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Ontology Supported Assistive Communications in Healthcare

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Abstract:

This article presents progress with a conceptual framework for providing interactive healthcare guidance to help Aboriginal and ethnic minority patients disadvantaged by inter-cultural biopsychosocial barriers present in medical consultations. Using computer ontology development and semantic Web principles, an assistive communications technology (ACT) concept is proposed for primary care consultation process that we have titled the Patient-Practitioner Interview Encounter (PPIE) in primary care. Activity is devoted to the development of Patient Practitioner Assistive Communications (PPAC) ontology for type 2 diabetes, and we present a simple case study projection to show its application. In the PPAC ontology, concepts of type 2 diabetes will be mapped with Aboriginal English Home Talk through ontology relations and constraints. Aboriginal English PPIE pragmatics comprises a voluminous and multilevel combination of structured and unstructured data, and this is also mapped to the Royal Australian College of General Practitioners (RACGP) T2DM Guidelines for management of type 2 diabetes. In addition to patients and primary-care practitioners, eventual end-users may include allied health professionals, family, and other carers, qualified and ad hoc interpreters. The ultimate goal from the contribution of all participants is improved wellbeing outcomes for patients. A range of technologies augmenting communication with patients, mostly in conceptual or prototype trial form have been viewed as potential for alignment with our concept.

Keywords: ontologies, type-2 diabetes management, assistive communication

Editor's Note: The article was handled by the Department Editor for Information Systems and Healthcare.

I. INTRODUCTION

This research describes efforts to build a conceptual framework with the ultimate aim of providing navigable interactive health care guidance to assist people such as Aboriginal and ethnic minorities disadvantaged by the inter-cultural psychosocial barriers that are present in medical consultations. Principally, this is based on an Assistive Communications Technology (ACT) concept that envelops and centres on the Patient–Practitioner Interview Encounter (PPIE) in primary care.

Assistive technology (AT) has been defined in the recent past and in regulatory descriptions as a tool intended to help people with disabilities. However, the pace of advancement in information and communications technology (ICT) together with imaginative mass societal uptake has quickly transformed the pragmatic application of assistive technologies into a more ubiquitous presence. Computer magazine articles point to AT growth in the education market and to leading software companies such as Microsoft and Apple to embed assistive technologies in their products [Lamb, 2008]. Mina Nagy [n.d.], commenting on e-health programs, writes that AT offers us a new lifestyle, that our view of 'disabled' is misleading, and that AT should be seen from a broader 'enabling' perspective. Vanderheiden [1998] perceptively tells us that the best situation would arise if AT is designed into all products so that regardless of abilities or disabilities, all people will benefit. This research utilises assistive communications technology (ACT) as a contemporary description in which 'disadvantaged' ultimately replaces 'disabled'.

Assistive communications technology is identified conceptually as the tool that will strengthen the cognitive pragmatic ability of Australia's Aboriginal type 2 diabetes mellitus (T2DM) patients to self-manage the demands of this chronic disease and its associated care complexities. The biopsychosocial model introduced by Engel [1978] brought recognition to a patient–practitioner engagement barrier. He proposed that a scientific and technical bias in clinician education leads to a lack of appreciation of the value of patient behavioural, psychological, and social factors. In Western Australia, profound demographic and logistical challenges for health service delivery commonly compound these disadvantages [Phillips, 2009]. Responses to these challenges has brought new difficulties, as overseas-trained doctors (OTDs) are often inadequately prepared for the acculturative impact of engagement with rural and remote communities [Muecke, Lenthall, and Lindeman, 2011], and even locally trained graduates may experience culture shock [Taylor, 2010].

A broad range of ambitious technological approaches for augmenting communication with patients exist, mostly in conceptual or prototype trial form. The MedSLT speech-to-speech translation platform was developed for use by physicians to treat patients regardless of the language used by the patient [Bouillon, Rayner, Chatzichrisafis, Santaholma, Starlander, et al., 2005]. While speech recognition is easier to use, the accuracy of such systems vary between 30 percent to 50 percent, making it inappropriate for use in a clinical setting. Approaches using social media is highly dynamic and presents society with experiences, opportunities, and end-user preferences that affect healthcare communications, for example, as peer-to-peer support [Fox, 2011]. But these market force developments are so volatile as to elude meaningful early term impact and trend analysis. The predominant mode of smart-phone communication continues to evolve [Bedno and Vicsik, 2012]. Presently, for example, it relies mostly upon unstructured, impromptu voice and text exchange, albeit with elaborative audiovisual and Web access options. Purposeful and reliable bi-directional knowledge transfer systems of communication aimed at improved wellbeing outcomes are very limited. Our observations of PPIE communications issues include work with an Aboriginal focus group, interactions with members of the Aboriginal healthcare community, and critical review of a substantial literature of comprehensively constructed educational studies into Aboriginal English [O'Brien and Plooij, 1973; Malcolm, 1995; Malcolm, Haig, Königsberg, Rochecouste, Collard, Hill, and Cahill, 1999; Cahill, 1998; Eades, 2000; Cahill, 2000; Western Australia Education Department, 2002; Eades, 1991, 1993; Sharifian, Rochecouste, Malcolm, Konigsberg, and Collard, 2004; Sharifian, Truscott, Konigsberg, Malcolm, and Collard, 2012; Department of Education and Department of Training and Workplace Development, 2012]. From this and from study of those broader societal Web-based accessibility trend indicators, we conclude that (a) disadvantages affecting Aboriginal and ethnic minority communications in healthcare are likely to be exacerbated as the 'digital divide' of accessibility to interactive information sources widens, and, therefore, (b) investment in building taxonomic and relational data servicing pragmatic communications systems is a priority.

This can be achieved by beginning a process of ontological organization of Aboriginal English pragmatics dwelling initially on a specific domain, with type 2 diabetes mellitus (T2DM) presenting an important disease with serious consequences and increasing prevalence suitable for such an effort. Tom Gruber [1993], referencing artificial

intelligence, defined ontology as 'an explicit specification of a conceptualization'. He also defined conceptualization as 'an abstract, simplified view of the world that we wish to represent for some purpose'. The term 'ontology' originates from philosophy, specifically the study of being or existence in basic category terms. Consequently, it is used to refer to what exists in a system model. In computer science, ontology is the effort to formulate an exhaustive and rigorous conceptual schema within a given domain, typically a hierarchical data structure containing all the relevant concepts and relationships between those concepts. The need to explicitly represent and share increasingly complex information in electronic form has led to the creation of OWL 2 Web Ontology Language, informally named OWL 2. This serves the Semantic Web through formally defined meaning in ontologies, documenting classes, properties, individuals, and data values. OWL 2 ontologies are primarily exchanged as Resource Description Framework **(**RDF**)** documents. The RDF is a family of World Wide Web Consortium (W3C) specifications based on a simple data model originating from a metadata system design.

Writing about the key strategies of semantic technologies, Cregan [2008] observes that if both structured and unstructured data can be directly linked in electronic form using a unique identifier, semantic technologies can work with them. Aboriginal English PPIE pragmatics comprises a voluminous and multilevel combination of structured and unstructured data. Noting that until quite recently information processing has been primarily at a syntactic or symbol processing level, Cregan leads her discussion into the promise of semantic technologies in using logical languages to provide explicit structure and meaning to data. Searching, querying, and reasoning across interoperable ontologies could, for example, lead to automation of the assistive communications process.

The aim for this work is to enable mapping of accurate information interpretation and explanatory annotations for the different cultural participants in the T2DM PPIE with sufficient flexibility to stimulate the transfer of valuable knowledge through bi-directional interaction, described by the term 'equitability'.

The hypothetical nature of the usage scenario described in this article reflects the challenge that this work is intended to meet, i.e., the absence of a comprehensive documented Aboriginal English (AE) lexicon for the many variables of healthcare service interactions. However, we have worked to illustrate this complexity and to illuminate the approach, the worth, and the objectives of the continued scientific search for and capture of AE pragmatic healthcare expressivity concept data. Moreover included in scenario examples is the reference in context to focus group output showing that at this juncture our understanding of AE usage and thereby conceptualisation is soundly based.

The choice of domain is justified by the urgency associated with the increasing rates of type 2 diabetes and the serious complications associated with the disease, affecting many body organs and the disproportionate incidence of T2DM and consequential morbidity and premature mortality in the Aboriginal community. Between 1999 and 2003, for persons aged thirty-five to fifty-four years, the age-standardised death rates from diabetes for Indigenous males were twenty-one times greater than for non-Indigenous males and thirty-seven times greater for Indigenous females than for non-Indigenous females [Australia's Health, 2012]. In 2004–2005, 6.3 percent (29,874) of Indigenous Australians had diabetes, three times as common among Indigenous Australians as in non-Indigenous Australians. Indigenous Australians were seven times more likely to have diabetes recorded on their death certificate for the period 2003–2007 [Australia's Health, 2012]. The clinical validity of the T2DM ontology is based upon the Royal Australian College of General Practitioners (RACGP) Guidelines for management of type 2 diabetes [Harris, Mann, Phillips, Bolger-Harris, and Webster, 2011].

II. LITERATURE REVIEW

Earlier work has discussed the characteristics of T2DM and the substantial contribution to the poor health of the Aboriginal population of Western Australia (WA) [Forbes, Sidhu, and Singh, 2010]. High rates of hospitalisation and bed days place demands upon an over-stretched healthcare system and the providers who staff it; multiple co-morbidities require the involvement of multiple subspecialties, fracturing the desirable one-on-one provider–patient relationship and along with many other elements amounts to what is termed 'the cultural disconnect'. Cultural disconnect potentially leads to 'inadequate information exchange, zero information exchange, potential but unqualifiable relevance/irrelevance in the exchange, misinformation, misinterpretation, and misunderstanding during patient–practitioner encounters' [Trudgen, 2000]. We categorise the literature into two groups—Assistive Communication and Type-2 Diabetes Management—for an understanding of previous work done in these domains.

Assistive Communication in Healthcare

The work to be described has been aided by pioneering research source material published by Western Australian (WA) educationalists and academic teams whose members include people from the Nyungar community, the original landowners and inhabitants of the southwest of Australia. Nyungar and other Aboriginal people code-switch among dialectal forms of conversation and personal interaction so as to contextually suit individual and often very

different cultural encounter circumstance. Our earlier work supported the prevailing perception in the literature that there is a dominant unidirectional clinician-biased form of communication. Our intention here is to promote a bi-directional patient empowerment model. We have previously emphasized 'the need to recognize that technology must go beyond technical capability to promote and augment productive PPIE relationships' [Forbes et al., 2011].

At that time, we were working on two ontologies, one named 'Community Healthcare', which was mapped to the second, named 'Aboriginal English'. Since then, further work has narrowed and enhanced the scope to provide a sharper focus on ontology contributions to ensure they will efficiently integrate with and into emerging and evolving assistive technology devices and applications, including interoperable Web-based systems.

Discussing lexical knowledge, Hirst [2003], in contemplating a domain-specific lexicon, initially states that words of interest are usually 'open-class or content words such as nouns, verbs and adjectives, rather than closed-class or grammatical function words such as articles, pronouns, and prepositions'. Yet he acknowledges that a lexicon is more than a vocabulary, providing some guidance on how a word is used and that it may include multi-word phrases and other common expressions. This is pertinent to ontological formulation of Aboriginal English. In the pragmatic communications assistive role, Aboriginal English will include and apply a form of grammatical functionality through constructs that are different from Standard Australian English and can defy understanding by non-Aboriginal English speakers. These ontologies will require and provide the lexis fuel of user-friendly cultural communications in healthcare.

Some influence in the research decision process has been exerted through reading of potentially synergic research implicitly describing other pathways toward patient community empowerment and knowledge transfer. These include a lexical database called 'Medical WordNet' [Smith and Fellbaum, 2004], an intelligent interactive system delivering individualized patient information [Buchanan, Moore, Forsythe, Carenini, Ohlsson, and Banks, 1995], and a considerable volume of work on computer-simulated healthcare interactions employing relational agents emanating from Timothy Bickmore [Bickmore and Giorgino, 2006; Bickmore, Pfeifer, and Paasche-Orlow, 2009; Bickmore, Schulman, and Sidner, 2011] and various co-authors. Common among these and similar sources is the inferred expectation that these are operating among a highly literate English-speaking population.

In our socio-linguistic knowledge-gathering activity, Arwood [2011] has helped us to further qualify the nature of cultural communications dissonance at play in Aboriginal and non-Indigenous conversations. English is considered to be a low-context language, in which assumptions and confident deduction are common; effectively participants mentally 'fill in the gaps' of the who, what, and where of the exchange topics. In other cultures, and this emphatically includes the Aboriginal people, the conversational interactions are high-context. High context is governed by relationships, and Aboriginal people have very strong connections with extended family, the land, and matters of a spiritual nature. Explanations must satisfy their needs before successful engagement, and there is considerable evidence that in PPIEs explanations by providers are often inadequate or absent [Forbes et al., 2011].

Indigenous Community Use of ICT

UNESCO world studies report that the most obvious challenge to Indigenous people using ICTs for intercultural dialogue is their inadequate access to technology [Dyson, Salazar, Hendriks, Underwood, and Kay, 2006]. A literature review in 2004 examined the hypothesis that low adoption of ICT by Indigenous Australians was influenced by Western values embodied in the technology. The researchers found instead that there was an 'overwhelmingly enthusiastic response towards computers' by school children, and capabilities were limited only by cost-associated technology access difficulties, isolation, poor telecommunications infrastructure, and low computer skills [Dyson, 2004]. Michael and Dunn [2006] state that the greatest gains have been made when Indigenous people have defined requirements that are then pattern-matched to an ICT solution. Reflecting on low ICT usage the authors invite the reader to hypothesise that, for the greater part, government agencies have assumed Indigenous needs. Several authors [Martini, 2006; Maar, Seymour, Sanderson, and Boesch, 2010; Cass, Lowell, Christie, Snelling, Flack, et al., 2002] point to the failure of planners and researchers to seek out culturally appropriate and effective Indigenous feedback communication methods. A preliminary study of mobile phone adoption on a remote island in the Torres Strait disclosed the unexpected use by the Indigenous community of text messaging on mobile phones, as well as calls and text messages in the local language. The tentative conclusion was that ICT must go beyond cultural oral strengths to match areas of motivation such as communication with family [Brady, Dyson, and Asela, 2008]. According to Xie, Rau, Tseng, Sui, and Zhao [2009], computer-based communications exacerbates ambiguity and misunderstanding among parties with different cultural backgrounds. The Health Interactive Technology Network (HITNet) develops and deploys creative media solutions to reduce Indigenous health inequalities. Its health information project in remote Queensland aims to measure change in knowledge, attitudes, behaviour, and local capacity. This involves new media modules, including one on adolescent diabetes. Adolescents in the community have proved particularly receptive to using new technology. Network expansion plans include multimedia and Web-ready products, with touchscreen video kiosks in sites in Queensland and Western Australia. These media concepts

favour the use of 'performative' and participative content in Indigenous communities (as opposed to narrative text) because *they are more attuned to listening and watching versus literacy-based media* [Travers, Hunter, Gibson, and Campion, 2007; Hunter, Travers, Pelham, Gibson, Hermawan, and Austin, 2009].

Ontology Representation of Type-2 Diabetes Management

A number of researchers have worked on developing a diabetes ontology. Chalortham, Buranarach, and Supnithi [2009] developed diabetes mellitus ontology that covers risk assessment, diagnosis and complication, treatment, and follow-up. The diabetes mellitus ontology was developed based on the 'Thailand Diabetes Mellitus Clinical Practice Guideline 2008' and suggestions by medical domain experts. Buranarach, Supnithi, Chalotham, Khunthong, Varasai, and Kawtrakul [2009] introduced the synopsis of chronic disease healthcare framework in which the importance of ontology for healthcare knowledge management system was pointed out. Lin and Sakamoto [2009] developed Glucose Metabolism Disorder ontology which was classified into diabetes mellitus, diabetes complication, hyperglycaemia, hyperrinsulinism, etc. The ontology was also linked to geographical regions ontology and Genetic Susceptibility Factor ontology to describe the genetic susceptibility factors to diabetes mellitus. Ganendran, Tran, Ganguly, and Ray [2002] developed ontology-based multi-agent systems in which diabetes management was applied as a case study involving three agents: specialist agent, patient agent, and Web agent. Shahar, Das, Tu, Kraemer and Musen [1994] developed Knowledge Based Temporal Abstraction (KBTA) focusing on shared knowledge representation and reuse.

Currently, no T2DM ontology has been developed based on Australian-recognised professional healthcare standard guidelines. There is also no evidence in the literature of any current effort, other than the work of the authors, to facilitate a cross-cultural biopsychosocial pragmatic ACT system to help Aboriginal patients or to support culturally and linguistically diverse immigrants whose healthcare communications and understanding of self-management is similarly challenged. There is, however, considerable promise from budding ACT vehicles capable of optimizing ontologies found in all forms of desktop computing, tablets, smart mobile phones, and telehealth systems. The appeal of all such capabilities is the mitigation of the barrier of physical distance.

III. PATIENT–PRACTITIONER ASSISTIVE COMMUNICATION ARCHITECTURE

Our current activity is devoted to the development of *PatientPractitionerAssistiveCommunications* (PPAC) ontology for type 2 diabetes*.* This name does not signify the primary intention of its function as a sharing and relational data source, which as stated is to assist Aboriginal patients to attain a greater level of understanding about their disease and to invigorate their own disease self-management capabilities. The specifics of this come in the ontology class *AboriginalEnglishHomeTalk.* In the future the ontology will benefit all members of the healthcare patient community and must be ready to map with different cultures and the pragmatic communications characteristics of them. This Aboriginal English (Home Talk) PPIE foundation modelling work involves considerable biopsychosocial complexity and is inadequately served in that context by the healthcare domain literature.

A key objective in T2DM management is persuading patients to understand the implications of the disease for personal wellbeing so as to embrace lifestyle change and then sustain healthy behaviours. Using computers to reinforce this has been explored in Fogg, Cuellar, and Danielson [2007] and Hayes and Aspray [2010]. The word 'captology' was invented by Fogg et al. to describe 'computers as persuasive technologies'. Relevant to our work and the adoption of information and communications technology (ICT) by Aboriginal patients, Fogg and colleagues advise that among general ways in which computers are persuasive, influential features are: simplification of explanatory terms; and skilful guidance of users through a computer process.

As discussed by Inui and Carter [1985] while advancing an argument for interactional analysis in PPIEs, both pre-encounter and post-encounter states are vital parts of the cycle of healthcare consultation, the latter in the context of PPIE outcomes. Our ontology construction is devised not as a substitute or intervention within the time-defined patient–practitioner meeting, but as an all-encompassing two-way knowledge-transfer support system. This reflects the proposed mode of enveloping pre- and post-encounters while centring on the PPIE. The projected case study here is based on our research, including a literature review and focus group analyses. Literature studied in particular depth includes leading educational works on the role and influence of the Aboriginal English dialect conducted over several decades [Cahill, 1998, 2000; Cahill and Collard, 2003; Department of Education and Department of Training and Workplace Development, 2012; Eades, 1991; Malcolm, 1995; Malcolm et al., 1999; Sharifian, Rochecouste, Malcom, Konigsberg, and Collard, 2004; Sharifian et al., 2012]. The scenario anticipates the availability of digital devices that are able to connect with the practitioner's computer systems. Applications pre-loaded include assistive communications support to improve the quality of T2DM knowledge sharing and exchange transfer. The ontology supporting this facility reflects the components of the Royal Australian College of General Practitioners (RACGP) Guidelines for management of type 2 diabetes.

Figure 1 illustrates the PPAC ontology positioning schema. As shown in Figure 1, there are two parts, i.e., the human entities and the Assistive Communications System.
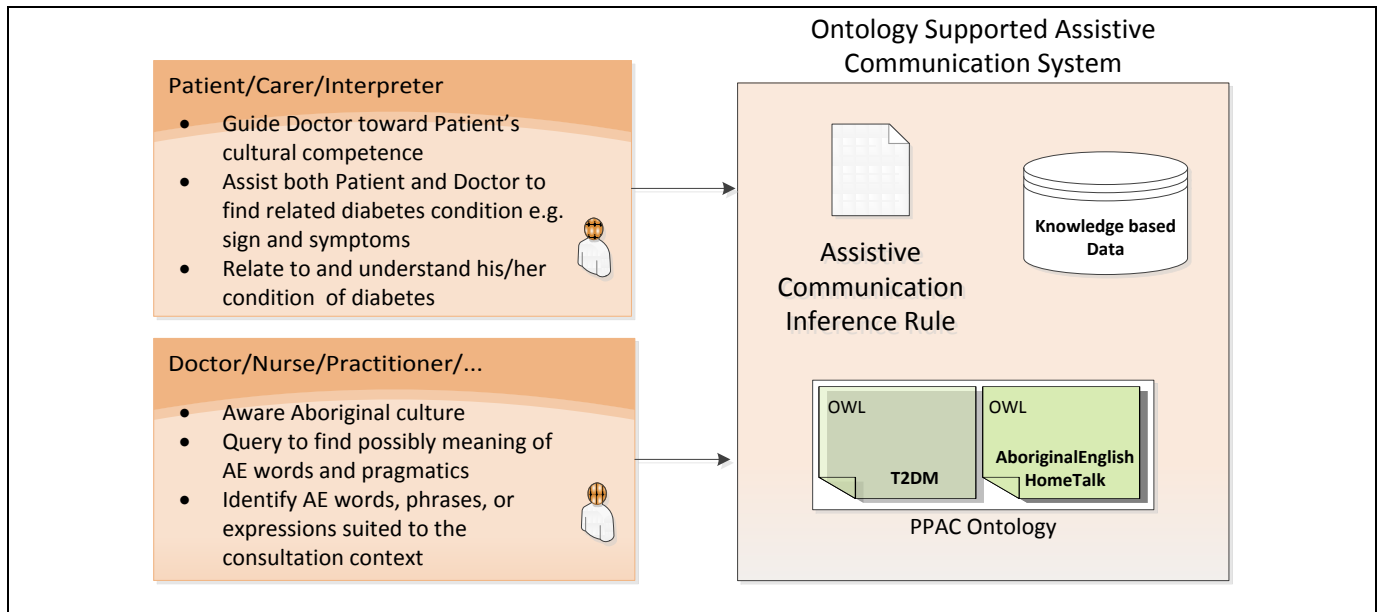

Figure 1. System Architecture of Type 2 Diabetes Patient Practitioner Assistive Communications

The context relevance and cross-cultural communications efficacy of information about the patient's health-related condition are facilitated by the Ontology Supported Assistive Communications Systems. These systems consist of three elements. Knowledge-based data is maintained in a repository and typically will provide user tutorial support, a store of retrievable contemporary information for response to domain specific queries, pictorial illustrations and links to related references including glossaries. Data held will be both human and machine-readable. The two ontology (OWL) files in combination support T2DM guidelines and Aboriginal English bi-directional communication with pragmatic user-appropriate (Standard Australian English or Aboriginal English) syntax and semantic construction of data drawn from the knowledge base. The Assistive Communication Inference Rule is the third element, denoting the ability through ontology disciplines to automatically generate new relationships, based upon existing relationships provided for in the explicit ontology design.

Also shown in Figure 1 are the human entities in the PPIE. Besides the essential engagement between patient and practitioner, cross-cultural communications may require a third non-patient–practitioner party to assist with overcoming pragmatic language difficulties, including speech and hearing disabilities. A carer or interpreter may or may not be qualified or appropriately equipped with healthcare domain-specific knowledge to overcome misunderstandings. Conditional access may be permitted to the Assistive Communications System so that the carer or interpreter (a) is able to help with the query and search process during the PPIE to identify the best matches of Aboriginal expression with T2DM clinical guideline terminology and (b) will be capable in both pre-encounter and post-encounter patient contact activities to assist patient T2DM self-management through a more reliable recall and/or clarification of healthcare provider advice, treatment, and care monitoring priorities.

The Aboriginal English (AE) concepts, including home talk and health talk, are mainly for access to and use by the general practitioner (GP) or allied practitioners so that they can query AE words and pragmatics, and, in the continuing education context, work toward understanding Aboriginal culture. The diabetes concepts are mainly for Aboriginal patients and carers to relate to and understand his/her condition of diabetes. For example, for Aboriginal patients our ontology can relate hyperglycaemia with AE expression of 'I need my sugar chopped'. The GP and allied practitioners know these diabetic concepts; the Aboriginal patients know the AE words and expressions. Therefore, we conceptualise concepts for those who do not or may not possess this knowledge.

When the GP and allied practitioner attempt to follow clinical processes, within the history-taking effort there is a need to identify a patient's prevailing signs and symptoms to enable diagnosis and to justify a treatment and care plan. This information may not be volunteered or easily and reliably secured. The patient may have been previously diagnosed and a history of T2DM is known to exist, or the patient may be asymptomatic and attending for reasons other than a diabetes-related complaint. For our purposes the PPAC ontology is predominantly concerned with patients who have already been diagnosed as suffering from T2DM. Notwithstanding, this may not always be communicated clearly when a patient and practitioner meet for the first time.

The general principles underpinning PPIE pragmatic interactions using domain ontology concepts and relationships coactively are two-fold: engagement and semantics. The goal is to surmount cultural-source schema barriers and achieve shared understanding. Without engagement between low- and high-context language users, semantics are elusive at best. Without semantic cognition (semantically driven verbal and nonverbal behaviour), coactive engagement is close to impossible. Engagement through shared semantic cognition invariably relies upon contextualisation. In later sections, we conceptually show queries from a GP who wishes to find out what certain AE words might be taken to mean in Standard Australian English (SAE). We also show queries from Aboriginal patients who may, for example, want to find the related diabetes condition.

We do not assume indifference on the part of either query source, nor do we attribute prior lack of knowledge to disinterest in learning. We have no evidence to suggest that Aboriginal English speakers are unwilling to learn or are incapable of recognizing the more techno-clinical terms used by practitioners. On the contrary there is evidence that Aboriginal and other ethnic minority patients wish to know and learn more about their healthcare so that they can understand the rationale of diagnosis, treatment, and care [Artuso, Cargo, Brown, and Daniel, 2013; Lowell, 1998; Scheppers, van Dongen, Dekker, Geertzen, and Dekker, 2006; Shahid, Finn, and Thompson, 2009].
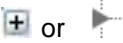
Aboriginal history and Aboriginal experiences of westernized healthcare interaction barriers provide an understanding of the challenges that healthcare providers face when negotiating the health service needs of Aboriginal people. Similar things occur for refugee migrants from less-known cultures, such as African countries, who face a much briefer window for assimilation and hybridisation with Australia's dominant English language [Australian Human Rights Commission, 2010; Hugo, 2009]. Of the 248,688 people born in Africa as reported in the 2006 Australian census, 72.6 percent are from southern and eastern Africa, with 22.9 percent from North Africa (including Sudan), and 4.5 percent from central and western regions of Africa [Australian Human Rights Commission, 2010]. Some sub-Saharan communities have less that 5,000 people, which is 2 percent or less of the total. When dealing with patients who are disadvantaged through the cultural disconnect of significant differences in ethnic values and practices, language/dialect, and poor health literacy, practitioners are also disadvantaged by the lack of effective support systems that can assist with countering these handicaps. We hypothesise that Aboriginal English Home Talk (AEHT) could also be a valuable, although unsuspecting, model for ethnic minority immigrant communications acculturation.

The traditional approach to improving PPIE communications with Aboriginal patients and ethnic minority immigrants who have limited English proficiency (LEP) has been through the use of official and ad hoc interpreters. We do not see this approach as sufficiently robust and accessible, as we do not expect that interpreter services can cope with demand. Cultural beliefs and practices, as well as linguistic and dialectal variations that influence communications, are considerable. Logistically and demographically, Australia, as a large land mass and a relatively small population, when taken together with service delivery cost implications, is not yet equipped to offer a complete and comprehensive range of safe and satisfactory real-time healthcare-competent interpreter services for ethnic minorities. One aspect of Australia's service efficiency barriers is a shortage of qualified healthcare workers, including doctors and nurses. Rural and remote areas suffer a high turnover of health staff, including Aboriginal health workers and overseas-trained doctors (OTDs) who have been essential to filling positions to provide primary care in these regional locations. These doctors receive little training to assist assimilation into Australia's working cultures and minimal support of an acculturative nature in order to treat and care for Aboriginal people [Arkles, Hill, and Pulver, 2007; Dahm, 2011; Gilles, Wakerman, and Durey, 2008; Sheikh-Mohammed, Macintyre, Wood, Leask, and Isaacs, 2006].

IV. ONTOLOGY MODELLING NOTATIONS

Before the PPAC ontology for T2DM is presented, graphical notations are discussed in this section to facilitate the PPAC ontology modelling process. Table 1 shows a list of notations.

Table 1: A List of Modelling Notations		
Notation	Terminology	Semantics
	Primitive Class	If something is a member of this class, then it is necessary to fulfil the conditions [Horridge, 2011].
	Defined Class	If something fulfils the conditions, then it must be a member of this class [Horridge, 2011].
	Subclass Relationship (pink colour)	Superclass–subclass hierarchy. Note that it has the same notation with instance relationship but in different colour, i.e., in pink colour.
⊞ or	More Subclasses	More subclasses in a hierarchy.
	Object Property Relationship (different colours represent different relationships)	Link two instances or classes together.
	Instance/Individual	Objects in the domain in which we are interested.
	Instance/Individual Relationship (blue colour)	Instances of the classes. Note that it has the same notation with subclass relationship but in different colour, i.e., in blue colour.

In context, class, property, and instance/individual are written in italic style to distinguish from the text. In order to maintain consistency with names, we have naming conventions for each ontology component. All class names start with a capital letter and have the remaining word(s) capitalised, and underscores are used to join words, for example, *Aboriginal_English_Home_Talk*. Property names or relationship names start with a lower-case letter, have no spaces and have the remaining word(s) capitalised. Relationship names are prefixed with verb or adverb, e.g., the words 'has', 'in', or 'related', for example, *hasComplicationRisk.* We use this naming convention to allow for the possibility to generate more human readable expressions for descriptions. Instance or individual names start with a lower-case letter and have the remaining word(s) in lower case, and underscores are used to join words, for example, *vision_impairment.*

V. PPAC ONTOLOGY FOR T2DM

The use of the PPAC ontology is mainly focussed on the representation and reorganisation of type 2 diabetes terminologies together with Aboriginal English Home Talk. The objective is to help GPs and Aboriginal patients storing and communicating general type 2 diabetes knowledge and patient-related information efficiently. The PPAC ontology supports the need of Aboriginal type 2 diabetes healthcare process to transmit, reuse, and share patient data. We design and implement the PPAC ontology by partitioning the domain concept into sub-classes. A set of object properties is defined to describe the relationships between the concepts. A set of constraints among those relationships describes the restrictions in those relationships. Note that the PPAC ontology has been developed in Protégé 4.2 featuring with Pellet reasoner, DL Query, SPARQL Query, and OntoGraf. Figures displayed in this article are then captured from the Protégé with capability of reasoning, querying, and graphical presentation to ease understanding.

There are two main concepts in the ontology, i.e., (i) type 2 Diabetes which classify all concepts related to type 2 diabetes and (ii) Aboriginal English Home Talk which classify all concepts used in Aboriginal communications as shown in Figure 2. These two main concepts are transformed into two main ontology classes which are linked together through object properties, i.e., class relationships and constraints, i.e., class restrictions. The two classes are self-standing concepts which we format as sub-classes of class *Independent_Concept*.
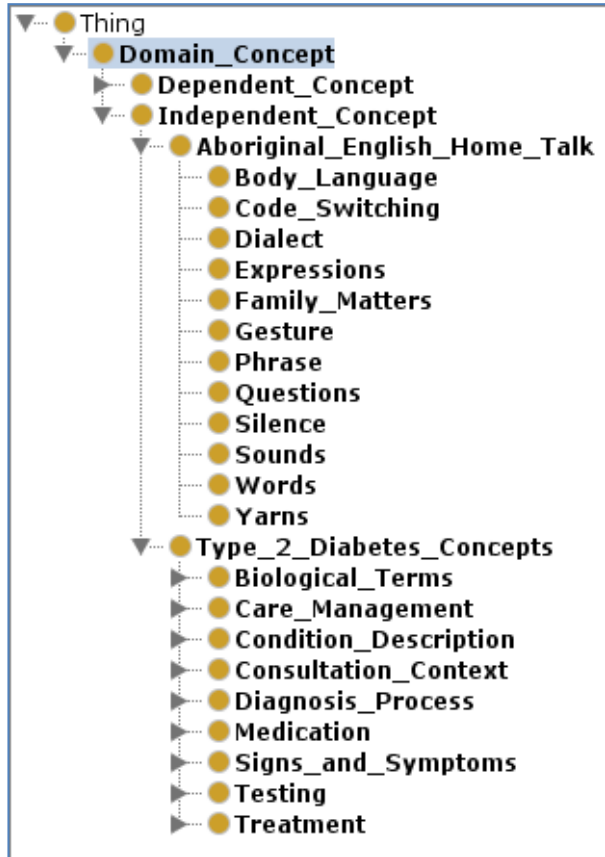
Figure 2. Class Independent_Concept and Its Sub-classes [Forbes, Wongthongtham, and Singh, 2012]

Ontology class 'Aboriginal_English_Home_Talk' describes the selective structuring of hitherto semi-structured and unstructured dialectal data, as compared with the formalized grammatical constructs of Standard English and other structurally established forms of English comprehension, including Standard Australian English. The Aboriginal English dialectal data collation activity comprises general, healthcare, and T2DM specific lexical labels and idiomatic expression, supported by user guidance annotation.

In the majority of semantic correlations, the related type 2 diabetes concepts drawn from published RACGP Guidelines are initially structured to facilitate relationship mapping of clinical language with the Aboriginal English Home Talk ontology via simplified Standard English.
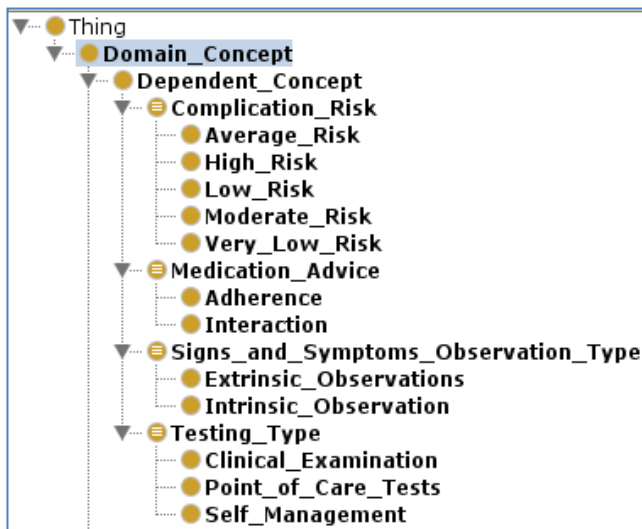

Figure 3. Class Dependent_Concept and Its Sub-classes [Forbes et al., 2012]

There are refining concepts which will add meaning to other concepts. We form these into class *Dependent_Concept,* as shown in Figure 3. Class *Complication_Risk* adds risk value to any sub-class of class *Type_2_Diabetes_Concepts* through relationship *hasComplicationRisk*. It can be restricted to particular risk of average risk, high risk, low risk, moderate risk, or very low risk. Class *Medication_Advice* adds value in terms of medication advice of adherence and/or interaction to any classes subsumed by classes *Care_Management*, *Treatment*, and *Medication* through relationship *hasMedicationAdvice*. Observation of particular sign and symptom of patient can be specific to extrinsic or intrinsic observation of the patient. This can be specified through relationship *hasObservationType*.

Figure 4 shows class *Testing_Type* adding value to class *Testing* through relationship *hasTestingType* in terms of types of testing, i.e., clinical examination, point of care tests, and self-management.
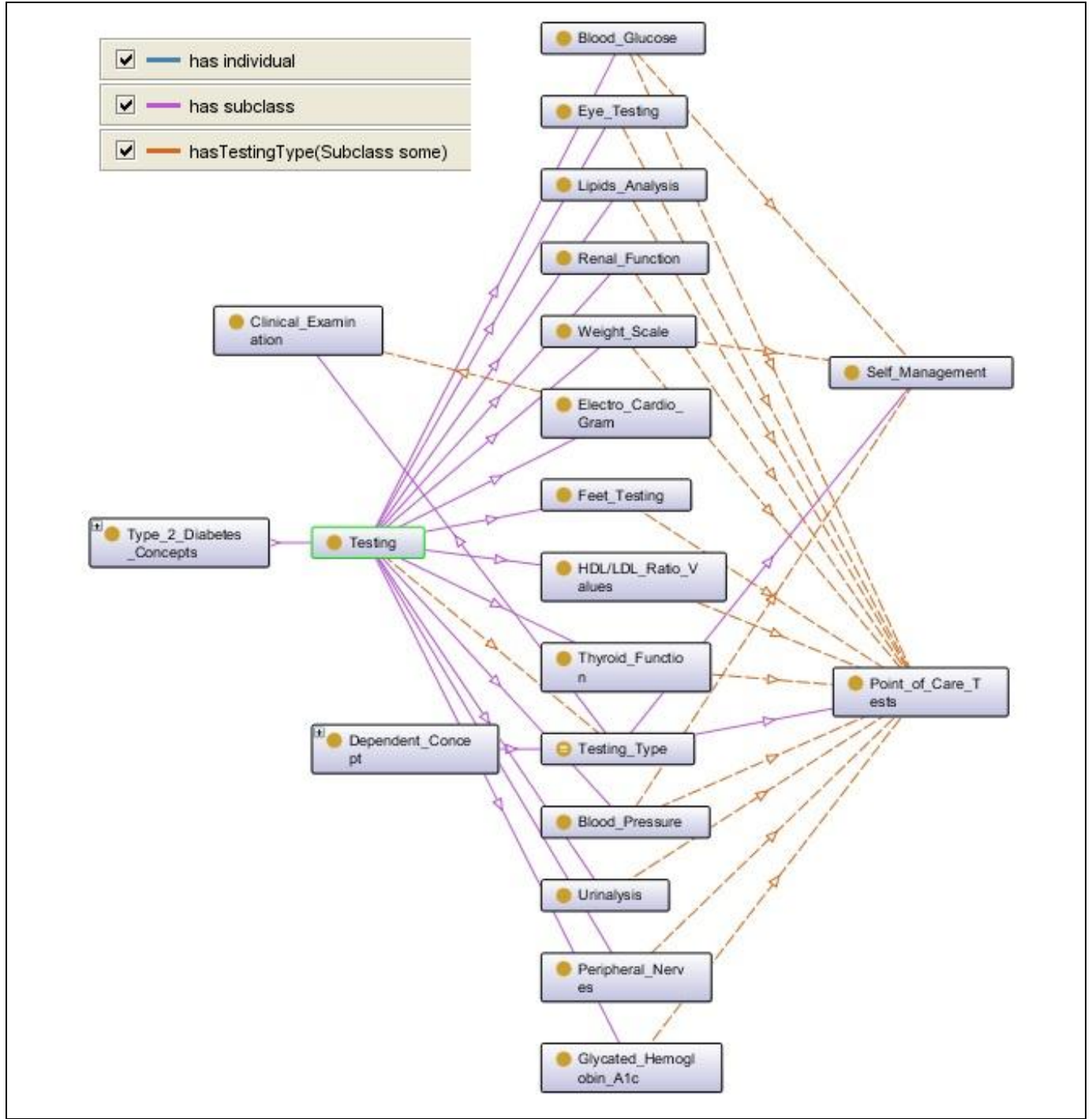

Figure 4. Class Testing Relates to Class *Testing_Type* Through Object Property *hasTestingType*
[Forbes et al., 2012]

Figure 5 shows ontology classes *Complication_Risk* and *Signs_and_Symptoms_Observation_Type* which are dependent concepts. As can also be seen from Figure 5, class *Complication_Risk* adds value to class *Condition_Description* through relationship *hasComplicationRisk.* Similarly, class *Signs_and_Symptoms_Observation_Type* adds value to class *Signs_and_Symptoms* through relationship *hasObservationType.*
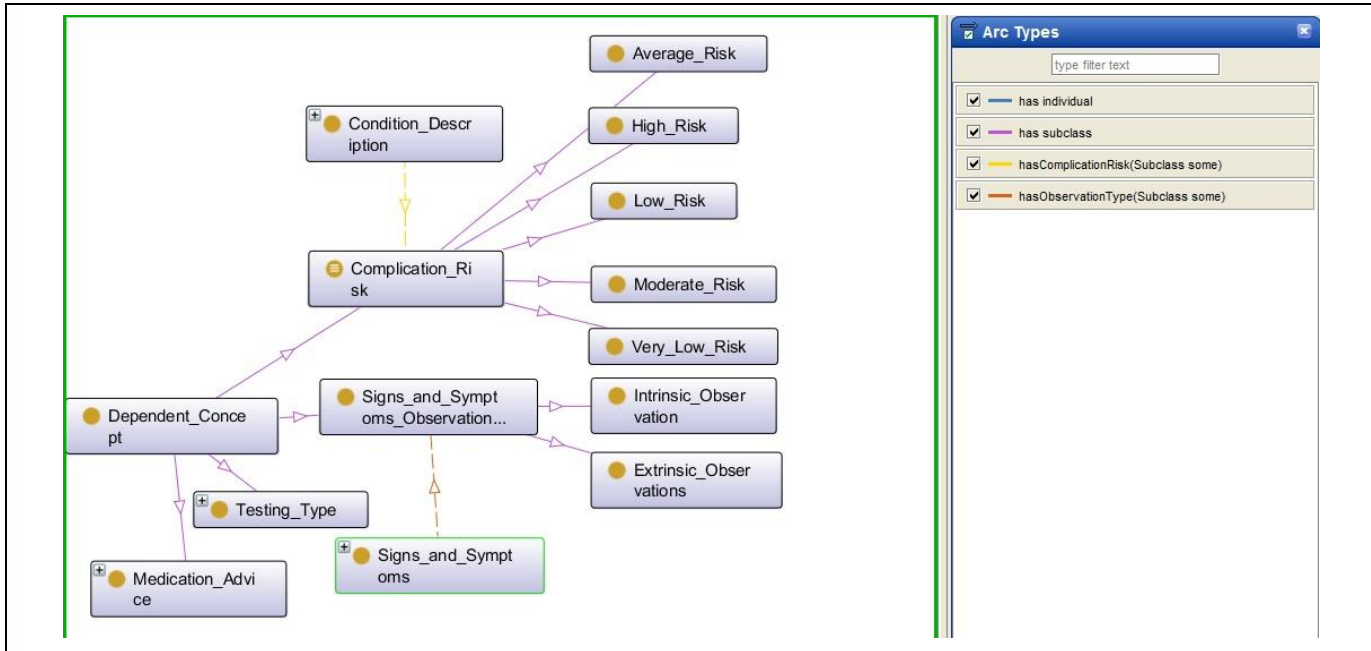

Figure 5. Dependent Concepts 'Complication_Risk' and 'Signs_and_Symptoms_Observation_Type'

Subsequent to the following case study description illustrates a sample from mapping of *Type_2_Diabetes_Concepts* with *Aboriginal_English_Home_Talk*.

VI. CASE STUDY

Based upon input from an ethics-approved focus group exercise involving Aboriginal trainee nurses, we have assembled a depiction of an Aboriginal PPIE problem situation as follows.

Case Study Scenario

A thirty-five-year-old male Aboriginal T2DM diagnosed patient from the Nyungar community lives in and travels around a remote area. He attends an appointment with a visiting doctor (general practitioner—GP) for the first time at a clinic in a rural town on the edge of the bush. His PPIE visits have been sporadic and include consultations at other clinics, with consequentially irregular patient healthcare records. The patient is more comfortable and proficient in Aboriginal English Home Talk dialectal conversation than in Standard Australian English. He knows the nurse who regularly works at the clinic, a three-hour walk from the patient's principal community home. The African-born and English-language-educated GP recently came to Australia from Nigeria and is on a drive-in, drive-out visit which he attends every two weeks for a six-hour PPIE session of consultations.

Issues Occuring in the Case Study Scenario

The doctor, not yet primed in working with Aboriginal communities, persists with a Western medical approach consisting of probing questions, repeatedly asking the questions 'When?' and 'How long?' and 'How much?' in an effort to find out how long certain symptoms had been present and any lifestyle influences that may be in play in relation to the patient's diagnosis. The patient does not wear or use a watch and is very protective of his cultural communication traditions. For example, it is unacceptable practice within his community for a stranger to make direct eye contact. Feeling shamed, he becomes agitated but silent, his body language inferring to the doctor that this patient may depart prematurely. As explained by Vallance and Tchacos [2001], 'shame' in the sense of personal inner emotion affecting Aboriginal people is a combination of feelings far exceeding the semantic limits of the word as found in an English dictionary. It is related to kinship, to extended family, and is a powerful engulfing experience that disempowers the individual and often results in silence and lack or termination of engagement. In this case, the respective sounds and expressions of the patient and the doctor indicate mutually difficult and unfamiliar forms of communication. The patient's style of conversation includes phrases and words that do not follow Standard Australian English grammatical constructs as hoped for by the doctor, but the patient does his best to code-switch to

help the doctor understand. Several times he talks about 'winyarn' and shakes his head. At one time, forming circles with his forefingers and thumbs, he holds these in front of his eyes and says 'Gooras. Winyarn'. This communication could be significant in the T2DM PPIE and diagnosis of relevant co-morbidities. However, the GP is unfamiliar with these words and expressions, although he wishes to learn much more about the patient's condition in order to draw conclusions and make a decision about future treatment and care.

A Potential Solution for the Case Study Challenges

The communication issues described can be solved by developing an application embedded with an Aboriginal English Home Talk assistive communications facility. This facility is an application bundle that would render biopsychosocial pragmatic options for end users to make sense of, adapt to, and engage with diverse PPIE communications modalities.

The application could help the Aboriginal patient to understand T2DM management and care advice through an easy-to-use interface. For example, graphical icons will guide the user to ontology-enriched explanations that will help clarify meaning and satisfy queries arising from uncertainty and ambiguity. The GP can discover that silence, detachment, or agitation on the part of the patient is annotated in the system with options that include the cross-cultural rationalization of 'shame'. Searching for 'Gooras' and 'Winyarn' under Aboriginal English Home Talk, after clicking or touching other icons, will identify the text and enable the GP to hear an Aboriginal (Nyungar) voice pronounce the words, thereby aiming to secure a match with what has been said by his patient. Further investigation with care and sensitivity is required before a reliable conclusion can be reached about the intended message. For instance, a solicitation asking the patient: 'Do you have blurred vision?' is unlikely to secure a satisfactory answer. Aboriginal English grammatical constructs commonly ignore prepositions, one of many characteristics that can obscure interpretation for a Western-trained non-Indigenous clinician. 'Bung eye' is another term used in Aboriginal English to self-describe some form of eye complaint, ranging in possible meanings from eye disease to dysfunctional vision. It is for the practitioner to take these clues and cues as investigative aids for the process of examination, testing, elimination of some possibilities, and eventual diagnosis leading to treatment and care. The possibility of the patient's intent being to convey some form of adverse alteration in vision is accommodated in the ontology annotation to reinforce the advice that 'gooras winyarn' is not sufficiently finite but more a guide toward a troubling eye complaint.

From material described earlier, we are able to gain sufficient grammatical and pragmatic aspects of Aboriginal English Home Talk to populate an ontology that will allow annotation that will enrich and disambiguate T2DM PPIE-related semantics and bi-directional cognitive capabilities. The ontology will respect the integrity of the RACGP Guidelines and offer options for framing personal enquiries and making system queries suited to participants who, in addition to patients and primary care practitioners, may include allied health professionals, family and other carers, and qualified and ad hoc interpreters.

PPAC Ontology as a Solution for Assistive Communication Support Particularly for T2DM

In this section we present two main cases which are important to diabetes Aboriginal patients, i.e., on vision and on consumption of alcohol. Permutations of concept relationships necessitate some reiterative explanations, as finer granulation and semantics vary the context of instances.

The 2011 AIHW paper 'Eye Health in Aboriginal and Torres Strait Islander People' summarises the findings of the 2008 National Indigenous Eye Health Survey (NIEHS) [Australian Institute of Health and Welfare, 2011]. The survey shows that, over the age of forty years, Aboriginal and Torres Strait Islander people have six times the rate of blindness of other Australians. Although diabetic retinopathy was not individually quantified, 13 percent of Aboriginal and Torres Strait Islander people with diabetes had visual impairment, with diabetes being the cause of 13 percent of low vision and 9 percent of blindness. Among people with all types of diabetes, diabetic retinopathy was present in 30 percent of people and was found in 6.3 percent of those who did not self-report the diagnosis of diabetes.

Frequency of alcohol intake and particularly binge drinking (excessive intake of alcoholic drinks in one continuous or protracted drinking event) will determine practitioner advice to the patient. The RACGP guidelines make reference to hazardous drinking being more prevalent among Indigenous males and females aged thirty-five to forty-four years than among the general population. Honest and accurate self-accounting for consumption is confronted by several barriers, one of which is the feeling of shame, akin to embarrassment. If the practitioner is disadvantaged through ignorance, the PPIE process will be far from complete or effective in the sense of the longer-term value of healthcare intervention.

Vision

The effort to secure and maintain explicit meaning and cognition in human conversation is benefitted by the power of human reasoning and the ability to contextualize, but significant barriers prevent or diminish understanding in cross-cultural exchanges when there are differences in the contextual capabilities and natural culture norms of participants. An important characteristic of machine language modelling is the step-by-step process of identifying and replicating logical relationships so that computer generated information systems can be trusted to deliver reliable accurate and true data in response to queries. The complexity of human conversational implicature, however, means that, for any such system to be dependable, it must have some inference capability. Translating, or rather transforming, words and phrases paralinguistically in the human conversation cultural context involves the sender and receiver of information in mental cross-checking of known pieces of information in order to validate what is being said and specifically what it means in the current context. A discussion in the PPIE about vision, and possible vision impairment, cannot depend upon the existence of guideline protocols and imperatives alone. Naturally members of the patient community are unpredictable in the sense of compliant active engagement with a clinician only on the latter's terms. The cooperation of the Aboriginal patient is subject to variable culture-based influences and circumstances. Implicature is ever present. Therefore, it is vital that, for machine translation purposes, ontology structures optimize linkages between concepts and do not depend on the limitations of taxonomic structures. When we consider the role of the word 'vision' in the T2DM classification, it extends semantically to several implicit meanings. Vision describes our ability to see physical things, and 'vision' is also a term attached to measurement of sight capability, i.e., visual acuity.

Therefore, the vision concept in PPAC ontology derives from T2DM implications for eyes/vision of the patient and relates to concepts in the Aboriginal English Home Talk/Health Talk context. Eyes/vision knowledge captured in the PPAC ontology is presented in this article as follows.

The Nyungar Aboriginal word 'Winyarn' generally means bad or weak. The Nyungar Aboriginal word 'Gooras' refers to eyes or in context to eyesight and glasses. 'Winyarn' may refer to poor general wellbeing, and together with 'Gooras', to such problems as blurred vision.

'Gooras winyarn' is then captured as an instance of class Phrase named *bad_eyes* which is a subclass of class *Aboriginal_English_Home_Talk*. Figure 6 shows its assertions, while Figure 7 shows its relationships with other instances in the graphic. Figure 6 shows instance *bad_eyes* in AE as goora winyarn and in SAE as weak eyes or bad eyes. In other words, we capture that gooras winyarn in AE can be taken to mean bad eyes or weak eyes in SAE. The instance *bad_eyes* also relates to other instances, i.e., instances *vision_impairment*, *blurred_vision*, *altered_vision*, and *retinopathy*. Figure 7 shows its relationship with other instances together with their ontology classes.
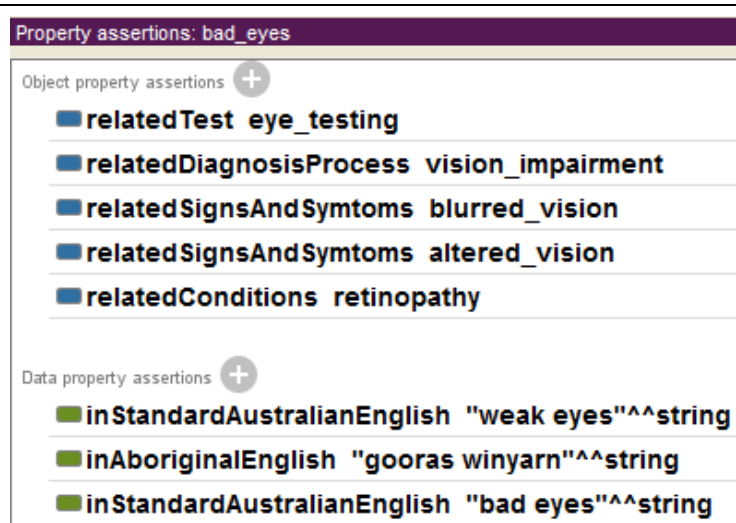

Figure 6. Phrase of Gooras Winyarn Captured in the PPAC Ontology as Instance Property Assertions

Instance *bad_eyes* has relationship named *relatedSignedAndSymptoms* with instances *blurred_vision* and *altered_vision* which are instances of class *Vision* subsumed by class *Signs_and_Symptoms* subsumed by class *Type_2_Diabetes_Concepts*. In other words, gooras winyarn or bad eyes relate to the Diabetes signs and symptom of blurred vision or altered vision. Diabetes patients with high blood sugar may suffer from blurred vision. This might

be a temporary condition or a precursor to more serious conditions such as retinopathy. An Aboriginal patient may walk into a clinic once he/she notices that vision is blurred. Typically, the patient will say he/she has "bad eyes" when seeing the doctor or might choose to say 'Gooras Winyarn'. If the condition is serious, the patient would use the Aboriginal English word as it not only provides a description of the problem but also the severity of it, which is not captured in Standard Australian English. If the patient says 'gooras winyarn' and the doctor, who has access to the PPAC ontology, can query or search for terms of 'gooras winyarn' to find out what the patient intends to say. This will then lead to further investigation before a conclusion can be reached about whether it refers to blurred vision or altered vision or both. It is for the practitioner to take these clues and cues as investigative aids for the process of examination, testing, elimination of some possibilities, and eventual diagnosis leading to treatment and care.

Figure 7. Ontology Relationships for Gooras Winyarn

Instance *bad_eyes* has relationship named *relatedConditions* with instance retinopathy which is instance of class *Retinophathy* subsumed by class *Condition_Description* subsumed by class *Type_2_Diabetes_Concepts*. Instance *bad_eyes* has relationship named *relatedDiagnosisProcess* with instance *vision_impairment* which is instance of class *Patient_Condition_Assessment* subsumed by class *Diagnosis_Process* subsumed by class *Type_2_ Diabetes_Concepts*. In other words, gooras winyarn or bad eyes relate to the diabetes condition of retinopathy. Retinopathy is any non-inflammatory disease of the retina. Diabetes retinopathy is the negative effects on the eye that can be caused by diabetes mellitus, some of which may result in blindness. Vision impairment is a key concern in the PPIE diagnosis process with Aboriginal patients. Retinopathy, in common with so much of diabetes associated phrases, is a Western medicine clinical term that reduces the prospect of reaching a reliable understanding of its meaning between healthcare providers and the more rural and regionally located Aboriginal patients.

Instance *bad_eyes* has relationship named *relatedTest* with instance *eye_testing* which is instance of class *Eye_Testing* subsumed by class *Testing* subsumed by class *Type_2_Diabetes_Concepts*. In other words, gooras winyarn or bad eyes relate to the diabetes testing of eye testing.

Class *Retina* which is sub-class of class *Biological_Term* subsumed by class *Type_2_Diabetes_Concepts* and class *Retinopathy* have relationship named *hasObservationType* with class *Extrinsic_Observations* which is subclass of class *Signs_and_Symptoms_Observation_Type* subsumed by class *Dependent_Concept*. In other words, retina and retinopathy can be observed by the GP.

The following AE phrases represent a limited regional set of descriptive concept instances as offered by the Aboriginal focus group activity. Coyee eyes is a AE description of conjunctivitis, which is inflammation of the

conjunctiva (the outermost layer of the eye and the inner surface of the eyelids). Bung eye is similar to Coyee eyes. Goora bludgers is AE for eye glasses/spectacles. Coke bottle or coke bottle lens are AE for eye glasses/spectacles.

Second eyes is AE for eye glasses/spectacles. These are captured and presented in Figure 8.
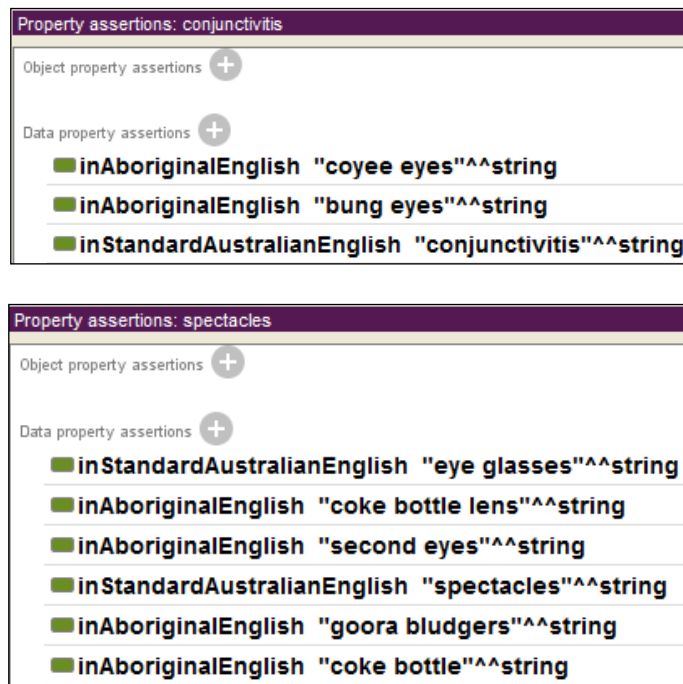

Figure 8. Vision Related Concepts, i.e., Conjunctivitis and Spectacles Captured in PPAC Ontology

Alcohol

Advice on consumption of alcohol emanating from professional healthcare sources presents some potential conflict. This occurs because the health impact of alcohol is dependent on individual metabolic and lifestyle factors. On one side studies have shown that moderate consumption of alcohol provides protection against development of type 2 diabetes, while on the other the diagnosed or undiagnosed type 2 diabetic is at risk from excessive alcohol intake. The risk increases with onset of co-morbidities. As many people with type 2 diabetes are overweight or obese, alcohol should be minimised. Australian guidelines at the time of publication recommend ≤2 standard drinks (20g) per day for men and women [Diabetes Australia The Royal Australian College of General Practitioners, 2011]. In this section, we present how we capture alcohol-related concepts in PPAC ontology for T2DM. Highlighting awareness of patient history-taking barriers via ontology relationships and their constraints, we have links with alcohol to contemplate as following.

Alcohol consumption concerns the healthcare context intake of alcoholic beverages. Hence, it is captured in class *Alcohol_Consumption* subsumed by class *Care_Management* subsumed by class *Type_2_Diabetes_Concepts*.

Cardiovascular complications from diabetes place consumers of alcohol at high risk of worsening health outcomes. Hence, class *Alcohol_Consumption* has relationship named *relatedCondition* with class *Cardiovascular_Disease* subsumed by class *Condition_Description* subsumed by class *Type_2_Diabetes_Concepts*. Also class *Alcohol_Consumption* has relationship named *hasComplicationRisk* with class *High_Risk* subsumed by class *Complication_Risk* subsumed by class *Dependent_Concept*. Due to sugar intake, blood glucose increases from alcohol, and this relates to hyperglycaemia condition, but the effect of sustained intake can lead to the opposite, i.e., hypoglycaemia condition. Hence, class *Alcohol_Consumption* has relationship named relatedCondition with class *Hyperglycaemia* subsumed by class *Condition_Description* subsumed by class *Type_2_Diabetes_Concepts*. Also class *Alcohol_Consumption* has relationship named *relatedCondition* with class *Hypoglycaemia* subsumed by class *Condition_Description* subsumed by class *Type_2_Diabetes_Concepts*. Figure 9 shows how we capture these concepts in the ontology through class *Alcohol_Consumption* relationships and constraints. Figure 9 also shows the relationship annotation connected class *Alcohol_Consumption* with class *Hypoglycaemia* as an example. Figure 10 shows class *Alcohol_Consumption* relationships and connected classes and their super classes in graph format.
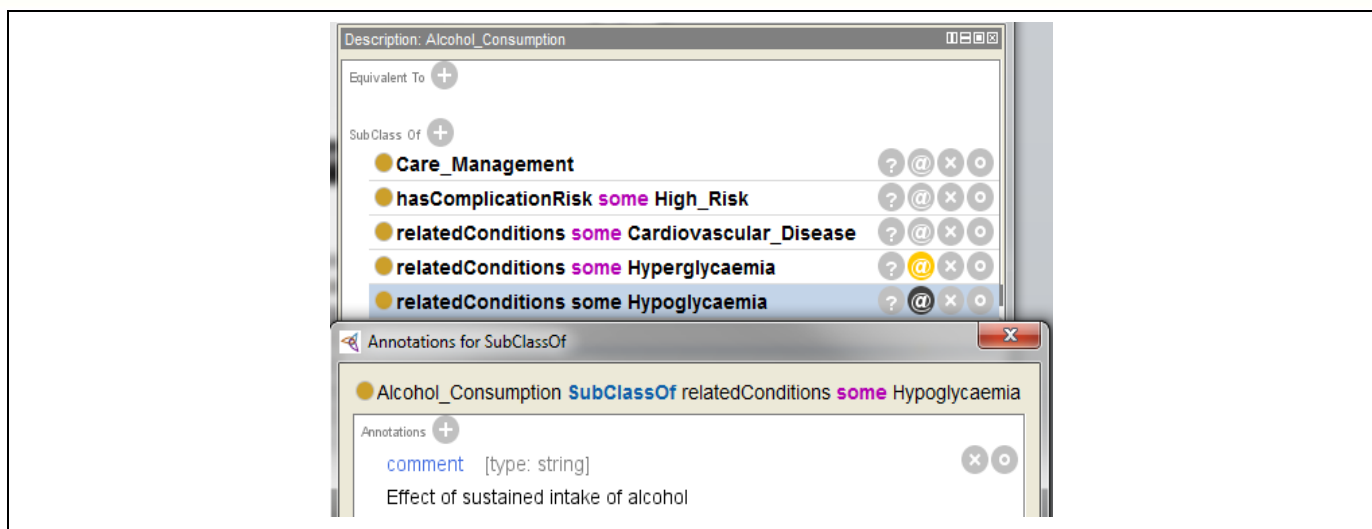
Figure 9. Relationships and Constraints of Class *Alcohol_Consumption*
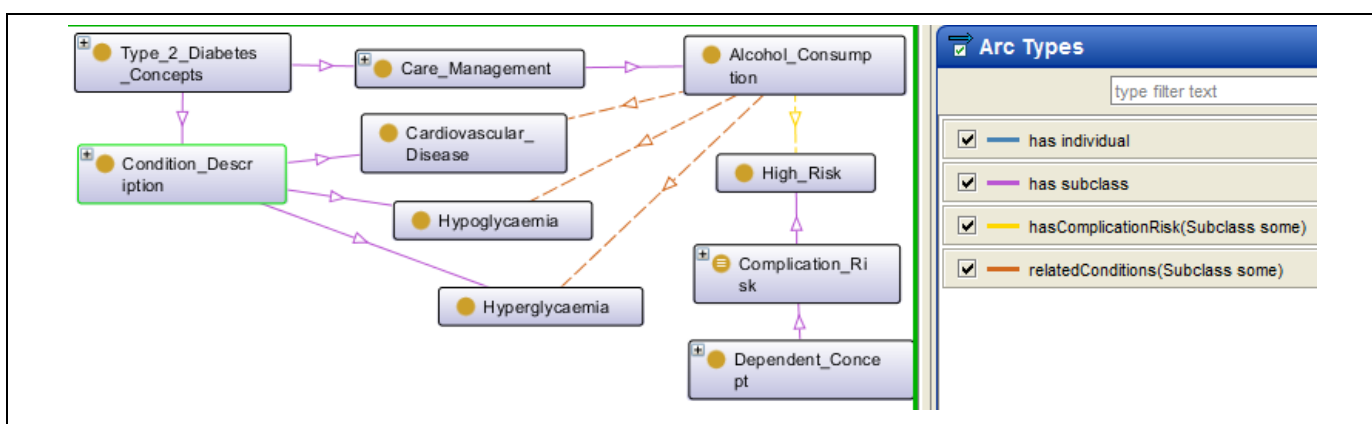
**Figure 10. Relationships and Connected Classes of Class *Alcohol_Consumption*
and Their Super Classes in Graph Format**

The subject of personal consumption of alcohol is invariably a matter subject to the nuance of disclosure preferences of the patients. The following shows how we capture personal consumption of alcohol as ontology instances. Alcohol consumed by a patient may affect clarity of vision, which relates to visual acuity. Visual acuity refers to the clarity or clearness of vision, a measure of how well a person sees. The patient may have experience of poor clarity of vision, as with visual acuity which could result from alcohol intake. The patient may then, as adjudged necessary by the GP, be prescribed metformin medication. Figure 11 shows how we capture these concepts through ontology instances for a particular patient. Figure 11 also shows annotation of particular relationship linked instance *poor_clarity* with instance *metformin* as example. Figure 12 shows them in graph format and presents instances of the class and their super classes.
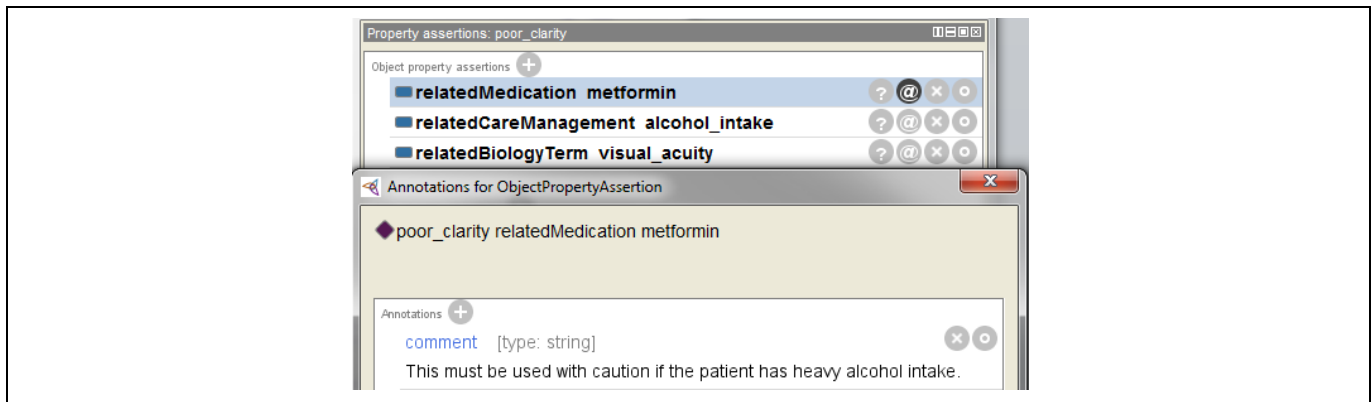
Figure 11. Relationships of Instance *poor_clarity* for a Particular Patient
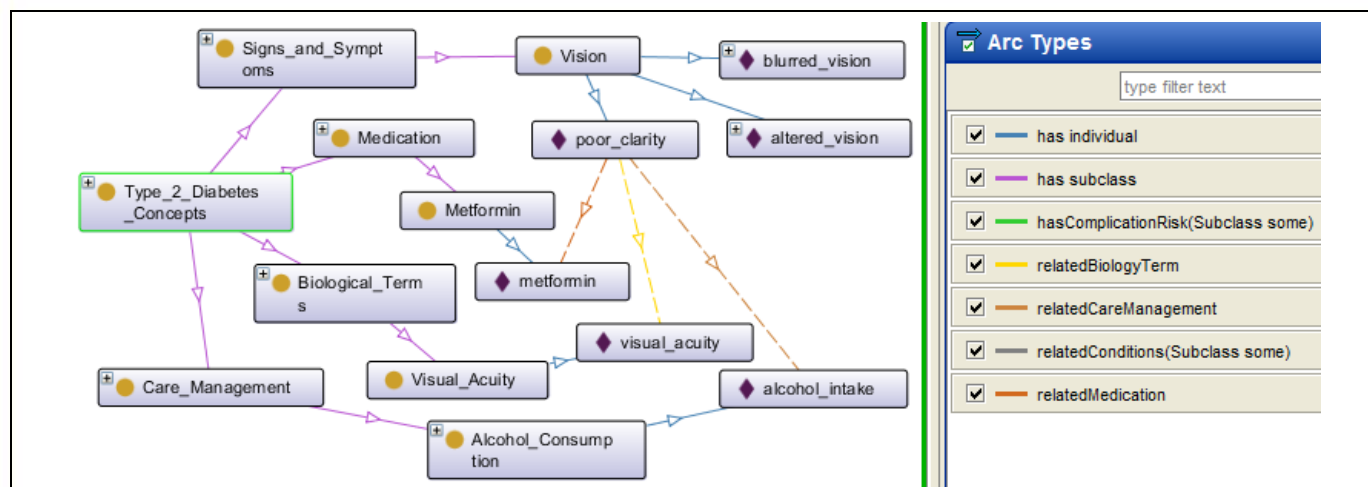
Figure 12. Relationships of Instance *poor_clarity* with Other Instances and Their Classes with Their Super Classes in Graph Format

Instance *poor_clarity* is an instance of class *Vision* subsumed by class *Signs_And_Symptoms* subsumed by class *Type_2_Diabetes_Concepts*. The instance *poor_clarity* has relationship called *relatedBiologyTerm* with an instance named *visual_acuity* which is instance of class *Visual_Acuity*. The instance *poor_clarity* also has relationship called *relatedCareManagement* with an instance *alcohol_intake* which is instance of class *Alcohol_Consumption* subsumed by class *Care_Management* subsumed by class *Type_2_Diabetes_Concepts*. The instance *poor_clarity* also has relationship called *relatedMedication* with an instance *metformin* which is instance of class *Metformin* subsumed by class *Medication* subsumed by class *Type_2_Diabetes_Concepts*.

VII. VALIDATION OF PPAC ONTOLOGY FOR T2DM

Validation of PPAC ontology for T2DM is twofold. Firstly we reason logical consistency of PPAC ontology for consistency validation. Secondly, we make queries answering for usability validation of PPAC ontology. For both parts the ontology reasoner is needed, and we use Pellet which is one of the built-in reasoners of Protégé 4.2. Note that type 2 diabetes concepts captured in the PPAC ontology through annotations are reviewed by a Fellow (and Examiner) of the Royal Australian College of General Practitioners.

Consistency Validation

Ensuring that an ontology is consistent is an important part of ontology development and testing. It is especially important when a shared ontology is necessary for meaningful communication. If a shared ontology is inconsistent, no reliable conclusion may be deduced.

Consistency validation through reasoner for PPAC ontology includes consistency checking, concept satisfiability, classification, and realization. These services are all the standard inference services traditionally provided by a reasoner, e.g., Pellet [Sirin et al., 2007]. The PPAC ontology does not contain any contradictory facts in which logical consistency of the ontology is checked through Pellet and Racerpro. The PPAC ontology has also concept satisfiability, i.e., a class in PPAC ontology can have instances. If a class is unsatisfiable, then defining an instance of that class will cause the whole ontology to be inconsistent. The PPAC ontology has a complete class hierarchy (classification service). The class hierarchy can be used to answer queries which we cover in the next section, usability validation. The most specific class that an instance belongs to can be found in the PPAC ontology (realization service). From our experiment the PPAC ontology is consistent and ready for consumption.

In the systems we allow what is known as code-switching to feed new information back into the systems so that the PPAC ontology will be able to self-populate additional instances. While conversation is taking place among GP and Aboriginal patient and carers or extended family, the GP could populate new instances from his/her observations into the knowledge base which may be of value for reuse by other practitioners. Hence, additional instances will be populated while the PPAC ontology is in use. In this case, the additional instances will also need to be checked concerning whether they conform to the PPAC ontology through consistency checking of the instances with reference to the PPAC ontology.

Usability Validation

By reasoning the PPAC ontology, we can derive facts that are not expressed explicitly in the ontology or in the knowledge base. It provides services to help users gain new knowledge. The system answers queries over PPAC

ontology classes and instances, for example, to find more general/specific classes or to retrieve instances matching a given query. We also use query responses to validate the PPAC ontology usability.

In the natural language process of preparation for building queries into the Protégé knowledge acquisition system, we provide two statement sets. These are designed to form queries for the purpose of PPAC ontology usability and also to reach shared semantic understanding.

The practitioner objective is:

- To identify T2DM SAE concept equivalents of patient AE words, phrases, or expressions

- To identify AE words, phrases, or expressions suited to the consultation context

- To semantically identify relevant AE properties

The patient-oriented objective is:

- To guide the practitioner toward cultural competence

- To find AE concept equivalents of T2DM words, phrases, or expressions

- To guide the practitioner toward links with relevant AE PPAC concepts

The complexity of the task of identifying concept relations, and the design of the query process to secure explicit information in this combined domain ontology, arise from the many-faceted cultural competence gaps. The principal users/participants will often lack prior semantic knowledge of the technical and dialectal lexicon used by the other. This may mean that each does not automatically recognize and employ those concepts that trigger and help to formulate queries. In our future work on application development, this will be anticipated and assistive tutorials will offer a wizard walk-through guide as a user-entry prelude to the PPAC ontology.

We focus query responses on the alcohol consumption issue which is one prevalent problem in the Aboriginal T2DM management domain. It is a subject matter replete with Aboriginal English euphemisms and metaphors with a fairly high risk of being missed by unfamiliar general practitioners. From our focus group of Aboriginal nurse trainee contributors, we know that if the doctor hears words such as or close to 'e bin chargin last night'; this is a reference to excessive drinking of alcohol. Physical gestures, for example, a patient curling his fingers as if holding a glass, lifting his hand toward his lips, may accompany such remarks. The GP may confirm the alcohol consumption factor by querying for 'bin' and 'chargin' as shown in Figure 13. The query is shown in the top and in the bottom shows the result.

Figure 13. Query Pose in DL Query—What could AE words 'bin' and 'chargin' be taken to mean?

From the query results, further details of each instance can be seen as shown in Figures 14 for 'bin' and Figure 15 for 'chargin'.
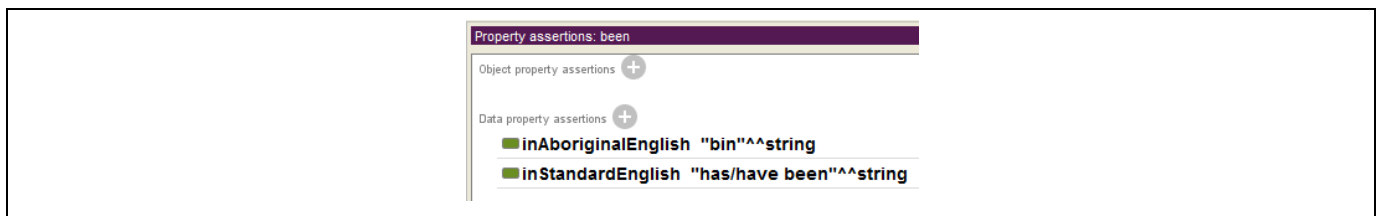
Figure 14. Query Response—AE word 'bin' could mean 'has or have been'.
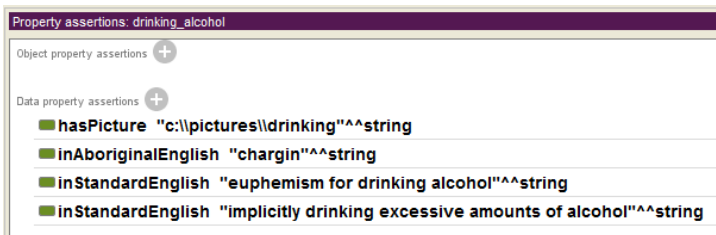
Figure 15. Query Response—AE word 'chargin' could mean 'euphemism for drinking alcohol' or 'implicitly drinking excessive amounts of alcohol'.

Again from our focus group, we have learnt that phrases identical or close to 'good breakfast, eggs and bacon' said in context are statements meaning that the subject has consumed a mix of alcoholic beverages. Practitioners can query for a word with 'bacon' in a phrase as shown in Figure 16 in SPARQL query. Note that in this particular query we will need to use SPARQL due to its capability in this type of query.
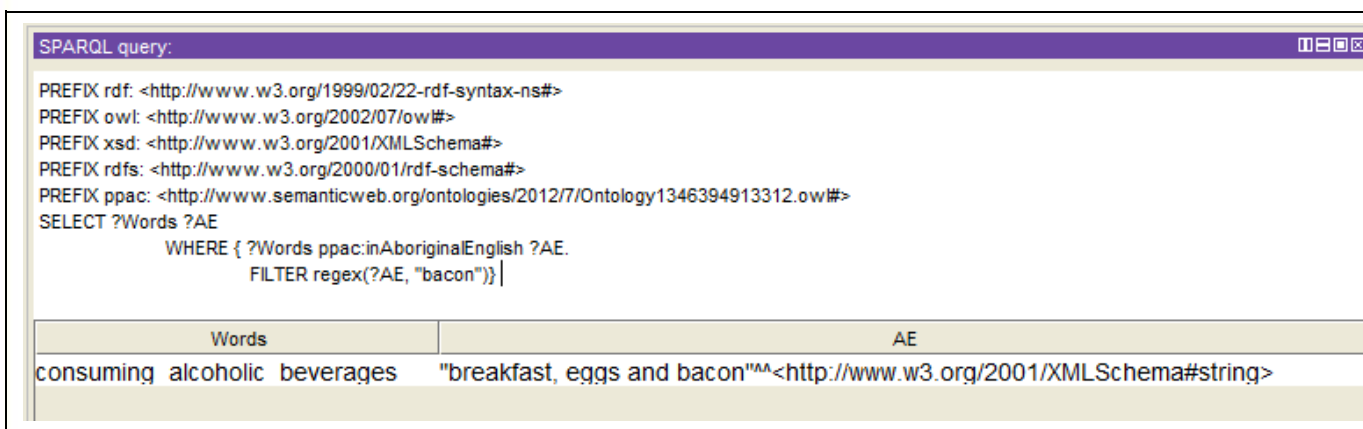
Figure 16. Query Pose in SPARQL—What could it be taken to mean for a phrase with 'bacon' in it?

Figure 17 shows the detail of the instance in which phrase in Aboriginal English of 'breakfast, eggs and bacon' can be taken to mean consuming a mix of alcohol beverages.
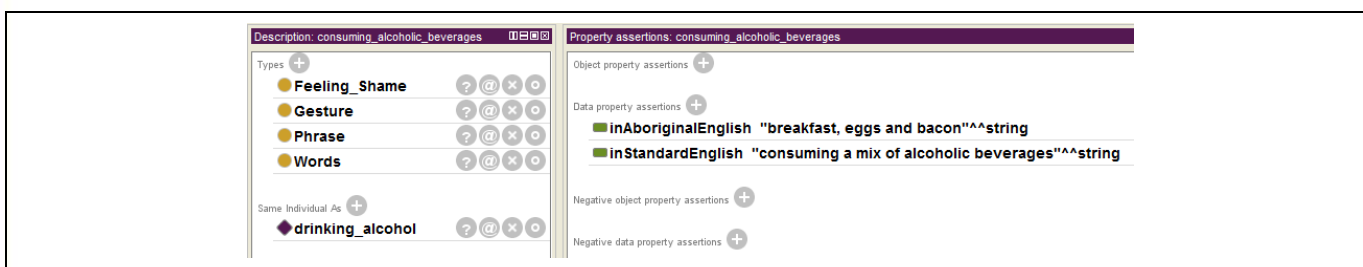
Figure 17. Query Response—phrase of 'breakfast, eggs, and bacon' in AE could be taken to mean consuming a mix of alcohol beverages.

From Figure 17, this instance is also an instance of classes *Feeling_Shame*, *Gesture*, *Phrase*, and *Words*. This indicates that it relates to feeling shame and having gesture captured as well. In this case, a movement and use of arms, hands, fingers, and head to convey a meaning of drinking is captured under class *Gesture* for drinking. Denoting shame, the PPIE communication could cause a drinking person to bow his head if managed without care. Hence, if GP looks further on feeling shame instance as can be seen in Figure 18, it can be confirmed such a sign of drinking person bowed head indicates that he feels shame. Another sign that indicates the possibility of feeling shame also includes physically turning away. The practitioner should also be cautious of an early premature unannounced departure by the patient.
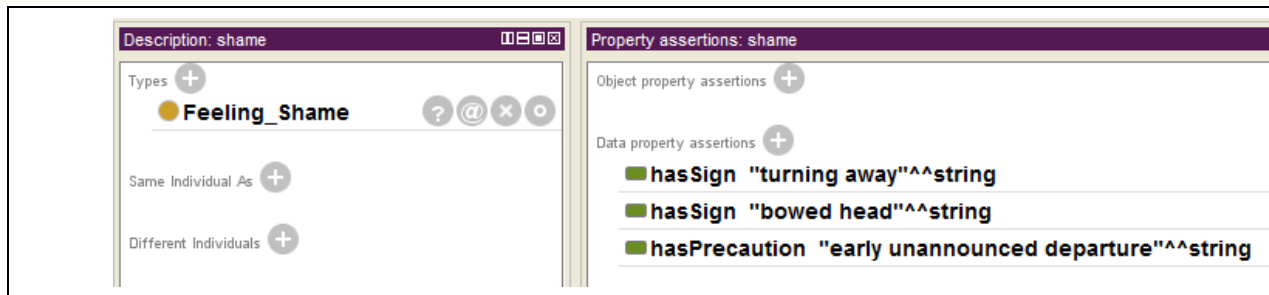
Figure 18. Relationships (Properties) of Instance *shame*

The design thinking for this is that, although there is no intention or attempt to implicitly or explicitly interfere with the work of the qualified medical professional, the overall aim of the model is to help participants move toward a shared compact for improved patient wellbeing outcomes. To that end the ontologies cross-map AE and T2DM guidelines to highlight differences in worldviews and thereby head off breakdowns in cognitively consonant communication.

VIII. CONCLUSION

In this research, ontology is a domain knowledge representation formed upon a controlled, standardised vocabulary for describing classes and the semantic relationships between them. The assistive technology concept does not provide nor interfere with professional diagnoses but assists the communications process in a manner designed to increase the PPIE quality of mutual understanding between the patient and the practitioner. The PPAC ontology for type 2 diabetes aims to overcome communication barriers that occur due to cultural communications gaps between the Aboriginal patient and the healthcare practitioner. Hence, in the ontology, a standardised vocabulary of type 2 diabetes care guidelines is captured along with Aboriginal English Home Talk. The Aboriginal diabetic patient uses the ontology to understand diabetic concepts in an Aboriginal discourse context. The practitioner and people involved in care, such as the interpreter, a carer family member, or a friend accompanying the patient, use the ontology to help mitigate cross-cultural misunderstandings, thereby finding a way to optimize shared cognition and understanding between provider and the Aboriginal patient. Over time, regular use of the PPAC by the patient and practitioners will increase and improve the sharing of knowledge about both T2DM and the patient's wellbeing in the disease context. Carers and interpreters closely involved with patients in need of their help will also gain knowledge and communications proficiencies as the PPAC system is accessed and gradually developed as a personalized tool.

IX. LIMITATIONS TO THE RESEARCH

A relatively small, albeit committed, number of Aboriginal advisers and contributors have been involved in this research to date, and there has been no direct engagement with remote Aboriginal communities. Similarly the cohort of both Indigenous and non-Indigenous healthcare practitioners providing advice has been limited in number, reflecting our desire to establish a proportional research strategy correlation for simultaneous interaction with both groups. As is inferred from our future work proposition, although the PPAC system concept is qualitatively well developed, at this writing it retains a hypothetical status as the data population of the Aboriginal English Home Talk/Health Talk ontology is quantitatively inadequate for real-world testing.

X. FUTURE WORK

Our perception from research to date is that developing applications will eventually enable Aboriginal use of this ontology in an aural and visual representative form, with limited use of the written text. Practitioners are already educated, trained in, and geared to text-driven forms of clinical documentation, and this may in time shift as new media gains credibility. Self-population of customized personal media data will help to grow the ontology taxonomy and accordingly the relationships among classes, sub-classes, their attributes (properties), and individual instances. Practical lexicography expertise will both complement and accelerate progress in this endeavour and will be essential support for efficiently managing lexical semantics volume and structural complexity. Future ontology classes, properties, and, at the granular detail level of instances, are likely to include the use of universal standardized iconography.

With the completion of the development of the conceptual framework and backbone implementation, the next stage toward introduction and productive use of the PPAC system within Aboriginal patient country communities and their healthcare service provider communities is threefold:

- Pragmatic content enrichment and scope expansion phase

- Development of commercial grade software application based on the completed conceptual framework

- Field trials of the PPAC system model using contemporary user-friendly devices

The future work schedule will be completed in three phases. The first is the preparatory and Aboriginal community engagement and field research phase. A major part of the preparation will involve T2DM Diabetes Australia/RACGP care guidelines schema abstraction. This part of the combined ontology is oriented toward mapping with Aboriginal English, and it should be noted that, for the purposes of mapping with other dialects, languages, and cultural pragmatics, this would differ. It will be employed to devise the focus group talking points and the face-to-face interview questionnaire. It contains some of the more techno-clinical terminology. Within this data collection process, we include digital media representation of concepts, e.g., recordings of spoken AE phrases.

Using ontologies to facilitate shared meaning through computer agents, we have not assumed that any clinical term should not be included, regardless of the complexity and difficulty in reaching a simplified explanation for people with a limited proficiency in English. To the contrary, we believe that more effort should be made to break down the institutional healthcare culture language barriers confronting patients and that Aboriginal communities, given the opportunity, can help this process.

The second phase is dedicated to data quality system content and software application development consolidation. It will require intensive debriefing of field researchers as a quality assurance measure to ensure that ontology semantics and contextualisation relationships are sufficiently robust to serve the objective of the eventual application.

The third phase will be field trials of the PPAC system model using contemporary user-friendly devices and community connections established during earlier work. This will invoke the need to refine the model through iterations leading to a viable commercial grade specification and application.

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Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the article on the Web, can gain direct access to these linked references. Readers are warned, however, that:
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