Table 1: Several classification of barriers to physical activity based on specialised studies [2, 4, 5, 7, 10, 11, 16, 17, 21, 25, 27–29]

	Health	Physical	Mental	Personal	Psychological	Logistical	Social	Environmental
Hypoglycemic [27, 28]	X [3, 17]				X [17, 28]			
Overweight/Obesity [21, 27]	X [17]	X [5, 17]						
Other disease [2, 21, 27]	X [7]	X [7]						
Time restriction [2, 10, 11, 16, 17, 17]				X [25]	X [2, 7, 29]	X [17, 28]		
Fear of hurting or injury [17, 20]		X [4]	X [4]		[2, 7]			
Lack of social support [2, 10]							X [2, 10, 17]	
Lack of safety [4, 12, 17, 29]								X [4, 17, 29]
Poor physical/health condition	X [7, 17]							
Lack of facilities (sidewalks) [4, 25]								X [7, 18, 28, 29]
Transport difficulties [5, 10]								X [10]
Changing jobs [5]				X [5]				
Financial problems [7, 28]				X [18]		X [17]		
Pain [10]	X [17]	X [4]	X [4]					
Decreased endurance and balance [4]		X [4]	X [4]					
Lack of company or partner [28]					X [7, 29]		X [5, 7]	
Dislike or unfamiliar [4]			X [4]	X [4]				
Emotion [5]					X [5, 11, 29]			
Feel depressed [28]			X [4]		X [5, 28]			
Lack of fitness or energy [2]	X [2]	X [2]						
Bad weather [2, 10, 17, 28]								X [4, 29]
Lack of motivation [5, 7, 12, 20]					X [2, 7, 29]			
Poor access [7, 10]								X [17, 25, 28]
Inactive or lazy [21]					X [5, 5]			
Others activities/priorities [2, 25, 28]				X [4]	X [2]			
Heavy traffic or Difficult parking [28]								X [4, 25, 29]
Climatic conditions [7]								X [16, 29]
Lack of enjoyment [17, 25, 28]					X [29]			
Poor body image [5, 17]		X [17]			X [5, 29]			
Health problems [10, 11, 17, 20]	X [7, 10]	X [7]			X [7]			
Cost of equipments [7, 17, 20, 28]								X [17, 25, 29]
Lack of self-efficacy [17]					X [29]			X [17]
Tired [25, 28]		X [29]						
Lack of family support [2, 11, 20]							X [29]	
Fear and shame [16, 17]					X [16, 17]			

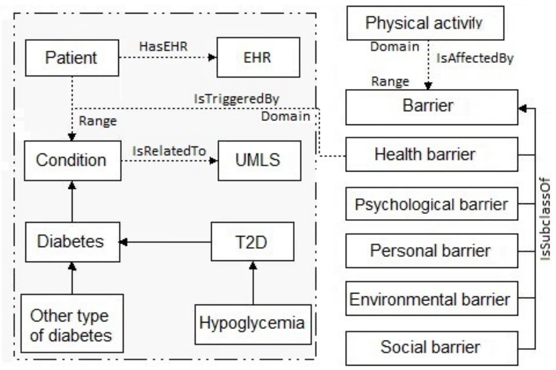

Figure 1: Framework for Barriers Classification

the backbone of the model. Its goal is to classify the barriers based on their signs or factors. It includes five main barriers: health or physical, personal, psychological or mental, social, and environmental barriers. The barrier's category links to the patient's condition (class) via the "IsTriggeredBy" property. The condition's class aims to capture the health barriers from different health domains. It links to three subcategories: diabetes, patient and biomedical ontology. The diabetes subclass aims to identify the barriers in the diabetic domain, such as the hypoglycaemia or brittleness barriers. The patient subcategory will import the medical record ontology, such as electronic health records (EHR).

The approach of Al Rector and other authors [24] suggests mapping the EHR information and corresponding links. In addition, the patient's class aims to link the EHR data with the condition's class via the "HasCondition" link. Clearly, the patient's condition determines the health barriers, not the patient. Consequently, the patient's class is outside of the scope of this paper.

The patient's condition also connects with biomedical ontology such as UMLS via the "IsRelatedTo" property. This provides mapping to various vocabularies and terminology systems. The shaded square on the diagram's left represents importing health barriers from several health domains, as mentioned above. The physical activity domain aims to model the patient's desired behaviour with specific physical activity. Furthermore, it determines the barrier's effect on physical activity. Thus, we contend that conditions such as diabetes (hypoglycaemia) or other health diseases affect the performance of regular physical activity, such as walking or jogging (Fig 1). The "IsAffectedBy" property shows the relationship between a barrier's class and the condition's class. The arrow's direction (the dotted arrow) remains a conflicting relationship because the behaviour establishes the condition, yet the condition also affects it.

4 RELATED WORK

A number of studies have explored managing diabetes through lifestyle changes. Ontology models is example of these developmental studies. Studies on physical activity are very rare compared with those addressing other types of lifestyle changes such as health and nutrition. This means the ontology field for physical activity still needs further research. Clearly, physical activity studies should include the barriers, recommendations and other elements. The paragraphs below summarise some of the related studies.

The authors in [23] develop an ontology based on a recommended system to manage diets for diabetic patients. The ontology can generate a diabetic nutrition plan based on patient conditions.

The authors classify food using 20 nutrients as attributes. Carbohydrates, energy, fat, protein and vitamins E and C are examples of these categories. The results of the system show improved accuracy and performance to produce a recommended diet plan for patients with diabetes.

Similarly, the authors in [8] create a food ontology as part of the PIPS (Personalised Information Platform for Health and Life Services) project. The system is able to determine the type and amount of nutrients, and the daily requirements of the suggested diet plan. The authors use the "Ontology 101 development process" by Noy and McGuiness [19] to develop this food ontology. The food ontology includes 177 classes, 53 properties and 632 instances.

The authors in [22] present a recommended exercise system based on ontology. The main goal of the system is to classify the diabetic patient's conditions and then produce a suitable physical activity for the patient. The system determines the physical activity based on the patient's medical evaluations. These evaluations include age, daily activities, food intakes and other factors. The resulting advice involves the intensity, frequency and duration for the suggested physical activity. The system's knowledge bases come from the American Diabetes Association (ADA).

5 DEVELOPMENT OF THE ONTOLOGY

A number of methodologies can help develop an ontology from scratch [13, 19, 30]. The "Ontology Development 101" paper by Noy and McGuinness will serve to develop the proposed ontology in the future. It is the most appropriate methodology for the suggested model because it provides a logical and clear sequence that enables a non-expert to understand it. The main barriers in the proposed model will be concepts (classes) in the ontology. The categories of barriers, such as lack of time and windy weather, will become a subclasses or properties, respectively, in the ontology. Existing medical ontologies such as UMLS and EHR could link with the suggested ontology by importing health barriers. A new extended ontology (physical activity) would serve to give a list of suggested exercises to patients. Naturally, this advice will draw from other related classes such as the class of barrier and also the patient's current health condition. The relationships between the classes, such as the "IsTriggeredBy" property, play a role in developing the ontology.

6 CONCLUSION AND FUTURE WORK

Managing and preventing complications of T2D by lifestyle changes poses a problem not only for individual patients but also for health providers. Physical activity is one type of lifestyle modification. Diabetic patients often understand the value of physical activity to manage the disease, but barriers prevent them from performing physical activity. Filtering several terms and classifications of the barriers from related studies will lead to a deeper understanding of the barriers. After that, establishing uniform vocabularies and categories will result from recognising the actual barriers rather than perceived barriers. Fixed domains, scopes, detected barriers, sub-barriers and the relationships among them will all lead to a model to enhance the ontology in the future. Importing other medical ontologies, such as UMLS and EHR, can increase both the value and reliability of the future ontology.

Developing the main proposed ontology (pertaining to barriers) would be the next step. Understanding the UMLS and EHR data will help create links with the main ontology. In addition, designing a model of physical activity behaviour could be the starting point to expand this ontology in the future. Consequently, translating the ontology in this study from one form to an exportable form would not be difficult. This would allow moving from one ontology to another. Assessment methods, samples of diabetic patients, or both methods can help evaluate the proposed ontology.

Whilst the model is focussed on T2D, the general approach, and hence the basic structure of the ontology of barriers, can be generalised to a number of conditions, and in general to all situations in which one seeks to model motivation and motivational advice, and therefore constitutes a contribution to the general field of persuasive technology, argumentation, and adaptive system modelling.

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