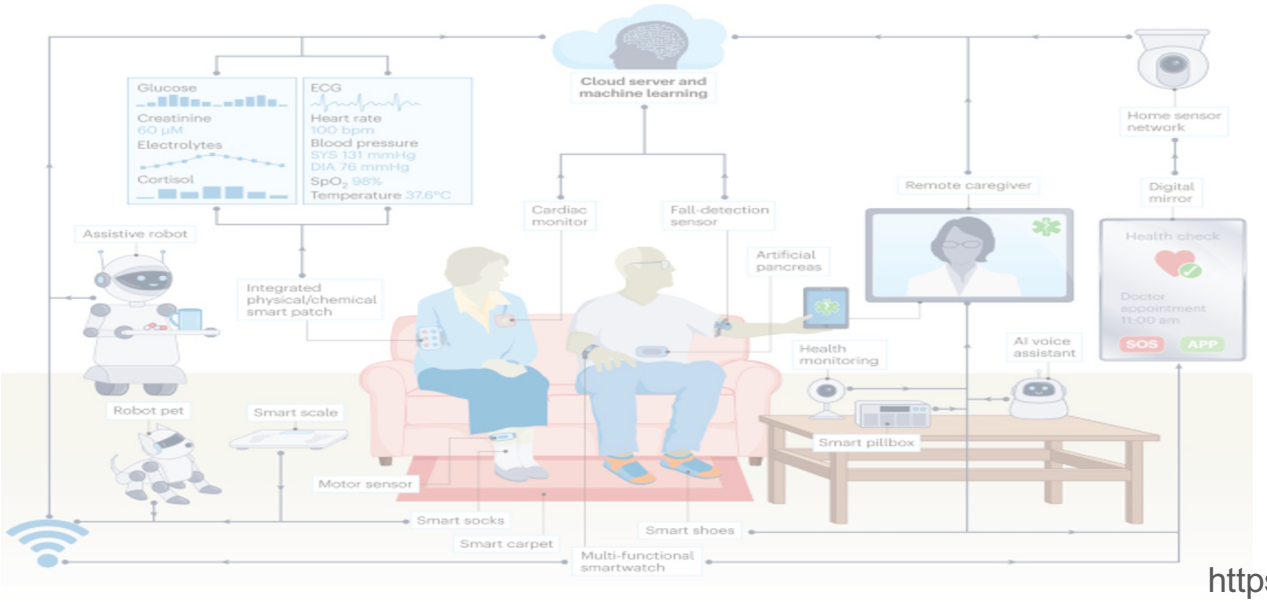
Digital technology to support healthy (psychological) aging :

Examples on **(1) smart home** (assistance)

and **(2) computerized cognitive training** (rehabilitation)



From Chen et al., 2023 *Nature*

https://www.medicalalertadvice.com/articles/aging-and-technology-digital-games-improve-senior-health/

What is a Digital technology for healthy aging ?

« Any device or ICT system that allows an individual to increase or to maintain their functional abilities in everyday-life setting» *(Czaja, 1997)*

« Tout dispositif ou système TIC qui permet à un individu d'augmenter ou de maintenir ses capacités fonctionnelles dans la vie quotidienne. »

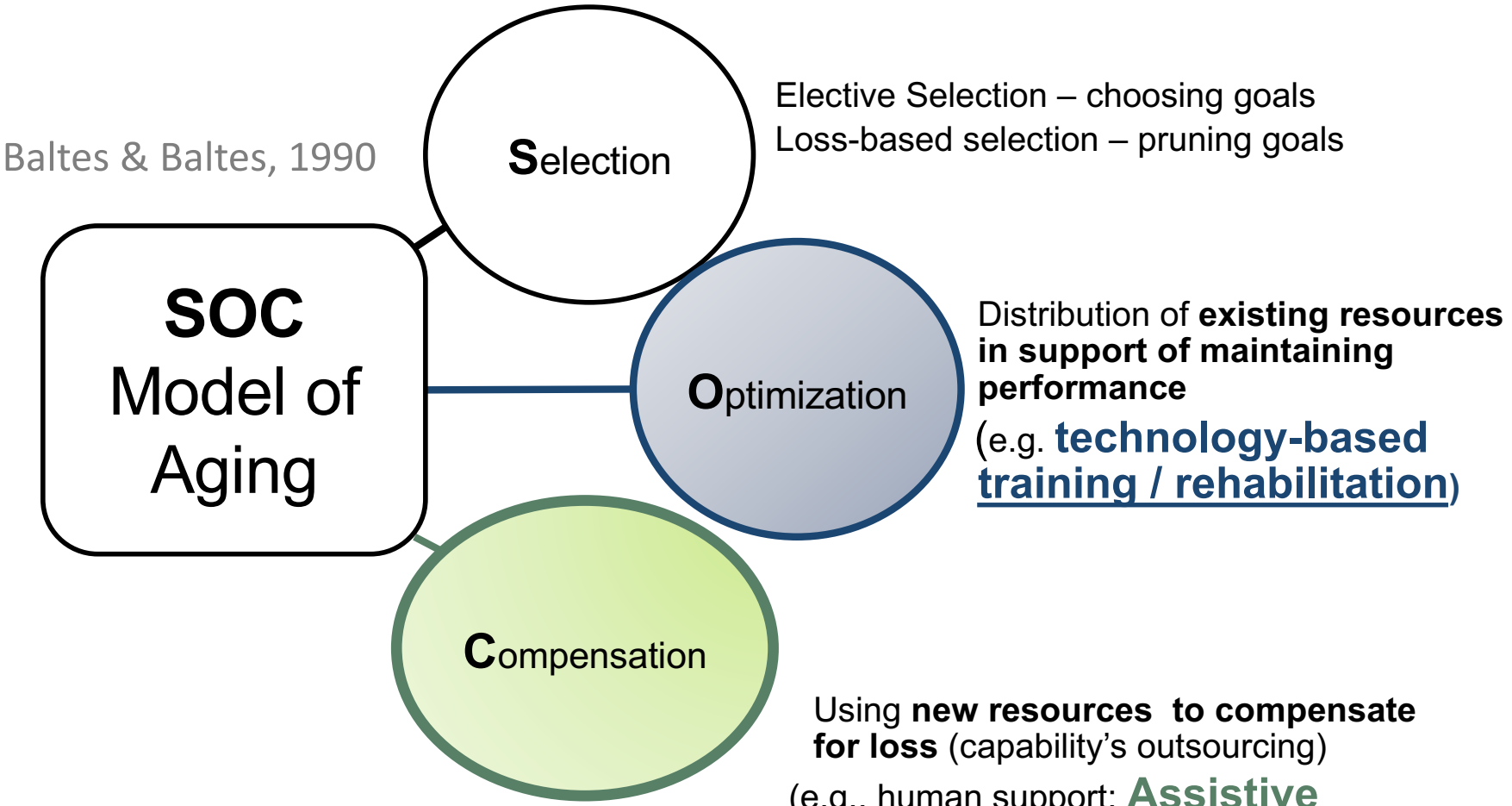
Technology = Environnemental support

Direct = Assistance
Indirect = training

Monitoring /Assessing
adaptative function
into technology

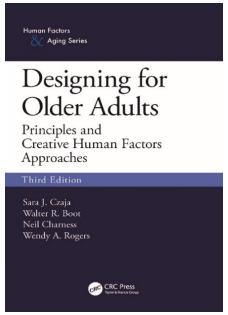
What is a Digital technology for healthy aging ?

- **Relies on Aging Model** *(Rogers et al. 2020)*



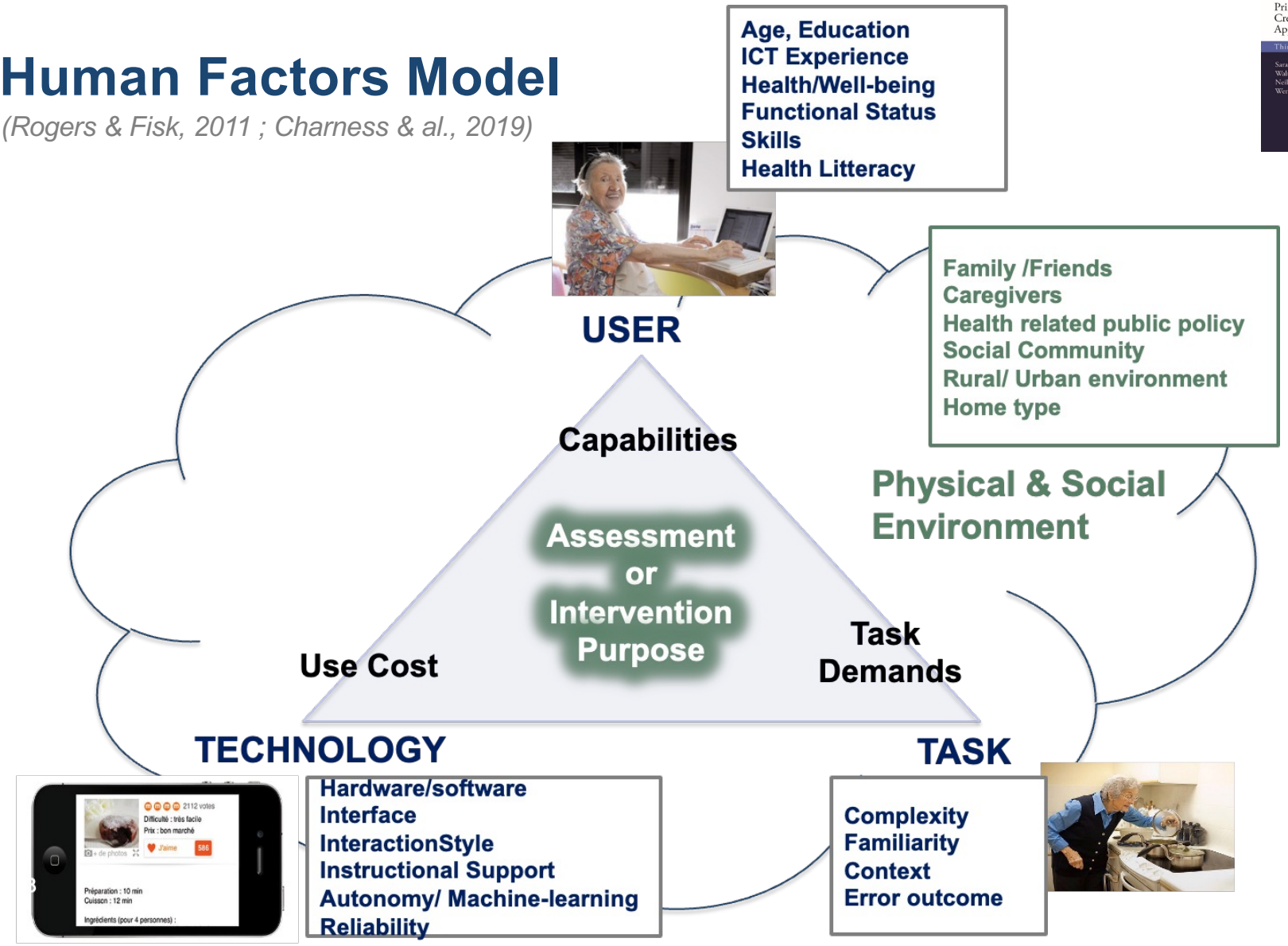
Variabilités inter et intra-individuelles augmentent avec le vieillissement

Technology design



- **Human Factors Model**

(Rogers & Fisk, 2011 ; Charness & al., 2019)



https://www.inria.fr/fr/technologies-personnes-agees-vieillesse-dependance

Innovative digital intervention in older adults :

*Self-determination –driven technologies as lever of **Optimization** and **Compensation***

- **Self-determination = intrinsic motivational mechanism for well-being** (Deci & Ryan, 2000)

Baltes & Baltes, 1990

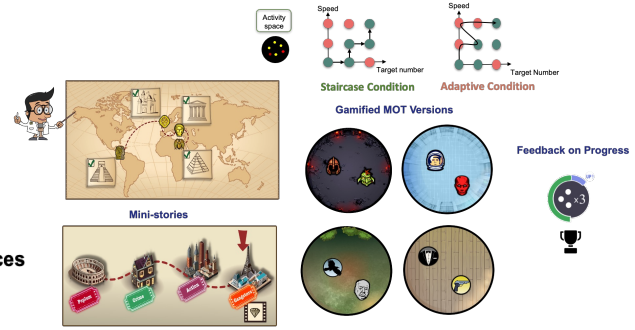
SOC Model of Aging

Selection — Elective Selection – choosing goals; Loss-based selection – pruning goals

Optimization — Distribution of **existing resources in support of maintaining performance** (e.g. **technology-based training / rehabilitation**)

Compensation — Using **new resources to compensate for loss** (capability's outsourcing) (e.g., human support; **Assistive technology**)

AI-based Attention training



https://flowers-ol.bordeaux.inria.fr/flowers_demo

Study of individualized cognitive intervention by machine-learning

HomeAssist – Assistive Smart Home

In-depth study of relations between HA usages and health

InnovCare (2024-28)
PPR Autonomie

1rst Example

Personalized Cognitive *Training*

Computerized-cognitive training (CT)

- **Lampit et al., 2014** **(SR – Typical aging)**
  - Market's **Solutions** (e.g. happy neuron ® ; Neurotracker®) **or Lab' solutions**
    (Global cognitive training vs. targeted training of specific functions)
  - **Significant overall effect but modest** (g de Hedges = 0.22)
  - **Training of Specific functions** : No significant effect for training of executive functions **;** verbal memory, g = 0,08 ; **Non-verbal memory**, g = 0,24 ; **Working Memory**, g = 0,22 ;**Processing Speed**, g = 0,31 ; **Visuospatial attention**, g = 0,30.

- **Lasaponara et al., 2021** **(SR – MCI, Alzheimer, Parkinson, DFT)**
  - Markets' **Solutions** (e.g. happy neuron ® ; Neurotracker®) **or Lab' solutions**
    (Global cognitive training vs. targeted training of specific functions)
  - **Benefits in MCI and AD for memory and Attention**
  - **Boosted** by association **with personalizing methods of training**
  - **Increased observance with gamification**

Attention training with Multiple-Objects-Tracking (MOT) · Project in progress

- **Training benefits observed with MOT**

(Belchior et al., 2013; 2019 ; Bediou et al., 2018, De Simoni & von Bastian 2018; Guye & von Bastian 2017, **Pèch et al.**, Accepted ***Acta Psychologica****)*

Including far effects and **transfer in Everyday functioning**

Fig. 1

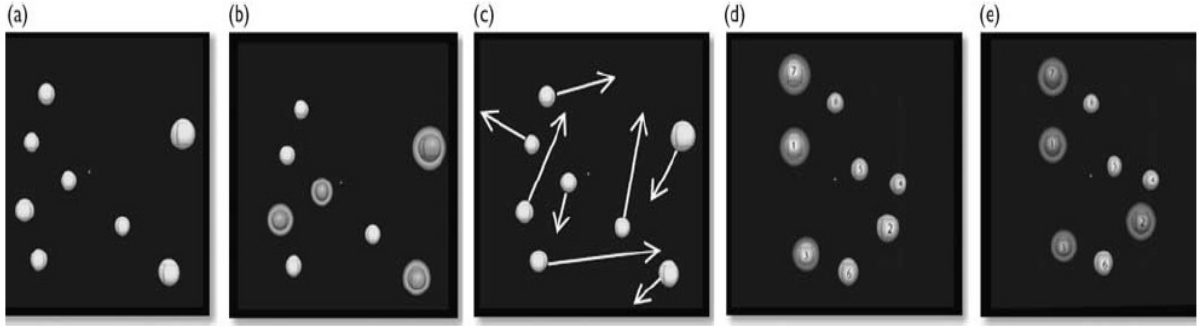


Illustration of the five critical phases: (a) presentation of randomly positioned spheres in a virtual volumetric space, (b) identification of the spheres to track during the trial, (c) removal of identification and movement of all spheres with dynamic interactions, (d) stoppage and observer's response by identifying the spheres, (e) feedback is given to the observers.

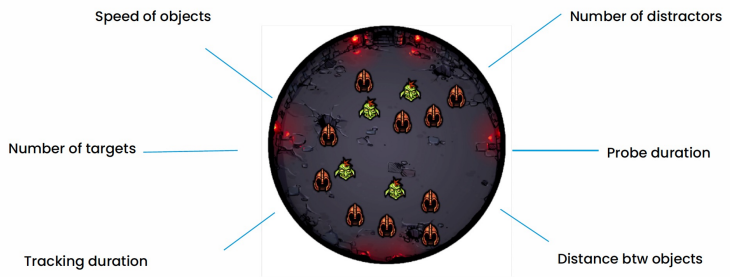
UNIVERSITÉ DE GENÈVE
FACULTÉ DE PSYCHOLOGIE ET DES SCIENCES DE L'ÉDUCATION

brain& learning | bavelier.lab

[9] FRANCONERI S. , et al - 2010
[10] ERICSON J.M., et al - 2013

Several parameters to configure the task:

Due to
Multiple parameters
varying in task



Road map

onepoint.

Simulation study

ZPD Reliability

N= 600 learners models

2 Pilot studies -Young

[2 * (11 ZPDES vs. 11 Predefined)]

Trainee experience

Cognitive Gains

(12 days of training)

RCT- Young vs. Old adults

(online exp.)

- Pech, M., Adolphe, M., Oudeyer P-Y & Sauzéon, H. (2025). Broadening the Lens: A Review of Multi-Object Tracking Task and its Use in Cognitive Training. In press. *Acta psychologica*.
- Adolphe, M., Pech, M., Sawayama, M., Maurel, D.,Delmas, A., Oudeyer, P-Y & Sauzéon, H. (2025). Exploring the Potential of Artificial Intelligence in Individualized Cognitive Training: a Systematic Review. *PlosOne*. . In press.
- Adolphe M., Pech, M.,Sawayama M., Clement B., Joessel F., Bavelier D., Delmas Alexandra., Maurel D., Oudeyer P-Y., Sauzéon H. Ai-enhanced multi-object tracking: toward individualized cognitive training. (In prep)
- Pech, M., Adolphe, M., Bavelier D, Maurel D., Delmas, A., Denkinger, S., Joessel, F., Oudeyer P-Y, Sauzéon H.. Benefits of Individualized Computerized Cognitive Training in older adults (In prep).

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onepoint.

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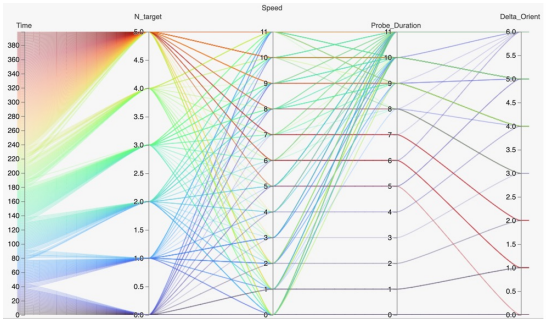
(online exp.)

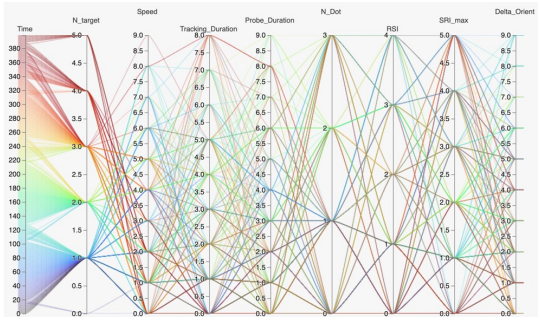
- **Predefined training**

(One expert path for all)



- **Personalized - training**

ZPD (diverse paths for all)



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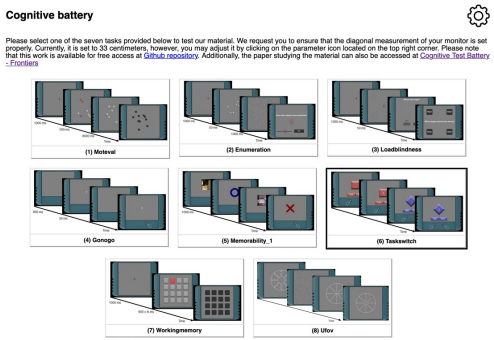
- **Test of 2 versions of ZPD (Lab version vs. Gamified MOT)**

- **Intra-training perf.**
- **Pre- vs. Post-Assessment**

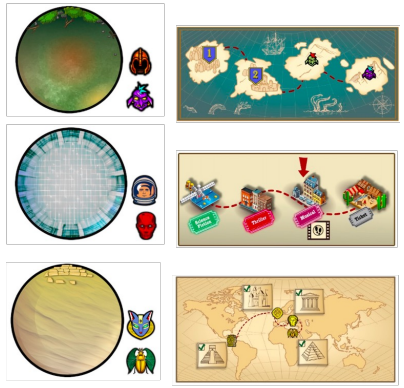
(Attention, Memory)

https://flowers-ol.bordeaux.inria.fr/flowers_demo



4 "stories":
- The goblins hunt
- The Amulet quest
- Cinema Classic: Part 1
- Cinema Classic: Part 2

16 VISUALS



Crayon + INKSCAPE

ZPDES > Predifined

Road map

onepoint.

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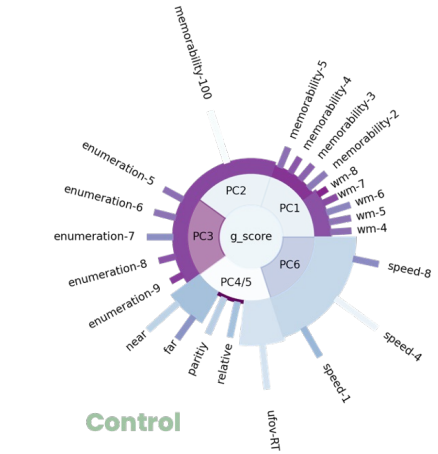
Trainee experience
Cognitive Gains
(12 days of training)

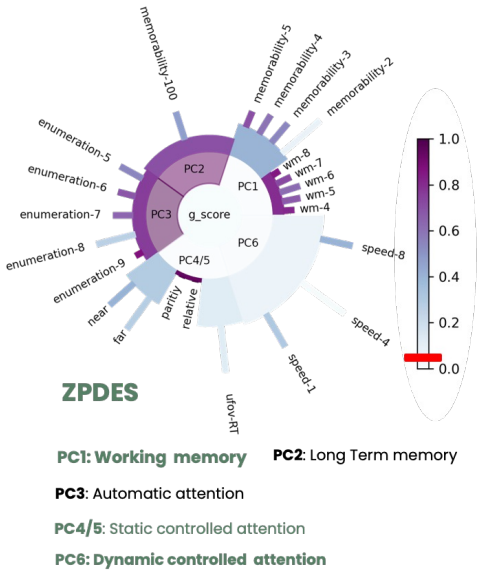
(online exp.)

RCT- Young vs. Old adults

Trainee experience
Cognitive Gains
(12 days of training)

- **Difference in pre-post evaluation in young adults**





ZPDES > Predefined

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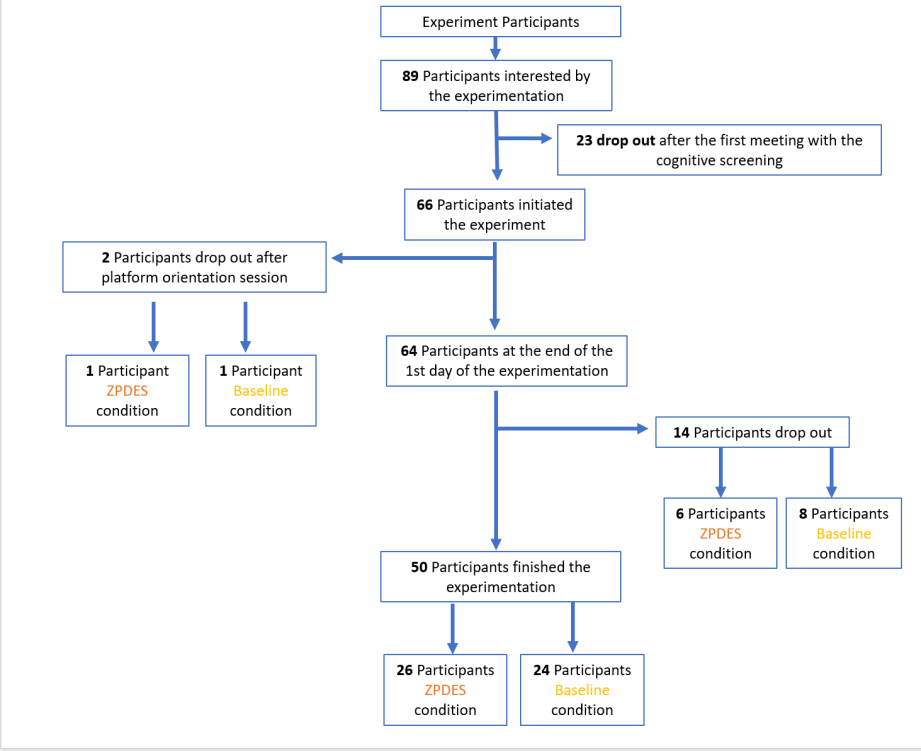
(12 days of training)

(online exp.)

RCT- Young vs. Old adults

Trainee experience
Cognitive Gains
(12 days of training)

- **Older Adults Sample**



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Cognitive Gains
(12 days of training)

(online exp.)

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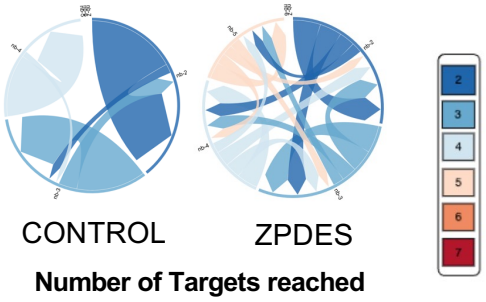
Trainee experience
Cognitive Gains
(12 days of training)

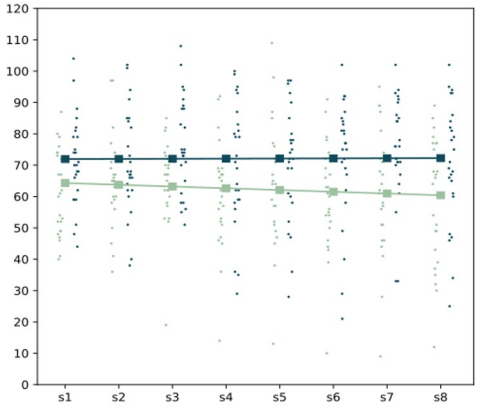


- Older Adults Sample

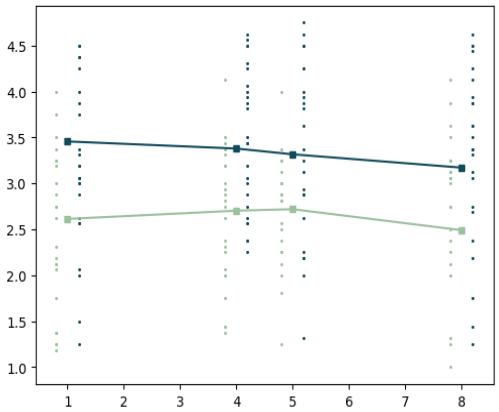
MOT-EVAL | UFOV | TASK SWITCH | MEMORABILITY | CORSI

(Post - Pre)>0 ; BF>1 ZPDES CONTRÔLE

Charge Cognitive



Compétence



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Simulation study

ZPDES Reliability

N= 600 learners models

2 Pilot studies -Young

[2 * (11 ZPDES vs. 11 Predefined)]

Trainee experience
Cognitive Gains
(12 days of training)

(online exp.)

RCT- Young vs. Old adults

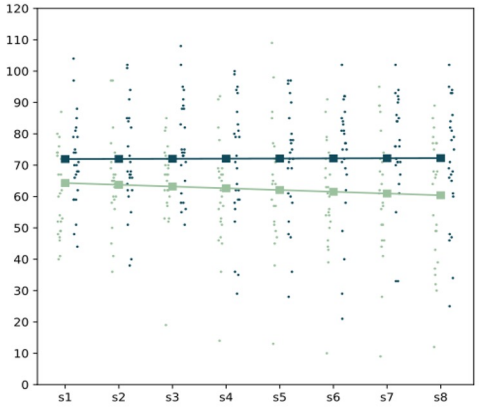
Trainee experience
Cognitive Gains
(12 days of training)

- **Older Adults Sample**

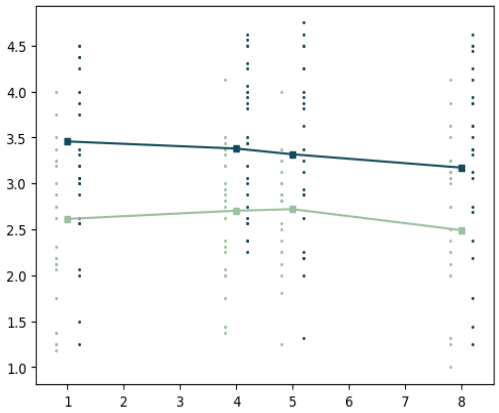
MOT-EVAL | **UFOV** | **TASK SWITCH** | **MEMORABILITY** | **CORSI**

(Post - Pre)>0 ; BF>1 ZPDES CONTRÔLE

Charge Cognitive



Compétence



VBHI Vascular Brain Health Institute BORDEAUX

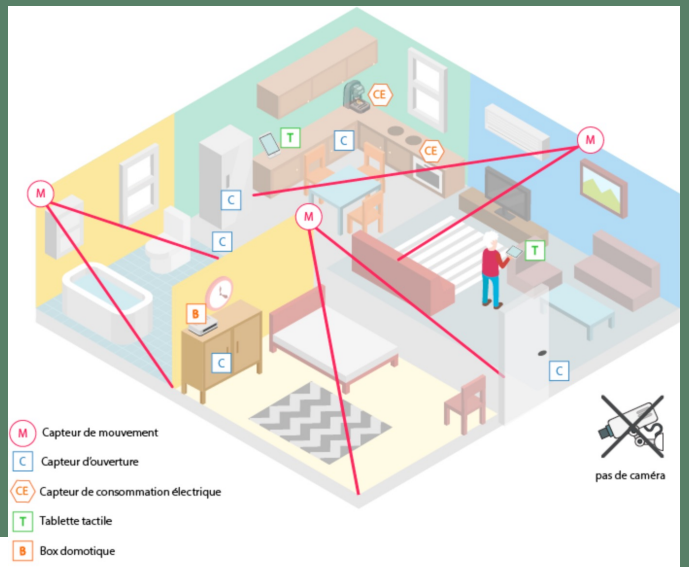
POC study

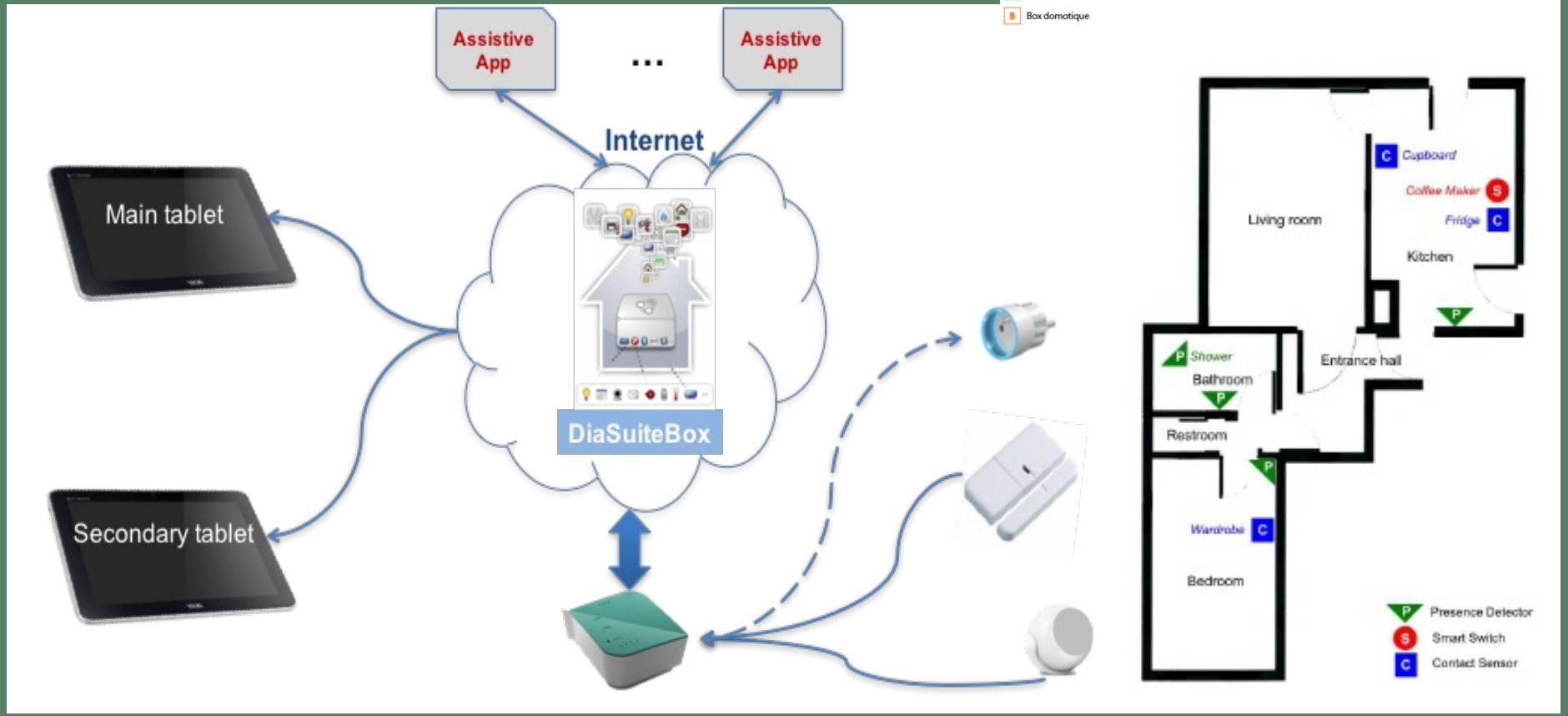
MCI Patients
with vascular changes

2nd Example

Smart Home

Home Assist platform



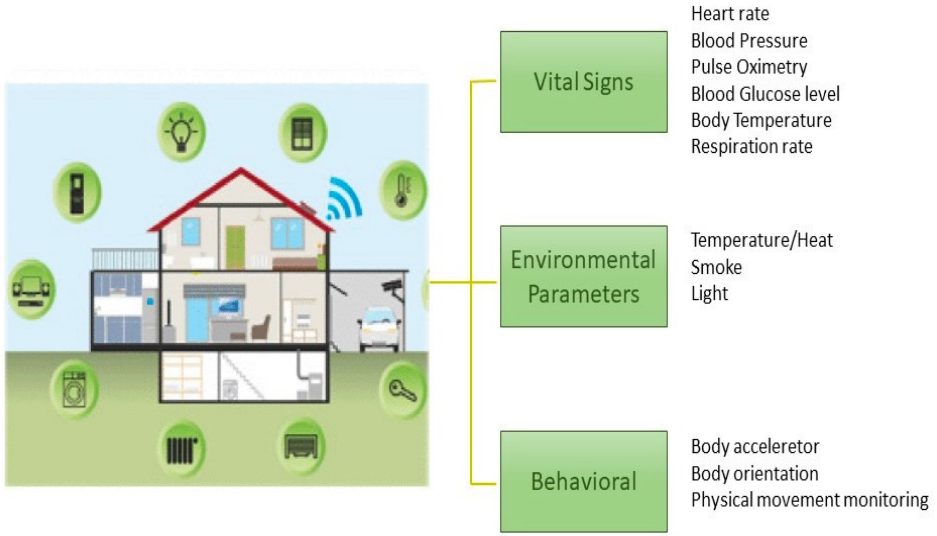


Smart Home / AAL Technologies

(Rashidi & Mihailidis, 2013; Reeder et al., 2013 ; Blackman et al., 2016; Quieros et al., 2015; Cicirelli et al., 2021)

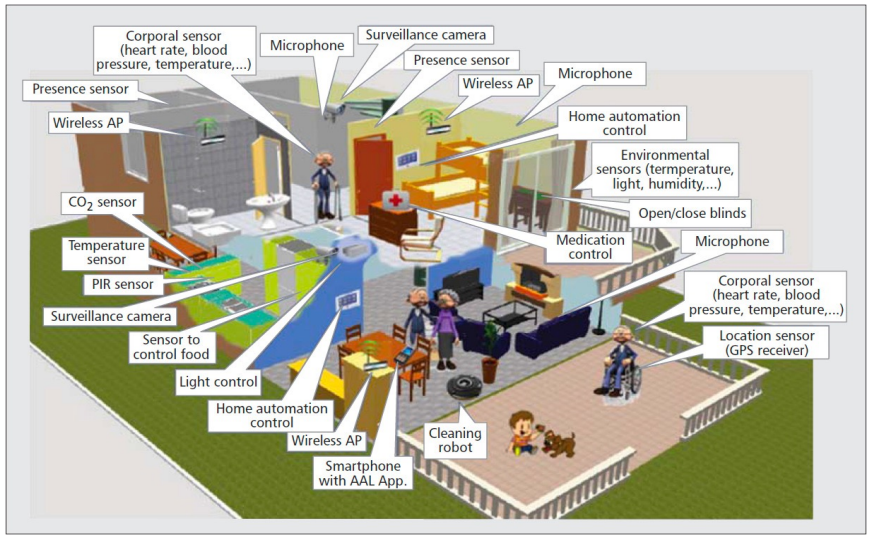
*« Ambient intelligence aimed at **empowering** people's capabilities by the mean of digital environments that are **sensitive**, **adaptive** and **responsive** to human needs. »*

Rashidi & Mihailidis, 2013



- **Monitoring and Assistive Services (AS) for Multi-domain activities** **(ADL, safety, social connectedness)**

- **Context awareness of AS**



HomeAssist : Domains of Assistance

Daily Activities

Medication Reminder

Medical Appointment

Daily Routine Monitoring

Meal Preparation

Dressing Guidance

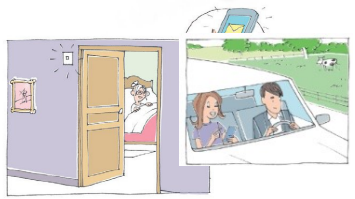
Home/Personal Safety

Home departure

Home Safety

Stove Monitor

Automatic alert for Unusual situations



Light Path

Social Participation

Agenda
Local events
Simplified communication

Photo sharing
Picture frame

Audio/Video library
Games

Summary of Results

(Dupuy, Consel & Sauzéon, *Computer & Human behavior*, 2016, Dupuy, Froger, Consel & Sauzéon et al., *Front. In Aging. Neurosc.*, 2017 ; Dupuy & Sauzéon, *Gerontechnology,* 2020 ; Sauzéon et al., JMIR2022)

1 **Multiple-cases studies (home)**

2 **Pilot study (24 equipped vs. 24 controls)**

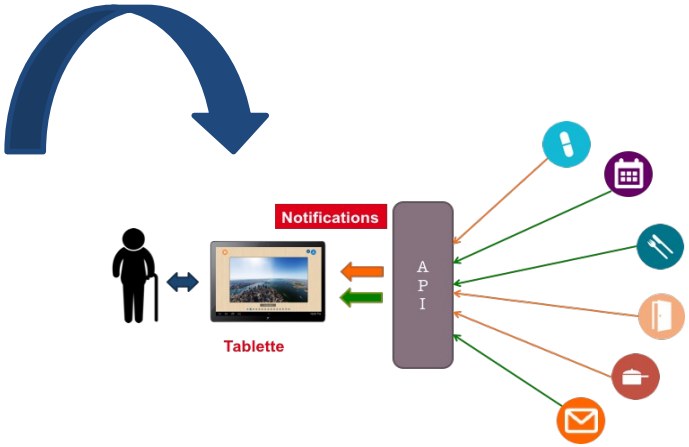
3 **Quasi-Experimental study (131 equipped vs. 478 controls)**

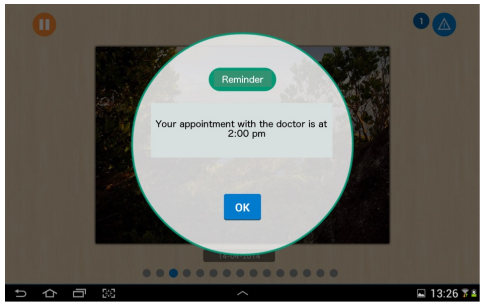
Participatory design

HA Reliability

- Assistive domains and functions **for frail individuals**
- Interface Design

- **8 ADL accurately detected** getup, dressing, cooking, …
- **Correct notifications**





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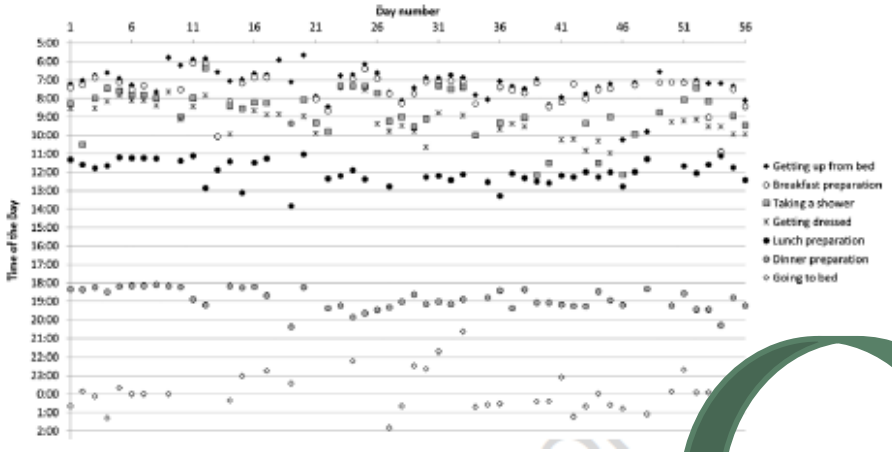


Participant profiles

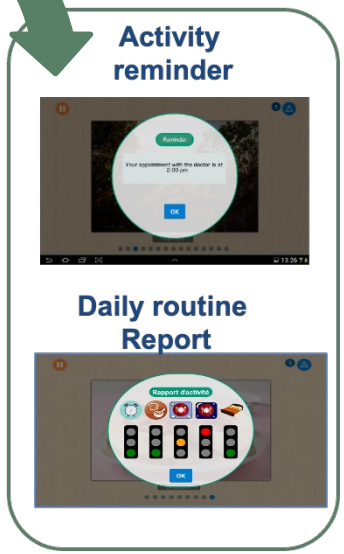
Participant profile	Mean *(SD)*
Age	82.0 *(5.80)*
Gender	6 women and 1 man
Education years	9.71 *(1.60)*
Family status	all widowed
MMSE [0–30]	27.14 *(0.90)*
Time-based IADL [5–15]	5.29 *(0.76)*
Self-reported IADL [9–45]	12.14 *(4.38)*
Routinization [0–40]	15.86 *(5.55)*

SD — Standard Deviation. Interval notations are used for score ranges.

- Detection Accuracy (SDT analyses)

HomeAssist vs. Clinician

$A' > .93 ; 0 < B''_D < 1$



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1 **Multiple-cases studies (home)**

2 **Pilot study (equipped vs. controls)**

3 **Quasi-Experimental study (131 equipped vs. 478 controls)**

Participatory design

HA Reliability

User Experience

Health gains

(at 6/9 months)

- Assistive domains and functions **for frail individuals**
- Interface Design

- **8 ADL accurately detected**
- getup, dressing, cooking, …
- Correct notifications

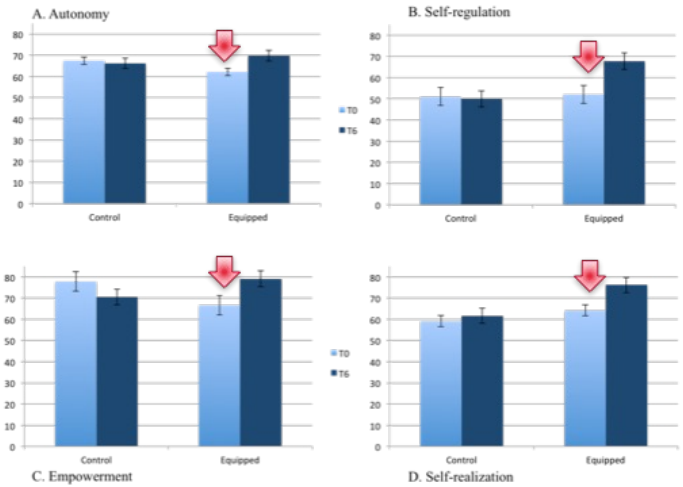
- Usability
- Learnability
- UX
- Acceptance

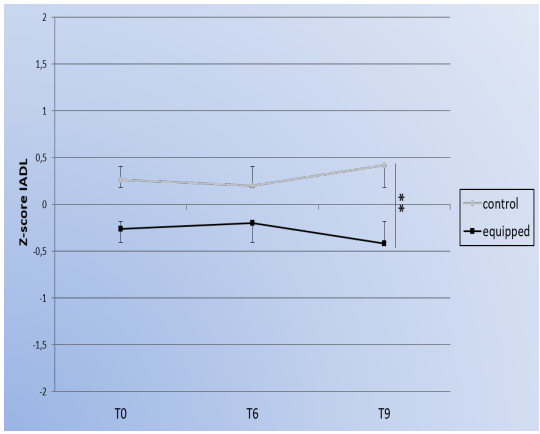
- Increased Self-determination feelings
- Neutralized decline of Everyday Fct.

TABLE 1 | Participants' characteristics for control and equipped group.

Old participants	Equipped group ($N = 16$) *Mean (SD)*	Control group ($N = 16$) *Mean (SD)*	Group comparison
Age	80.38 (1.52)	82.88 (1.61)	$p > 0.200$
Gender	4 males	4 males	
Family Status	15 widowed/1 single	16 widowed	
MMSE [0–30]	27.81 (0.38)	27.56 (0.55)	$p > 0.700$
MNA [0–30]	24.13 (0.50)	23.88 (0.45)	$p > 0.700$
Body/Lean Mass Value	4.62 (0.18)	4.08 (0.33)	$p > 0.150$
Perceptive status [0–4]	2.69 (0.28)	2.75 (0.19)	$p > 0.800$
Physical status [0–11]	9.00 (0.43)	8.33 (0.86)	$p > 0.400$
Static Balance Testing [0-4]	3.37 (0.24)	3.06 (0.40)	$p > 0.500$
Timed Get Up and Go Test [0-3]	2.19 (0.19)	2.20 (0.23)	$p > 0.900$
Gait Speed Test [0-4]	3.44 (0.20)	3.07 (0.29)	$p > 0.300$
Perceived Health			
SF-36 physical [0-100]	58.78 (5.86)	52.84 (5.42)	$p > 0.400$
SF-36 mental [0-100]	68.12 (5.06)	66.30 (4.80)	$p > 0.700$
GHQ-28 [0-84]	19.87 (3.42)	20.69 (2.61)	$p > 0.800$
CDS [0–148]	30.97 (3.85)	43.93 (6.66)	$p > 0.100$
EPR [0–40]	15.68 (1.57)	15.81 (1.56)	$p > 0.900$

MMSE, Mini Mental State Examination; MNA, Mini Nutritional Assessment; SF-36, Short Form-36; GHQ-28, General Health Questionnaire; CDS, Cognitive Difficulties Scale; EPR, Echelle de Préférence de Routinisation.





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1 **Multiple-cases studies (home)**

2 **Pilot study (24 equipped vs. 24 controls)**

3 **Quasi-Experimental study (131 equipped vs. 478 controls)**

Participatory design

HA Reliability

User Experience

Health gains (at 6/9 months)

Health gains (at 12 months)

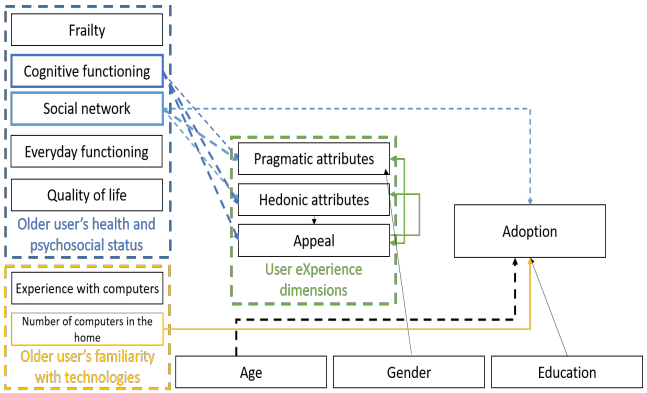
- Assistive domains and functions **for frail individuals**
- Interface Design

- **8 ADL accurately detected**
- getup, dressing, cooking, …
- **Correct notifications**

- Usability
- Learnability
- UX
- Acceptance

- Increased Self-determination feelings
- Neutralized decline of Everyday Fct.

- Enhanced Everyday Fct.



- Initial UX did not predict long-term adoption of HA
- **Education & multiple prior technology practices are persistent predictors of HA adoption in frail individuals**

InnovCare
(2024-28)
PPR Autonomie

In-depth study of relations between HA usages and health

Conclusion and perspectives

- **Overall results supports Digital technologies as efficient support for healthy aging**

  - Human centered design of technology (accessibility, usability and UX)
  - Powerfulness of adaptive features for personalizing the interventions
  - Positive response bias related to effectiveness study

- **Perspectives – Understand the "active" mechanisms of digital interventions**

  - Link between intervention content, technology features (adaptive properties, and health benefits
  - Role of user experience on motivation to use technology

Acknowledgments

- **Colleagues**
  - Maxime Adolph (Doc.)
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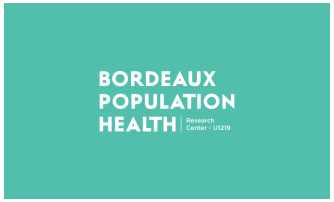
- **Partners**
  - Older adults and their caregivers
  - Professional caregivers and services for aging in place
  - Université du temps libre de Bordeaux

Partenaires & Soutiens financiers



Fine-tuning of ZPDES for MOT training

Simulation study

ZPDES Reliability

N= 600 trainees models

Pilot studies -Young

Trainee experience
Cognitive Gains
(10 days of training)

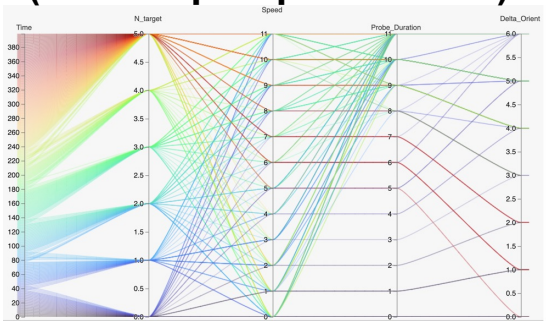
RCT- Young vs. Old adults

Trainee experience
Cognitive Gains
(10 days of training)

(online exp.)

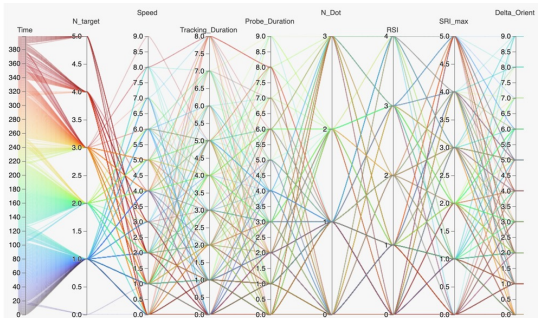
- **Staircase "control"**

(One "expert path" for all)

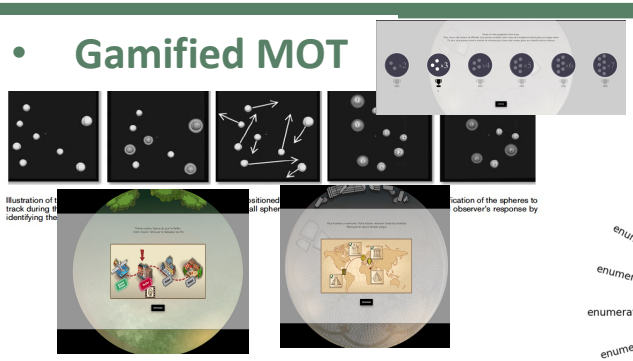


- **Personalized - training**

ZPDES (Multiple paths for all)

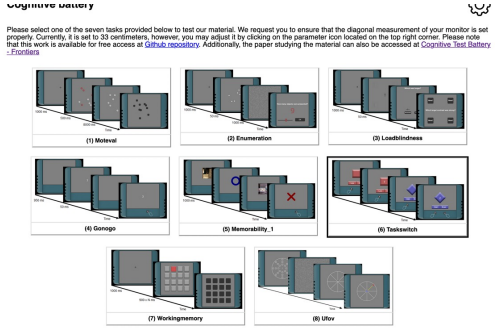


- **Gamified MOT**



- **Intra-training perf.**
- **Pre- vs. Post-Assessment**

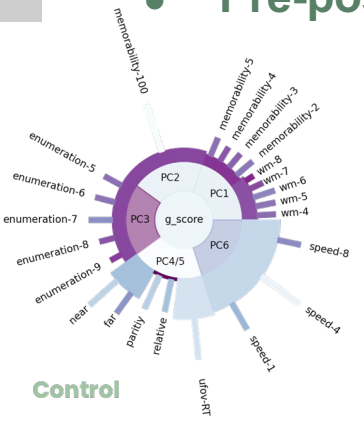
(Attention, Memory)



https://flowers-ol.bordeaux.inria.fr/flowers_demo

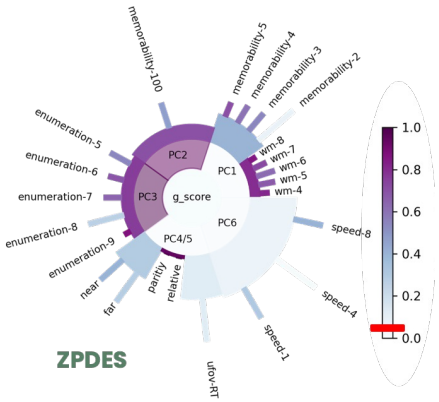
Staircase control << ZPDES

- **Pre-post Outcomes**



Control

PC1: Working memory **PC2**: Long Term memory
PC3: Automatic attention
PC4/5: Static controlled attention
PC6: Dynamic controlled attention



ZPDES

PC1: Working memory **PC2**: Long Term memory
PC3: Automatic attention
PC4/5: Static controlled attention
PC6: Dynamic controlled attention

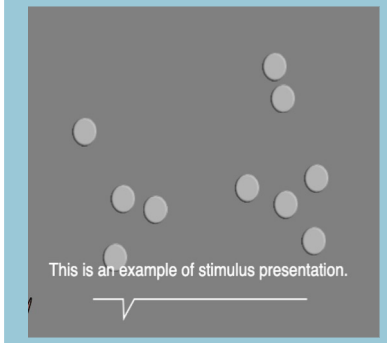
Staircase control << ZPDES

VBHI (IHU)

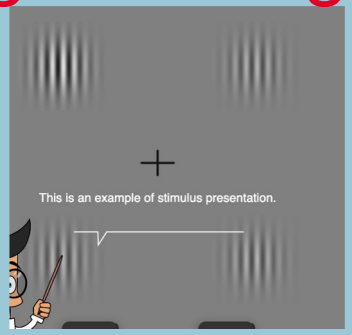
FRANCE ALZHEIMER & MALADIES APPARENTÉES

Older adults
with subtle vascular changes

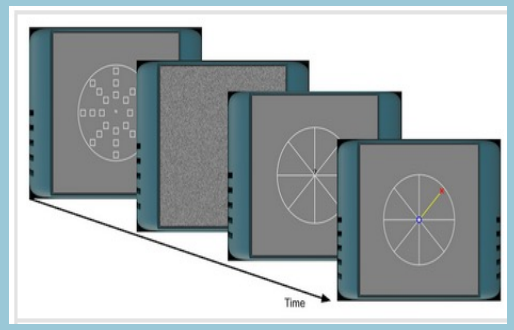
MOT training and Cognitive assessemnt



Multi Object Tracking (MOT)

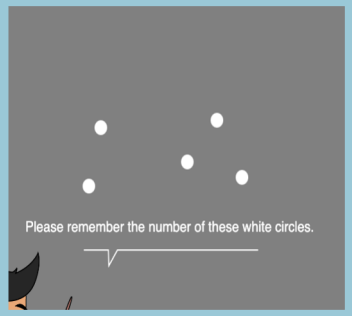


Load-induced blindness

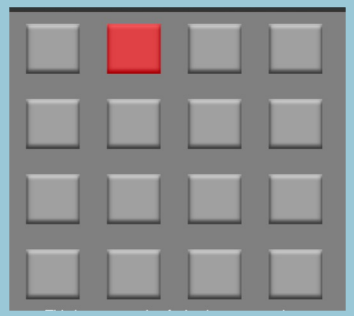


Useful field of view task (UFOV)

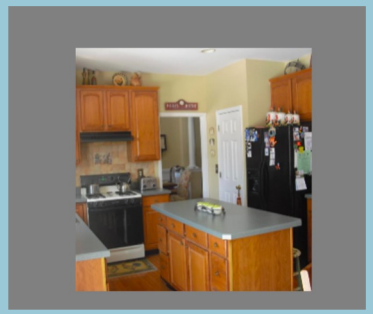
Task switching



Enumeration



Working memory

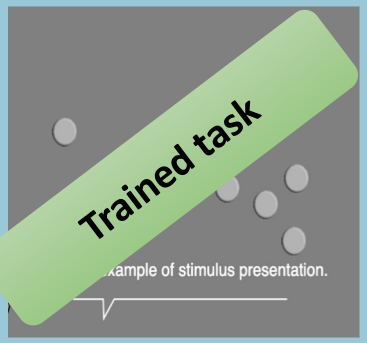


Memorability

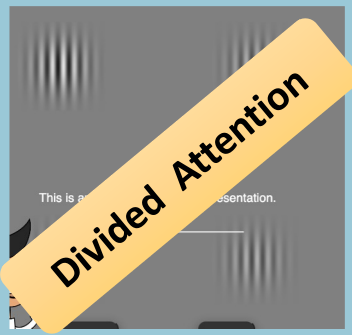
Go-Nogo

[14] Adolphe, Sawayama & al. (2022)
[15] Yung & al. (2015)

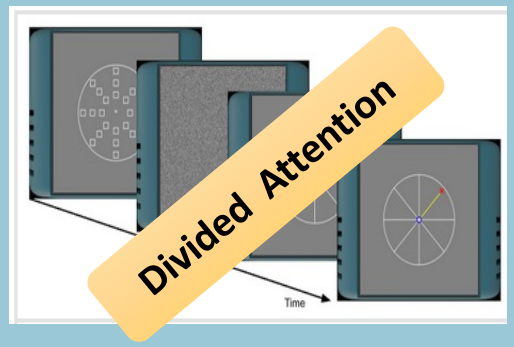
29



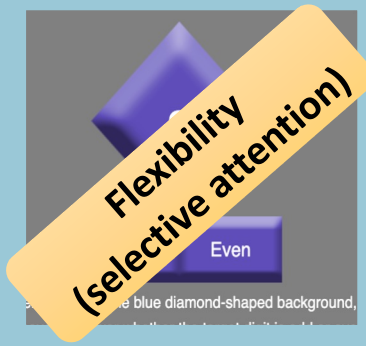
Multi Object Tracking (MOT)



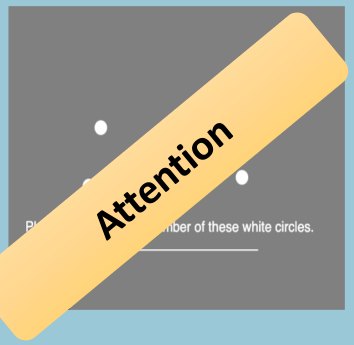
Load-induced blindness



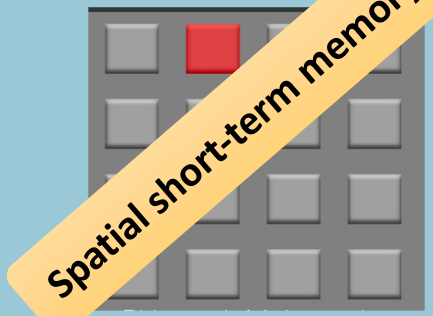
Useful field of view task (UFOV)



Task switching

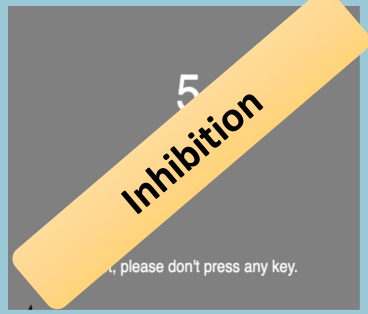


Enumeration



Working memory

Memorability

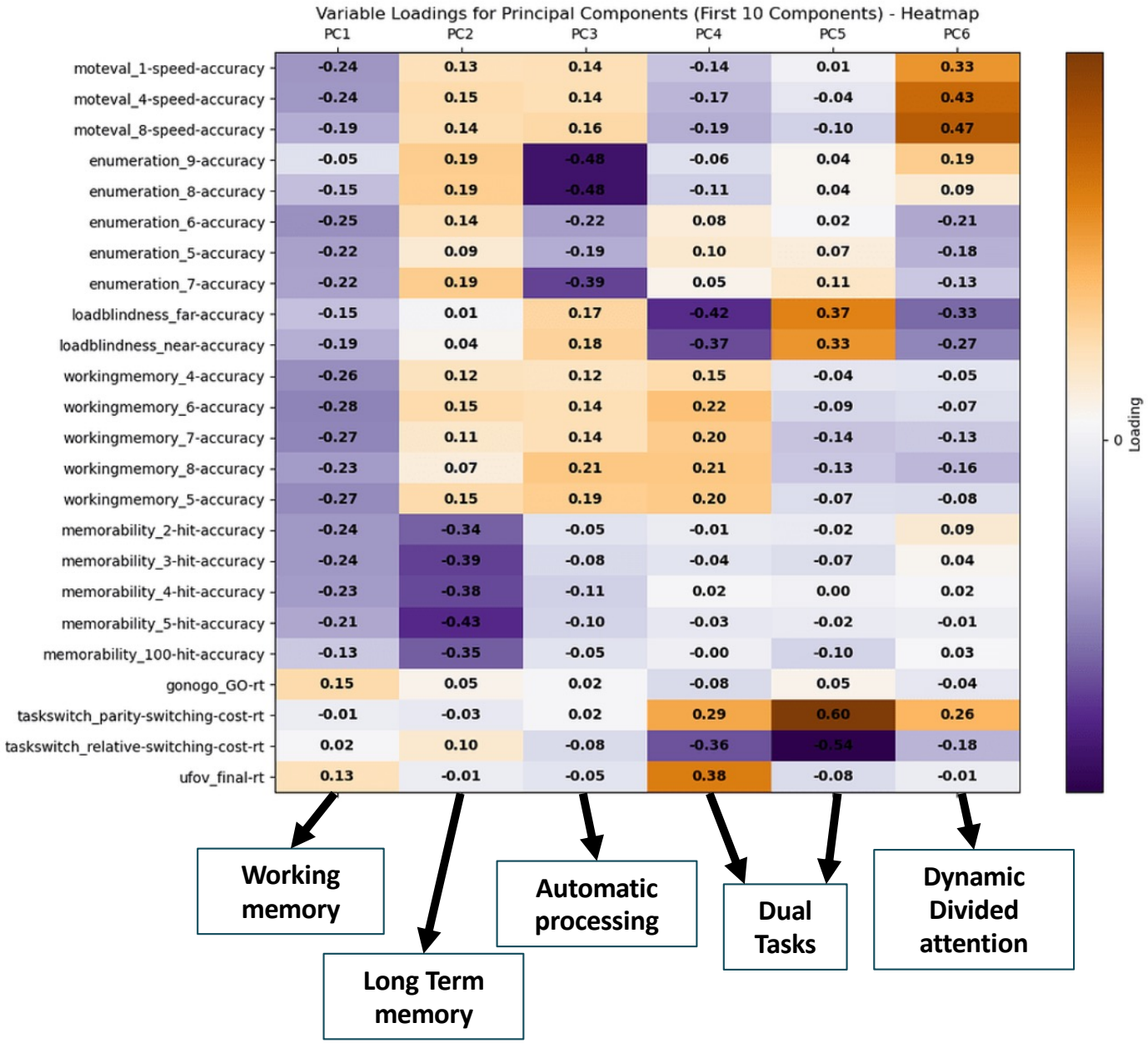


Go-Nogo

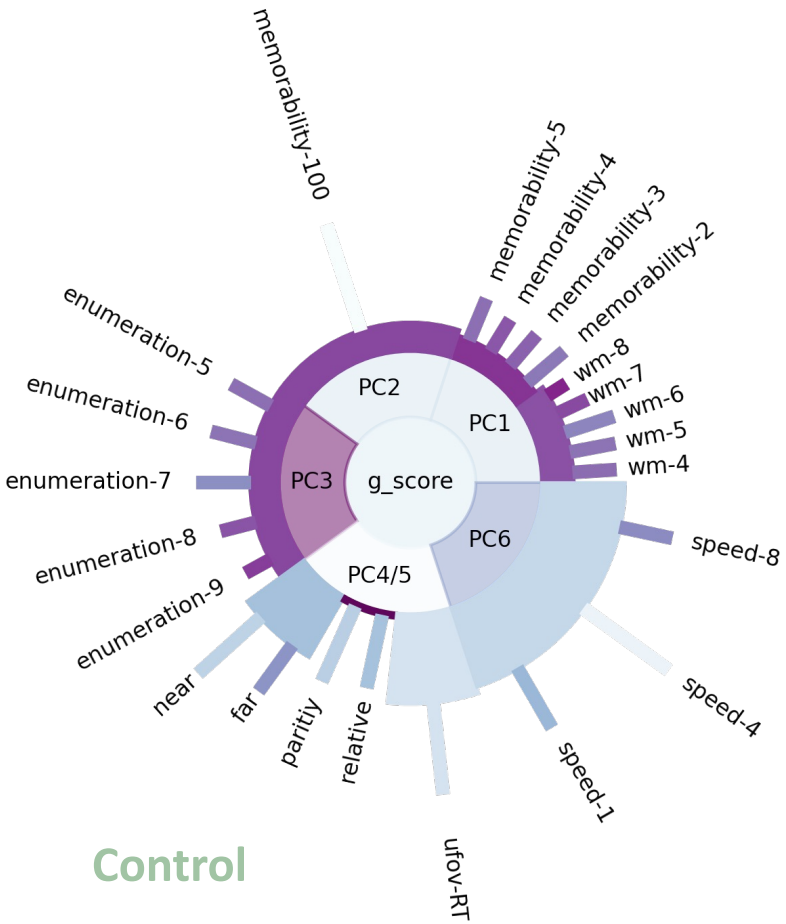
[14] Adolphe, Sawayama & al. (2022)
[15] Yung & al. (2015)

30

PCA projection



- # Difference in pre-post evaluation in young adults



Control

PC1: Working memory

PC2: Long Term memory

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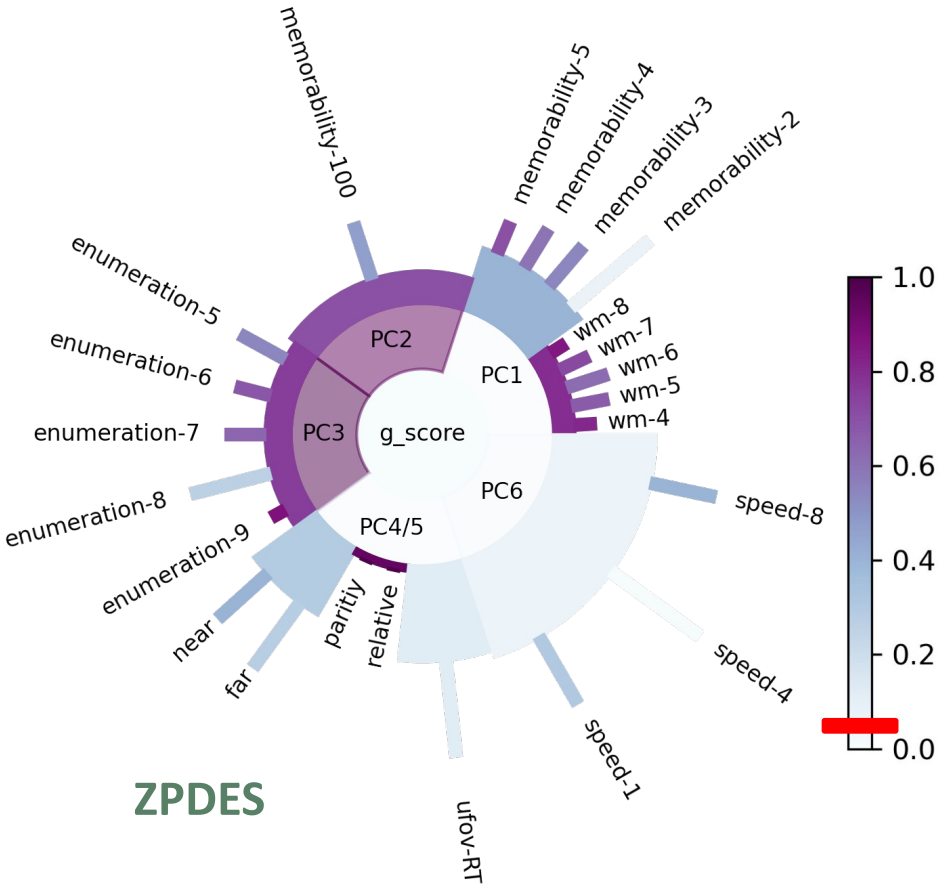
PC4/5: Static controlled attention

PC6: Dynamic controlled attention



ZPDES

PC1: Working memory

PC2: Long Term memory

PC3: Automatic attention

PC4/5: Static controlled attention

PC6: Dynamic controlled attention

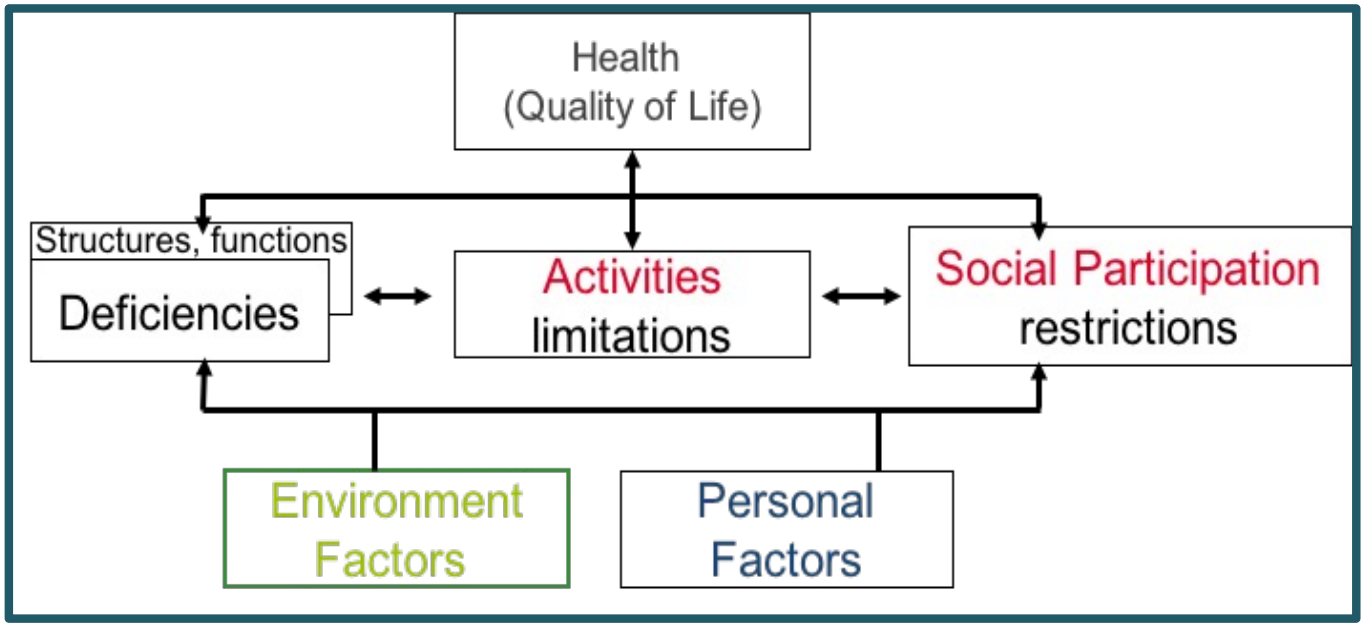
Main Topic

To support Everyday cognition

of older adults or persons with **cognitive difficulties**

For enhancing their **social participation and health**

UNDERSTAND & ASSESS



ICF, WHO-2001

REHABILATE & COMPENSATE

ACTIVE
Aging, chronic diseases, technology, disability, and environment

BORDEAUX POPULATION HEALTH Research Center - U1219

Digital technologies

Flowers
flowing epigenetic robots and systems

Inria
INVENTEURS DU MONDE NUMÉRIQUE

Everyday Cognition (EC)

- **Daily activities is mainly defined by three properties**

  - **Goal-driven (« Usefulness » facet)**

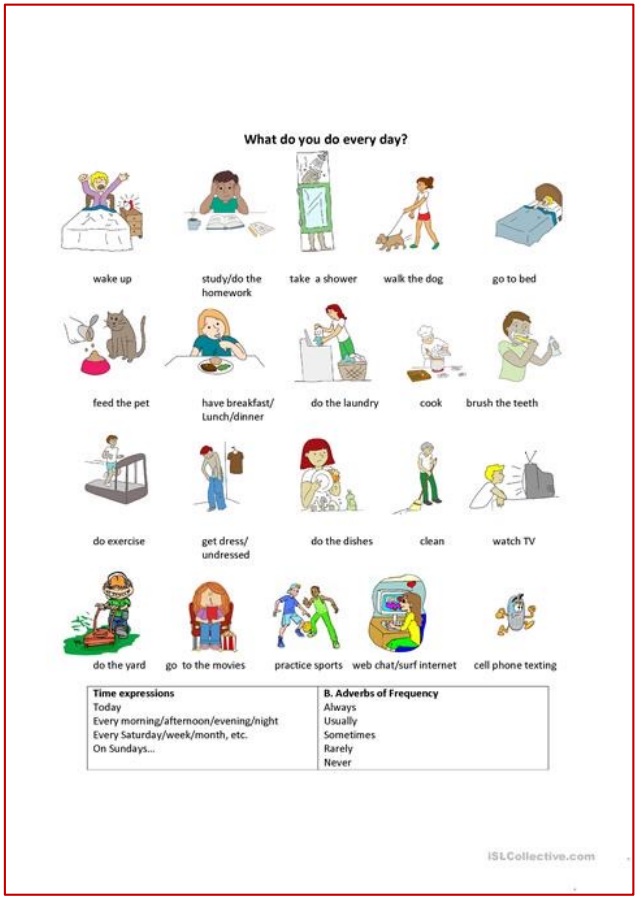
    → related to high cognitive functioning
    (Executive and decision-making functions)

  - **Situated (« context » facet)**

    → related to Memory systemS

  - **Enacted (« Body » facet)**

    → related to Physical functionning
    (sensory and motor processing)



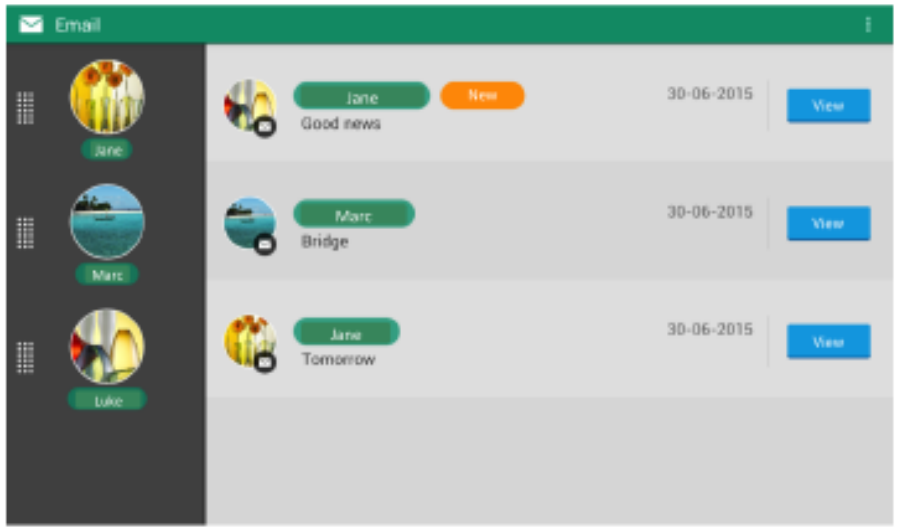
https://en.islcollective.com/resources/printables/worksheets_doc_docx/daily_life_activities/adverbs-actions-elementary/51791

Strong Relationship
EC Disorders & Aging or Brain-damage conditions

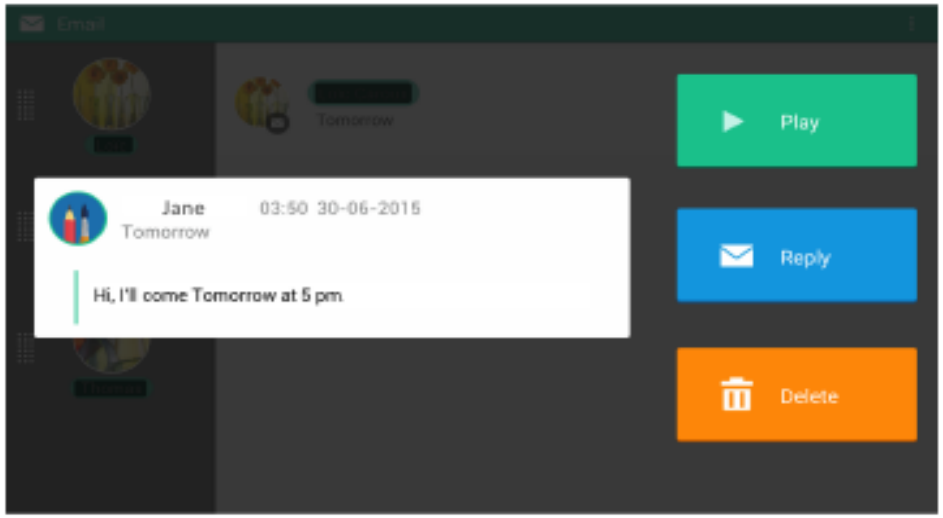
Interface tablette secondaire – Detection AVQ

Exemple du Messagerie (Caroux, Consel, C., Sauzéon, H., & Dupuy, L. , *IEEE –UIC- 2017)*

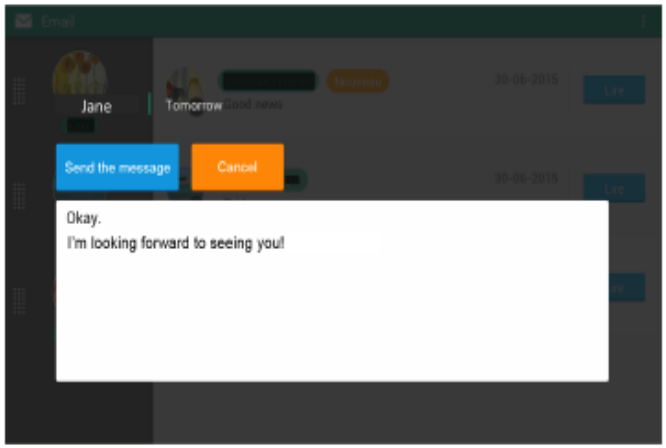
Page principale …

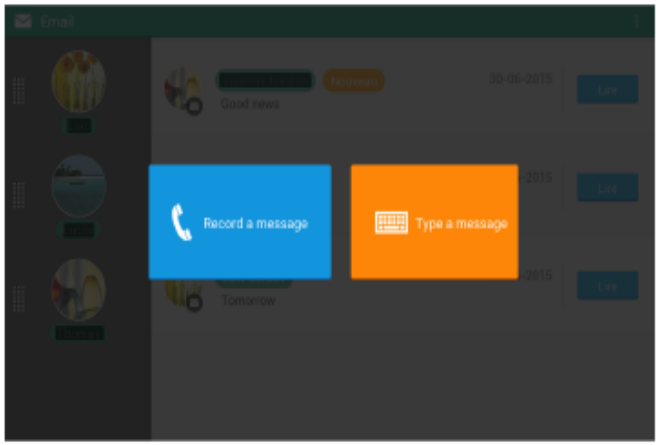


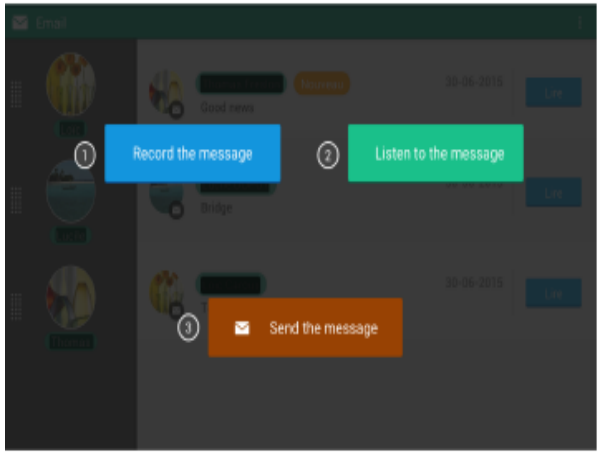
Recevoir…



envoyer…



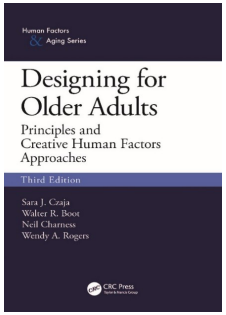




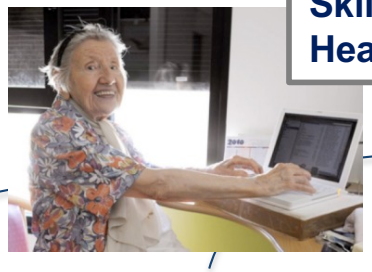
Technology design

- **HF models**

(Rogers & Fisk, 2011 ; Charness & al., 2019)



Age, Education
ICT Experience
Health/Well-being
Functional Status
Skills
Health Litteracy



USER

Family /Friends
Caregivers
Health related public policy
Social Community
Rural/ Urban environment
Home type

Capabilities

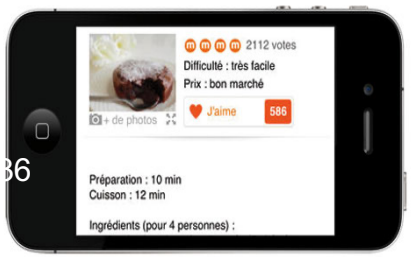
Physical & Social Environment

Assessment or Intervention Purpose

Use Cost

Task Demands

TECHNOLOGY



Hardware/software
Interface
InteractionStyle
Instructional Support
Autonomy/ Machine-learning
Reliability

TASK

Complexity
Familiarity
Context
Error outcome