

RESEARCH ARTICLE

Developing an ontology for representing the domain knowledge specific to non-pharmacological treatment for agitation in dementia

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Abstract

Introduction: A large volume of clinical care data has been generated for managing agitation in dementia. However, the valuable information in these data has not been used effectively to generate insights for improving the quality of care. Application of artificial intelligence technologies offers us enormous opportunities to reuse these data. For health data science to achieve this, this study focuses on using ontology to coding clinical knowledge for non-pharmacological treatment of agitation in a machine-readable format.

Methods: The resultant ontology—Dementia-Related Agitation Non-Pharmacological Treatment Ontology (DRANPTO)—was developed using a method adopted from the NeOn methodology.

Results: DRANPTO consisted of 569 concepts and 48 object properties. It meets the standards for biomedical ontology.

Discussion: DRANPTO is the first comprehensive semantic representation of non-pharmacological management for agitation in dementia in the long-term care setting. As a knowledge base, it will play a vital role to facilitate the development of intelligent systems for managing agitation in dementia.

KEYWORDS

agitation, artificial intelligence, dementia, knowledge base, knowledge representation, long-term care, non-pharmacological treatment, ontology, semantic web

1 | INTRODUCTION

With population aging, the number of people with dementia is increasing rapidly.¹ The economic and social impact of dementia makes it stepping into “a public health priority” declared by the World Health Organization (WHO).¹ As there is no effective cure to dementia, the major focus of the current health and social care system is supporting

healthcare professionals and providing them with evidence about the best care for people living with dementia. Management of Behavioral and Psychological Symptoms of Dementia (BPSD) is one of the most challenging aspects in dementia care.^{2,3} Agitation is a common BPSD, with prevalence rates up to 70% in people with dementia.⁴

Agitation is a general term that describes a diverse range of behaviors, including physically aggressive behaviors (eg, hitting and pushing

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people), physically non-aggressive behaviors (eg, restlessness and pacing), verbally aggressive behaviors (eg, threat and cursing), and verbally non-aggressive behaviors (eg, groaning and ceaseless talking).⁵ It often leads to physical and psychological burden on people taking care of people with dementia such as heavy workload, disruptions to daily care routines, depression, and poor quality of life.^{2,3,6,7} Some other adverse outcomes may include the patients' premature institutionalization⁸ and health care professionals' compensation because of injuries caused by the patients' physical agitated behaviors.^{6,9}

1.1 | Agitation management

Agitation is manageable.¹⁰ The efficacy of pharmaceutical treatment for agitation is modest, but it often carries the risk of serious adverse effects.¹⁰⁻¹² For example, antipsychotic drugs may increase the risk of cardio-metabolic disorders and mortality.^{10,13} That is the reason for the US Food and Drug Administration (FDA) to issue a black-box warning, the strictest warning put in the labeling of perception drugs by the FDA, for all antipsychotic medications.^{13,14} Therefore, the use of drugs to treat agitation is not recommended unless it is unavoidable, such as when there is a considerable risk to the person or others.¹²

A safer and more effective agitation management strategy is non-pharmacological therapies,^{10,15} that is, treatment without the use of drugs. This strategy encompasses psychological, psychosocial, interpersonal, cultural, behavioral, emotional, spiritual, environmental interventions, and physical activities.^{10,16,17} Examples of non-pharmacological therapies include exercise therapy, music therapy, aromatherapy, pet therapy, bright light therapy, multisensory therapy, doll therapy, and simulated presence therapy.^{10,11,17} Some researchers suggest that one or a combination of non-pharmacological therapies can yield better treatment results than pharmacological treatments.^{12,15} The current good practice guidelines recommend that non-pharmacological interventions should be used as the first-line treatment approach to agitation.^{11,18-20}

Despite the reported effectiveness of the non-pharmacological interventions for agitation management, researchers indicated that these strategies have neither been widely implemented in long-term care facilities^{21,22} nor effectively used in clinical practice, and many general practitioners do not even consider them as credible approaches.²³ Some barriers identified to the use of these interventions include: (1) hard to identify the triggers of agitation,²² (2) time constraint faced by healthcare professionals,^{15,22,24} and (3) limited knowledge in agitation management.^{13,21,22,25}

Healthcare professionals should meet their obligation to deliver optimal health care to people with dementia.¹ Due to the above-identified barriers, healthcare professionals are limited in their capacity to fulfill this duty. Therefore, providing information and tool support is vital for these professionals to effectively implement the non-pharmacological strategies.¹⁵ It is also consistent with World Health Organization's (WHO's) Global Action Plan¹ on supporting people with dementia and health care professionals by developing

HIGHLIGHTS

- This study builds an ontology Dementia-Related Agitation Non-Pharmacological Treatment Ontology (DRANPTO) for dementia care in the long-term care setting.
- DRANPTO maps knowledge on non-pharmacological management for agitation in dementia.
- DRANPTO is developed using a method adopted from the NeOn methodology.
- DRANPTO consists of 569 concepts and 48 object properties.
- DRANPTO is rigorously evaluated and meets the standards for biomedical ontology.

RESEARCH IN CONTEXT

1. **Systematic review:** Literature about non-pharmacological management for agitation in dementia using were reviewed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. An ontology Dementia-Related Agitation Non-Pharmacological Treatment Ontology (DRANPTO) is built to represent the knowledge from the literature.
2. **Interpretation:** To date, dementia care has rarely benefited from big data analytics and artificial intelligence. For the first time, DRANPTO provides a computable, formal representation of knowledge in this domain. It facilitates researchers and practitioners to map the relationships between concepts in this domain.
3. **Future directions:** More ontologies to represent other Behavioral and Psychological Symptoms of Dementia (BPSD) management knowledge, such as apathy and depression, need to be developed to form a comprehensive BPSD non-pharmacological management ontology. The ontology can be used to drive the development of person-centered online training material or data mining from the existent electronic health records to provide intelligent decision support for practitioners to manage agitation in dementia.

information tools for "systematic collection, analysis and use of dementia specific data."

1.2 | Problem statement

To date, a large volume of clinical care data has been generated for the management of agitation, particularly in the long-term care facilities,²⁶

such as clinical documentation from medical and nursing staff, and information collected from care recipients' relatives and friends. However, the valuable information in these data sets has not been effectively reused to generate insights for the improvement of quality of care.^{27,28} Failure to address agitation can result in a catastrophic reaction, such as the considerable loss of quality of life for people with dementia and their families and health care professionals.^{2,3,7}

Application of artificial intelligence (AI) technologies, including data mining and machine learning technology, offers enormous opportunity for us to effectively use health data to better understand triggers and risk factors of agitation, its manifestation, and the most effective non-pharmacological interventions to manage it. For health data science to achieve this, first we need to code clinical knowledge in a machine-readable format using a specific computer dictionary—ontology, which recodes concepts, terms, and their relationships for agitation non-pharmacological management. Therefore, this study aims to explore and develop a machine-readable ontology representing agitation non-pharmacological treatment knowledge in dementia care, named DRANPTO (Dementia-Related Agitation Non-Pharmacological Treatment Ontology). The ultimate goal is to effectively reuse health data to develop nursing knowledge to support agitation management practice, that is, to facilitate and simplify the development of clinical decision-support systems for assisting health care professionals to manage agitation in the long-term care setting.

1.3 | Ontology definition

The word ontology is first introduced by ancient Greek philosopher Aristotle to mean the science of existence.²⁹ In information science, ontology is defined as “a formal explicit specification of shared conceptualization” by the AI community,³⁰ and is recognized as essential elements of AI technology.³¹ According to this definition, the proposed ontology of this study is a formal representation of a shared conceptualization of the domain knowledge in agitation non-pharmacological management.

Ontology, by its nature, is a conceptual domain model presented with a controlled vocabulary in a formal language.³² It can thus represent knowledge in a machine-processable format.³² A conceptual domain model describes a specific domain as a collection of concepts and their inter-relationships, which correspond to entities in the real world.³³ In this study, the agitation non-pharmacological treatment knowledge was conceptualized into defined concepts, the relationships between these concepts, and attributes of the concepts.

1.4 | Ontologies in health domain

A great effort has been made on the development of ontologies in the health domain. One example is SNOMED CT ontology, a comprehensive clinical healthcare terminology, whose current release contains 350,830 concepts.³⁴ Another example is the LOINC ontology, currently with 91,388 terms about medical laboratory test and patient observations.³⁵ The WHO developed an ontology of International

Classification of Diseases (ICD) as the global standard for diagnostic health information. The latest version, ICD-11, was released in June 2018, and contains $\approx 55,000$ codes.³⁶

Ontologies have been applied in the dementia domain. For example, Zhang et al.³⁷ have developed the mild cognitive impairment (MCI) ontology to assist physicians in diagnosing MCI efficiently. To assess the individual's risk of developing dementia, Roantree et al.³⁸ built the In-MINDD ontology, which models the risk factors that can cause dementia. Skarzynski et al.³⁹ created the SOLOMON ontology for the semantic online searches of resources related to dementia neurodegeneration. To emphasize the importance of placing people with dementia in the center of care, Pennington⁴⁰ introduced an ontological model that represents the relationships between people with dementia and the different entities with which they interact. In addition, Refolo et al.⁴¹ developed the Common Alzheimer's Disease Ontology (ADO) as a dynamic portfolio analysis tool for funding agencies on strategic planning and coordination of Alzheimer's disease (AD) research.

To the best of our knowledge, there is no comprehensive ontology containing concepts representing each specific non-pharmacological intervention that is appropriate for agitated behaviors of dementia. Thus, this study is an important contribution to the research community in the domain of agitation management for people with dementia.

2 | METHODS

To achieve the aim of this study, the NeOn methodology⁴² was adapted to develop DRANPTO. The NeOn methodology is one of the proven methods for ontology engineering.⁴³ It has been used to build many ontologies successfully in the health domain, such as TrhOnt ontology to assist physiotherapists in managing patients' rehabilitation processes⁴⁴ and a histological ontology of the human cardiovascular system.⁴³ The proposed method for building DRANPTO is illustrated in Figure 1. A detailed description of each component of the proposed method is presented next.

2.1 | Ontology requirement specification

The purpose of this activity was to specify the requirements that the expected ontology need to meet. The output was the ontology requirements specification document (ORSD), which includes the information about the purpose, the scope, the target group, the intended use of the ontology, and the competency questions (CQs). The ORSD for DRANPTO was developed through literature review and brainstorming with domain experts, including two established researchers in dementia care and two experts in the development of digital technology for aged care.

2.2 | Method of resource reuse

The knowledge in the domain of agitation non-pharmacological management is highly complex. Resource reuse process was carried out

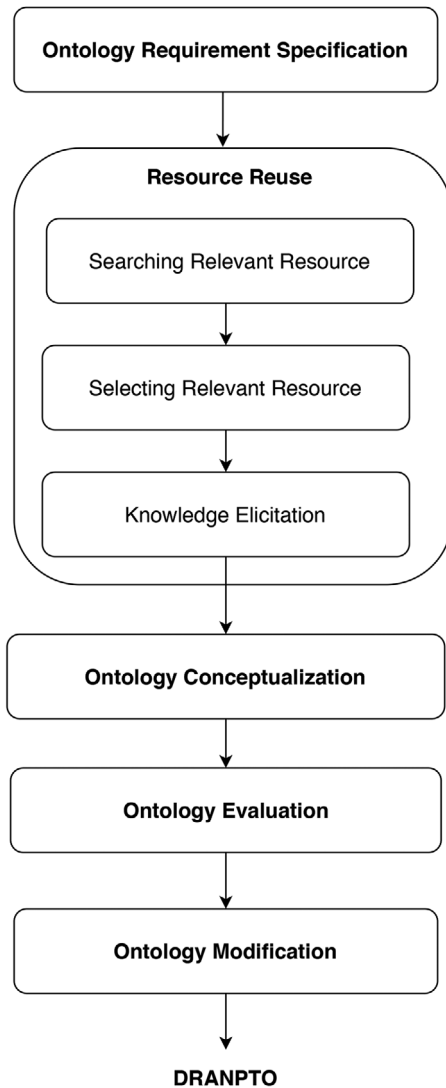


FIGURE 1 Proposed DRANPTO development method (adapted from the NeOn methodology⁴²)

to capture non-pharmacological treatment knowledge of agitation in dementia from the existing resource, such as the published relevant ontologies in the biomedical ontology repositories and literature of current evidence-based practice in the domain of agitation management. In this stage, three activities were performed: (1) search relevant resource, (2) select the most appropriate resource, and (3) extract the knowledge for building DRANPTO.

2.2.1 | Method of searching relevant resource

First, a comprehensive search using keywords “agitation,” “challenging behavior,” “behavior of concern,” “management,” “dementia care,” “non-pharmacological intervention,” and “non-pharmacological treatment” was performed in the most relevant biomedical ontology repositories, including the National Center for Biomedical Ontology (NCBO) BioPortal⁴⁵ and the Open Biological and Biomedical Ontology (OBO)

Foundry.⁴⁶ No ontologies representing the knowledge of agitation non-pharmacological management were found. Then, a systematic literature search was conducted to identify potentially relevant literature. The literature search strategy was developed through a consultation with a librarian not associated with the project on August 26, 2019. Through using this strategy, five databases were searched, including MEDLINE, CINAHL Plus with Full Text, the Cochrane Library, PsycINFO, and Web of Science. The MeSH search term “dementia” AND “agitation or agitated behavior” AND “non-pharmacological or psychosocial” AND “intervention or treatment or management or therapy or strategy or best practice or guideline” was used to identify literature. To ensure literature saturation, the reference lists of included studies were also scanned.

2.2.2 | Method of selecting relevant resource

Once the relevant literature was collected, the resource selection activity was performed to identify the most appropriate articles. Selected articles were analyzed and critically appraised using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines⁴⁷ (see Figure 2). A total of 931 articles were collected, and 110 articles were included in this study. Articles were selected according to the five inclusion criteria: (1) written in English; (2) published from database inception onward to August, 26 2019; (3) published in peer-reviewed scientific journals; (4) articles about non-pharmacological treatment to agitation (or as a part of BPSD) for people with dementia in the long-term care facilities; and (5) the study types include case studies, descriptive studies, systematic reviews, meta-analyses, and randomized controlled trials of non-pharmacological treatments, as well as practical guidelines for agitation in dementia. Articles were excluded according to the following exclusion criteria: (1) about pharmacological interventions for agitation management; (2) about multicomponent interventions with a component of pharmacological intervention; (3) about electroconvulsive therapy (ECT); (4) conducted in the home care environment, hospital environment, and community day care center; (5) only contain the study protocol without outcome; and (6) conference abstract, poster abstract, and editorial material.

2.2.3 | Method of knowledge elicitation

Based on the selected literature, a systematic knowledge elicitation approach was performed to abstract terms for representing knowledge in the domain of agitation non-pharmacological management. This process was undertaken manually by the first author, in consultation with two other authors. Through carefully reading of the selected literature, the sentences which describe the key concepts and their inter-relationships in the agitation non-pharmacological treatment domain were extracted and documented in the document “DRANPTO Building Documentation: agitation non-pharmacological treatment knowledge - captured from literature” (see Appendix). For example,

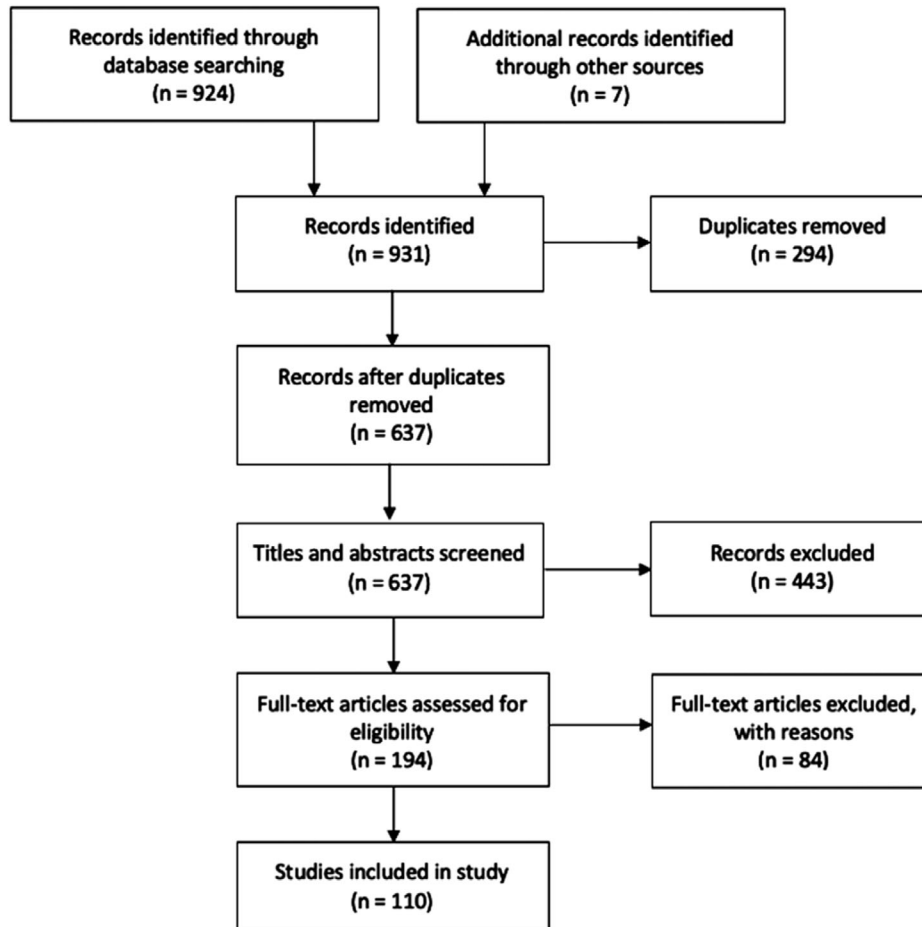


FIGURE 2 Publication search process according to the modified PRISMA flowchart

the sentence “Simulated presence and preferred music both proved effective in reducing counts of physically agitated behaviors” was extracted from a study “A comparison of two treatments of agitated behavior in nursing home residents with dementia: simulated family presence and preferred music”⁴⁸ and then documented with the reference. Software NVivo 12⁴⁹ was used to manage the selected literature and code the relevant sentences.

2.3 | Ontology conceptualization

After the Knowledge Elicitation process, the knowledge of non-pharmacological treatment for agitation in dementia was captured. In the Ontology Conceptualization process, the captured knowledge was organized into a conceptual model. First, the important terms representing agitation non-pharmacological treatment knowledge were elicited from the documented sentences and coded in the ontology edit software Protégé.³¹ These terms were nouns and verbs. The nouns were identified as concepts, attributes, and instances. Classes in the ontology were extracted from the relevant nouns. Each class has a description/definition, a label, abbreviation, and synonyms if applicable. Then according to the subsumption relationship (*is-a-superclass-of*,

the converse of *is-a-subclass-of*) between classes, the class hierarchy tree was built. For example, the terms of “Music Therapy” and “Sensory Therapy” were elicited and defined as classes. Because “Music Therapy” is a subclass of “Sensory Therapy,” “Music Therapy” was defined as a subclass of the class “Sensory Therapy.”

The elicited verbs were used to create the properties for describing inter-relationships or attributes of classes. Object properties were defined to connect classes with domain and range. For example, the verb “conducts” was elicited and defined as an object property for describing the relationships between the class “Health Care Professional” and “Agitation Management Activity.” Here, the class “Health Care Professional” is defined as the domain of this property, and the class “Agitation Management Activity” is defined as the range of this property. Thus, the knowledge of “health care professional conducts agitation management activity” was captured and represented formally in Protégé.

The formal ontological model was implemented in Web Ontology Language (OWL) 2, which is the W3C standard ontology representation language.⁵⁰ Protégé 5.2.0,³¹ a free, open-source ontology editing tool developed by the Stanford Center for Biomedical Informatics Research at the Stanford University, was used for editing the ontology.

2.4 | Evaluation and modification methods

Evaluation of the developed DRANPTO was performed in five steps: first, during the implementation process, a semantic reasoner Pellet that uses description logic to perform reasoning⁵¹ was run to test the consistency of the ontology, as Pellet supports full incremental classification,⁵² and has strong reasoning ability.⁵³ Afterward the Ontology Pitfall Scanner (OOPS!)⁵⁴ was applied to detect pitfalls in DRANPTO. OOPS! is a web-based tool for evaluating ontologies against a set of 41 potential pitfalls classified in the structural, functional, and usability dimensions of an ontology in the health domain.⁵⁵ Examples of the pitfalls are creating synonyms as classes, defining wrong inverse relationships, and including cycles in a class hierarchy.⁵⁴ These potential pitfalls of OOPS! were defined by analyzing existing ontologies and extracting the existing pitfalls from articles on ontology evaluation, and evaluated by analyzing user feedback and an empirical study of the pitfalls detected over 969 ontologies.⁵⁶ The usefulness of OOPS! has been tested in building TrhOnt ontology for physiotherapists to manage patients' rehabilitation processes,⁴⁴ and a histological ontology of the human cardiovascular system.⁴³ Furthermore, a dementia care expert and an experienced nursing manager in a residential aged care facility were invited, as the domain experts, to manually evaluate the developed ontology in terms of accuracy, clarity, and completeness. In addition, evaluation of the capability of the developed DRANPTO to answer the CQs was conducted using SPARQL query language.⁵⁷ SPARQL is a semantic query language for retrieving and manipulate data stored in the ontology that are expressed in Resource Description Framework format.⁵⁸ In this study, SPARQL query language was used to create queries to represent the CQs to retrieve data from the ontology. The retrieved data were verified to test if the ontology can generate the correct answer for each CQ. At last, the quality of DRANPTO was assessed by the criteria for biomedical ontology,⁵⁹ including accuracy, clarity, completeness, conciseness, and consistency. Based on the results of evaluation, the proposed ontology was modified and then finalized.

3 | RESULTS

3.1 | Results of ontology requirements specification

As the results of specification, the ORSD for DRANPTO was developed (see Table 1).

3.2 | Results of resource reuse

The document "DRANPTO Building Documentation: agitation non-pharmacological treatment knowledge - captured from literature" (see Appendix) was produced as the results of Resource Reuse. An excerpt of this documentation is shown in Table 2.

3.3 | Resultant ontology

The resultant ontology has 569 classes, which were categorized in a hierarchy with nine granular levels. It contains 11 top-level classes (see Figure 3). Each top-level class has a number of subclasses. For example, there are 12 subclasses under the top class of "Agitation Management Approach" (see Figure 4). Moreover, 48 object properties were built to connect the classes with the identified domains and ranges (see Figure 5). A simplified ontology graph was drawn to show the major classes and their relationships in DRANPTO (see Figure 6). The oval shapes in the graph depict the classes in DRANPTO. Between the oval-shaped classes, a solid line connects two classes to signify a relationship (object property), and a dotted line depicts a subsumption relationship. DRANPTO has been made publicly available at the NCBO BioPortal⁶¹ because it is "the world's most comprehensive repository of biomedical ontologies"⁶² developed by the U.S. NCBO.⁴⁵

3.4 | Results of evaluating the ontology

This section describes the evaluation results and the refinement made to the ontology based on five methods of evaluation described in the Methods section.

3.4.1 | Results of automatic evaluation by Pellet and OOPS!

First, DRANPTO was checked by the built-in automatic reasoner Pellet. No logic inconsistency was reported. Then, an evaluation via OOPS! was performed. OOPS! classifies three levels of pitfalls: minor, important, and critical. For DRANPTO, one minor pitfall and two important pitfalls were detected (see Table 3). The minor pitfall was that three elements of this ontology lacked human readable annotations to define them. They were class "Reading Large Print Book," "Watching Bird," and "Speaking in Gentle Voice." To fix this pitfall, the definition annotations of these classes were created and then attached to them correspondingly. The annotation property of "rdfs:comment" was used to conduct this modification in Protégé.

For the two important pitfalls, one of which was that three pairs of classes might be equivalent, yet not explicitly declared in the proposed ontology. They were "Hunger" versus "Thirst," "Shouting" versus "Yelling," and "Delusion" versus "Hallucination." To address this issue, face-to-face consultations were held with a dementia care expert and a biomedical semantics expert. Both experts had the same opinion. For the first pair of classes "Hunger" versus "Thirst," they were not equivalent concepts because "Hunger" is "an uneasy sensation occasioned by the lack of food,"⁶³ whereas "Thirst" is "a sensation of dryness in the mouth and throat associated with a desire for liquid"⁶⁴ according to Merriam Webster Dictionary. Therefore, the corresponding descriptions were added for these two concepts in Annotations in the ontology. The annotation property of "rdfs:comment" was used to conduct this modification in Protégé.

TABLE 1 Ontology requirements specification documentation for DRANPTO

Ontology requirements specification documentation
Purpose
The purpose of DRANPTO is to provide a reference model for the representation of the knowledge in the domain of dementia-related agitation non-pharmacological management.
Scope
The ontology will focus on dementia-related agitation non-pharmacological management strategies that could be used in the long-term care facilities.
Implementation language
The ontology will be implemented in the ontology representation language OWL 2 using Protégé 5.2.0.
Intended users
<ul style="list-style-type: none"> • Direct users: biomedical researchers who conduct academic research to generate insights for the improvement of quality of care; software engineers for developing ontology-driven information systems to assist health care professionals in the management of agitation in dementia • End-users: health care professionals working in the long-term care facilities to look after people with dementia
Intended use cases
<ul style="list-style-type: none"> • Use case 1: to share a common understanding of agitation non-pharmacological treatment knowledge between people and machines in processes such as automatic recognition and identification of agitation symptoms, manifestations of agitation, non-pharmacological interventions, and causative factors that cause the exhibition of agitation from the existing health records. • Use case 2: to advise health care professional about the appropriate non-pharmacological interventions for a person who is exhibiting agitation, given all the information that it is known about him/her. • Use case 3: to support the organizational improvement initiatives in agitation non-pharmacological management for health care professionals in the long-term care facilities. • Use case 4: to build online educational material about agitation non-pharmacological management for people with dementia.
Ontology requirements
<ol style="list-style-type: none"> a. Non-functional requirements (not applicable) b. Functional requirements: competency questions (CQs) <ol style="list-style-type: none"> 1. What are agitated behaviors? 2. What causes agitation in people with dementia? 3. What non-pharmacological interventions are used for agitation in dementia? 4. What are the main activities for agitation management in dementia care? 5. What are the major approaches to agitation management? 6. What tools are used to measure agitation in dementia? 7. What background information of people with dementia is related to agitation management? 8. What factors affect the implementation of non-pharmacological interventions to agitation in dementia?
Pre-glossary of terms
Dementia, BPSD, agitation, non-pharmacological intervention, treatment, management, strategy, long-term care, causative factor, manifestation, exhibition, assessment tool, background information, people with dementia, implementation.

The second reported pair of classes were “Shouting” versus “Yelling.” Experts agreed with the automatic recommendation of OOPS! that they are equivalent classes because they convey the same concept of making a loud cry due to agitation. Therefore, “Yelling” was annotated as a synonym of “Shouting” instead of a new concept in the ontology. In the case of “Delusion” versus “Hallucination,” they represent different psychotic symptoms: “Delusion” is “a false belief regarding the self or objects outside the self that persists despite the facts, and is not considered tenable by one’s associates,”⁶⁵ whereas “Hallucination” is “subjectively experienced sensations in the absence of an appropriate stimulus, but which are regarded by the individual as real.”⁶⁶ Therefore, the original classification was kept, with clear annotation added.

The other important pitfall was that the ontology metadata omitted information about the license that applies to DRANPTO. To fix it, the license information was added to the ontology, which clearly stated

that DRANPTO is licensed under Creative Commons Attribution-NonCommercial-ShareAlike (CC BY-NC-SA) license version 4.0.⁶⁷ In Protégé, the annotation property “dcterms:license” was created and then used to conduct this modification.

3.4.2 | Results of evaluation by domain experts

A dementia care expert and an experienced nursing manager in a residential aged care facility, as the domain experts, manually evaluated the developed ontology in terms of accuracy, completeness, and clarity. The dementia care expert performed the manual evaluation first. She confirmed the accuracy. Following her suggestions about the completeness, four new concepts were added as new classes in the ontology. They were: “Management Support” as a subclass of “Facilitator To Implement Non-pharmacological Intervention”; “Time Management

TABLE 2 An excerpt of “DRANPTO Building Documentation: agitation non-pharmacological treatment knowledge—captured from literature”

Reference	Information elicited
(Baillon et al. 2004) ⁶⁰	Both Snoezelen therapy and one-to-one themed reminiscence therapy have a positive effect in reducing agitated behavior. Agitated behavior is associated with carer stress and the likelihood of institutionalization. The Cohen-Mansfield Agitation Inventory (CMAI) and Agitation Behavior Mapping Instrument were used in this study.
(Garland et al. 2007) ⁴⁸	Both simulated presence intervention and preferred music intervention have a positive effect in reducing physically agitated behavior. Simulated family presence used in this study: a 15-minute audiotape of dialogue in imitation of a telephone conversation prepared by a family member about cherished experiences and anecdotes from earlier life. Music preferred by the resident in earlier life proved effective in reducing agitated behaviors. The agitated behaviors exhibited by nursing home residents with dementia stem from a multitude of factors, including confusion, loneliness, pain, anxiety, depression, and psychosis. Some behaviors settle quickly with reassurance and distraction. Agitated behavior can lead to staff burnout, physical restraint, and overmedication. CMAI was used in this study.

Training” as a subclass of “Health Care Professional Education Intervention”; “Having Regular Staff” as a subclass of “Social Environmental Intervention”; and “Feeding Animal” as a subclass of “Recreational Activity.” In addition, following her recommendation about the clarity, the term “Health Care Professional” was used to replace “Caregiver”

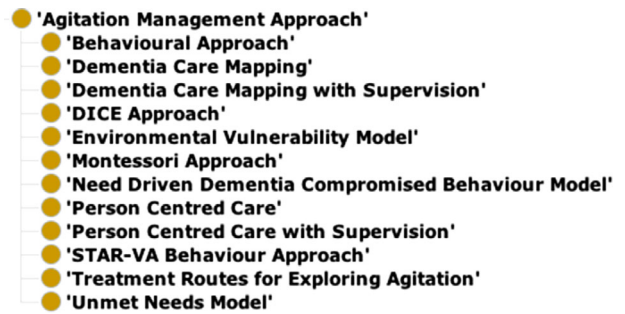


FIGURE 4 Twelve sub-classes of the top-class “Agitation Management Approach” in DRANPTO

as the class name to represent the concept “Professional care workers providing care to person with dementia in the long-term care facilities.” The reason was the term “Caregiver” which has more than one interpretation (professional caregiver, family caregiver, or both) could cause the occurrence of semantic ambiguity. The modified ontology was then evaluated by the nursing manager. He confirmed the accuracy, clarity, and completeness with no modification.

3.4.3 | Results of evaluation by competency questions using SPARQL query

In order to assess the capability of the developed DRANPTO to answer the CQs, each CQ was represented by SPARQL queries to retrieve data from the ontology. For example, CQ6 “What are the tools used to assess agitation in dementia” in SPARQL language was

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PREFIX rdf: < http://www.w3.org/1999/02/22-rdf-syntax-ns# >
PREFIX owl: < http://www.w3.org/2002/07/owl# >
PREFIX rdfs: < http://www.w3.org/2000/01/rdf-schema# >
PREFIX xsd: < http://www.w3.org/2001/XMLSchema# >
PREFIX: < http://www.semanticweb.org/zhenyuzhang/ontology
es/2019/8/non-pharmacological-intervention-for-agitation-in-
dementia-ontology/>

SELECT ?AgitationAssessmentTool ?Name
WHERE { ?AgitationAssessmentTool rdfs:subClassOf
:AgitationAssessmentTool; rdfs:label ?Name}
```

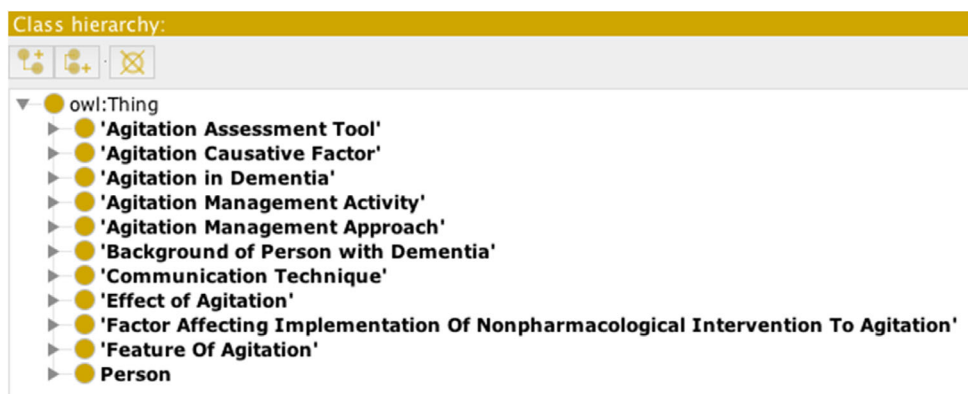


FIGURE 3 Eleven top-classes of DRANPTO

Object Property	Domain	Range	Inverse
owl:topObjectProperty			
is affected by	Nonpharmacological Intervention	Factor Affecting Implementation of Nonpharmacological Intervention to Agitation	affects
is hindered by	Nonpharmacological Intervention	Barrier to Implement Nonpharmacological Intervention	hinders
is facilitated by	Nonpharmacological Intervention	Facilitator to Implement Nonpharmacological Intervention	facilitates
composes	Individual Therapy for Agitation	Multicomponent Intervention for Agitation	is composed of
conducts	Health Care Professional	Agitation Management Activity	is conducted by
applies	Health Care Professional	Agitation Management Approach	is applied by
has agitation	Person with Dementia	Agitation in Dementia	is agitation of
reduce agitation caused by	Nonpharmacological Intervention	Agitation Causative Factor	is addressed to reduce agitation by
has communication technique	Health Care Professional	Communication Technique	is communication technique of
causes	Agitation Causative Factor	Agitation in Dementia	is caused by
has family member	Person with Dementia	Family Member of Person with Dementia	is family member of
is communication technique of	Communication Technique	Health Care Professional	has communication technique
is matched by	Background of Person with Dementia	Person with Dementia Focused Intervention	matches
is applied by	Agitation Management Approach	Health Care Professional	applies
is provided by	Background of Person with Dementia	Person	provides background information
provides background information	Person	Background of Person with Dementia	is provided by
is conducted by	Agitation Management Activity	Health Care Professional	conducts
is addressed to reduce agitation by	Agitation Causative Factor	Nonpharmacological Intervention	reduce agitation caused by
is effect of	Effect of Agitation	Agitation in Dementia	has effect
is family member of	Family Member of Person with Dementia	Person with Dementia	has family member
has background	Person with Dementia	Background of Person with Dementia	is background of
is background of	Background of Person with Dementia	Person with Dementia	has background
has feature	Agitation in Dementia	Feature of Agitation	is feature of
has frequency	Agitation in Dementia	Frequency of Agitation	is frequency of
has severity	Agitation in Dementia	Severity of Agitation	is severity of
has duration	Agitation in Dementia	Duration of Agitation	is duration of
has context	Agitation in Dementia	Context of Agitation	is context of
cares for	Health Care Professional	Person with Dementia	is cared by
is friend of	Friend of Person with Dementia	Person with Dementia	has friend
has effect	Agitation in Dementia	Effect of Agitation	is effect of
is agitation of	Agitation in Dementia	Person with Dementia	has agitation
treats	Intervention	Agitation in Dementia	is treated by
is assessed by	Agitation in Dementia	Agitation Assessment Tool	assesses agitation
is treated by	Agitation in Dementia	Intervention	treats
is cared by	Person with Dementia	Health Care Professional	cares for
is composed of	Individual Therapy for Agitation	Individual Therapy for Agitation	composes
affects	Factor Affecting Implementation of Nonpharmacological Intervention to Agitation	Nonpharmacological Intervention	is affected by
facilitates	Facilitator to Implement Nonpharmacological Intervention	Nonpharmacological Intervention	is facilitated by
hinders	Barrier to Implement Nonpharmacological Intervention	Nonpharmacological Intervention	is hindered by
matches	Person with Dementia Focused Intervention	Background of Person with Dementia	is matched by
has friend	Person with Dementia	Friend of Person with Dementia	is friend of
is caused by	Agitation in Dementia	Agitation Causative Factor	causes
assesses agitation	Agitation Assessment Tool	Agitation in Dementia	is assessed by
is feature of	Feature of Agitation	Agitation in Dementia	has feature
is severity of	Severity of Agitation	Agitation in Dementia	has severity
is context of	Context of Agitation	Agitation in Dementia	has context
is frequency of	Frequency of Agitation	Agitation in Dementia	has frequency
is duration of	Duration of Agitation	Agitation in Dementia	has duration

FIGURE 5 Object properties in DRANPTO

The retrieved data were the English names of 15 tools for assessing agitation captured from the selected literature (see Figure 7). The consistency between the retrieved data and the original concepts suggests that the developed ontology can generate the correct answer for each CQ.

3.4.4 | Quality of DRANPTO

The evaluation results ensured the quality of the developed ontology as assessed by the criteria for biomedical ontology,⁵⁹ including accuracy, clarity, completeness, conciseness, and consistency.

Accuracy has two meanings: accuracy of the definitions and accuracy of the descriptions of the classes and the properties in an ontology.^{59,68} DRANPTO meets this standard because the concepts and their definitions and descriptions in DRANPTO were extracted from the peer-refereed, published literature in the domain, and further evaluated by the domain experts. For example, DRANPTO has the class “Sundowning,” which represents the concept that sundowning during the evening could trigger the manifestation of agitated behaviors in people with dementia. This class meets the accuracy standard because the concept of “Sundowning” was extracted from three peer-refereed, published articles including Cohen-Mansfield and Billig’s “Agitated behaviors in the elderly. I. A conceptual review,”⁶⁹ Putman and Wang’s “The closing group: therapeutic recreation for nursing home residents with dementia and accompanying agitation and/or anxiety,”⁷⁰ and Alexopoulos et al.’s “Treatment of dementia and agitation: a guide for families and caregivers.”⁷¹ To ensure the accuracy of

this class, it was further manually evaluated by two aged care nursing experts.

Clarity measures “how effectively the ontology communicates the intended meaning of the defined terms.”⁶⁸ Names of concepts and their definitions should be understandable and non-ambiguous.^{59,68} Clarity of DRANPTO is achieved by assigning to the non-ambiguous label or description to each class using “rdfs:label,” “rdfs:comment,” or “skos:definitions” (see an example about “Music Therapy” in Figure 8). This also ensures DRANPTO can communicate the concepts and their relationships clearly to the readers.

Completeness measures the coverage of the domain knowledge by the ontology.^{59,68} Completeness of DRANPTO was evaluated by two methods: manual evaluation by two domain experts, a nursing academic, and an experienced nursing manager in a residential aged care facility; and evaluation by the CQs specified in the ORSD. The evaluation results suggest that DRANPTO meets the completeness standard.

Conciseness measures “if the ontology includes irrelevant elements with regards to the domain to be covered or redundant representations of the semantics.”⁶⁸ Conciseness of DRANPTO is realized by a rigorous ontology development process. First, resource selection followed the well-established PRISMA guideline. Because the selected literature of agitation non-pharmacological management is the foundation of the developed ontology, the ontology does not contain irrelevant terms with regard to the domain that is being covered. In addition, using OOPS! to evaluate the ontology has discarded the presence of redundant terms (see pitfall P30 in Table 3).

Consistency describes that “the ontology does not include or allow for any contradictions.”⁶⁸ By passing the test of Reasoner



FIGURE 6 A simplified ontology graph of DRANPTO with the major classes and their relationships

Pellet and OOPS!, it suggests that DRANPTO meets the consistency standard.

4 | DISCUSSION

4.1 | Comparisons to other biomedical ontologies

The final result of the study is a comprehensive DRANPTO, which represents the domain knowledge specific to non-pharmacological treatment for agitation in people with dementia living in the long-term care facilities. Many ontologies have been developed in the health domain. However, they have a shortage in terms of coverage of agitation

non-pharmacological management domain. For example, ADO representing the knowledge of the AD domain⁷² does not contain any concepts representing agitation symptoms and specific non-pharmacological interventions to manage them. Similarly, the International Classification for Nursing Practice Ontology,⁷³ as a standardized nursing terminology, includes many non-pharmacological therapies and symptoms of health problems, but there is no concept to represent various agitated behaviors specifically such as cursing, screaming, and inappropriate dressing.

What appears distinct in the proposed ontology is the coverage of the agitation non-pharmacological management domain in terms of the richness, complexity, and granularity. For richness, it has 569 classes to represent the various concepts in the target domain. For example,

TABLE 3 Pitfalls reported by OOPS!

Minor pitfall P08: missing annotations	
Description	Three elements have neither "rdfs:comment" or "skos:definition" defined.
Appears in	Class "Reading Large Print Book," "Watching Bird," and "Speaking in Gentle Voice"
Correction	The corresponding annotations were added to these classes.
Important pitfall P30: equivalent classes not explicitly declared	
Description	Missing the definition of equivalent classes (owl:equivalentClass) in case of duplicated concepts.
Appears in	"Hunger" versus "Thirst," "Shouting" versus "Yelling," "Delusion" versus "Hallucination"
Correction	"Yelling" was defined as a synonym of "Shouting." No correction was made to others.
Important pitfall P41: no license declared	
Description	Omitting information about the license that applies to the ontology.
Appears in	This pitfall applies to the ontology in general instead of specific elements.
Correction	The license information of using CC BY-NC-SA license version 4.0 was added to the ontology.

it contains 71 various agitated behaviors (eg, "Screaming" and "Inappropriate Dressing"), 114 risk factors that may cause the manifestation of agitated behaviors (eg, "Confrontational Communication" and "Malnutrition"), 222 non-pharmacological interventions (eg, "Singing" and "Robotic Animal-Assisted Therapy"), 29 concepts related to the background of people with dementia (eg, "Preference" and "Superstitious Belief"), and 30 specific communication techniques (eg, "Speaking in Audible Voice" and "Asking Permission") for health care professionals to communicate with people with dementia and better understand their needs, so as to prevent and reduce the exhibition of agitation.

Notably, many new concepts that have not been included in other biomedical ontologies of the NCBO BioPortal and the OBO Foundry were extracted from the selected literature and included in DRANPTO,

such as the class "Robotic Animal-Assisted Therapy" to represent the concept of using robotic animals as a means of therapy. Although both SNOMED CT ontology³⁴ and MESH ontology⁷⁴ contain the class "Animal-Assisted Therapy" to represent the concept of using real animals as a means of therapy, neither of them has the concept equivalent to "Robotic Animal-Assisted Therapy." To date, robotic animals have been developed as an alternative to real animals and applied to manage dementia-related agitation in long-term care facilities.⁷⁵⁻⁷⁷ A well-known robotic animal is called PARO,⁷⁵⁻⁷⁷ which is a therapeutic pet-type robotic seal. Studies show that using PARO has a positive effect in reducing agitation for people with dementia.⁷⁵⁻⁷⁷ Therefore, this concept was extracted and coded as a non-pharmacological intervention in DRANPTO. Another similar example of new concepts included in DRANPTO is the concept of using plush and stuffed toy animals (eg, teddy bear) as a means of therapy, which was coded as the class "Toy Animal-Assisted Therapy." This concept has also not been included in other biomedical ontologies of the NCBO BioPortal and the OBO Foundry. Adding these new concepts increases coverage of DRANPTO in the agitation non-pharmacological management domain, which distinguishes it from the previous biomedical ontologies.

For complexity, DRANPTO has 48 object properties to connect the classes. A simplified ontology graph (draw by OntoGraf) placing the class "Person with Dementia" in the center shows the complex relationships among classes in the proposed ontology (see Figure 9).

For granularity, DRANPTO is elaborated in greater detail with nine granular levels to represent the knowledge of non-pharmacological treatment to agitation in dementia. An excerpt of the hierarchy of class "Agitation Management Activity" presents the nine granular levels (see Figure 10).

4.2 | Potentialities of DRANPTO

As a domain ontology, DRANPTO has many potentials. One is to transform the clinical text data into machine-processable data by creating semantic annotations.⁷⁸ A semantic annotation is a mapping of a data element to an ontology concept, suggesting that the data element

AgitationAssessmentTool	Name
NeuropsychiatricInventory	"Neuropsychiatric Inventory"@en
MiniMentalStateExamination	"Mini Mental State Examination"@en
ScaleForTheObservationOfAgitationInPersonsWithDementia	"Scale for the Observation of Agitation in Persons with Dementia"@en
SevereImpairmentBattery	"Severe Impairment Battery"@en
PANSSExcitedComponent	"PANSSE Excited Component"@en
CohenMansfieldAgitationInventoryShortForm	"Cohen Mansfield Agitation Inventory Short Form"@en
CohenMansfieldAgitationInventory	"Cohen Mansfield Agitation Inventory"@en
AgitationBehaviourMappingInstrument	"Agitation Behaviour Mapping Instrument"@en
AgitatedBehaviourInDementiaScale	"Agitation Behaviour In Dementia Scale"@en
BriefAgitationRatingScale	"Brief Agitation Rating Scale"@en
BuchananAgitationScale	"Buchanan Agitation Scale"@en
NeuropsychiatricInventoryNursingHomeVersion	"Neuropsychiatric Inventory - Nursing Home Version"@en
BehaviouralPathologyInAlzheimersDiseaseRatingScale	"Behavioural Pathology in Alzheimer's Disease Rating Scale"@en
DisruptiveBehaviourRatingScale	"Disruptive Behaviour Rating Scale"@en
PittsburghAgitationScale	"Pittsburgh Agitation Scale"@en

FIGURE 7 Obtained SPARQL query results for CQ6

Annotations: 'Music Therapy'

Annotations +

rdfs:label [language: en]
Music Therapy

definition [language: en]
The American Music Therapy Association (AMTA) defines music therapy as “the clinical and evidence-based use of music intervention to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program” (American Music Therapy Association 2006).

rdfs:comment [language: en]
It refers to the use of music and its influence on people with dementia.

abbreviation [language: en]
MT

synonym [language: en]
Music Intervention

FIGURE 8 Annotations for “Music Therapy” in DRANPTO

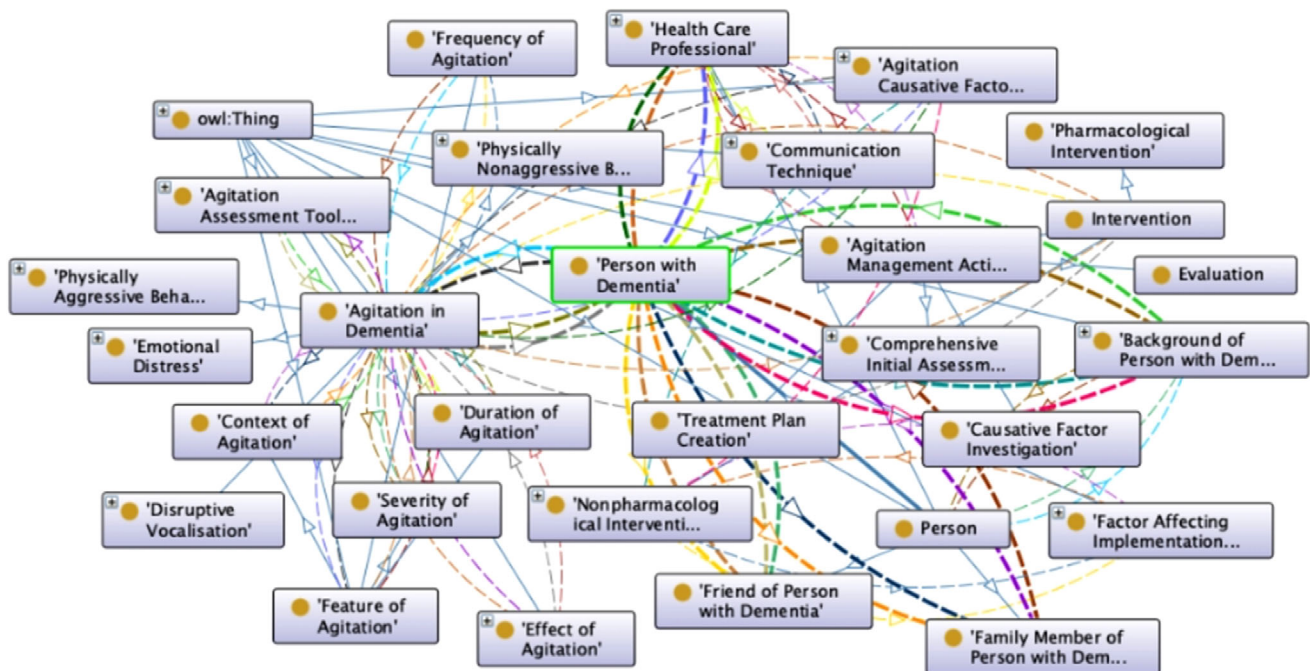


FIGURE 9 A simplified ontology graph with the class “Person with Dementia” in the center

refers to the concept.⁷⁸ Currently DRANPTO is being employed as a semantic index for the semantic annotation of nursing progress notes about the management of BPSD in dementia by a team member in our research group. This project involves 389,430 clinical records of 1192 people with dementia from 40 long-term care facilities in Australia. These clinical records are all written in natural language in free-text form, that is, they are unstructured text data, which poses a challenge for further information processing in terms of search, retrieval, and analysis. Therefore, for artificial intelligence (AI) technologies (eg, machine learning technology) to be able to process these clinical texts directly, it is necessary to transform these unstructured text data into structured data, applying DRANPTO ontology. The first step is to

identify and annotate the relevant agitated behaviors (eg, kicking and biting) in the clinical text. A simple analysis of the data of these agitated behaviors has produced some interesting results. For example, about 13% of people with dementia have the agitated behavior of kicking; about 4% of people with dementia have the agitated behavior of biting. Once the annotation process of the clinical text was completed and all data became machine-processable data, more insights about agitation in dementia would be generated from this corpus of nursing progress notes.

These insights would help researchers and the health care professionals better understand agitation, its manifestation, the effective non-pharmacological management, and eventually guide the health



FIGURE 10 An excerpt of the hierarchy of class “Agitation Management Activity”

care professionals to better manage agitation and improve the quality of care for people with dementia. It can also be used to extract meaningful data to improve organizational efficiency, and to produce easily understandable health reports for a variety of users (eg, front-line clinicians and care staff, managers of the long-term care facilities, family members, and researchers). In addition, the ontology will form the base for the development of the intelligent systems that can provide real-time support for health care professionals in care delivery. Together with other ontologies that have been developed and applied in dementia care,⁷⁹⁻⁸¹ DRANPTO has opened the opportunity to realize all these possibilities, and thus has made an important contribution to the research community in the agitation management domain and will help improve the quality of life for people living with dementia.

4.3 | Challenges of the study

Five challenges were encountered in developing DRANPTO. The first challenge was identifying the relevant resource as the foundation to extract knowledge in the target domain because there is no standardized document that provides comprehensive coverage of knowledge base for the non-pharmacological management of agitation in dementia. Various BPSD management guides were developed, such as the International Psychogeriatric Association Complete Guides to BPSD—Nurse Guide,⁸² Reducing Behaviors of Concern Guide,¹¹ and Managing

Behavioral and Psychological Symptoms of Dementia: A Clinician’s Field Guide to Good Practice.⁸³ However, they are only small part of the knowledge base for the non-pharmacological management of agitation in dementia. Therefore, we took the PRISMA-based⁴⁷ approach to systematically collect and select the relevant literature as the foundation to extract knowledge in the target domain. The disadvantage of this approach was its time-consuming nature. The advantage was assurance of quality of the original articles that provides credible and comprehensive knowledge base for computerization into ontology.

The second challenge was using the manual approach to construct DRANPTO from text. This approach requires lots of human effort to extract the ontological entities and then compile and organize them appropriately.^{84,85} Alternatively, many (semi)automatic approaches have been developed to build ontology from text. For example, Kumar et al.⁸⁶ proposed an automatic method to build ontology from text using statistical and natural language processing techniques; Sánchez and Moreno⁸⁵ also presented an automatic approach to create domain ontologies using ontology learning techniques. One major drawback of these methods is that most of them only can extract domain terms and their taxonomic relationships to a certain degree, whereas their ability to extract the non-taxonomic relationships is limited.^{84,85} However, manual ontology construction does not have this issue. Therefore, to achieve the aim of this study to develop an ontology that includes concepts in the agitation non-pharmacological treatment domain and their relationships (both taxonomic and non-taxonomic), we applied the manual approach to build DRANPTO.

The third challenge was finding an efficient ontology evaluation method to assess DRANPTO, because of the lack of standardized approaches to evaluate ontologies in the biomedical domain.⁵⁹ Many ontology evaluation methods have been developed and implemented to assess ontologies, such as the gold standard-based evaluation, the domain expert-based evaluation, the digital assessment tool-based evaluation, the CQ-based evaluation, and the quality criteria-based evaluation.^{51,54,87} In practice, ontology developers commonly use one or a combination of these evaluation approaches to assess the quality of ontologies. For example, Malhotra et al.⁷² applied both CQ evaluation and domain expert evaluation to assess the quality of their proposed ADO for AD. In addition, Berges et al.⁴⁴ used OOPS! (a digital assessment tool) and also quality criteria to assess their TrhOnt ontology for assisting rehabilitation processes.

In this study, to ensure the quality of the proposed DRANPTO, all evaluation approaches mentioned in the preceding were evaluated. This led to the selection of the optimal five approaches that were applied to evaluate DRANPTO. These include: (1) running reasoner Pellet; (2) using OOPS!; (3) involving domain experts for manual evaluation; (4) answering CQs; and (5) applying ontology quality criteria, as presented in Section 2.4. This multi-method, comprehensive evaluation has yielded excellent results: DRANPTO meets the quality standards for biomedical ontology.⁵⁹ It is worth noting that the gold standard-based evaluation approach was not applied for assessing the quality of DRANPTO due to a lack of such gold standard in the domain of this study, as found by Amith et al.⁵⁹ Therefore, it was not possible to compare DRANPTO with any gold standard ontology.

The fourth challenge was involving domain experts in manual evaluation of DRANPTO. The domain expert-based evaluation approach that was applied in this study requires human experts in the target domain to manually review all entities (concepts and relationships) of the proposed ontology one by one. Because it requires lots of efforts and time of domain experts, this approach is regarded as an “expensive” evaluation approach.⁸⁸ Therefore, many ontologies were developed by either applying other evaluation approaches or involving only a few domain experts as evaluators to manually assess the quality of their proposed ontologies. For example, one clinical expert in the AD domain performed a manual evaluation of ADO⁷²; two experts in the infectious disease domain evaluated the accuracy of Bacterial Clinical Infectious Disease Ontology⁸⁹; and two domain experts (an infectious diseases fellow and a pharmacist) evaluated the accuracy of the ontology for guiding appropriate antibiotic prescribing.⁹⁰ Similarly, in this study, two domain experts including a dementia care expert and an experienced nursing manager in a residential aged care facility manually evaluated the developed ontology in terms of accuracy, clarity, and completeness. It ensured that DRANPTO is an accurate representation of the non-pharmacological treatment knowledge in the domain of agitation management for people with dementia.

The fifth challenge was dealing with the unexpected results of evaluation by OOPS! This automatic evaluation tool detected three pitfalls for DRANPTO. One of them was unexpected—three pairs of classes might be equivalent, yet not explicitly declared in the proposed ontology. They were “Hunger” versus “Thirst,” “Shouting” versus “Yelling,” and “Delusion” versus “Hallucination.” They were detected because the names of these pairs of classes appear in a common synset (a set of cognitive synonyms) in WordNet.⁵⁶ WordNet, a lexical database for English language,⁹¹ used by OOPS! to conduct linguistic analysis to concepts included in the ontology.⁵⁶ In WordNet, both “Hunger” and “Thirst” appear in the synset expressing the concept—“strong desire for something (not food or drink).”⁹² In other words, they are synonyms under this concept. For example, “a hunger for knowledge” has the same meaning with “a thirst for knowledge.” However, it is not the concept that these two classes aim to represent in the proposed ontology. In DRANPTO, they were not equivalent concepts because “Hunger” represents “an uneasy sensation occasioned by the lack of food,”⁶³ whereas “Thirst” represents “a sensation of dryness in the mouth and throat associated with a desire for liquid.”⁶⁴ Therefore, the original classification was kept, with clear annotation added. This action also applied to the second pair of classes “Delusion” versus “Hallucination,” as they represent different symptoms of dementia, regardless of the automatic recommendation of OOPS! In the case of “Shouting” versus “Yelling,” we agreed with OOPS! that they are equivalent classes because they convey the same concept of making a loud cry due to agitation. Thus, “Yelling” was annotated as a synonym of “Shouting” instead of a new concept in the ontology.

At last, it is worth noting that we excluded electroconvulsive therapy (ECT) in the proposed ontology. ECT, also called electroshock therapy, is a medical treatment that involves passing carefully controlled electric currents through the brain to relieve severe psychotic symptoms.⁹³ Research has found that ECT is safe and effective in treat-

ing agitation in people with dementia.^{94,95} Because it does not involve the use of drugs, it is a non-pharmacological treatment. ECT is typically administered by a team of medical professionals, such as an anesthesiologist, a psychiatrist, and a nurse.⁹³ It is impractical for health care professionals to apply this therapy appropriately to treat agitation for people with dementia in the long-term care facilities. Therefore, it is beyond the scope of this ontology, which focuses on non-pharmacological treatment for dementia-related agitation that could be used in the long-term care facilities; thus leading to the exclusion of ECT in the proposed ontology.

5 | CONCLUSIONS

In this article, we presented DRANPTO representing the domain knowledge specific to non-pharmacological intervention for agitation in dementia, particularly for the long-term care setting. It was built by adapting NeOn methodology and was based on the current best evidence. This ontology is the first comprehensive semantic description of the agitation non-pharmacological management domain. It meets the standards for biomedical ontology including accuracy, clarity, completeness, conciseness, and consistency. It will serve as the semantic knowledge base to facilitate and simplify the development of clinical decision-support systems for assisting health care professionals to manage agitation in person with dementia.

In the future, we will develop more ontologies for representing other BPSD management knowledge, such as apathy, depression, delusion, and hallucination. Then by integrating them together, we will eventually build a comprehensive BPSD non-pharmacological management ontology containing concepts representing each specific non-pharmacological intervention that is applicable to a variety of BPSD symptoms. This will enable the applications based on it to assist health care professionals to address specific challenging behaviors in the long-term care facilities by providing them with specific non-pharmacological treatment recommendations.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. World Health Organization. *Global Action Plan on the Public Health Response to Dementia 2017-2025*; 2017.
2. Arthur PB, Gitlin LN, Kairalla JA, Mann WC. Relationship between the number of behavioral symptoms in dementia and caregiver distress: what is the tipping point? *Int Psychogeriatr*. 2018;30(8):1099-1107. <https://doi.org/10.1017/S104161021700237X>.
3. Cerejeira J, Lagarto L, Mukaetova-Ladinska EB. Behavioral and Psychological Symptoms of Dementia. *Front Neurol*. 2012;3:73. <https://doi.org/10.3389/fneur.2012.00073>.

4. Ijaopo EO. Dementia-related agitation: a review of non-pharmacological interventions and analysis of risks and benefits of pharmacotherapy. *Transl Psychiatry*. 2017;7(10):e1250. <https://doi.org/10.1038/tp.2017.199>.
5. Cohen-Mansfield J, Marx MS, Rosenthal AS. A description of agitation in a nursing home. *J Gerontol*. 1989;44(3):M77-M84.
6. Cubit K, Farrell G, Robinson A, Myhill M. A survey of the frequency and impact of Behaviours of Concern in dementia on residential aged care staff. *Australas J Ageing*. 2007;26(2):64-70. <https://doi.org/10.1111/j.1741-6612.2007.00217.x>.
7. Feast A, Orrell M, Charlesworth G, Melunsky N, Poland F, Moniz-Cook E. Behavioural and psychological symptoms in dementia and the challenges for family carers: systematic review. *Br J Psychiatry*. 2016;208(5):429-434. <https://doi.org/10.1192/bjp.bp.114.153684>.
8. Wharton TC, Ford BK. What is known about dementia care recipient violence and aggression against caregivers? *J Gerontol Soc Work*. 2014;57(5):460-477. <https://doi.org/10.1080/01634372.2014.882466>.
9. Gates DM, Fitzwater E, Meyer U. Violence against caregivers in nursing homes. Expected, tolerated, and accepted. *J Gerontol Nurs*. 1999;25(4):12-22.
10. International Psychogeriatric Association. The IPA complete guides to behavioral and psychological symptoms of dementia: specialists guide. Published online 2015.
11. Wallace T, Chand R, Buck E, et al. *ReBOC: Reducing Behaviours of Concern: A Hands on Guide: A Resource to Assist Those Caring for People Living with Dementia*. Alzheimer's Association (SA) Inc.; 2012.
12. Tible OP, Riese F, Savaskan E, von Gunten A. Best practice in the management of behavioural and psychological symptoms of dementia. *Ther Adv Neurol Disord*. 2017;10(8):297-309. <https://doi.org/10.1177/1756285617712979>.
13. Daly JM, Bay CP, Levy BT, Carnahan RM. Caring for people with dementia and challenging behaviors in nursing homes: a needs assessment geriatric nursing. *Geriatr Nur*. 2015;36(3):182-191. <https://doi.org/10.1016/j.gerinurse.2015.01.001>
14. Yan J. FDA extends black-box warning to all antipsychotics. *Psychiatr News*. Published online July 18, 2008. <https://doi.org/10.1176/pn.43.14.0001>
15. Ervin K, Finlayson S, Cross M. The management of behavioural problems associated with dementia in rural aged care. *Collegian*. 2012;19(2):85-95. <https://doi.org/10.1016/j.colegn.2012.02.003>.
16. Burns K, Jayasinha R, Tsang R, Brodaty H. Behaviour Management: A Guide to Good Practice, Managing Behavioural and Psychological Symptoms of Dementia. Dementia Collaborative Research Centre, University of New South Wales; 2012. <https://www.dementia.com.au/getattachment/947c82e7-841f-49cd-bdb8-43486b446b01/Behaviour-Management-A-Guide-to-Good-Practice-5.aspx>. Accessed April 5, 2019.
17. Dimitriou T-D, Verykoui E, Papatriantafyllou J, Konsta A, Kazis D, Tsolaki M. Non-pharmacological interventions for agitation/aggressive behaviour in patients with dementia: a randomized controlled crossover trial. *Funct Neurol*. 2018;33(3):143-147.
18. American Geriatrics Society, American Association for Geriatric Psychiatry. Consensus statement on improving the quality of mental health care in U.S. nursing homes: management of depression and behavioral symptoms associated with dementia. *J Am Geriatr Soc*. 2003;51(9):1287-1298.
19. Douglas S, James I, Ballard C. Non-pharmacological interventions in dementia. *Adv Psychiatr Treat*. 2004;10(3):171-177. <https://doi.org/10.1192/apt.10.3.171>
20. Savaskan E, Bopp-Kistler I, Buerge M, et al. Recommendations for diagnosis and therapy of behavioral and psychological symptoms in dementia (BPSD). *Praxis*. 2014;103(3):135-148. <https://doi.org/10.1024/1661-8157/a001547>.
21. Brodaty H, Draper B, Low L-F. Behavioural and psychological symptoms of dementia: a seven-tiered model of service delivery. *MJA*. 2003;178:231-234. https://www.mja.com.au/system/files/issues/178_05_030303/bro10530_fm.pdf.
22. Ervin K, Cross M, Koschel A. Barriers to managing behavioural and psychological symptoms of dementia: Staff perceptions. *Collegian*. 2014;21(3):201-207. <https://doi.org/10.1016/j.colegn.2013.04.002>.
23. Buhagiar K, Afzal N, Cosgrave M. Behavioural and psychological symptoms of dementia in primary care: a survey of general practitioners in Ireland. *Ment Health Fam Med*. 2011;8:227-234.
24. Nishtala PS, McLachlan AJ, Bell JS, Chen TF. Psychotropic prescribing in long-term care facilities: impact of medication reviews and educational interventions. *Am J Geriatr Psychiatry Off J Am Assoc Geriatr Psychiatry*. 2008;16(8):621-632. <https://doi.org/10.1097/JGP.0b013e31817c6abe>
25. Department of Health and Human Services. *What Is Person-Centred Health Care? A Literature Review*. Victorian Government Department of Human Services; 2011.
26. Ienca M, Vayena E, Blasimme A. Big data and dementia: charting the route ahead for research, ethics, and policy. *Front Med*. 2018;5:13. <https://doi.org/10.3389/fmed.2018.00013>
27. Davies JM, Gao W, Sleeman KE, et al. Using routine data to improve palliative and end of life care. *BMJ Support Palliat Care*. 2016;6(3):257-262. <https://doi.org/10.1136/bmjspcare-2015-000994>.
28. Jones KH, Laurie G, Stevens L, Dobbs C, Ford DV, Lea N. The other side of the coin: harm due to the non-use of health-related data. *Int J Med Inf*. 2017;97:43-51. <https://doi.org/10.1016/j.ijmedinf.2016.09.010>
29. Guarino N. Understanding, building and using ontologies. *Int J Hum-Comput Stud*. 1997;46(2-3):293-310. <https://doi.org/10.1006/ijhc.1996.0091>
30. Gruber TR. Toward principles for the design of ontologies used for knowledge sharing. In: *International Journal of Human-Computer Studies*. Kluwer Academic Publishers; 1993:907-928.
31. Musen MA. The protégé project: a look back and a look forward. *AI Matters*. 2015;1(4):4-12. <https://doi.org/10.1145/2757001.2757003>.
32. Sawsaa A, Lu J. Building Information Science ontology (OIS) with Methontology and Protégé. *J Internet Technol Secur Trans*. 2012;1(4):100-109. <https://doi.org/10.20533/jitst.2046.3723.2012.0014>
33. Globa L, Novogrudska R, Koval A, Senchenko V. Ontology for application development. In: Thomas C, ed. *Ontology in Information Science*. InTech; 2018. <https://doi.org/10.5772/intechopen.74042>
34. SNOMED International. *SNOMED: 5-Step Briefing*. SNOMED International; 2019. <http://www.snomed.org/snomed-ct/five-step-briefing>. Accessed November 19, 2019.
35. LOINC. LOINC - The international standard for identifying health measurements, observations, and documents. LOINC. 2019. <https://loinc.org>. Accessed November 19, 2019
36. World Health Organization. *WHO | International Classification of Diseases, 11th Revision (ICD-11)*. WHO. 2019. <http://www.who.int/classifications/icd/en/>. Accessed April 20, 2019
37. Zhang X, Hu B, Ma X, Moore P, Chen J. Ontology driven decision support for the diagnosis of mild cognitive impairment. *Comput Methods Programs Biomed*. 2014;113(3):781-791. <https://doi.org/10.1016/j.cmpb.2013.12.023>.
38. Roantree M, O' Donoghue J, O' Kelly N, et al. Mapping longitudinal studies to risk factors in an ontology for dementia. *Health Informatics J*. 2016;22(2):414-426. <https://doi.org/10.1177/1460458214564092>.
39. Skarzynski M, Craig A, Taswell C. SOLOMON: An ontology for Sensory-Onset, Language-Onset and Motor-Onset dementias. In: *2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*. IEEE; 2015:969-972. <https://doi.org/10.1109/BIBM.2015.7359814>

40. Pennington DR. Keys to their own voices: social tags for a dementia ontology as a human right. In: *Social Tagging for Linked Data Across Environments*. Facet Publishing; 2018:19.
41. Refolo LM, Snyder H, Liggins C, et al. Common Alzheimer's disease research ontology: National Institute on Aging and Alzheimer's Association Collaborative Project. *Alzheimers Dement*. 2012;8(4):372-375. <https://doi.org/10.1016/j.jalz.2012.05.2115>.
42. Suárez-Figueroa MC, Gómez-Pérez A, Fernández-López M. The NeOn methodology for ontology engineering. In: *Ontology Engineering in a Networked World*; Springer; 2012.
43. Mazo C, Salazar L, Corcho O, Trujillo M, Alegre E. A histological ontology of the human cardiovascular system. *J Biomed Semant*. 2017;8(1):47. <https://doi.org/10.1186/s13326-017-0158-5>
44. Berges I, Antón D, Bermúdez J, Goñi A, Illarramendi A. TrhOnt: building an ontology to assist rehabilitation processes. *J Biomed Semant*. 2016;7. <https://doi.org/10.1186/s13326-016-0104-y>
45. Whetzel PL, Noy NF, Shah NH, et al. BioPortal: enhanced functionality via new Web services from the National Center for Biomedical Ontology to access and use ontologies in software applications. *Nucleic Acids Res*. 2011;39(suppl):W541-W545. <https://doi.org/10.1093/nar/gkr469>.
46. Smith B, Ashburner M, Rosse C, et al. The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration. *Nat Biotechnol*. 2007;25(11):1251-1255. <https://doi.org/10.1038/nbt1346>.
47. Moher D, Liberati A, Tetzlaff J, Altman DG, for the PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339(jul21 1):b2535-b2535. <https://doi.org/10.1136/bmj.b2535>.
48. Garland K, Beer E, Eppingstall B, O'Connor DW. A comparison of two treatments of agitated behavior in nursing home residents with dementia: Simulated family presence and preferred music. *Am J Geriatr Psychiatry*. 2007;15(6):514-521. <https://doi.org/10.1097/01.JGP.0000249388.37080.b4>.
49. QSR International. *NVivo Qualitative Data Analysis Software*; 1999. <https://www.qsrinternational.com/nvivo/home>. Accessed January 7, 2018
50. W3C. OWL - Semantic Web Standards. 2013. <https://www.w3.org/OWL/>. Accessed April 29, 2019
51. Sirin E, Parsia B, Grau BC, Kalyanpur A, Katz Y. Pellet: a practical OWL-DL reasoner. *Softw Eng Semant Web Web Semant Sci Serv Agents World Wide Web*. 2007;5(2):51-52. <https://doi.org/10.1016/j.websem.2007.03.004>
52. Abburu S. A survey on ontology reasoners and comparison. *Int J Comput Appl*. 2012;57(17):33-39.
53. Parsia B, Matentzoglou N, Gonçalves RS, Glimm B, Steigmiller A. The OWL Reasoner Evaluation (ORE) 2015 competition report. *J Autom Reason*. 2017;59(4):455-482. <https://doi.org/10.1007/s10817-017-9406-8>.
54. Poveda-Villalón M, Gómez-Pérez A, Suárez-Figueroa MC. OOPS! (Ontology Pitfall Scanner!): an on-line tool for ontology evaluation. *Int J Semantic Web Inf Syst*. 2014;10:7-34. <https://doi.org/10.4018/ijswis.2014040102>
55. Poveda M. OOPS! - Ontology Pitfall Scanner! - Pitfall Catalogue. 2016. <http://oops.linkeddata.es/catalogue.jsp>. Accessed May 4, 2019
56. Poveda Villalón M. Ontology Evaluation: a pitfall-based approach to ontology diagnosis. Published online 2016. <https://doi.org/10.20868/UPM.thesis.39448>
57. Prud'hommeaux E, Seaborne A. SPARQL Query Language for RDF. 2008. <https://www.w3.org/TR/rdf-sparql-query/>. Accessed May 4, 2019
58. W3C. SPARQL 1.1 Query Language. W3C Recommendation. 2013. <https://www.w3.org/TR/sparql11-query/>. Accessed April 12, 2019
59. Amith M, He Z, Bian J, Lossio-Ventura JA, Tao C. Assessing the practice of biomedical ontology evaluation: gaps and opportunities. *J Biomed Inform*. 2018;80:1-13. <https://doi.org/10.1016/j.jbi.2018.02.010>.
60. Baillon S, Van Diepen E, Prettyman R, Redman J, Rooke N, Campbell R. A comparison of the effects of Snoezelen and reminiscence therapy on the agitated behaviour of patients with dementia. *Int J Geriatr Psychiatry*. 2004;19(11):1047-1052. <https://doi.org/10.1002/gps.1208>.
61. Zhang Z. Dementia-Related Agitation Non-Pharmacological Treatment Ontology. 2020. <https://bioportal.bioontology.org/ontologies/DRANPTO>. Accessed June 6, 2020
62. Geller J, Keloth VK, Musen MA. How sustainable are biomedical ontologies? *AMIA Annu Symp Proc*. 2018;2018:470-479.
63. Merriam-Webster. hunger. Merriam-Webster. 2019. <https://www.merriam-webster.com/dictionary/hunger>. Accessed November 20, 2019
64. Merriam-Webster. thirst. Merriam-Webster. 2019. <https://www.merriam-webster.com/dictionary/thirst>. Accessed November 20, 2019.
65. U.S. National Library of Medicine. Delusions. U.S. National Library of Medicine MeSH. 2015. <https://meshb.nlm.nih.gov/record/ui?ui=D003702>. Accessed November 20, 2019.
66. U.S. National Library of Medicine. Hallucinations. U.S. National Library of Medicine MeSH. 1999. <https://meshb.nlm.nih.gov/record/ui?ui=D006212>. Accessed November 20, 2019.
67. Creative Commons. *Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International*. Creative Commons. 2019. <https://creativecommons.org/licenses/by-nc-sa/4.0/>. Accessed November 2, 2019.
68. Vrandečić D. Ontology Evaluation. Published online 2010. http://simia.net/download/ontology_evaluation.pdf. Accessed May 27, 2019
69. Cohen-Mansfield J, Billig N. Agitated behaviors in the elderly. I. A conceptual review. *J Am Geriatr Soc*. 1986;34(10):711-721. <https://doi.org/10.1111/j.1532-5415.1986.tb04302.x>.
70. Putman L, Wang J. The closing group: therapeutic recreation for nursing home residents with dementia and accompanying agitation and/or anxiety. *Am J Alzheimers Dis Other Dement*. 2007;22(3):167-175. <http://ezproxy.uow.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=106157325&site=ehost-live>.
71. Alexopoulos G, Jeste D, Chung H, Carpenter D, Ross R, Docherty J. Treatment of dementia and agitation: a guide for families and caregivers. *J Psychiatr Pract*. 2007;13(3):207-216. <http://ezproxy.uow.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=106170299&site=ehost-live>.
72. Malhotra A, Younesi E, Gündel M, Müller B, Heneka MT, Hofmann-Apitius M. ADO: a disease ontology representing the domain knowledge specific to Alzheimer's disease. *Alzheimers Dement*. 2014;10(2):238-246. <https://doi.org/10.1016/j.jalz.2013.02.009>.
73. BioPortal. International Classification of Diseases, Version 10 - Summary | NCBO BioPortal. 2018. <https://bioportal.bioontology.org/ontologies/ICD10>. Accessed April 20, 2019.
74. U.S. National Library of Medicine. Medical Subject Headings - Summary | NCBO BioPortal. BioPortal. 2019. <https://bioportal.bioontology.org/ontologies/MESH>. Accessed June 4, 2020.
75. Mervin MC, Moyle W, Jones C, et al. The cost-effectiveness of using PARO, a therapeutic robotic seal, to reduce agitation and medication use in dementia: findings from a cluster-randomized controlled trial. *J Am Med Assoc*. 2018;19(7):619-622.e1. <https://doi.org/10.1016/j.jama.2017.10.008>.
76. Jøranson N, Pedersen I, Rokstad AMM, Ihlebæk C. Effects on symptoms of agitation and depression in persons with dementia participating in robot-assisted activity: a cluster-randomized controlled trial. *J Am Med Dir Assoc*. 2015;16(10):867-873. <https://doi.org/10.1016/j.jamda.2015.05.002>.
77. Jones C, Moyle W, Murfield J, et al. Does cognitive impairment and agitation in dementia influence intervention effectiveness? Findings

- from a cluster-randomized-controlled trial with the therapeutic robot, PARO. *J Am Med Dir Assoc*. 2018;19(7):623-626. <https://doi.org/10.1016/j.jamda.2018.02.014>.
78. Tchechmedjiev A, Abdaoui A, Emonet V, Zevio S, Jonquet C. SIFR annotator: ontology-based semantic annotation of French biomedical text and clinical notes. *BMC Bioinformatics*. 2018;19(1):405. <https://doi.org/10.1186/s12859-018-2429-2>.
 79. Jeon H, Park S, Choi J, Lim Y. Ontology-based Dementia Care Support System. In: *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*; 2018:3318-3321. <https://doi.org/10.1109/EMBC.2018.8512965>
 80. Sadeghi R, Banerjee T, Hughes JC, Lawhorne LW. Sleep quality prediction in caregivers using physiological signals. *Comput Biol Med*. 2019;110:276-288. <https://doi.org/10.1016/j.combiomed.2019.05.010>.
 81. Yordanova K, Koldrack P, Heine C, et al. Situation model for situation-aware assistance of dementia patients in outdoor mobility. *J Alzheimers Dis*. 2017;60(4):1461-1476. <https://doi.org/10.3233/JAD-170105>.
 82. International Psychogeriatric Association. The IPA complete guides to behavioral and psychological symptoms of dementia: nurses guide. Published online 2012.
 83. Burns K, Jayasinha R, Brodaty H. Managing Behavioural and Psychological Symptoms of Dementia: A Clinician's Field Guide to Good Practice. Published online 2014. <https://www.dementia.com.au/getattachment/b6bd72cf-d2e4-48ee-868c-8db3f8a11362/Clinician%E2%80%99s-Field-Guide-to-Good-Practice,-Managing.aspx>. Accessed April 19, 2019.
 84. Konys A. Knowledge systematization for ontology learning methods. *Procedia Comput Sci*. 2018;126:2194-2207. <https://doi.org/10.1016/j.procs.2018.07.229>
 85. Sánchez D, Moreno A. Learning medical ontologies from the web. In: Riaño D, ed. *Knowledge Management for Health Care Procedures*. Vol 4924. Berlin Heidelberg: Springer; 2008:32-45. https://doi.org/10.1007/978-3-540-78624-5_3
 86. Kumar N, Kumar M, Singh M. Automated ontology generation from a plain text using statistical and NLP techniques. *Int J Syst Assur Eng Manag*. 2016;7(S1):282-293. <https://doi.org/10.1007/s13198-015-0403-1>
 87. Raad J, Cruz C. A Survey on Ontology Evaluation Methods. In: *Proceedings of the 7th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management*. SCITEPRESS - Science and Technology Publications; 2015:179-186. <https://doi.org/10.5220/0005591001790186>
 88. Sekandar K. A quality measure for automatic ontology evaluation and improvement. Published online 2018.
 89. Gordon CL, Pouch S, Cowell LG, et al. Design and evaluation of a bacterial clinical infectious diseases ontology. *AMIA Annu Symp Proc*. 2013;2013:502-511.
 90. Bright TJ, Yoko Furuya E, Kuperman GJ, Cimino JJ, Bakken S. Development and evaluation of an ontology for guiding appropriate antibiotic prescribing. *J Biomed Inform*. 2012;45(1):120-128. <https://doi.org/10.1016/j.jbi.2011.10.001>.
 91. Fellbaum C. WordNet and wordnets. In: *Encyclopedia of Language and Linguistics*. 2nd ed. Elsevier; 2005:665-670.
 92. WordNet. Word to search for: thirst. WordNet Search - 3.1. 2019. <http://wordnetweb.princeton.edu/perl/webwn?s=thirst&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00000>. Accessed November 27, 2019.
 93. American Psychiatric Association. What is Electroconvulsive therapy (ECT)? American Psychiatric Association. 2019. <https://www.psychiatry.org/patients-families/ect>
 94. Glass OM, Forester BP, Hermida AP. Electroconvulsive therapy (ECT) for treating agitation in dementia (major neurocognitive disorder) - a promising option. *Int Psychogeriatr*. 2017;29(5):717-726. <https://doi.org/10.1017/S1041610216002258>.
 95. Ujkaj M, Davidoff DA, Seiner SJ, Ellison JM, Harper DG, Forester BP. Safety and efficacy of electroconvulsive therapy for the treatment of agitation and aggression in patients with dementia. *Am J Geriatr Psychiatry*. 2012;20(1):61-72. <http://ezproxy.uow.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=108215028&site=ehost-live>.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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