaviour and behaviour change focuses on physical activity behaviour for T2D. However, we can generalise or extend the general approach (and hence the basic structure of the ontology of barriers) to a number of conditions (e.g. asthma). In general, it also extends to all situations in which one seeks to model motivation and motivational advice, and therefore constitutes a contribution.

REFERENCES

[1] Barbara E Ainsworth, William L Haskell, Stephen D Herrmann, Nathanael Meckes, David R Bassett Jr, Catrine Tudor-Locke, Jennifer L Greer, Jesse Vezina, Melicia C Whitt-Glover, and Arthur S Leon. 2011. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine and science in sports and exercise* 43, 8 (2011), 1575–1581.

[2] Yousef Alfaifi, Floriana Grasso, and Valentina Tamma. 2016. Developing a Motivational System to Manage Physical Activity for Type 2 Diabetes. *Artificial Intelligence for Diabetes* (2016), 22.

[3] Yousef Alfaifi, Floriana Grasso, and Valentina Tamma. 2017. Towards an Ontology to Overcome Barriers to Physical Activity for Type 2 Diabetes. *Digital Health Conference, London* (2017).

[4] American Diabetes Association et al. 2016. Standards of medical care in diabetes-2016. *Diabetes care* 39, Supplement 1 (2016), S1–S112.

[5] Robert J Bensley, Nelda Mercer, Judith Anderson, Deanne Kelleher, John J Brusk, Ric Underhile, Jason Rivas, Melissa Lupella, and André C De Jager. 2004. The eHealth Behavior Management Model: a stage-based approach to behavior change and management. *Preventing chronic disease* 1, 4 (2004).

[6] Olivier Bodenreider. 2004. The unified medical language system (UMLS): integrating biomedical terminology. *Nucleic acids research* 32, suppl 1 (2004), D267–D270.

[7] Laurien M Buffart, Tessa Westendorp, Rita J Van Den Berg-Emons, Henk J Stam, and Marij E Roebroeck. 2009. Perceived barriers to and facilitators of physical activity in young adults with childhood-onset physical disabilities. *Journal of Rehabilitation Medicine* 41, 11 (2009), 881–885.

[8] Kim Buxton, Jon Wyse, and Tom Mercer. 1996. How applicable is the stages of change model to exercise behaviour? A review. *Health Education Journal* 55, 2 (1996), 239–257.

[9] Bruce F Chorpita, Mary Jane Rotheram-Borus, Eric L Daleiden, Adam Bernstein, Taya Cromley, Dallas Swendeman, and Jennifer Regan. 2011. The old solutions are the new problem: How do we better use what we already know about reducing the Burden of mental illness? *Perspectives on Psychological Science* 6, 5 (2011), 493–497.

[10] Gene Ontology Consortium et al. 2015. Gene ontology consortium: going forward. *Nucleic acids research* 43, D1 (2015), D1049–D1056.

[11] Eva del Hoyo-Barbolla, Rita Kukafka, María Teresa Arredondo, and Marta Ortega. 2006. A new perspective in the promotion of e-health. *Studies in health technology and informatics* 124 (2006), 404.

[12] Elisabetta Erriquez and Floriana Grasso. 2008. Generation of personalised advisory messages: an ontology based approach. In *Computer-Based Medical Systems, 2008. CBMS'08. 21st IEEE International Symposium on*. IEEE, 437–442.

[13] Paul A Estabrooks, Maureen Boyle, Karen M Emmons, Russell E Glasgow, Bradford W Hesse, Robert M Kaplan, Alexander H Krist, Richard P Moser, and Martina V Taylor. 2012. Harmonized patient-reported data elements in the electronic health record: supporting meaningful use by primary care action on health behaviors and key psychosocial factors. *Journal of the American Medical Informatics Association* 19, 4 (2012), 575–582.

[14] Brian J Fogg. 2009. A behavior model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology*. ACM, 40.

[15] Dominik Heckmann, Tim Schwartz, Boris Brandherm, Michael Schmitz, and Margeritta von Wilamowitz-Moellendorff. 2005. GUMO-the general user model ontology. *Lecture notes in computer science* 3538 (2005), 428.

[16] Matthew Horridge, Simon Jupp, Georgina Moulton, Alan Rector, Robert Stevens, and Chris Wroe. 2009. A practical guide to building owl ontologies using protégé 4 and co-ode tools edition1. 2. *The University of Manchester* 107 (2009).

[17] Anthony Hunter. [n. d.]. Towards a framework for computational persuasion with applications in behaviour change. *Argument & Computation* Preprint ([n. d.]), 1–26.

[18] Steven H Kelder, Deanna Hoelscher, and Cheryl L Perry. 2015. How individuals, environments, and health behaviors interact. *Health behavior: Theory, research, and practice* 159 (2015).

[19] Kai R Larsen, Susan Michie, Eric B Hekler, Bryan Gibson, Donna Spruijt-Metz, David Ahern, Heather Cole-Lewis, Rebecca J Bartlett Ellis, Bradford Hesse, Richard P Moser, et al. 2017. Behavior change interventions: the potential of ontologies for advancing science and practice. *Journal of behavioral medicine* 40, 1 (2017), 6–22.

[20] Ling-Ling Lee, Antony Arthur, and Mark Avis. 2008. Using self-efficacy theory to develop interventions that help older people overcome psychological barriers to physical activity: a discussion paper. *International journal of nursing studies* 45, 11 (2008), 1690–1699.

[21] Susan Michie, Stefanie Ashford, Falko F Sniehotta, Stephan U Dombrowski, Alex Bishop, and David P French. 2011. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & health* 26, 11 (2011), 1479–1498.

[22] S Michie and R West. 2016. A guide to development and evaluation of digital behaviour change interventions in healthcare. *London: UCL Centre for Behaviour Change* (2016).

[23] Susan Michie, Caroline E Wood, Marie Johnston, Charles Abraham, Jill Francis, and Wendy Hardeman. 2015. Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). *Health Technology Assessment* 19, 99 (2015).

[24] David C Mohr, Stephen M Schueller, Enid Montague, Michelle Nicole Burns, and Parisa Rashidi. 2014. The behavioral intervention technology model: an integrated conceptual and technological framework for eHealth and mHealth interventions. *Journal of medical Internet research* 16, 6 (2014).

[25] Natalya F Noy, Deborah L McGuinness, et al. 2001. Ontology development 101: A guide to creating your first ontology. (2001).

[26] James M Olson. 1992. Psychological Barriers to Behavior Change: How to indentify the barriers that inhibit change. *Canadian Family Physician* 38 (1992), 309.

[27] World Health Organization et al. 2013. How to use the ICF: A practical manual for using the International Classification of Functioning, Disability and Health (ICF). *Exposure draft for comment. Geneva: WHO* (2013), 5.

[28] World Health Organization et al. 2016. Global Report on Diabetes. Geneva: World Health Organization; 2016. (2016).

[29] James O Prochaska and Wayne F Velicer. 1997. The transtheoretical model of health behavior change. *American journal of health promotion* 12, 1 (1997), 38–48.

[30] Caroline R Richardson, Kathleen S Mehari, Laura G McIntyre, Adrienne W Janney, Laurie A Fortlage, Ananda Sen, Victor J Strecher, and John D Piette. 2007. A randomized trial comparing structured and lifestyle goals in an internet-mediated walking program for people with type 2 diabetes. *International Journal of Behavioral Nutrition and Physical Activity* 4, 1 (2007), 59.

[31] Jo Salmon, Neville Owen, David Crawford, Adrian Bauman, and James F Sallis. 2003. Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference. *Health psychology* 22, 2 (2003), 178.

[32] Bonnie Sanderson, MaryAnn Littleton, and Lea Vonne Pulley. 2002. Environmental, policy, and cultural factors related to physical activity among rural, African American women. *Women & health* 36, 2 (2002), 73–88.

[33] Lynn Marie Schriml, Cesar Arze, Suvarna Nadendla, Yu-Wei Wayne Chang, Mark Mazaitis, Victor Felix, Gang Feng, and Warren Alden Kibbe. 2011. Disease Ontology: a backbone for disease semantic integration. *Nucleic acids research* 40, D1 (2011), D940–D946.

[34] R. Studer, V.R. Benjamins, and D. Fensel. 1998. Knowledge engineering, principles and methods. *Data and Knowledge Engineering* 25, 1-2 (1998), 161–197.

[35] John R Weisz, Mei Yi Ng, and Sarah Kate Bearman. 2014. Odd couple? Reenvisioning the relation between science and practice in the dissemination-implementation era. *Clinical Psychological Science* 2, 1 (2014), 58–74.