Development of computer-based methods for the study of individual factors in spatial thinking

Datorizētu metožu izstrāde individuālo faktoru izpētei telpiskajā domāšanā

Santa Bartušēvica
Supervisor: Dr.phil. Jurģis Šķilters

About me

Education

Bachelor's Degree - University of Latvia

Computer Science (Specialization-Software Engineering)

Master's Degree - University of Latvia

Computer Science (Specialization-Bioinformatics)

First year of PhD - University of Latvia

Computer Science and Mathematics (subprogramme Computer Science)

About me

Work experience

Programmer, SIA "DIVI grupa", Rīga (until 2022)

Laboratory assistant, Laboratory for Perceptual and Cognitive Systems at the Faculty of Computing, Rīga

Lecturer - University of Latvia, Faculty of Medicine, Rīga

SIA "Cēsu Skaņa", Cēsis

Objectives

1. To conduct in-depth research on the impact of individual factors on spatial thinking.
2. Conduct research on digital tools and medical systems and comparisons of existing solutions.
3. Development of digital tools for tracking spatial perception and cognitive processes.

PhD plans

Two projects investigating spatial abilities in various age groups (VPP and FLPP)

2023/2024	2024/2025	2025/2026	2026/2027
Dissertation,	Dissertation,	Dissertation,	Dissertation,
Data collection and first analysis on FLPP,	Data collection on VPP,	Final analysis on VPP,	Conferences/publications
Internship at University of Surrey,	Data collection and analysis on FLPP,	Final analysis on FLPP,	
Design and development of test sets for VPP,	Development of an experimental design study	Data collection and analysis	
Conferences/publications	Conferences/publications	Conferences/publications	

Development of an integrative approach to the assessment of cognitive abilities in patients with neurodegenerative diseases of the central nervous system

Aim of the project

The aim of the project is 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.

Fundamental and Applied Research project (FLPP)
Project agreement No. lzp-2022/1-0100

Project realization: 01.01.2023 → 31.12.2025

University of Latvia, Riga Stradiņš University

RĪGA STRADIŅŠ UNIVERSITY

UNIVERSITY OF LATVIA
FACULTY OF COMPUTING

The main research tasks

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.

Background

NEUROCASE
2010, 16 (6), 466–487

Psychology Press
Taylor & Francis Group

Visual spatial cognition in neurodegenerative disease

Katherine L. Possin

Department of Neurology, University of California, San Francisco, CA, USA

TABLE 1
Typical constellation of visual spatial impairments in the early stages of neurodegenerative diseases

	Bottom-up/Top-down	*Dorsal/Ventral*	*Allocentric/Egocentric*
Alzheimer's disease	Bottom-up most patients, although some patients show top-down	Both are often affected	Allocentric
Posterior cortical atrophy	Bottom-up, all patients	Dorsal more than ventral, although both are affected with disease progression	Patients cannot use either frame of reference well due to severe bottom-up impairments
Parkinson's disease	Top-down	Dorsal	Egocentric
Lewy body dementias	Both, nearly all patients	Both, nearly all patients	Unknown, likely both in most patients
Corticobasal syndrome	Variable, top-down likely more common but in some patients bottom-up can be prominent, as discussed in text	When visual spatial processing is affected, dorsal impairments are usually more severe	Unknown, likely egocentric
Progressive supranuclear palsy	Top-down attentional impairment is common	Patients have difficulty orienting spatial attention, but cortical dorsal/ventral streams are usually intact	Unknown, likely egocentric
Behavioral variant frontotemporal dementia	Top-down, most patients, although in early stages no visual spatial impairment may be evident	Not impaired	Unknown, may vary with pathologic subtypes
Semantic dementia and Progressive nonfluent aphasia	Not impaired	Neither impaired early, although SD may affect ventral stream processing with disease progression	Not impaired

```
  EEEE        HHHHHHHH
 EE  EE       HHHHHHHH
EE    EE      HH
EEEEEEEE      HHHHHHHH
EEEEEEEE      HHHHHHHH
EE    EE      HH
EE    EE      HHHHHHHH
EE    EE      HHHHHHHH
```

Figure 3. Navon figures. Patients with impaired global processing will identify the smaller letters but will fail to identify the global letters (i.e., in this example, they would report seeing only an E in the first figure and an H in the second figure).

RESEARCH ARTICLE

Small Saccades Restrict Visual Scanning Area in Parkinson's Disease

Hideyuki Matsumoto, MD, PhD,[1]* Yasuo Terao, MD, PhD,[1] Toshiaki Furubayashi,[1] Akihiro Yugeta, MD, PhD,[1] Hideki Fukuda, PhD,[2] Masaki Emoto, PhD,[3] Ritsuko Hanajima, MD, PhD,[1] and Yoshikazu Ugawa, MD, PhD[4]

[1]Department of Neurology, University of Tokyo, Tokyo, Japan
[2]Segawa Neurological Clinic for Children, Tokyo, Japan
[3]Interfaculty Initiative in Information Studies, University of Tokyo, Tokyo, Japan
[4]Department of Neurology, School of Medicine, Fukushima Medical University, Fukushima, Japan

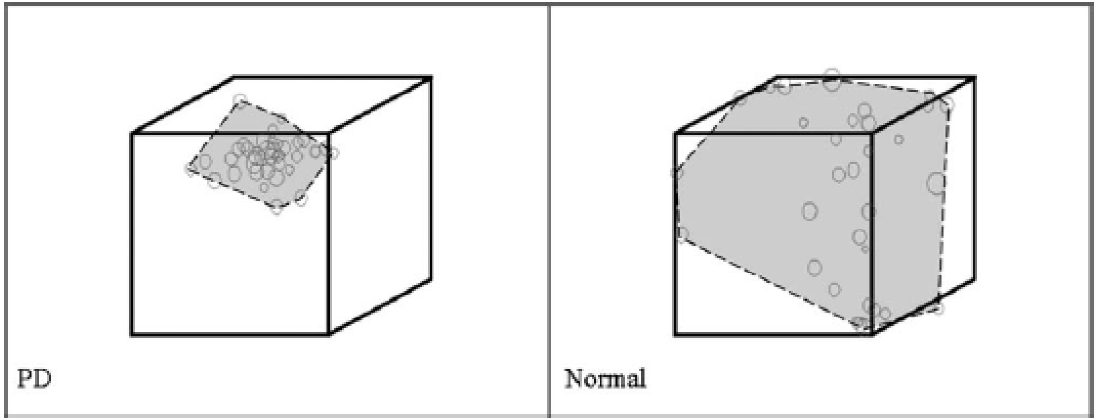


FIG. 1. Examples of scanned area analysis. These are the results of an eye-fixation analysis for a PD patient and a normal subject scanning image 1. The scanned area is defined as the ratio of the area enclosed by the outline of the eye-fixation positions (gray shaded area) to the area of the whole image.

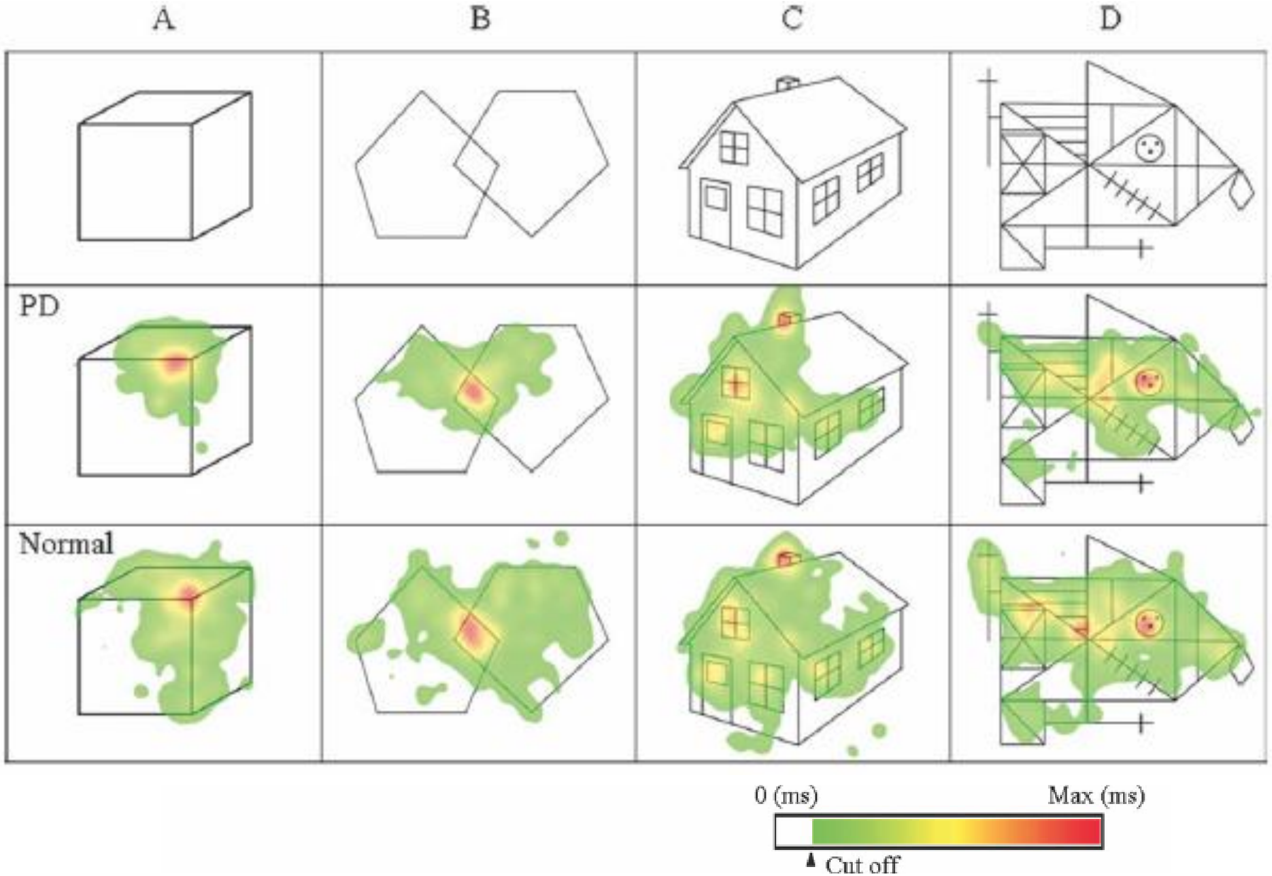
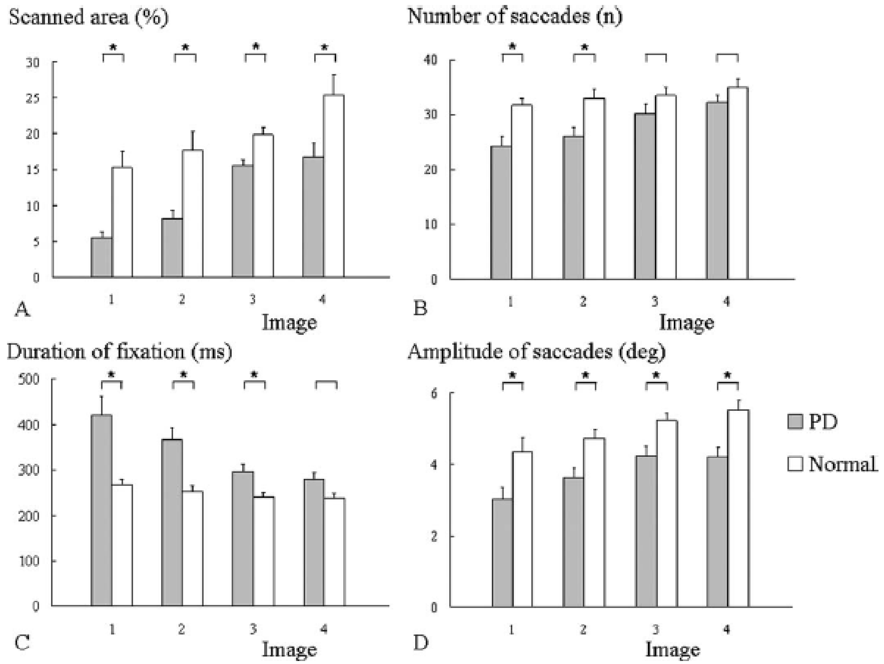


FIG. 2. Presented images and heat maps. **A:** Image 1—a cube. **B:** Image 2—2 overlapping pentagons. **C:** Image 3—a house. **D:** Image 4 —the Rey-Osterrieth complex figure. The upper panels show the images presented to subjects, the middle panels show the heat maps of the PD patients, and the lower panels show those of the normal subjects. In all images, the distribution of eye-fixation positions (green area) in PD patients was narrower than that in normal subjects.



Saccade -a quick, simultaneous movement of both eyes between two or more phases of fixation in the same direction.

Fixation - A fixation is a period of time during which a specific part of the text on the screen is looked at and thereby projected to a relatively constant location on the retina.

Although the impacts differ depending on the particular disease, gaze patterns are sensitive to a variety of neurological diseases – Alzheimer’s disease, Parkinson’s disease, epilepsy, osteoarthritis, and rheumatoid arthritis, to mention just a few.

Primary neurological examination (MoCA, PHQ9, MDS UPDRS)

MRI data collection / analysis

Task driven / Top-down processes

Higher cognitive processes

Higher perceptual processes

Language

Object perception / recognition

Spatial Cognition

Stimulus driven / bottom-up processes

Primary perceptual processes (perceptual organization) / midlevel vision

Visual segmentation

Directionality effects

Visual grouping

Inclusion criteria for the clinical group

Central nervous system diseases

- Alzheimer’s disease
- Parkinson’s disease
- Huntington’s disease

Exclusion criteria

- Diagnosed CNS tumors or metastases, cerebrovascular event, encephalitis
- Any brain injury other than concussion
- Decompensated arterial hypertension
- Diabetes (type 1, 2)
- Metabolic syndrome
- Neurodegenerative disease other than Parkinson's disease or Alzheimer's disease
- Any thyroid disease (CA, hypothyroidism, autoimmune diseases - Hashimoto's thyroiditis, atrophic thyroiditis, partial or complete removal of thyroid tissue, radiotherapy - Iodide I131, congenital hypothyroidism, use of medications - amiodarone, lithium preparations, interferon alfa, Graves' disease, Toxic nodular goiter)
- etc

Overall order of tests

Eye tracing

- Grouping
- Segmentation
- Accentuating

Testing

- Perspective Taking Test
- Mental Rotation Test
- Visual Perception Task (Snowy pictures)
- Category test

Demography

- Language
- Education Level
- Field of education
- Occupation
- Dominant hand
- Hobbies
- Visual impairment

Eye tracking

Duration of the eye-tracking task: ~ 10 minutes (including calibration).

Before seeing the stimuli images, participants do a calibration task to ensure accurate eye-tracking measurement.

Three groups of stimuli images:

- Grouping,
- Segmentation,
- Accentuation.

Eye-tracking

Low-level vision

Representations of edges, colors, and lights.
Low-level input: image (orientation, contrast, color)

Mid-level vision

Mid level vision is where the visual system begins to make inferences about the world based on those measurements.
Mid-level processes: perceptual organization (grouping, visual segmentation, shape assignment)

High-level vision

Representations of objects, faces, and scenes.
Higher level perceptual processes: e.g., object recognition, categorization

Order of stimuli

For the "Grouping" and "Segmentation" stimuli:

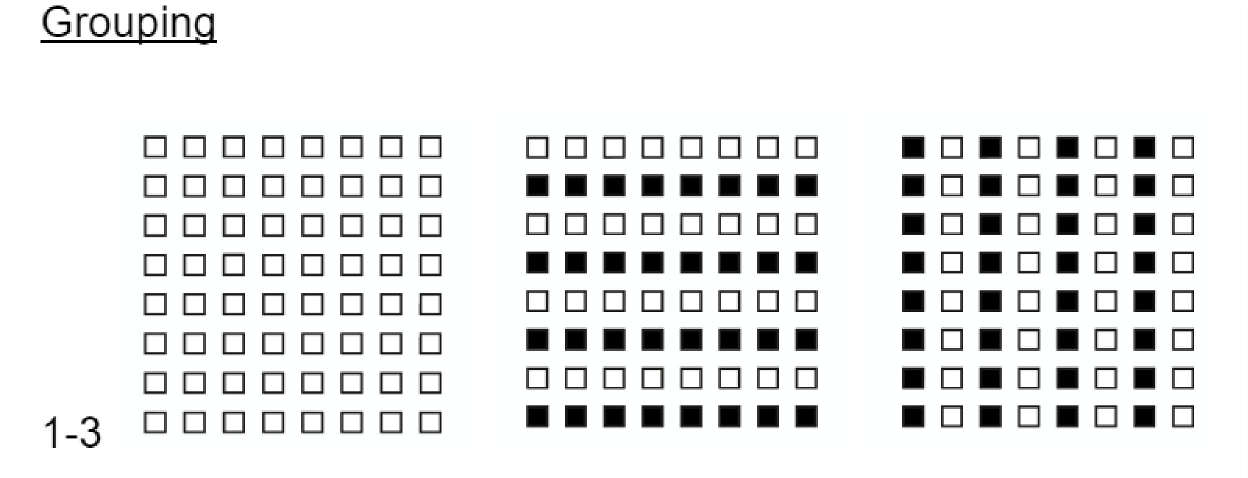
the first image is the neutral image (no clear groups or accentuated segments of the image), and then the rest of the stimuli images are in randomised order.

The "Accentuating" group:

stimuli are in a completely randomised order

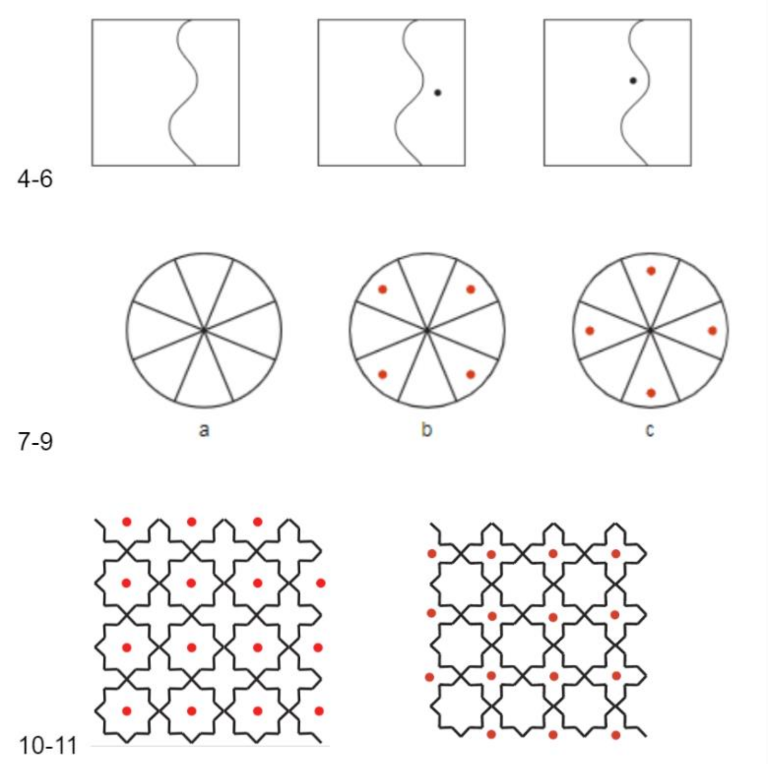
After each group, the participants view filler stimuli containing six pictures with different scenes.

Examples of stimuli

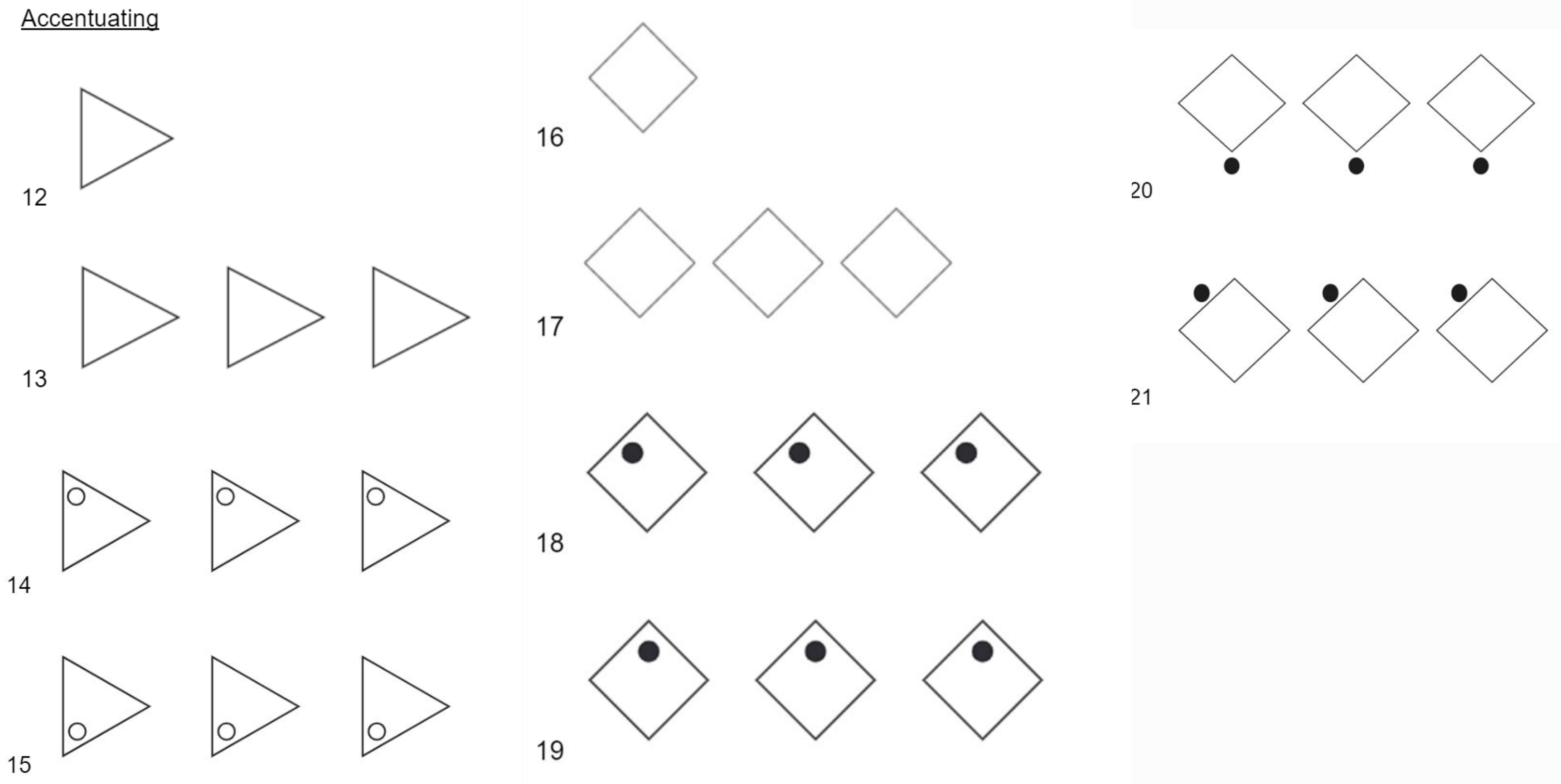


Prof. Baingio Pinna
University of Sassari, Italy

Examples of stimuli



Examples of stimuli



Eye tracking

We are looking at:

Perceptual grouping
Accentuation
Figure-ground segmentation

https://www.tobii.com/products/eye-trackers/screen-based/tobii-pro-spectrum

Measured variables:

Fixation length and frequency
Gaze path
Saccade speed, amplitude

Processes that are examined:
Mid-level vision
(Perceptual Organization, Segmentation)
Bottom-up processing

Testing

All tests are given in a random order.

The order in which each participant completes the tests is recorded.

Perspective Taking Test

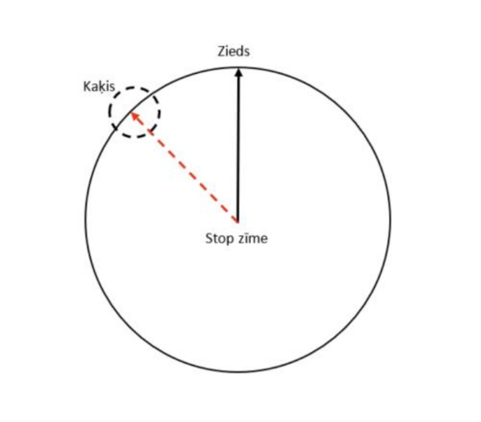
Kozhevnikov & Hegarty, 2001, Hegarty & Waller, 2004

The test consists of 12 tasks.

A trial example: before the test.

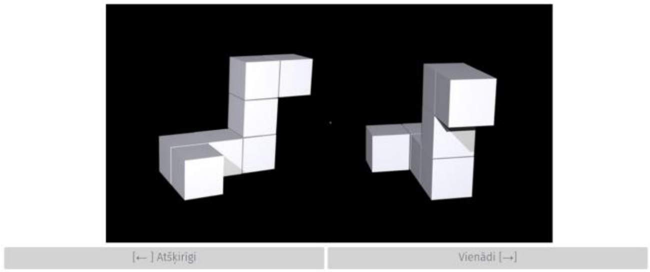
The participant's task: to mark the angle on the circle line, showing the direction of the third object in relation to himself.

The number of correct answers is counted (within 15 degrees offset).



Mental Rotation Test

Shepard & Metzler, 1971,
Shepard & Metzler, 1988



The test consists of 48 tasks.

2 trial examples: before the test.

The number of correct answers and reaction speed are counted.

The participant's task: to determine whether the figures shown in the picture are the same or a mirror image.

Visual Perception Task (Snowy pictures)

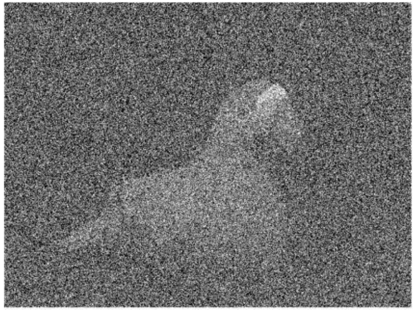
Ekstrom et al., 1976

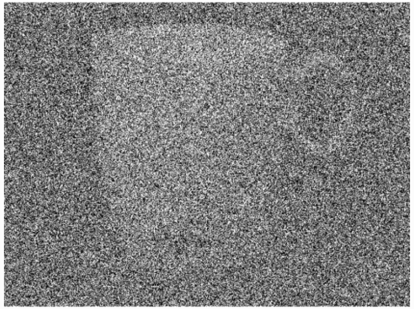
The test consists of 10 tasks.

2 trial examples: before the test.

As soon as the participant recognises the object depicted in the picture, they have to press the long key ('Space') and then name the object they saw.

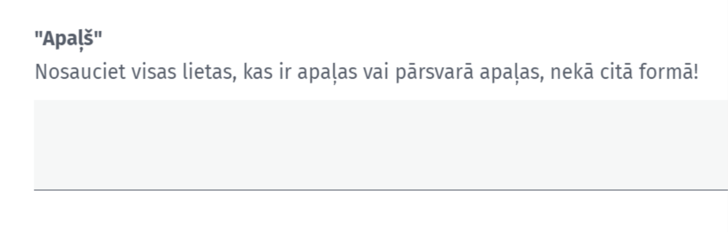
The number of correct answers and reaction speed are counted.





Category test

Ekstrom et al., 1976


"Apaļš"

Nosauciet visas lietas, kas ir apaļas vai pārsvarā apaļas, nekā citā formā!

The test consists of 2 tasks.

A trial example: before the test.

The participant is given 3 minutes for each of the two parts of the task, where they have to list (verbally) things according to a given characteristic.

The number of correct association words is counted.

Why our approach is unique?

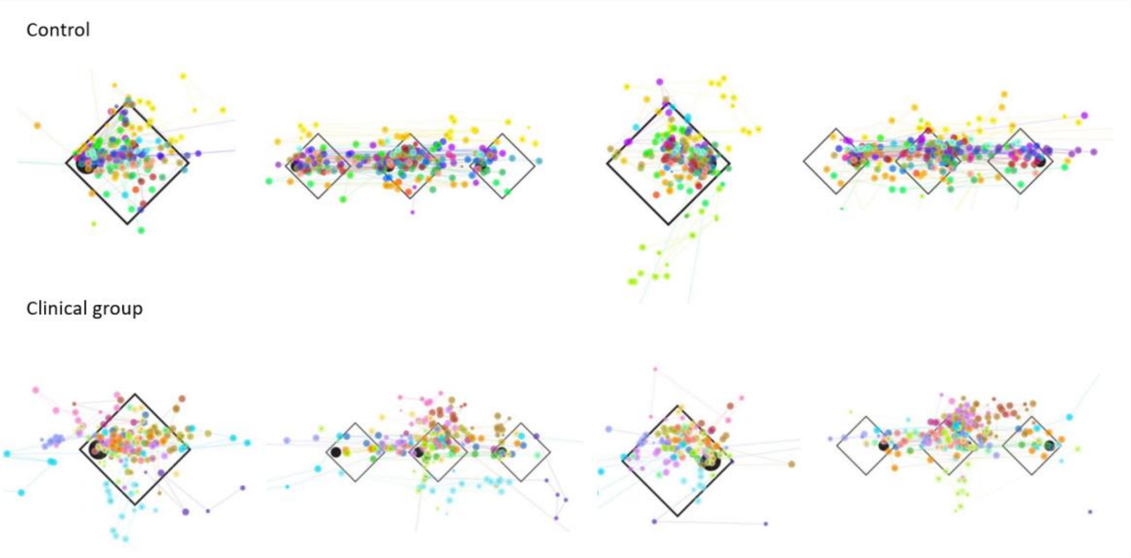
Both top-down and bottom-up processes are examined

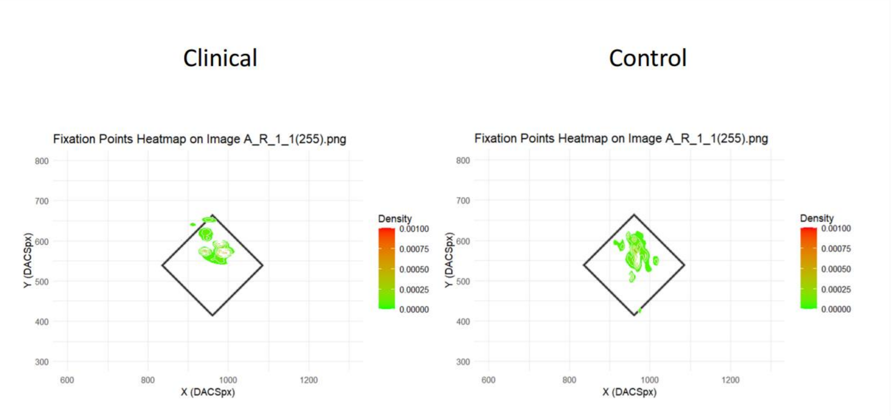
Perceptual organization is examined (mid-level vision analysis)

Preliminary results

n=12 Clinical
n=29 Control

Preliminary results





Preliminary results

In all groups and experimental settings:

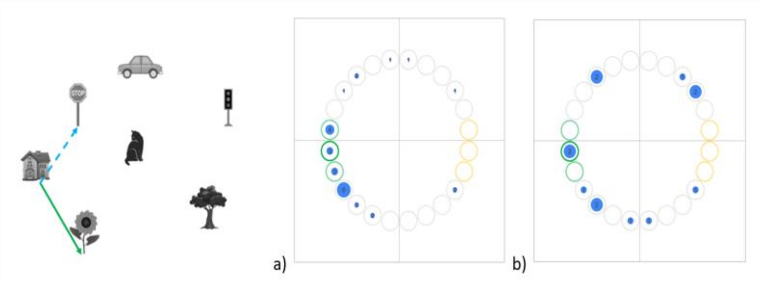
- there are huge differences in perceiving accent, segmenting, and grouping.

In clinical tests:

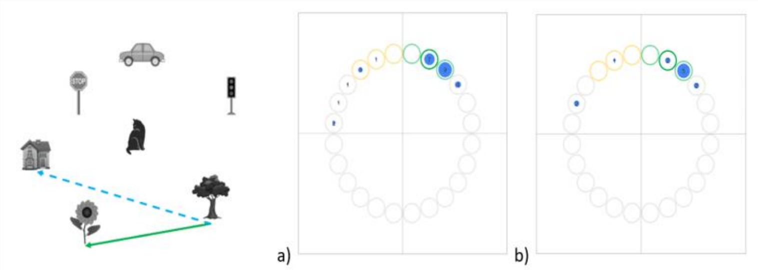
- neurodegenerative impairments:
  - cause the increase in fixation number in case of directional stimuli (accent)
  - decrease the gaze duration in perception of accent but increase in grouping and segmenting
  - narrower scan area

Preliminary results

Imagine you are standing at the **house** and facing the **flower.** Point to the **stop sign**.



Imagine you are standing at the **tree** and facing the **flower.** Point to the **house**.



Innovations, methodologies and recommendations for the development and management of the sports sector in Latvia

This will be joint project implemented by the five research institutions/ higher education institutions-
Rīga Stradiņs University (RSU),
Rīga Technical University (RTU),
University of Latvia (UL),
Latvian Academy of Sport Education (LASE) and
Liepāja University (LiepU)

Funding
Latvian Council of Science:
No. VPP-IZM-Sports-2023/1-0001

RĪGA STRADIŅŠ UNIVERSITY
RIGA TECHNICAL UNIVERSITY
UNIVERSITY OF LATVIA
LATVIAN ACADEMY OF SPORT EDUCATION
LIEPĀJAS UNIVERSITĀTE

Aim of the project

1) Develop evidenced based recommendations for coaches, parents and sport leaders about the training of youth athletes (12-18 years old) with disability involved in adapted sports.

2) Develop research methods and knowledge base on monitoring the mental and physical health of athletes involved in grassroot sports.

Cognitive and perceptual components in sports

The sport performance is constrained not just by physical abilities and overall body condition but also by **cognitive and perceptual components** such as emotion regulation, visuospatial abilities, and personality features.

To achieve a sustainable and successful performance in sport, **emotion regulation is critical** as the athlete's ability to balance emotions impacts her/his performance. **Visuospatial abilities are also critical** for successful performance in sport and results in visuospatial tests have a diagnostic and predictive value.

Visuospatial abilities

Visuospatial abilities critical for both **successful performance in sport** (although to a different degree in different sports (Lord, & Garrison, 1998, Millard et al., 2021, Zeļģe, 2023a, 2023b) **supports and scaffolds learning abilities in STEM fields**

https://pxhere.com/en/photo/932093

Included set of tests

The overall sample will be screened with shortened and combined versions of :

An adapted version of Geneva Wheel of Emotions (GWE) (Schlegel & Scherer, 2016);

Perspective test to examine the accuracy of egocentric spatial ability (Kozhevnikov & Hegarty, 2001, Hegarty & Waller, 2004);

Mental rotation test to examine allocentric spatial abilities, reaction time and accuracy (Shepard & Metzler, 1971, Shepard & Metzler, 1988);

The concise version of Big 5 Personality test (Gosling, Rentfrow, & Swann, 2003)

Included set of tests

In-Depth analysis tests conducted in lab:

a. Santa Barbara Sense of Direction scale to examine the overall sense of direction (Hegarty et al., 2002);

b. Experiments on eye movements in midlevel vision (perceptual organization)

c. testing navigational abilities by applying an experimental tool of spatial learning (Bartušēvica, 2023, Brunec et al., 2023).

LATVIAN ACADEMY OF SPORT EDUCATION

Measurements in the LASE

- body composition;
- aerobic capacity;
- musculoskeletal fitness;
- flexibility profile;
- etc.

Internship


Robert Blumberg Distinguished
Lecture in Cognitive Science 2022
Navigation,
the spatial domain
and STEM
Prof. Emily Farran
University of Surrey,
United Kingdom
Art Museum RIGA BOURSE
Doma laukums 6, Riga
Remote version on Zoom
16.01.2023 13:00
Registration and more information:
www.lpcs.lu.lv
Robert Blumberg Distinguished Lecture in Cognitive Science was initiated 2018 in collaboration between the Laboratory of Perception and Cognitive Systems at the Faculty of Computing, University of Latvia, and Robert Blumberg, honorary member of UL, patron, board member of the organization "Friends of the University of Latvia", and the Honorary Consul of the Republic of Latvia in the State of Illinois. Supporters: Riga Stradins University, University of Latvia Foundation.
FACULTY OF COMPUTING
Laboratory for Perceptual and Cognitive Systems
UNIVERSITY OF LATVIA FOUNDATION
RIGA STRADIŅŠ UNIVERSITY

Internship

University of Surrey, UK

SPATIAL COGNITION TO ENHANCE MATHEMATICAL LEARNING (SPACE)

In this study, researchers from the University of Surrey, Loughborough University, University College Dublin, and Birkbeck (the SPACE team) are using spatial training to enhance spatial skills. An independent team from the Centre of Evidence & Implementation (CEI) will evaluate the effectiveness and feasibility of the SPACE program for Year 2 maths lessons.

Results

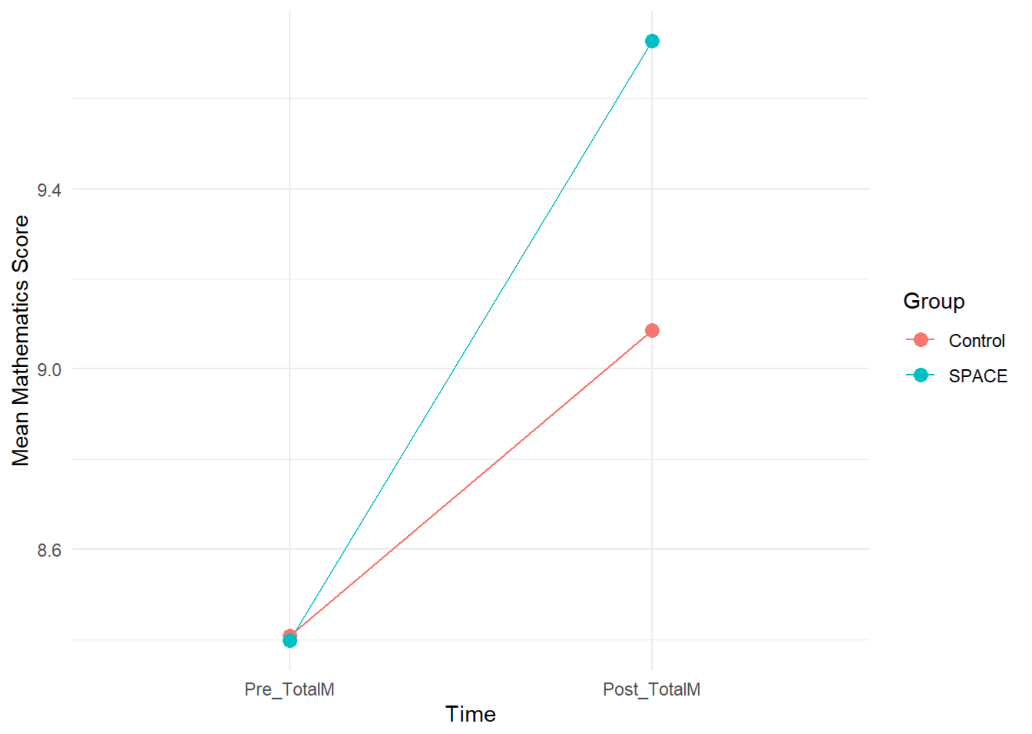
1. Are associations between spatial ability and mathematics at 6 years moderated by gender or school-based socioeconomic status?

2. Exploring gender and SES differences in spatial language, mental rotation, and mathematics before and after intervention with LEGO Activities.

Results

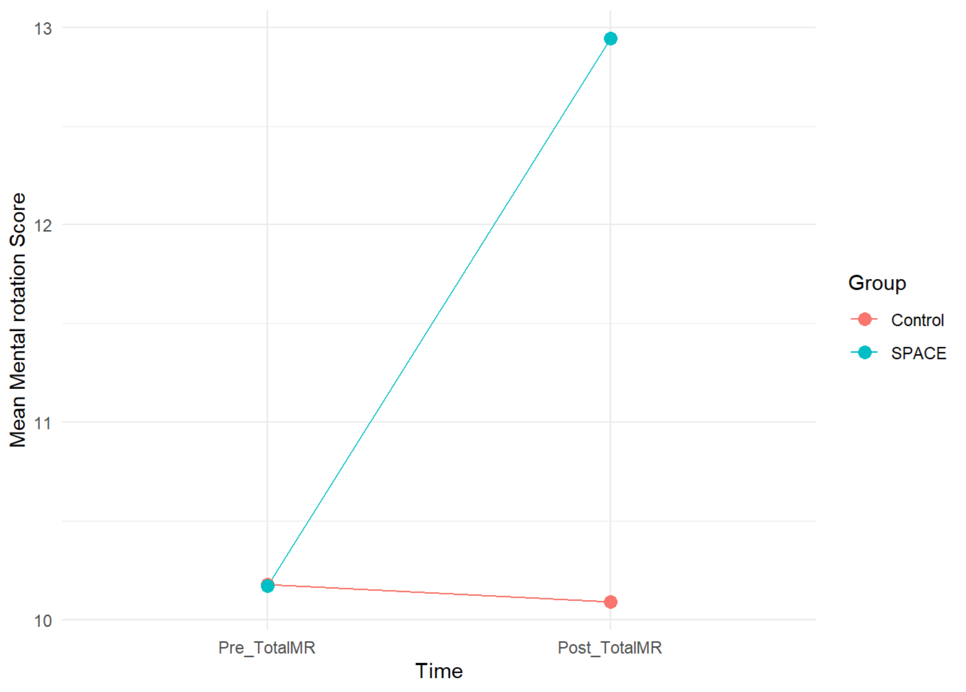
	Mathematics score	**Mental rotation score**	**Spatial language score**
Age (months)	0.188***	0.157***	0.196***
Mathematics score (pt)		0.347***	0.566***
Mental rotation score (pt)			0.314***
*** p < .001, ** p < .01			

Results



Mean in pre M		Mean in post M	
Control	Space	Control	Space
8.408602	8.397606	9.086022	9.727394

Results



Mean in pre MR		Mean in post MR	
Control	Space	Control	Space
10.1791	10.17193	10.08955	12.94386

Conferences

Data Analysis Methods for Software Systems. 14th Conference Druskininkai, Lithuania.
Santa Bartušēvica, Jurģis Šķilters, Solvita Umbraško, Līga Zariņa, Laura Zeļģe, Agnese Anna Pasare, Ardis Platkājis, Jānis Mednieks, Aleksejs Ševčenko, Nauris Zdanovskis, Artūrs Šilovs, Edgars Naudiņš
"Development of an Integrative Approach to the Assessment of Cognitive Abilities in Patients With Neurodegenerative Diseases of the Central Nervous System"

82nd International Scientific Conference of the UL session "Cognitive Science". (2024)
Santa Bartušēvica, Laura Zeļģe, Jurģis Šķilters, Solvita Umbraško and Līga Zariņa.
Exploring spatial abilities and individual factors in athletes.

82nd International Scientific Conference of the UL session "Cognitive Science". (2024)
Agnese A. Pastare, Jurģis Šķilters, Solvita Umbraško, Santa Bartušēvica, Līga Zariņa, Laura Zeļģe, Ardis Platkājis, Jānis Mednieks, Aleksejs Ševčenko, Nauris Zdanovskis, Artūrs Šilovs, Edgars Naudiņš.
Depresijas iezīmju saistība ar kognitīvām spējām pieaugušajiem ar un bez neirodeģeneratīvām saslimšanām.

82nd International Scientific Conference of the UL session "Cognitive Science". (2024)
Jurģis Šķilters, Megija L. Gintere, Elza Klūģe, Baingio Pinna, Santa Bartušēvica, Līga Zariņa, Solvita Umbraško, Laura Zeļģe, Agnese A. Pastare, Ardis Platkājis, Jānis Mednieks, Aleksejs Ševčenko, Nauris Zdanovskis, Artūrs Šilovs, Edgars Naudiņš.
Perceptual organization, perception of accent and their neurodegenerative distortions.

82nd International Scientific Conference of the UL session "Cognitive Science". (2024)
Agnese A. Pastare, Jurģis Šķilters, Solvita Umbraško, Santa Bartušēvica, Līga Zariņa, Laura Zeļģe, Ardis Platkājis, Jānis Mednieks, Aleksejs Ševčenko, Nauris Zdanovskis, Artūrs Šilovs, Edgars Naudiņš.
Vizuāli telpisko spēju saistība ar galvas smadzeņu domēnu tilpumu mērījumiem pieaugušajiem ar un bez neirodeģeneratīviem traucējumiem.

Conferences

Approved applications for conferences:

- Spatial Cognition 2024, Dublin;
- COGSCI 2024, Rotterdam.

Thank you!