Development of an Integrative Approach to the Assessment of Cognitive Abilities in Patients With Neurodegenerative Diseases of the Central Nervous System

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Abstract

The project aims to develop a set of cognitive and perception measurement tools that would allow early identification of neurodegenerative diseases based on the comparison of different experimental cognitive and perception measurements with patient clinical condition (which would be investigated by standard validated clinical neurological tests) and magnetic resonance imaging (MRI) measurements.

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Introduction

Neurodegenerative disorders are diseases of the central nervous system that affect mostly the elderly population worldwide and lead to serious perceptual, cognitive and movement problems, reducing the quality of human life and leading to severe disability. In 2015, there were 46 million cases of Alzheimer's disease (AD) and other dementias and approximately 6 million cases of Parkinson's disease (PD) worldwide (GBD 2015). From 1990 to 2015, the prevalence of both disorders has more than doubled, and the burden for society has increased with increasing age (GBD 2015). Individual neurodegenerative disorders are heterogeneous in their clinical presentations and underlying physiology, although they often have overlapping features. Diagnostic accuracy is critical because it allows for more reliable prognostication and often guides specific treatment and management (Erkkinen et al., 2018).

Detecting cognitive deficits in neurodegenerative diseases is crucial. The **Montreal Cognitive Assessment (MoCA)** is a reliable screening tool that correlates with neuropsychological performance (Roalf et al., 2016). **MRI** complements MoCA for neurological diagnosis, revealing changes like volumetric alterations, cortical thinning, and structural connectome impairment. Additional methods include tractography - a 3D modelling technique using diffusion MRI, and connectometry for early nerve damage detection.

Visual-spatial impairment, an early neurodegenerative symptom, is often overlooked in standard dementia evaluations. These diseases cause specific neural network atrophy, affecting visual-spatial cognition uniquely (Possin, 2010). The importance of spatial processes is underscored by Nobel-winning discoveries, emphasizing the intricate nature of neural correlates in spatial cognition (Burgess, 2014; Moser, 2014; Gardner et al., 2022).

The **main research tasks** to be carried out during the implementation of the project are:

a) to develop a set of non-invasive methods (i.e. cognitive tests) for diagnosing early symptoms of neurodegenerative diseases and
b) to understand and identify neural correlations of visual-spatial and verbal processing disorders that could be diagnostically informative in the case of neurodegenerative diseases.

Results

As part of this project, we have developed a system for data collection and analysis.

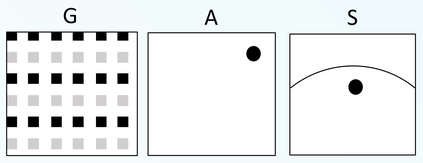
Participant logistics

1st appointment	2nd appointment	3rd appointment
Neurological testing	Assessment of perception and cognitive abilities	Radiological examinations
MoCA, PHQ9, MDS UPDRS tests are performed	Measurements of perception (recording of eye movements) and Cognitive tests	Head MRI

Perceptual and cognitive testing sequence

1.Eye tacking	2. Visuospatial tests	3. Demography
Grouping Segmentation Accentuating	Perspective Taking Test Mental Rotation Test Visual Perception Task *(Snowy pictures)* Category test	Language Education Level Field of education Occupation Dominant hand Hobbies Visual impairment

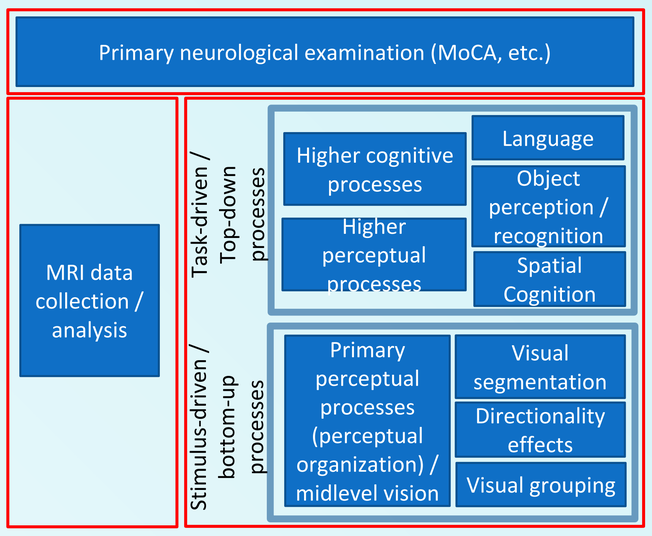
This study uses eye tracking to investigate various independent variables, including **perceptual grouping**, **accentuation**, **figure-background segmentation**, parts in whole, and shape discrimination. The dependent variables measured include **fixation length** and **frequency**, **gaze path**, and **saccade speed** and **amplitude**. The processes under examination encompass mid-level vision, focusing on perceptual organization and segmentation, and involve a bottom-up processing approach.



	Mental Rotation	Category Test	Snowy pictures (object recognition)	Perspective Test
Processes	Visuo-spatial (object rotation)	Verbal categorization, lexical processing	Object perception, recognition	Spatial orientation, perception of reference frame
Description	Measured variables: 1) Reaction time, 2) Error rate The test includes 48 tasks, with two trial examples beforehand. Participants assess correctness and reaction speed by determining if displayed figures are identical or mirror images.	Measured variables: 1) Number of items mentioned, 2) Correctness of answers, 3) First three items The test includes two tasks with a trial example. Participants list items verbally based on a given characteristic in two 3-minute segments, and we count correct associations.	Measured variables: 1) Correctness of answers, 2) Reaction time The test consists of 10 tasks with two trial examples. Participants press the 'Space' key when they recognize the depicted object, then name it. We record correct answers and reaction times.	Measured variables: 1) Correctness of answers The test contains 12 tasks, including a trial example. Participants must mark the angle on a circle indicating the direction of the third object in relation to themselves. Answers are considered correct with a 15-degree offset allowance.
Test referance	Ganis, G., & Kievit, R. A. (2015). A New Set of Three-Dimensional Shapes for Investigating Mental Rotation Processes: Validation Data and Stimulus Set. Journal of Open Psychology Data, 3(1), e3.	Ekstrom, Ruth B. Kit of factor-referenced cognitive tests. Educational Testing Service, 1976.	Ekstrom, Ruth B. Kit of factor-referenced cognitive tests. Educational Testing Service, 1976.	Perspective Taking/Spatial Orientation Test, Mary Hegarty, Maria Kozhevnikov, David Waller, 2004
All visuospatial assessments were generated utilizing the QuestionPro survey software. We amalgamated the inherent capabilities of the platform with customized coding to replicate visuospatial tests that are predominantly administered in a traditional paper-and-pen format.				

Currently, our project has started data collection. We have collected the control group data and are starting to collect data from clinical groups.

Methodology



Task-driven / Top-down processes

We prioritize visuospatial processes for early neurodegenerative disease detection. These processes, vital for cognitive tasks, impact perceptual functions and human intelligence (Taylor et al., 2015; Malanchini et al., 2020). Visuospatial tests, indicated by studies (e.g., Possin, 2010), detect early neurological symptoms.

Stimulus-driven / bottom-up processes

Eye movement analysis, particularly saccadic processes, is a sensitive indicator for various neurological disorders, including Alzheimer's and Parkinson's diseases (Bianchi & Laurent, 2015; Bueno et al., 2019). Verbal processes, like progressive semantic loss, provide diagnostic insights into neurological disorders (Vonk et al., 2020).

There are two groups of participants:

- **Clinical group** - patients with Parkinson's disease or Alzheimer's disease;
- **Control group** - without any neurodegenerative diseases.

An innovative methodological solution of this research is:

(a) linking the MRI findings with cognitive assessment (visuospatial and verbal processes) to detect early biomarkers of neurodegenerative diseases and

(b) a successful outcome of (a) will allow non-invasive diagnosis of early symptoms of neurodegenerative diseases using (b.1.) a set of cognitive tests of visuospatial perception and verbal processes, as well as (b.2.) measuring saccadic processes in the context of visual perceptual organisation (grouping, segmentation and shape perception).

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