QoL assessment with XR

(Orientation and mobility test in virtual reality, a quantitative assessement of functional vision : datasets and evaluation)

Patrick Le Callet – VQEG Spring Meeting 2025

institut universitaire de France

Nantes Université

Definition of Quality of Life?

ELSEVIER

Progress in Retinal and Eye Research

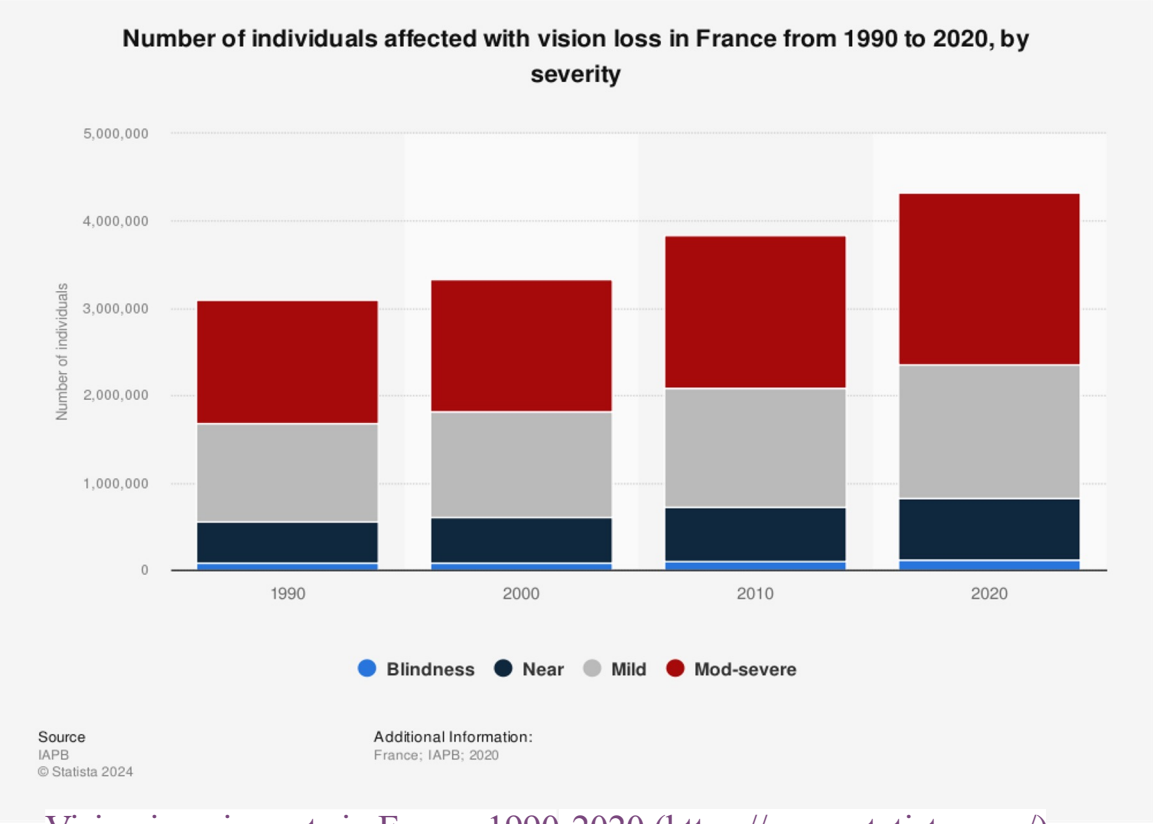
journal homepage: www.elsevier.com/locate/preteyeres

Endpoints for clinical trials in ophthalmology

Leopold Schmetterer [a,b,c,d,e,f,g,*], Hendrik Scholl [g,h], Gerhard Garhöfer [e], Lucas Janeschitz-Kriegl [g,h], Federico Corvi [i], SriniVas R. Sadda [j,k], Felipe A. Medeiros [l]

« Although there is no generally accepted definition of health-related Quality of life (QoL), it is usually understood as a measure of a subject's well-being and/or how a certain medical condition may affect a patient on an individual level Karimi and Brazier, 2016

Low vision: a societal challenge



Vision impairments in France 1990-2020 (https://www.statista.com/)

By 2020 in France:

- 2% of the population affected by visual impairment;
- Numbers are rising.

By 2020 in the world[1]:

- 596 million people affected by visual impairment;
- Predicted 896 million people affected by 2050.

[1] Bourne R, Steinmetz J D, Flaxman S, et al. Trends in prevalence of blindness and distance and near vision impairment over 30 years: an analysis for the Global Burden of Disease Study[J]. The Lancet global health, 2021, 9(2): e130-e143.

Context

Visual Function

Visual Acuity

Visual Field

Contrast Sensitivity

- Focus: Organ[1];
- Assessment: Clinical standardized quantitative measurement tools.

Independently measured, quantitative

Functional Vision

Activity of daily living

Quality of Life

- Focus: Person[1];
- Assessment: Questionnaire.

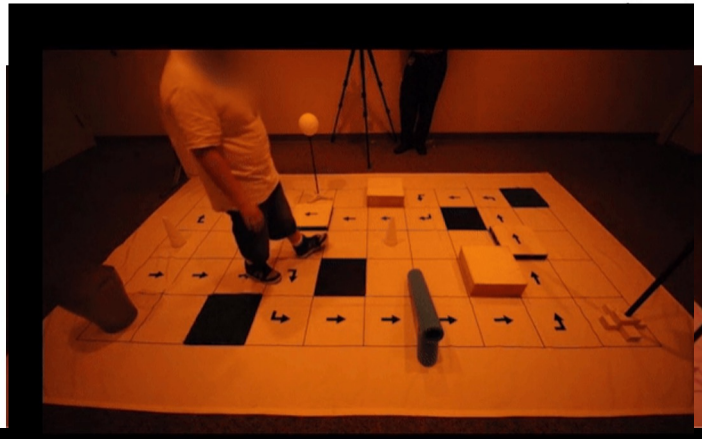
Easy score, subjective, not reliable.

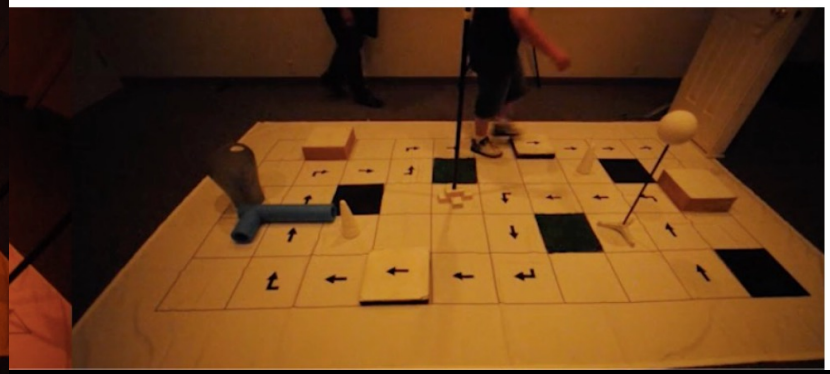
[1] Bennett C R, Bex P J, Bauer C M, et al. The assessment of visual function and functional vision[C]//Seminars in pediatric neurology. WB Saunders, 2019, 31: 30-40.

Published in final edited form as:
Clin Exp Ophthalmol. 2018 April ; 46(3): 247–259. doi:10.1111/ceo.13022.

Novel mobility test to assess functional vision in patients with inherited retinal dystrophies

Daniel C Chung, DO[1], **Sarah McCague, BA**[2], **Zi-Fan Yu, ScD**[3], **Satha Thill, MS**[3], **Julie DiStefano-Pappas, BA**[4], **Jean Bennett, MD PhD**[2,5], **Dominique Cross, MPH**[2], **Kathleen Marshall, COT**[2], **Jennifer Wellman, MS**[1], and **Katherine A High, MD**[1]

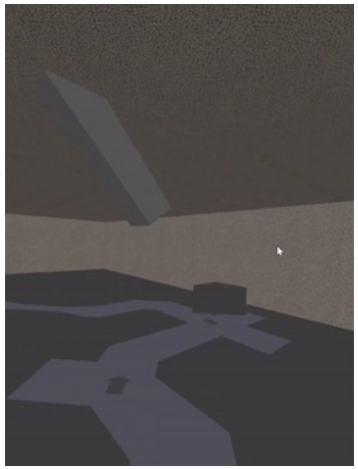




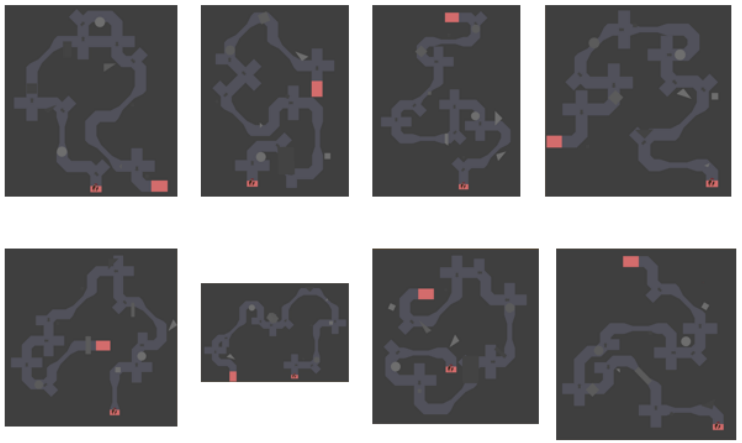
Our VR seated orientation and mobility test (VR-S-O&M)[4,5]

- Flexible design & reconfigurable;
- Safer;
- Cheaper;
- Access to behavior data;

(a) A participant was doing the test



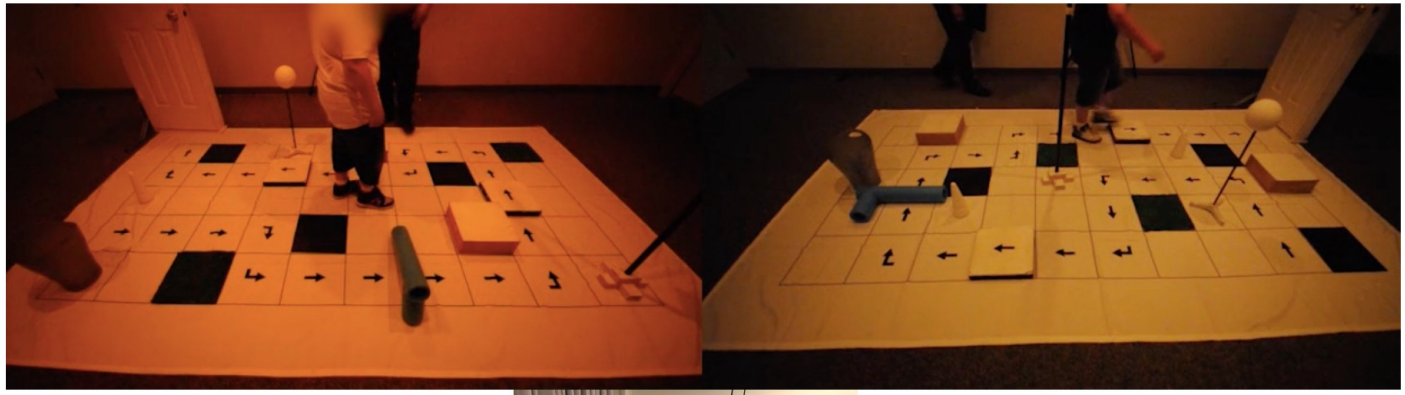
(b) The point of view of this participant

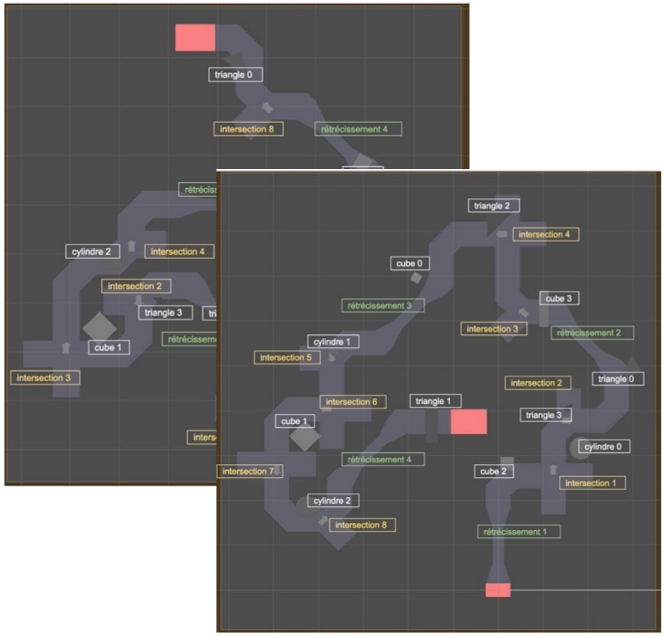


(c) Multiple test virtual environment

[4] Crozet A, Communier L, Vigier T, et al. A Virtual Mobility Test to Evaluate Functional Vision of Visual Impaired Patients[C]//IMXw'23: ACM International Conference on Interactive Media Experiences Workshops. ACM, 2023.
[5] Huang Y, Crozet A, Vigier T, et al. Orientation and mobility test in virtual reality, a tool for quantitative assessment of functional vision: dataset and evaluation in healthy subjects[J]. arXiv preprint arXiv:2504.13735, 2025.

MOVING TO VR

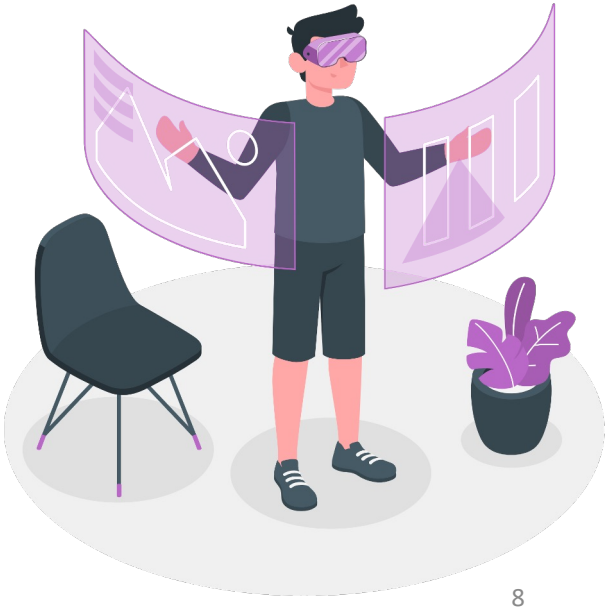



triangle 0
intersection 8
rétrécissement 4
cylindre 2
intersection 4
intersection 2
triangle 3
cube 1
intersection 3
triangle 2
intersection 4
cube 0
rétrécissement 3
cube 3
intersection 3
rétrécissement 2
cylindre 1
intersection 5
intersection 2
triangle 0
intersection 6
triangle 1
cube 1
triangle 3
cylindre 0
rétrécissement 4
intersection 7
cube 2
intersection 1
cylindre 2
intersection 8
rétrécissement 1

Refining Functional Vision Assessment in Virtual Reality

Speaker: Yujie HUANG [1]
Supervisor: Patrick LE CALLET [1,2]
Co-Supervisor: Alexandre BRUCKERT [1]

1. Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, F-44000 Nantes, France
2. Institut universitaire de France (IUF)



Performance Analysis/KPIs

Research Questions:

- RQ1: Are the current metrics sufficient to our VR-S-O&M test?
- RQ2: How to take advantage of our rich behavior data to refine the scoring system?

Dataset with Healthy subjects[5]	**Preliminary data collected from Visually impaired subjects**
42 Participants;	9 Participants (2 were excluded due to little tolerance);
Each did 12 runs;	Each did 1~2 runs;
479 valid runs collected;	12 valid runs collected;
6 virtual labyrinths randomly used;	6 virtual labyrinths randomly used;

[5] Huang Y, Crozet A, Vigier T, et al. Orientation and mobility test in virtual reality, a tool for quantitative assessment of functional vision: dataset and evaluation in healthy subjects[J]. arXiv preprint arXiv:2504.13735, 2025.

Conventional scoring system

"15 s added for each simple error, 30s added for each redirect. " [2,3]

$$TimeScore = t_{duration} + \boxed{t_{penalities}}$$

$$AccuracyScore = \frac{N_{penalities}}{N_{obstacles}}$$

[2] Chung D C, McCague S, Yu Z F, et al. Novel mobility test to assess functional vision in patients with inherited retinal dystrophies[J]. Clinical & experimental ophthalmology, 2018, 46(3): 247-259.
[3] Aleman T S, Miller A J, Maguire K H, et al. A virtual reality orientation and mobility test for inherited retinal degenerations: testing a proof-of-concept after gene therapy[J]. Clinical Ophthalmology, 2021: 939-952.

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Two based metrics

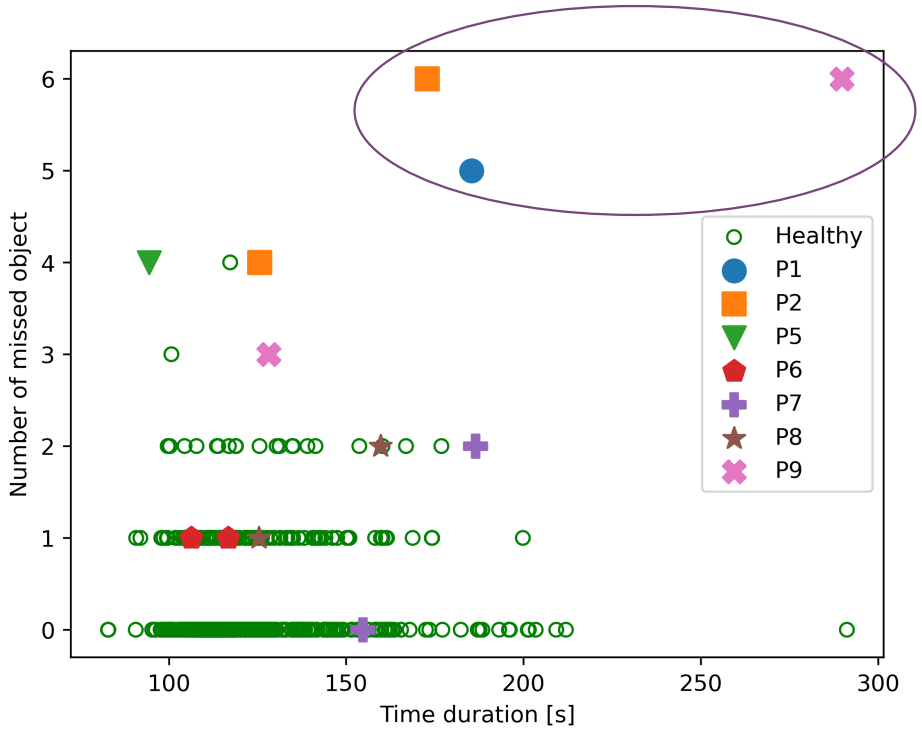
$t_{duration}$

N_{error}

Missed object

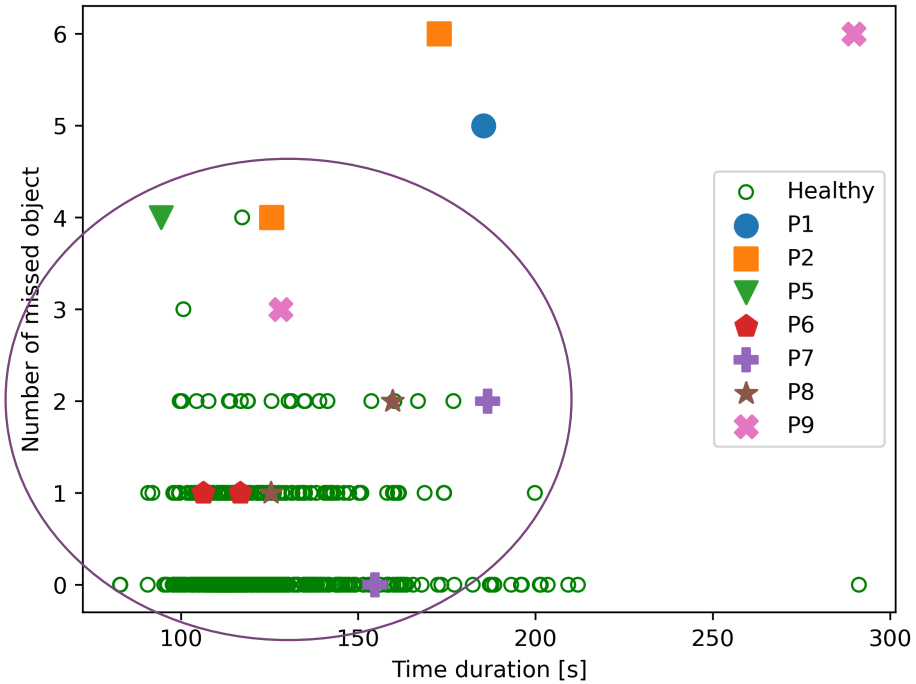
[2] Chung D C, McCague S, Yu Z F, et al. Novel mobility test to assess functional vision in patients with inherited retinal dystrophies[J]. Clinical & experimental ophthalmology, 2018, 46(3): 247-259.
[3] Aleman T S, Miller A J, Maguire K H, et al. A virtual reality orientation and mobility test for inherited retinal degenerations: testing a proof-of-concept after gene therapy[J]. Clinical Ophthalmology, 2021: 939-952.

RQ1: Are the current metrics sufficient to our VR-S-O&M test?



- Even though these two metrics are discriminant for certain patients;

RQ1: Are the current metrics sufficient to our VR-S-O&M test?



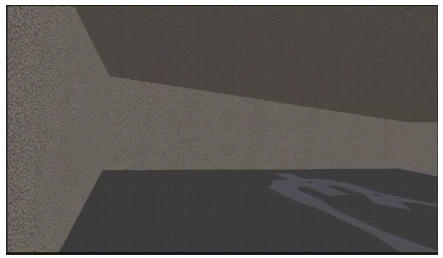
- Although these two metrics are discriminative for certain patients;
- however, using only these metrics may not explain the outcome of many other patients.

The current metrics are superficial and lack explanatory power.

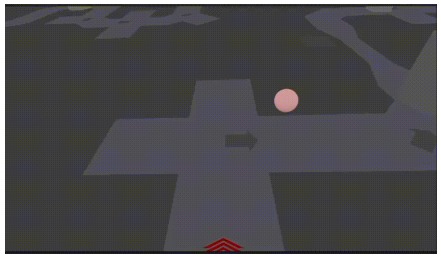
Building KPI using behavorial data

RQ2: How to take advantage of our rich behavior data to refine the scoring system?

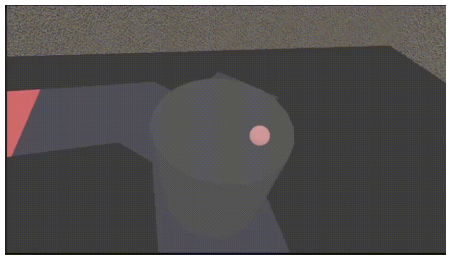
Using the **recorded behavior data**, we annotated three types of error existing in the test[6]:



Type A Missed object is out of FOV.



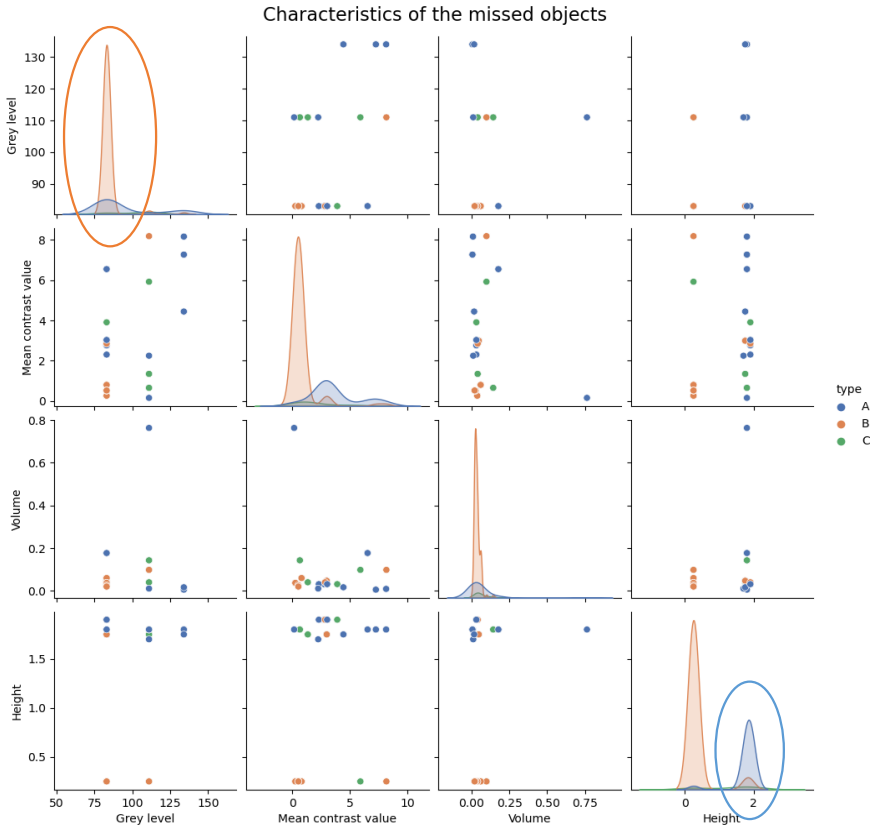
Type B Missed object is in FOV but not seen.



Type C Missed object is seen.

[6] Huang Y, Li C, Bruckert A, et al. Refining Functional Vision Assessment: Challenges in Adapting Orientation and Mobility Tests to Virtual Reality[C]//IEEE Conference on Virtual Reality and 3D User Interfaces (IEEE VR). 2025.

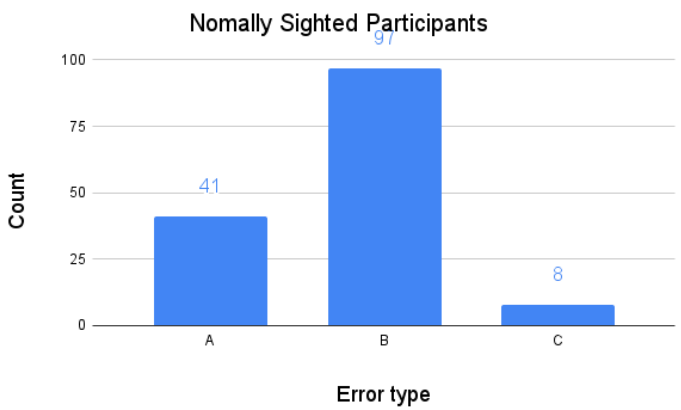
RQ2: How to take advantage of our rich behavior data to refine the scoring system?



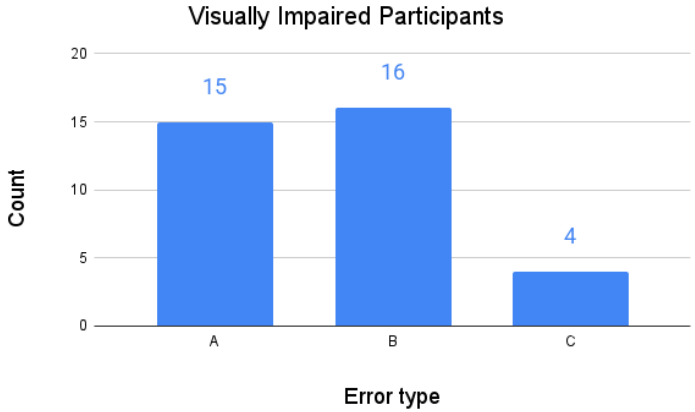
- Type A: related to objects in high position;
- Type B: related to objects with low contrast;
- Type C: No specific characteristic (may due to unfamiliarity with VR)

RQ2: How to take advantage of our rich behavior data to refine the scoring system?

error occurrence among healthy participants and patients:



(a) Among healthy participants (N=479)



(b) Among patients(N=12)

Focus on A and B

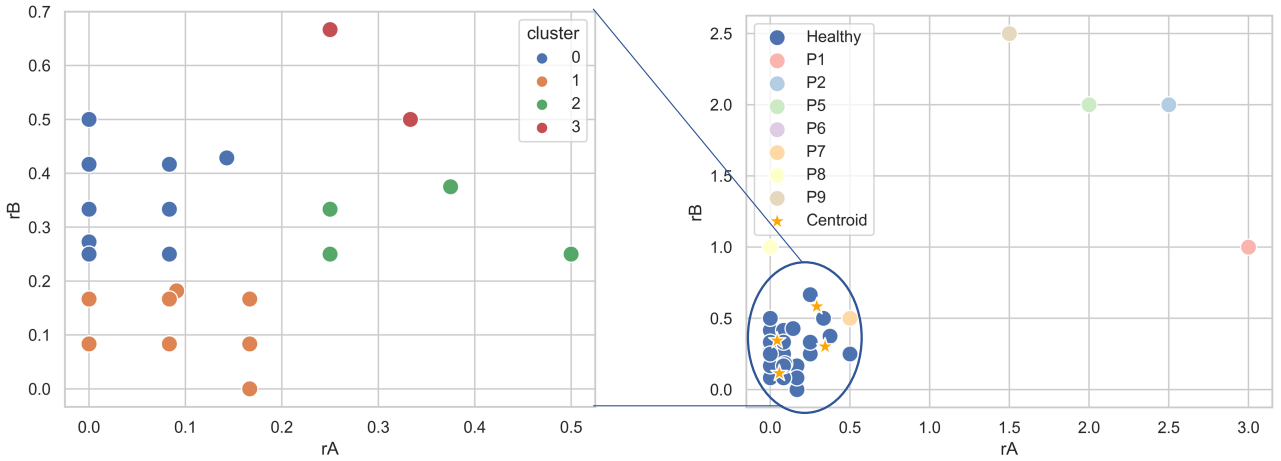
RQ2: How to take advantage of our rich behavior data to refine the scoring system?

error occurrence rate (Type A & Type B)

$$r_A = \frac{N_A}{N}$$

$$r_B = \frac{N_B}{N}$$

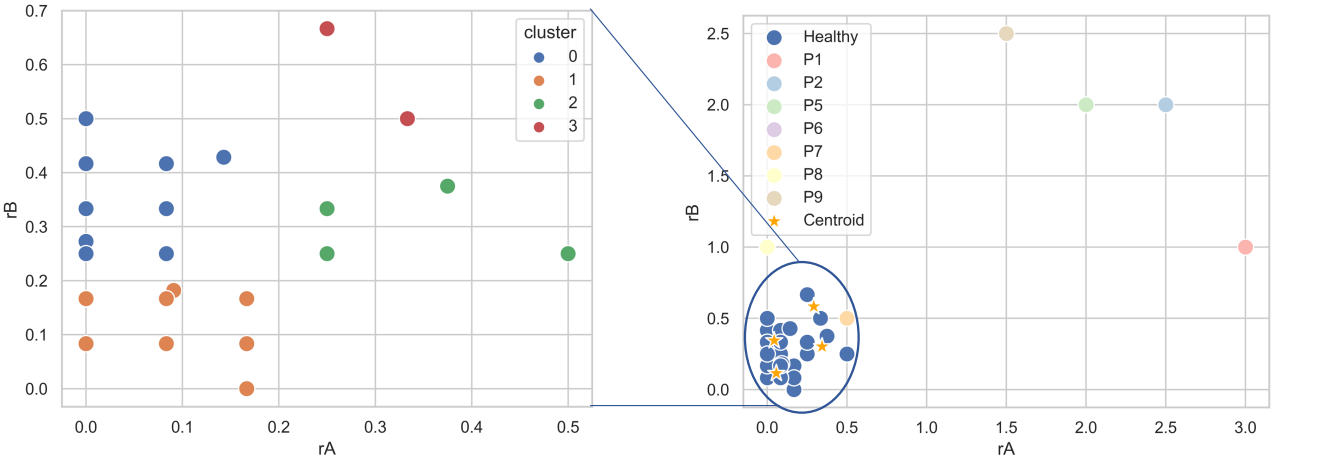
Based on these two features, 4 clusters were found in the Healthy group.



(a) 4 clusters in Healthy participants

(b) Healthy and visually impaired participants

RQ2: How to take advantage of our rich behavior data to refine the scoring system?



(a) 4 clusters in Healthy participants

(b) Healthy and visually impaired participants

Baseline

For patients:

- The distance to each cluster centroid is calculated: $Dist_0, Dist_1, Dist_2, Dist_3$
- A general functional vision score is represented by calculating a overall distance:

$$s = \sqrt{{Dist_0}^2 + {Dist_1}^2 + {Dist_2}^2 + {Dist_3}^2}$$

- Two refined scores are represented by:

$r_A \downarrow$: Describes the capacity of high peripheral exploration;

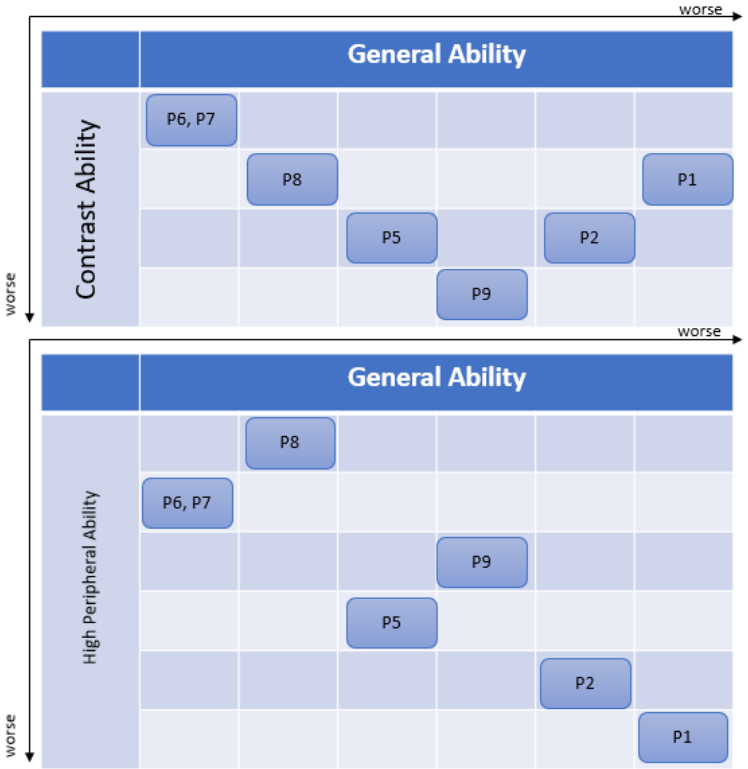
$r_B \downarrow$: Describes the capacity of contrast-related vision.

Analysis and result

RQ2: How to take advantage of our rich behavior data to refine the scoring system?

Patient	Dist_0	Dist_1	Dist_2	Dist_3	s
P1	3.029	3.074	2.746	2.740	5.803
P2	2.963	3.086	2.745	2.624	5.720
P5	2.563	2.708	2.372	2.219	4.945
P6	0.483	0.588	0.252	0.224	0.832
P7	0.483	0.588	0.252	0.224	0.832
P8	0.657	0.887	0.800	0.509	1.443
P9	2.602	2.788	2.483	2.266	5.084

(a) Calculated general score



(b) Patients ranking with new scores

With the refined scores:

- A general functional vision score can be calculated for an overall assessment;
- Two sub scores can capture subtle performance.

Analysis and result

RQ2: How to take advantage of our rich behavior data to refine the scoring system?

With the refined scores:

- A general functional vision score can be calculated for an overall assessment;
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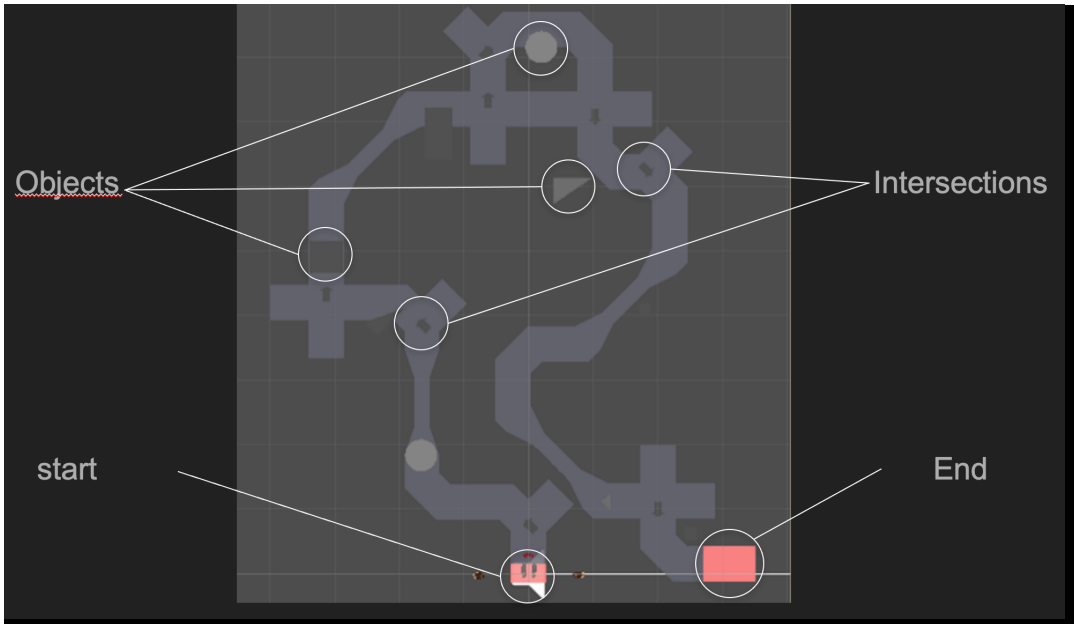
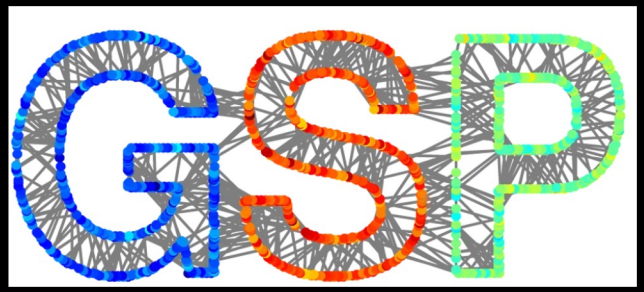
(a) Calculated general score

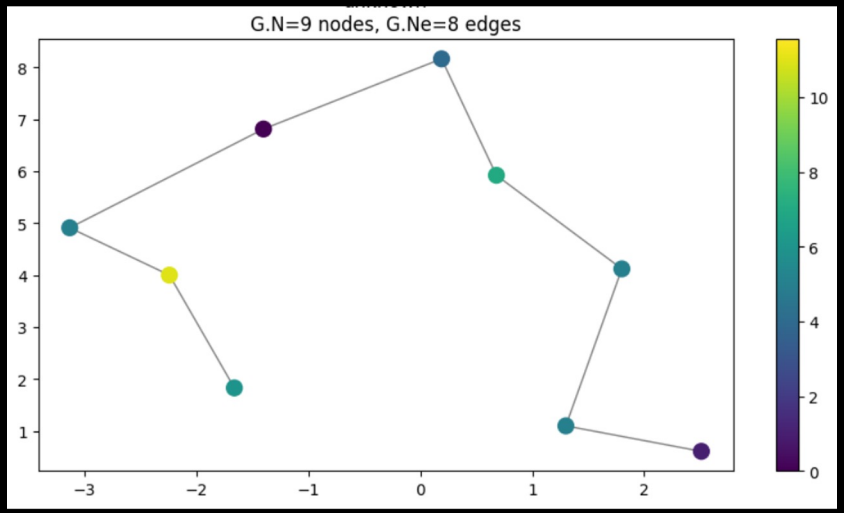
(b) Patients ranking with new scores

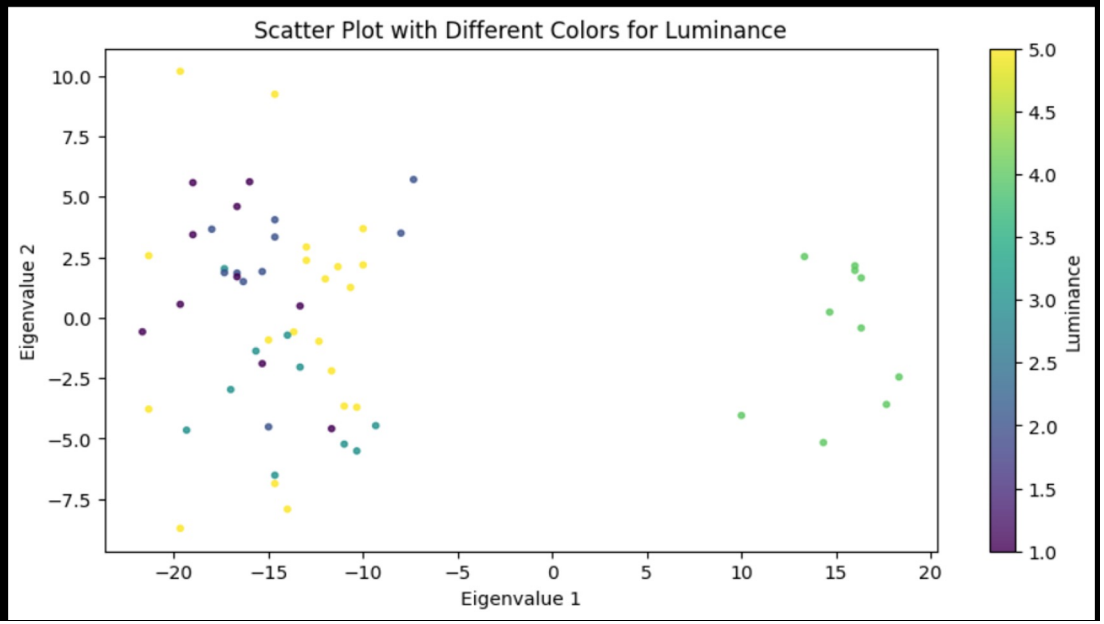
Analysis of behavorial data (Head movement)



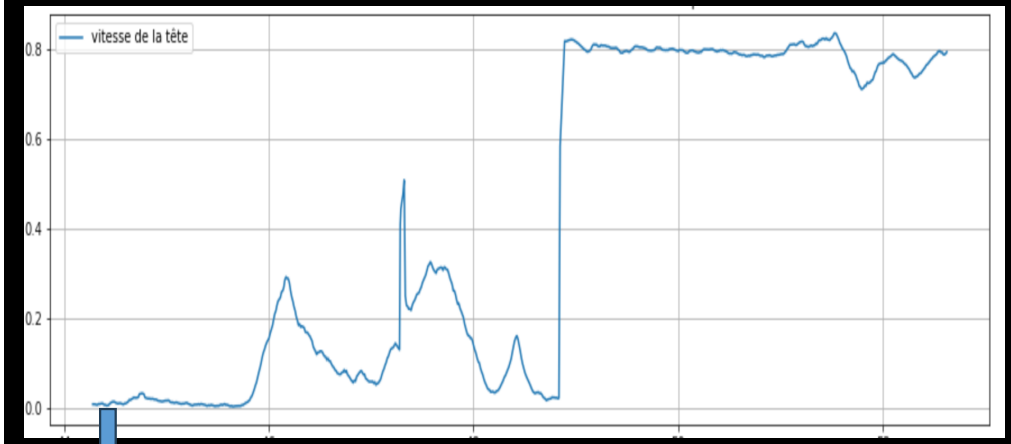
ADVANCED CLUSTERING OF BEHAVORIAL DATA

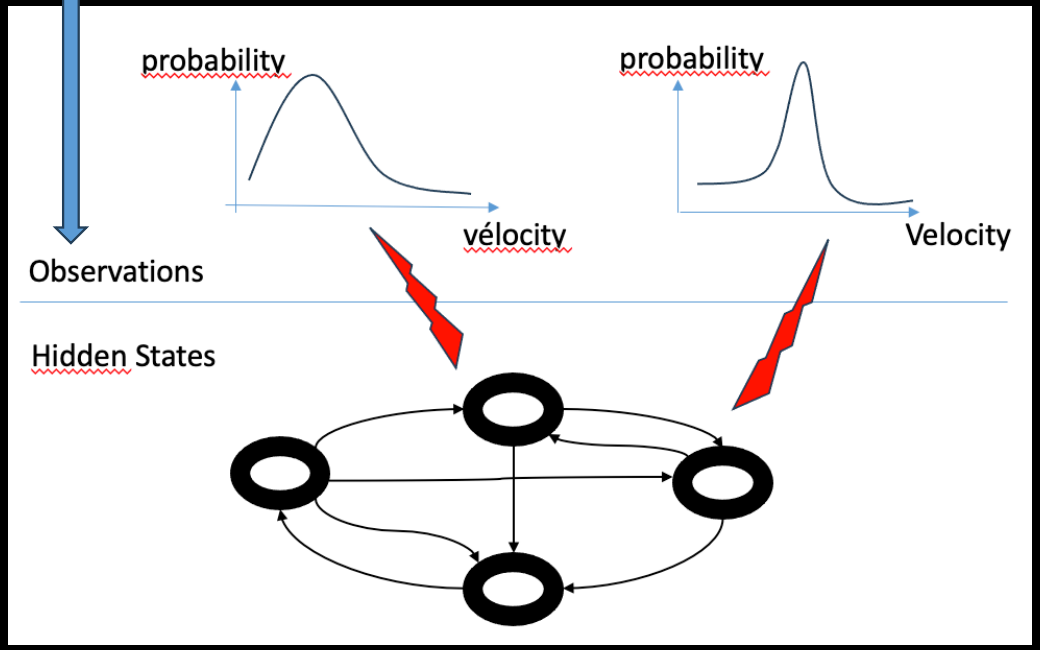


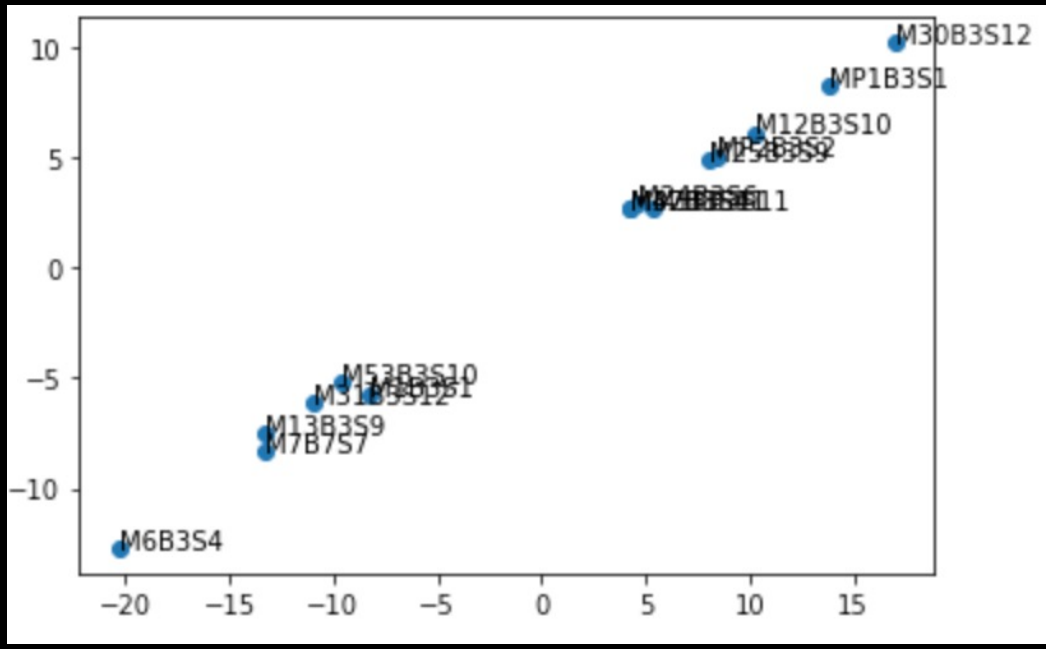




ADVANCED CLUSTERING OF BEHAVORIAL DATA (HMM+ T-SNE)



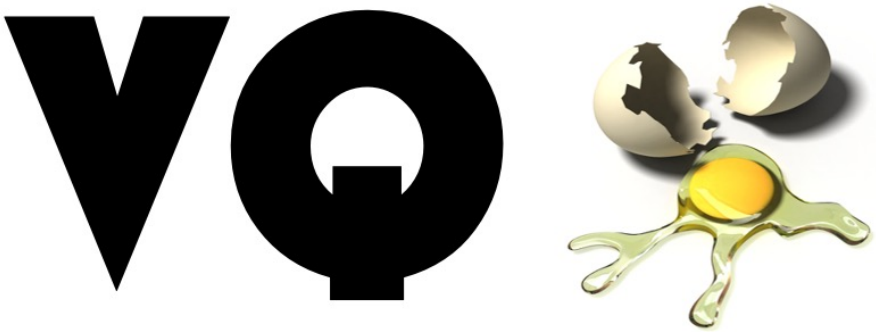




DR (Diminished Reality) for

Data augmentation

and empathy



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