Recent Refinements of the NeuroPsychological Testing Ontology

Alexander P. Cox [1], Kiernan L. Johnson [1], Lauren M. Wishnie [1], Aaron S. Kemp [2,3], Jonathan P. Bona [3], and Alexander D. Diehl [1]

[1] *Department of Biomedical Informatics, University at Buffalo, 77 Goodall St., Buffalo, New York 14203, USA*
[2] *Department of Psychiatry, University of Arkansas for Medical Sciences (UAMS), 4301 W. Markham, Little Rock, AR 72205, USA*
[3] *Department of Biomedical Informatics, UAMS, 4301 W. Markham, Little Rock, AR 72205, USA*

Abstract

The NeuroPsychological Testing Ontology is designed to represent neuropsychological assessments, the cognitive processes and functions they assess, and associated data. This paper provides an overview of recent ontology development efforts as well as its current data applications and future development goals.

Keywords

Neuropsychological testing, cognitive domains, ADNI, applied ontology

1. Introduction

The NeuroPsychological Testing Ontology (NPT) [1, 2, 3] is designed to represent standardized neuropsychological assessments, such as those used by the Alzheimer's Disease Neuroimaging Initiative (ADNI) [4]. NPT provides a set of classes for the annotation of neuropsychological testing data and is designed to enable integration of results from a variety of neuropsychological tests by (i) representing the tests in greater granularity, and (ii) connecting assays and sub-assays to the cognitive function(s) they measure. In this way, data generated from multiple tests that are about a given cognitive domain can be readily aggregated and studied. This is true regardless of whether the data are from entire tests, test sub-sections, or individual test components. The selected cognitive domain can be as broad or specific as desired and multiple domains can be combined. NPT's overarching goal is to increase the accuracy and usability of neuropsychological tests to support efforts to increase understanding of cognitive domains and the conditions that affect them.

Many diseases are associated with, result in, or are diagnosed based on the presence or absence of certain neuropsychological signs and symptoms. Hence, neuropsychological testing plays an important role in the development of clinical pictures used in the diagnosis of patients with a range of neurological diseases and disorders such as Alzheimer's disease, multiple sclerosis, or following stroke or traumatic brain injury. Two initial goals of this project are to leverage the results of neuropsychological assessments to (i) test hypotheses about the diagnosis of Alzheimer's disease and (ii) identify patient populations that are likely to convert from mild cognitive impairment to dementia.

NPT is being developed in compliance with the OBO Foundry principles [5]. It extends the Ontology for Biomedical Investigations (OBI) [6]. NPT is a corollary project of the Neurological Disease Ontology (ND) [1, 7], which represents diseases, disorders, and syndromes that are associated with neurodegeneration.

In building NPT, we have relied upon source tests, such as the Folstein Mini-Mental State Exam [8] and Montreal Cognitive Assessment [9], as well as upon textbooks [10, 11] and articles about these neuropsychological tests and the cognitive functions they measure. NPT is built using the schema for representing assays that has been developed in OBI and consequently currently imports all of OBI.

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EMAIL: apcox@buffalo.edu (A. 1); kj55@buffalo.edu (A. 2); lmwishni@buffalo.edu (A. 3); ASKemp@uams.edu (A. 4); JPBona@uams.edu (A. 5); addiehl@buffalo.edu (A. 6)
ORCID: 0000-0002-6969-2784 (A. 1); 0000-0003-0278-3371 (A. 2); 0000-0002-7245-3450 (A. 3); 0000-0001-6925-5667 (A. 4); 0000-0003-1402-9616 (A. 5); 0000-0001-9990-8331 (A. 6)

2. New Developments

The NeuroPsychological Testing Ontology (NPT) was initially developed during 2012-2013. At the end of this initial development stage, NPT was at version 1.7.2. NPT version 2.0 is pending release and contains approximately 550 NPT terms. This number is expected to grow quickly as representations of additional neuropsychological tests get added.

While the previous effort provided a good start on these efforts, there are multiple reasons for continuing the NPT effort. First, there are many more neuropsychological tests in use. These tests provide supplementary perspectives and data for identical, overlapping, or additional cognitive functions and domains. Second, there are often many versions of the "same" test and it is important to capture which test version is used as well as the differences between versions so their results can be combined as accurately as possible. This is particularly important to ensure greater fidelity when conducting meta-analyses. Third, many NPT terms previously either lacked definitions or benefited from improved or more informative definitions or other annotations. Fourth, while NPT already included many logical axioms to provide built-in reasoning, some axioms have been refactored while others have been added.

The status of neuropsychological assessments represented in NPT is shown in Table 1.

Table 1
Neuropsychological Tests Represented in NPT

Neuropsychological Test	Status in NPT
Folstein Mini-Mental State Examination (MMSE)	Completed, Revised
Montreal Cognitive Assessment (MoCA)	Completed, Revised
Alzheimer's Disease Assessment Scale (ADAS-COG)	Under Review
Auditory Verbal Learning Test (AVLT)	Completed
Trail-Making Test	Completed
Boston Naming Test	Completed, Revised
Clock Drawing Test	Completed
Linguistic Fluency (Semantic/Phonetic)	In Progress
Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV)	In Progress
Wechsler Memory Scale - Fourth Edition (WMS-IV)	Planned
Hopkins Verbal Learning Test (HVLT)	Planned
Brief Visuospatial Memory Test – Revised (BVMT-R)	Planned

The overarching goal of the current NPT development effort is to ensure robust test representations to support mapping, ingestion into triple stores, and the retrieval and compilation of neuropsychological assessment data. An important component of this is to account for variation in test versions and test administration by representing, for example, the specific word list, prompts, and scoring used for a given word recall assay. This is accomplished, in part, by the creation of the NPT-ADNI application ontology. While NPT is designed to represent "generic" versions of standardized neuropsychological assessments, NPT-ADNI is designed to represent highly specific terms that may be unique to a single version of a generic assessment. For example, NPT contains the term '*MoCA delayed recall assay*' and NPT-ADNI adds the term '*MoCA delayed recall daisy assay*' to specify one of the target words for that version of the MoCA. The increased semantic content is intended to facilitate more fine-grained analysis of data, which is hypothesized to be useful for both clinical and test design analyses.

NPT and NPT-ADNI are currently being applied to MoCA and MMSE data from the ADNI dataset. MoCA and MMSE ADNI data has been mapped using the Karma data integration tool [12]. These mappings are then used to generate triples for the entire ADNI dataset, which includes more than 6,800 MoCA and 12,100 MMSE test results as of January 2021. The triples are loaded into a GraphDB instance where they can be queried using customizable SPARQL queries to further analyze the aggregated data. The power of these queries will increase as additional assay data are added.

3. Future Work

Future work will expand NPT's coverage to include additional cognitive tests and enhance current test representations. Despite the use of different assessment instruments, applying NPT to disease-specific data repositories, such as ADNI [4] or the Parkinson's Progression Markers Initiative [13], will confer the ability to identify neuroimaging measures that correspond with cognitive impairment profiles across common functional domains. Accordingly, NPT offers a basis for the semantic representation of impaired cognitive functions across distinct neurodegenerative pathologies (e.g., Alzheimer's disease vs. Parkinson's disease). This will be used to mine neuroimaging measures to identify candidate biomarkers of cognitive impairment specific to a given etiology. In this way we expect NPT will serve as a valuable tool to integrate neuropsychological data from multiple sources to look for commonalities and differences that will give insights into diagnosis and treatment of neurodegenerative disease.

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