DEVELOPMENT OF AN ONTOLOGY TO CHARACTERIZE MENTAL FUNCTIONING

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Motivation for our work – Use Case

- United States Social Security Administration
  - Provide support for the disability determination process with the goal of improving the timeliness, consistency, and accuracy of decisions

- NIH-SSA inter-agency agreement in 2008
  - Two broad objectives
    - Develop systematic, data-driven analytic tools using SSA data
    - Support better standardized data collection through development of the Work Disability Functional Assessment Battery
  - Development of clinical informatics tools using Natural Language Processing (NLP) addresses the first broad objective
Mental Disorders and Functioning

- SSA adjudicators need to evaluate how a “mental disorder” limits functioning.
- SSA criteria for mental functioning in a work setting:
  - understand, remember, or apply information;
  - interact with others;
  - concentrate, persist, or maintain pace; and
  - adapt or manage oneself.

Disability Evaluation Under Social Security. 12.00 Mental Disorders – Adult.

https://www.ssa.gov/disability/professionals/bluebook/12.00-MentalDisorders-Adult.htm
Aim

- Develop, and extract information on mental functioning, and to translate that insight into tools and methods that can support clinical care, program implementation, and scientific advancements.
Our Objectives

- Provide a conceptualization of mental functioning that could structure the development of clinical informatic evidence-review tools for disability determination.

- Describe how we restructured and adapted the ICF to characterize mental functioning more fully, highlighting features of the ICF that were helpful and those where greater conceptual and organizational refinement would be beneficial.
The Internal Classification of Functioning, Disability and Health (ICF)
– World Health Organization, 2001
Determine areas of functioning

- LEARNING AND APPLYING KNOWLEDGE
- GENERAL TASKS AND DEMANDS
- COMMUNICATION
- MOBILITY
- SELF-CARE
- DOMESTIC LIFE
- INTERPERSONAL INTERACTIONS AND RELATIONSHIPS
- MAJOR LIFE AREAS
- COMMUNITY, SOCIAL AND CIVIC LIFE
Person-External Factors-Activities –Participation Model

Human Functioning = MENTAL FUNCTIONING + PHYSICAL FUNCTIONING

MENTAL FUNCTIONING
The Thinking

PHYSICAL FUNCTIONING
The Doing
Steps to develop an Ontology of Mental Functioning

1. Identify and catalog the language of mental functioning by practitioners and patients
   - Catalog the concepts/terms used
   - Catalog the relationships between mental functioning concepts
2. Build tools to extract mental functioning concepts from practitioners’ notes
3. Build an ontology that defines the concepts we should be looking for
4. Build a theoretical model to guide the ontology
Reorganizing of ICF concepts for the Ontology
Theoretical base

- Explored different models – the ICF, Person-Environment-Occupations theories in OT, Human ecological theories
- Selected Open Systems Model – easier for persons from diverse backgrounds to understand
- Challenges of discipline-specific conceptual language were handled when working in a team that included non-clinician professionals
Human Open System (von Bertalanffy, 1968)

**INPUT**
- Sensory information
- Perception

**THROUGHPUT**
- Neurocognitive Sensorimotor processing, interpretation, Response decision

**OUTPUT**
- Action
- No-action

**FEEDBACK**
- Adaptive? Maladaptive?

**ENVIRONMENT**
- Social
- Physical
- Cultural
- Virtual...

**CONTEXT**
- Work
- Community
- Home
- Roles...

Contextual Factors

ICF Contextual factors

- Environmental
  - Social factors
  - Physical factors

- Personal
  - Not classified

Ontology External Factors

- Context
  - ICF Societal Environmental level
    - Distal - Cultural, sociopolitical, economic...
    - The situational background to one’s life and living
    - Temporal aspects

- Environment
  - ICF Individual Environmental level
    - Proximal - Physical and social

- Input
Where is the person?

ICF Separate Components

- Health condition
- Body Structures
- Body Functions

Ontology Person Factors

- Intrinsic to the individual
  - Health condition
  - Body Structures
  - Body Functions
- Throughput
Person Factors

<table>
<thead>
<tr>
<th>ICF</th>
<th>Ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Personal Factors are contextual</td>
<td>□ Person factors are intrinsic attributes internal to the individual:</td>
</tr>
<tr>
<td>▶ Not classified</td>
<td>▶ Personal Background factors</td>
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<tr>
<td></td>
<td>▶ Body Structures</td>
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<tr>
<td></td>
<td>▶ Body Functions</td>
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<tr>
<td></td>
<td>▶ Health conditions/comorbidities</td>
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</tbody>
</table>
# Activities and Participation

<table>
<thead>
<tr>
<th>ICF</th>
<th>Ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity</strong>: “the execution of a task or action”.</td>
<td><strong>Mental Functioning</strong>: “Mind-directed observable behaviors”</td>
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<tr>
<td><strong>Participation</strong>: “involvement in a life situation”.</td>
<td><strong>Participation</strong>: engagement in a life situation that is made up of activities one wants to do, needs to do, or is expected to do within one’s roles, environment, and cultural context.</td>
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<tr>
<td></td>
<td><strong>Output</strong></td>
</tr>
</tbody>
</table>
Feedback

ICF

- No conceptualization of feedback in the ICF.

Ontology

- Feedback
  - sensory input to the person about the external world and the internal world of the body.
- Feedback appraisal
  - neurocognitive processing of feedback information
  - allows the person to adjust their behaviors and actions as they interact with, and adapt to, their environments and contextual situations.
ECOLOGICAL MODEL OF MENTAL FUNCTIONING (EMMF)
External Factors: Contextual and Environmental

Environmental Factors

Contextual

Impose demands. Influence.
Provide sensory information of the external world

COVID-19

External Factors: Contextual and Environmental
External Factors: Contextual and Environmental

ICF
- Body Structures
- Person Factors

INPUT
Sensory organs Receive sensory information from the internal body and external environment

THE SEVEN SENSORY SYSTEMS
- Proprioception
- Vestibular
- Tactile
- Auditory
- Visual
- Gustatory
- Olfactory
INPUT
Receives sensory information

External Factors: Contextual and Environmental
- Body Structure: Brain
- Body Functions: Mental
- Personal Factors
- Health Condition

THROUGHPUT
Perception
- Brain perceives input of sensory information

Processing Organizing
- Neurocognitive processes and organizes information

Decides Response
- Mind interprets and decides upon a response
- Decision superimposed by Person Factors
THROUGHPUT: Processing

- Mind
  - Will
  - Intent
  - Choice and Decision

- Personal Factors
  - Interests
  - Life experiences...

- Mental Functions
  - Perceives
  - Processes
  - Organizes
  - Appraises...
**INPUT**
*Receives* sensory information

**THROUGHPUT**
*Perceives* sensory and Feedback information and
*Processes* using neurocognitive functions
*Feedback Appraisal* (outcomes Adaptive? Effective?)
*Organizes* and *Interprets* information
*Decides* upon a response

**OUTPUT**
Observable behavior

- Impose demands. Influence.
- Provide sensory information of external world
- Travels. Sent. Sensory information travels/is sent to the brain.
- Activates. Neurological Motor pathways
OUTPUT is Mental Functioning

- *Mind-directed observable external behaviors* of what the person actually *decides* to do (or not do), and *does* (or does not do), in relation to real-time transactions with environmental factors (physical, social) and contextual situations (life situation, roles) as they unfold moment by moment in daily life and over time.
Takeaway: Output is what the person does. Mind-directed observable behaviors of physical and mental functioning in everyday life activities the person has chosen to do.
**INPUT**

*Receives* sensory information

**THROUGHPUT**

*Perceives* sensory information and sensory feedback

*Processes* using neurocognitive functions

*Feedback Appraisal* (outcomes Adaptive? Effective?)

*Organizes* and *Interprets* information

*Decides* upon a response

**OUTPUT**

*Observable behavior*

**FEEDBACK**

Results of one’s actions

*Provides*

External Factors: Contextual and Environmental

- Impose demands. Influence.
- Provide sensory information of external world
- Travels. Sent. Sensory information travels/is sent to the brain.

External Factors: Contextual and Environmental

- Activates. Neurological Motor pathways

Travels. Sent. Sensory information and sensory feedback travels/is sent

External Factors: Contextual and Environmental
Feedback

Takeaway: Sensory feedback provides continual processing of information allowing the person to make adjustments to their behaviors and actions.
EXTERNAL FACTORS: CONTEXT & ENVIRONMENT

INPUT

Person Receives sensory information through the body

Imposes demands. Influence. Provide sensory information of external world

Sensory information travels/is sent to the brain for processing

THROUGHPUT

The person...
Perceives sensory and Feedback information and
Processes using neurocognitive functions
Feedback Appraisal (outcomes Adaptive? Effective?)
Organizes and Interprets information
Decides upon a response

FEEDBACK

Results of one's actions

Provides external information

OUTPUT

Observable behavior


Provides internal information

Activates. Neurological Motor pathways

EXTERNAL FACTORS: CONTEXT & ENVIRONMENT

Sensory information travels/is sent to be received
INPUT
Receives sensory information (including sensory feedback)

THROUGHPUT
Perceives sensory and Feedback information and
Processes using neurocognitive functions
Feedback Appraisal (outcomes Adaptive? Effective?)
Organizes and Interprets information
Decides upon a response

OUTPUT
Observable behavior

FEEDBACK
Results of one’s actions

EXTERNAL FACTORS
- Contextual Factors
- Environmental

INPUT
- Body Structures: Eye

THROUGHPUT
- Body Structure: Brain
- Body Functions: Mental
- Health Condition
- Person Factors

OUTPUT
Functioning
- Mental Functioning
- Physical Functioning Activities & Participation
Informatics of the Ontology of Mental Functioning (OMF):

- Where on the Ontology Spectrum is the OMF?
- Known similar efforts
- Our Goal: Catalog Mental Functioning
- The OMF Named Entity Extraction Tool
How this fits into other efforts (1)

Fig. 1. The Mental Functioning Ontology upper level aligned to BFO. Unlabelled arrows represent subsumption relations.

Janna Hastings et al, 2012
Unified Medical Language System (UMLS)

An agglomeration of 166 controlled/curated terminologies in biomedical sciences.

Viewed as a comprehensive thesaurus and ontology of biomedical concepts.

Facilitates the storage and retrieval of biomedical information through the computer science discipline of Natural Language Processing (NLP).

UMLS terms found in medical text used to count/describe/inform providers and researchers.
Our Goal: Catalog Mental Functioning (1)

- Upper-Level Ontology
  - Activities of Daily Living
    - Actions
    - Non-Actions
  - Observable External Behaviors
  - Adaptive Behaviors
  - Maladaptive Behaviors

- Concepts
  - Making Lunch
  - Cooking Dinner
  - Preparing Meal
  - Forgetting to turn off stove
  - Breaking dishes

- Semantic Network
  - Mental Functioning
  - Upper-Level Ontology
  - Thesaurus
Our Goal: Catalog Mental Functioning (2)

- Identify mental functioning concepts (dictionary)
- Identify synonyms of mental functioning concepts (terminology)
- Identify the upper-level mental functioning concepts/organizing categories (taxonomy)
- Identify the relationships that organize the upper-level categories (domain ontology)
- Organize the categories and relationships around mental functioning (Formal Ontology)
Ontology of Mental Functioning

(On one slide)
An OMF Named Entity Extraction Tool

- A Dictionary lookup/rule-based NER
- Terminology derived from the OMF
- Leverages the UMLS/ICF hierarchies to derive descendent OMF terms
- Enhanced with VerbNet* for IPIR and Communication and Cognition Terminology
- Subclassifies IPIR/Com/Cog mentions to ICF 3 Digit Codes*
References

- Nordenfelt, L. (2006). On health, ability and activity: Comments on some basic notions in the ICF. Disability and Rehabilitation, 28(23), 1461-1465. DOI:10.1080/09638280600925886
Thank you and Discussion