9 Mars 2022

MESURER ET DÉTECTER LES EFFETS SECONDAIRES DE LA RÉALITÉ VIRTUELLE AU TRAVAIL : INFINITY CAS APPLIQUÉ AVEC LES FORCES DE POLICE

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GDR Groupement de recherche IG-RV Informatique Géométrique et Graphique, Réalité Virtuelle et Visualisation

INFINITY

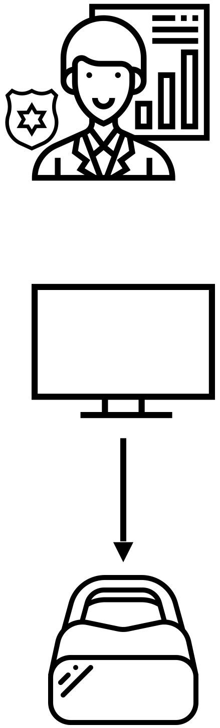
heudiasyc

Alliance Sorbonne Université

utc

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under **grant agreement No 883293**

Research and Innovation Action (RIA)



- Recueillir et traiter des données provenant de diverses sources
- Création de graphiques et visualisation de données (par exemple, cartes, tracés)
- Explorer et analyser visuellement des données
- Visualisation de plusieurs médias (textes, images, vidéos)
- Saisir du texte et éditer des documents
- Conduite de réunions (briefings, présentations de données...)
- Collaborer avec d'autres utilisateurs en VR (et vues d'objets)
- Se déplacer dans l'environnement virtuel ou dans divers graphiques
- Prendre des décisions partagées pour des enquêtes en cours (réunions)

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Manque de travaux expérimentaux, pas d'études sur le moyen et long terme, se concentre sur le grand public.

Anses (2021)

Les dispositifs de RV et de RA peuvent également être une source de ***risques*** *en raison de la distraction, de la surcharge d'informations, de la désorientation, du cybersickness et de la fatigue visuelle.*

Digitalisation and Occupational Safety and Health (2019)

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Les travailleurs des forces de police utilisant la VR s’exposent aux risques d’effets secondaires

Essayer de garantir performances tâches, la santé et la sécurité à l’usage de la VR

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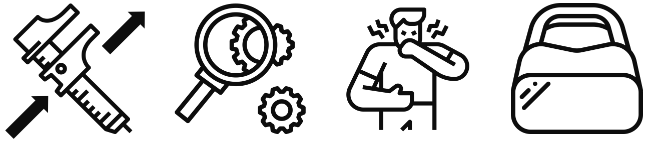
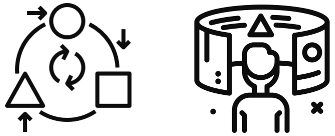
Notre rôle en bref



Mesurer / détecter et mieux documenter effets secondaires de la réalité virtuelle

Abaisser les effets secondaires



Adapter les contenus/interfaces selon état et profil utilisateur

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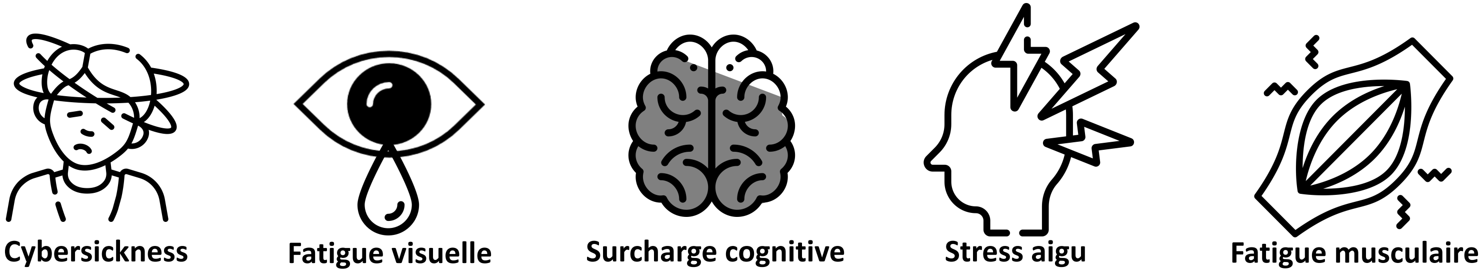
Focus sur 5 Effets secondaires de la VR

VRISE = Virtual Reality Induced Symptoms and Effects

Cobb *et al.* (1999) ; Grassini and Laumann (2021) ; Chen *et al.* (2021)



80 % présentent des effets secondaires Stanney *et al.* (2021)

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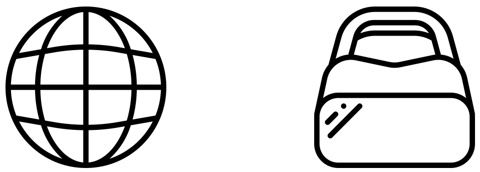
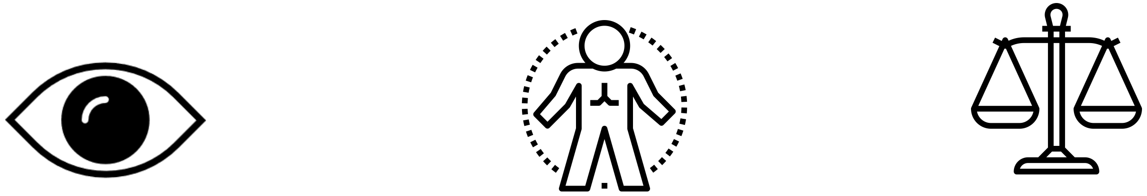


CONFLITS SENSORI-MOTEURS (fatigue visuelle, cybersickness)

O'Regan and Noë, 2001; Fuchs, 2018; Brun *et al.,* 2018; Reason 1978; Watt, 1983 Davis *et al.*, 2014; Lawson, 2014; Rebenitsch & Owen, 2016; Nesbitt & Nalivaiko, 2018; Descheneaux *et al.*, 2020; Stanney *et al.*, 2020; Chang *et al.*, 2020

inadéquation entre la rétroaction sensorielle prévue et réelle, produisant à la fois des perturbations sensorielles et motrices



Pas de consensus théorique sur les effets secondaires de la VR en général

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Cybersickness incline à **adaptation** ou **désensibilisation**
aux conflits sensori-moteurs

Gavgani *et al.*, 2017; Stanney *et al.*, 2020

Donc

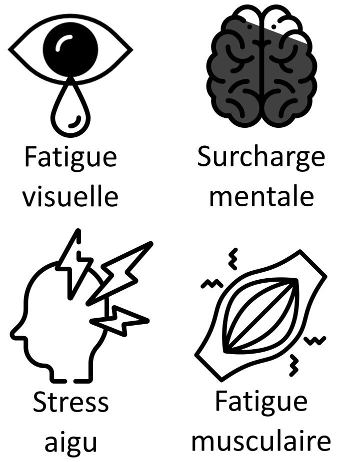
une exposition répétée pourrait
réduire les symptômes de cybersickness

Mais

cela peut impliquer une **mauvaise adaptation au monde réel**

Gallagher & Ferrè, 2018

?



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FACTEURS INFLUENÇANT VRISE AU TRAVAIL

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En l’état : information dispersée, floue, pas appliquée au travail

± 500

- Synthèse de la littérature sur 5 VRISE au travail
- Identification facteurs influençant VRISE
- Identification risques particuliers travail / analystes
- Désambiguation entre VRISE
- Identification de liens entre états
- Agenda de recherche

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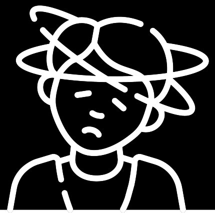
FACTEURS INFLUENÇANT VRISE AU TRAVAIL



50 facteurs influençant le cybersickness d'après Rebenitsch and Owen, 2021

Demographics	Hardware	Software
Experience	**screen**	**Movement**
Experience with real-world task	Resolution/Blur	Rate of linear rotational acceleration
Experiences with simulator (habituation)	Horizontal and vertical field of view	Self-movement speed and rotation
Video game play	Weight of the display	Vection
Duration	Display type	Altitude above terrain
	Lag variance	Degree of control
Physical attributes	**Tracking**	**Appearance**
Eye dominance	Method of movement	Screen luminance
Stereoscopic visual ability	Calibration	Color
Postural stability	Position tracking error	Contrast
History of headaches/migraines	Tracking method	Scene content or scene complexity
BMI	Head movements	Global visual flow
		Orientation cues
Demographics	**Rendering**	**Stabilizing information**
Age	Stereoscopic rendering	Focus areas
Gender	Inter-pupillary distance	Ratio of virtual to real world
Ethnicity	Screen distance to the eye	Independent visual backgrounds
Vision correction	Update rate	Siting versus standing
History of motion sickness		
Mental attributes	**Non-visual feedback**	
Concentration level	Type of haptic feedback	
Mental rotation ability	Ambient temperature	
Perceptual style	Olfactory feedback	
	Audio feedback	

Souchet et al. IG-RV & AfIA - Collège Interaction avec l'Humain: journée "Environnements virtuels : adaptation du système à l'humain ou de l'humain au système ?« Mars 2022

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FACTEURS INFLUENÇANT VRISE AU TRAVAIL

14 facteurs influençant la fatigue visuelle en VR selon nos ajouts à Bando *et al.* 2012

Demographics	**Hardware**	**Software**
Age	Vergence-accommodation conflict	Duration of display use
Stereoscopic visual ability (stereo-blindness)	Optical misalignment (between HMD lenses and eyes)	Binocular disparity (possible and comfortable fusion)
	Geometrical distortion	Motion parallax
	Luminance	Texture gradients
	Blue light	Occlusion
		Blur
		Colors

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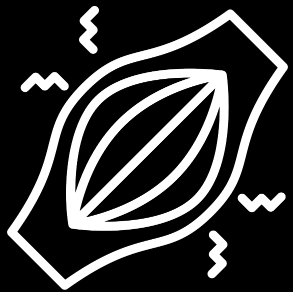
FACTEURS INFLUENÇANT VRISE AU TRAVAIL

15 facteurs influençant la fatigue musculaire en VR



Demographic	Hardware	Software
Age	HMD Weight	Duration of immersion
Body mass index	Belts (attaching HMD to head)	Object angle location
	Interaction devices	Gesture amplitude
	Position tracking error	Tasks repetition
	HMD Resolution	Head rotations required
		General posture and body rotation
		Sitting or standing
		Body parts representation and feedback (avatar)

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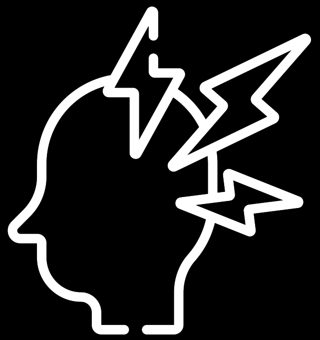
FACTEURS INFLUENÇANT VRISE AU TRAVAIL



16 facteurs influençant la fatigue musculaire en VR au travail

Demographics	Hardware	Software
Age	Techno-stress	Techno-overload
Gender	Apparatus malfunctions	Noise
Experience with a real-world task		Public speaking
Experiences with a simulator (habituation)		Task difficulty
History of headaches/migraines		Time pressure
Body mass index		Exposure to distressing material
Personality traits		
Anxiety and stress prior to VR use		

Souchet et al. IG-RV & AfIA - Collège Interaction avec l'Humain: journée "Environnements virtuels : adaptation du système à l'humain ou de l'humain au système ?« Mars 2022

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Cybersickness	Locomotion + durée immersion
Fatigue visuelle	Affichage de stéréoscopie + durée immersion
Surcharge mentale	Difficulté tâche en VR + Pression temporelle
Stress aigu	Techno-stress, bruits, type médias, tâches et prise de parole
Fatigue musculaire	Poids du casque, gestes pour interaction

→ **GUIDELINES**

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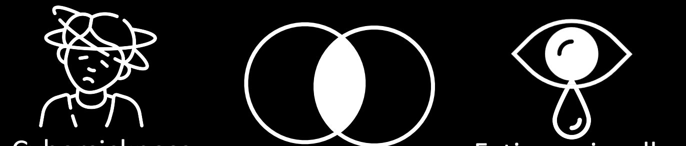
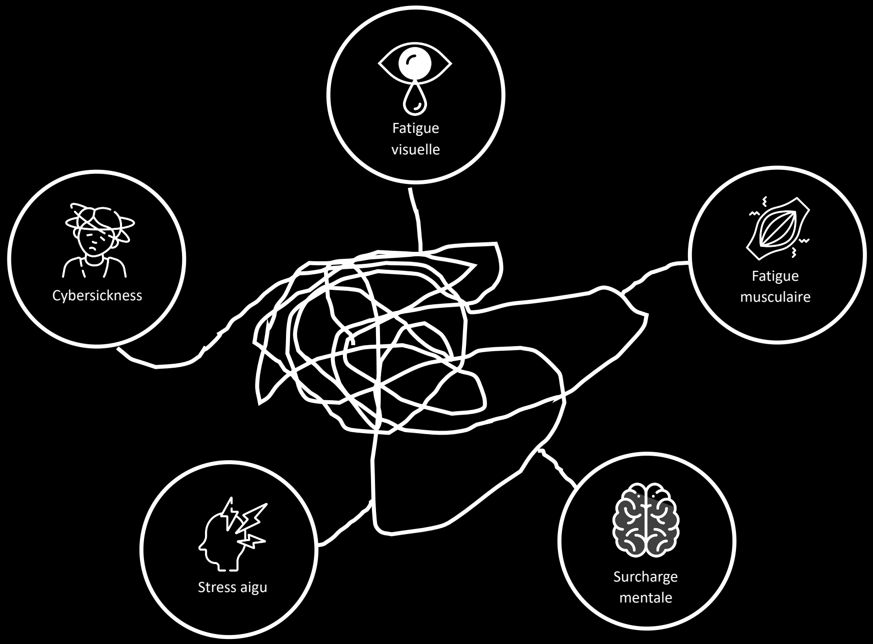
FACTEURS INFLUENÇANT VRISE AU TRAVAIL

Intersection mais différents



Incertitudes sur mesures

Complexes, entrelacés



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Publications en cours

Q1 Human Computer Interaction

Five year impact factor
5.521 (2020)

Souchet, A., Lourdeaux, D., Pagani, A., Rebenitsch, L. **(Soumis)**. *A narrative review of immersive virtual reality's ergonomics and risks at the workplace: Cybersickness, Visual fatigue, Muscular fatigue, Acute stress, and Mental overload*. Virtual Reality.

Souchet, A., Lourdeaux D., Burkhardt J.M., Hancock P. A. **(Soumis)**. *Design guidelines for limiting and eliminating Virtual Reality Induced Symptoms and Effects (VRISE) at Work: A comprehensive, factor-oriented assessment*. Virtual Reality.

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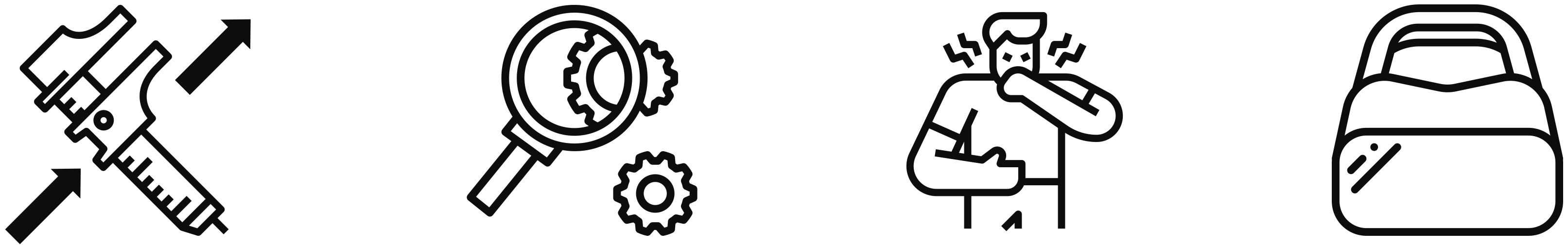
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING



Mesurer / détecter et mieux documenter effets secondaires de la réalité virtuelle

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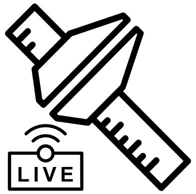
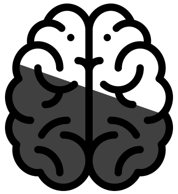
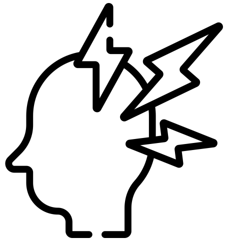
Mesurer live fatigue visuelle, charge mentale et stress







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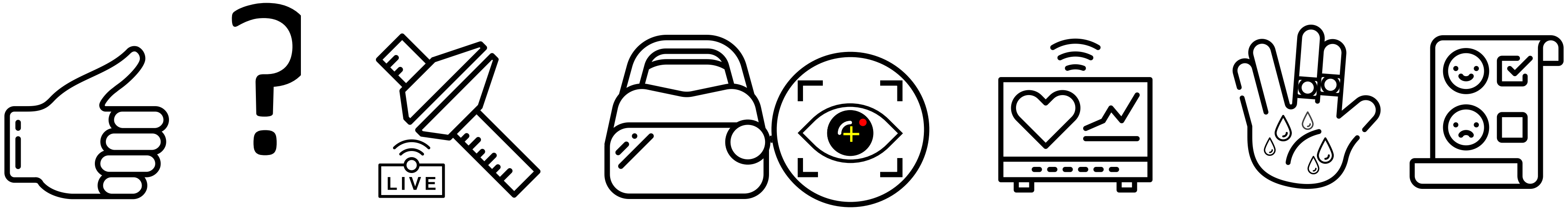
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Détecter et Différencier Etats avec eye tracking, ECG, EDA



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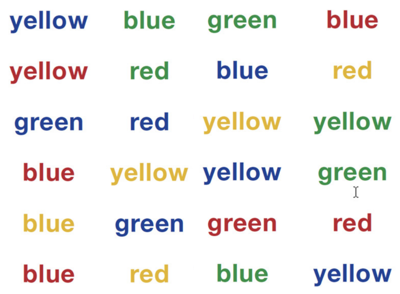

Pourquoi Stroop ?

Fonctions exécutives (cognition)

Attention sélective / Inhibition

Simplification expérimentale de conditions écologiques
Interactions Homme-Machine pour induire
charge mentale, stress et fatigue visuelle en VR

4 conditions : control, dual task, stressfull, stereoscopy

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Stimuli Stoop, à vous de jouer !

JAUNE

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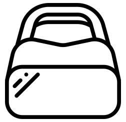
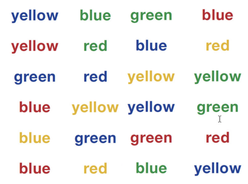
25 congruent words + 25 incongruent words | Subjects answer orally

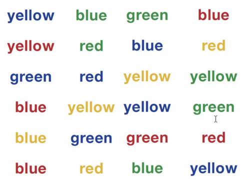
Conditions coexpérimentales



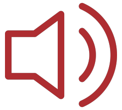
1 Control — Stroop task



2 Dual task

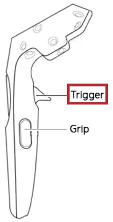


\+ IF Red

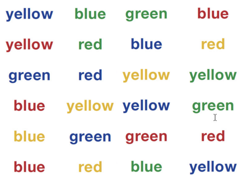


25 times randomly

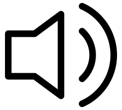
THEN



3 Stressfull



\+ Alarm



< 80 dB

25 times randomly in time
\+ random duration

4 Stereoscopy

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DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Text to Speech & interaction contrôleur + voix

1. Calibration eye tracker

2. **Baseline**

+

3. **Instructions**

Expérience de Stroop

Dans cette tâche vous allez voir des noms de couleurs affichés dans des couleurs différentes. Par exemple :

VERT

Vous devrez alors dire à voix haute le nom de la couleur du texte et non celle écrite. Ici, il faudra dire "Rouge".

Suivant

Expérience de Stroop

Lançons la reconnaissance vocale. Dîtes à tour de rôle "Rouge"; "Vert"; "Bleu"; et "Jaune"; en attendant que le mot s'allume avant de dire le suivant. Une fois chaque couleur validée, regardez le bouton OK pour passer au test.

ROUGE VERT BLEU JAUNE

Suivant

4. Calibration eye tracker

5. **Stroop task** = 25 congruents + 25 incongruents

ROUGE

6. **Questionnaires**

Dans quelle mesure ressentez-vous une brûlure au niveau des yeux ?

Pas du tout · Rarement · Parfois · Souvent · Toujours

OK

Je me sens calme

Non · Plutôt non · Plutôt oui · Oui

OK

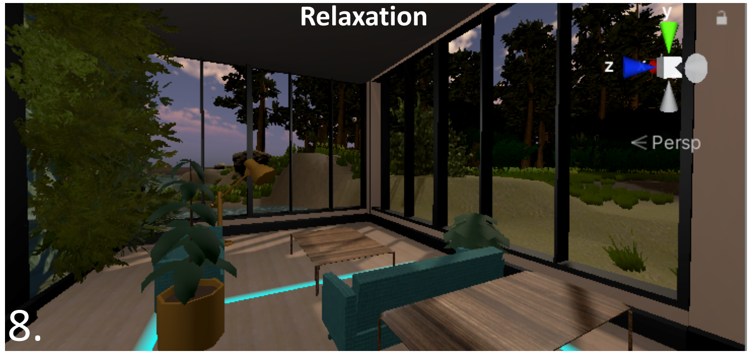
Quel effort (mental et physique) avez-vous dû fournir pour atteindre votre niveau de performance ?

Faible · Elevee

OK

7. Calibration eye tracker

8. **Relaxation**



9. **« Endline » après**

+

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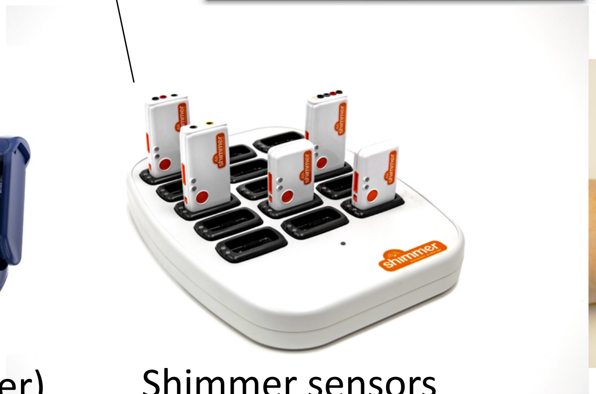
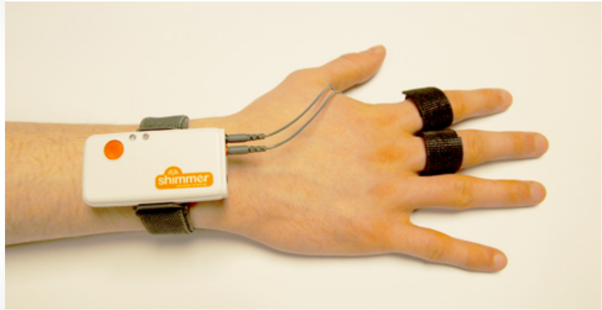
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

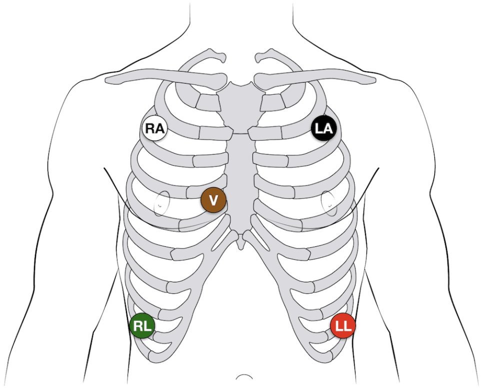
Hardware

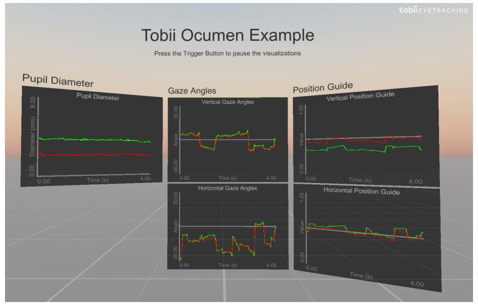
HTC Vive Pro Eye (tracker)



Shimmer sensors

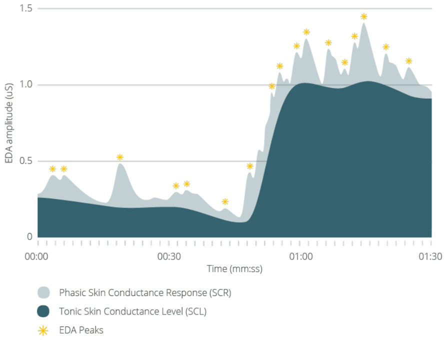




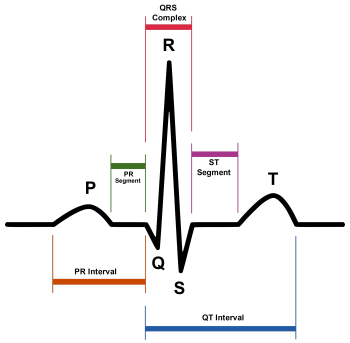


TimeStamp OS

EDA



ECG



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DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Software

C#

unity

SDK Unity

tobii EYETRACKING

Microsoft SpeechSDK

Github: https://bit.ly/362VQjY

C# API

shimmer DISCOVERY IN MOTION

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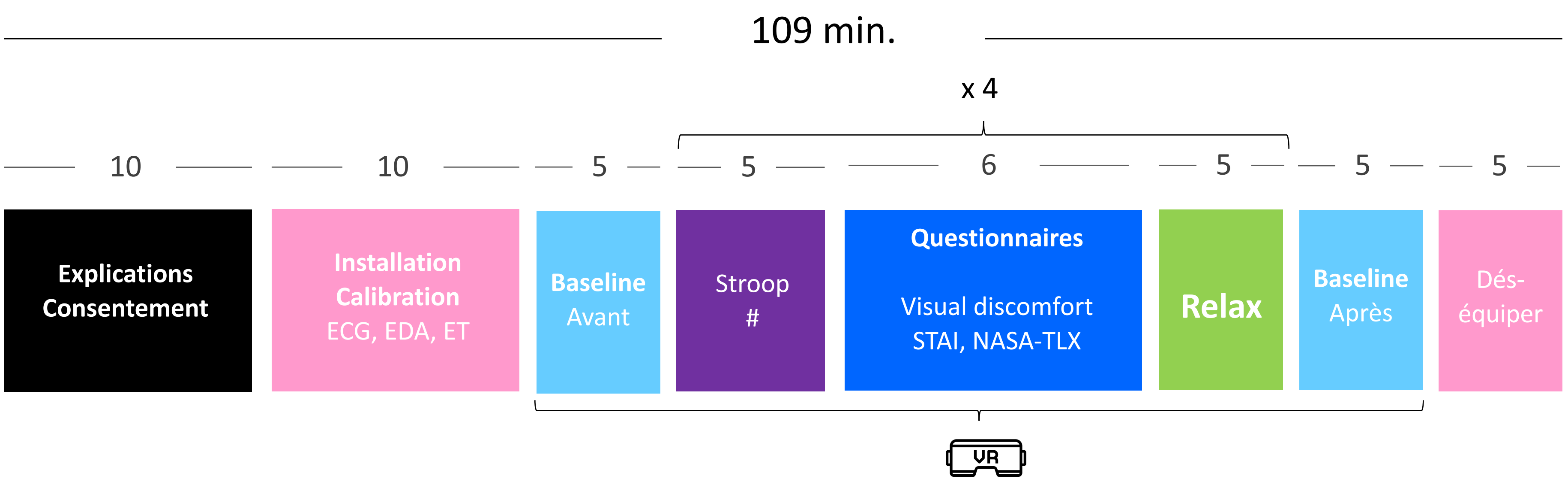
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Expérience Pré-Tests



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Weifei XIE

Master ANDROIDE de Paris 6

Développement Pipe traitement data + Pré-tests

Mémoire de Master

INFORMATIQUE
SPÉCIALITÉ AGENTS DISTRIBUES, ROBOTIQUE, RECHERCHE OPÉRATIONELLE, INTERACTION, DÉCISION (ANDROIDE)

Proposition d'un modèle reposant sur le Machine Learning pour détecter les états physiologiques induits par les effets secondaires de la Réalité Virtuelle

par

Weifei XIE

2021

Sorbonne université

Encadrement :

Dr. Alexis SOUCHET, Post-doctorant au CNRS-UMR 7253 Heudiasyc

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Soutenance 04/10/2021

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DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Participants

6

SUJETS

entre 22 et 31 ans
M= 24.16 ± 4.12

1 femme

5 hommes

Tous connaissaient l'environnement virtuel

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Traitement signaux physiologiques

Étape	ECG	EDA	Eye tracking
Filtrage signaux	Filtre passe-bas de 50 Hz. DWT (discrete wavelet transform) sera appliquée pour reproduire la procédure de Maldonado *et al.* (2020) Bibliothèques et algorithmes : neurokit, pyphisio de Bizzego et al. (2019)	Filtre passe-bas basé sur Liu and Du (2018) de 1 Hz. Algorithme de déconvolution pour diviser le signal en deux parties tonique (basse fréquence) et phasique (haute fréquence)	Classification IVT (Velocity-Threshold Identification fixation classification) comble les données manquantes et écarte les mouvements impossibles. Classement en trois types de mouvements (saccade, fixation, clignement) avec l'algorithme de Lin et al. (2019)
Extraction des features	**neurokit2** Makowski et al. (2021)		
Normalisation	Z-score and min max normalization		
Sélection des features	k-cross-validation et tests statistiques ANOVA, MANCOVA		

https://github.com/neuropsychology/NeuroKit

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Hypothèses de travail

H1 Les informations physiologiques permettent de prédire les effets secondaires de VR

H2 Les informations physiologiques permettent de distinguer charge mentale et stress

H3 Les informations physiologiques permettent de distinguer cybersickness et stress

H4 Les informations physiologiques permettent de distinguer cybersickness et charge mentale

H5 Différentes variations des features des signaux physiologiques (Eye tracker, ECG, EDA) permettent de détecter les effets secondaires de la VR

H6 La technique SVM permet d'atteindre le meilleur niveau de détection des effets secondaires de la VR comparés à d'autres

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Résultats Pré-Tests Etapes

1) Division binaire des scores de questionnaires
2) Normalisation avec toutes les features physiologiques et les techniques de machine learning pour réaliser une pré-sélection des meilleures techniques ML
3) Sélection des features en testant chaque technique ML et leur combinaison
4) Réduction du nombre de features nécessaires pour réaliser la détection et son efficacité

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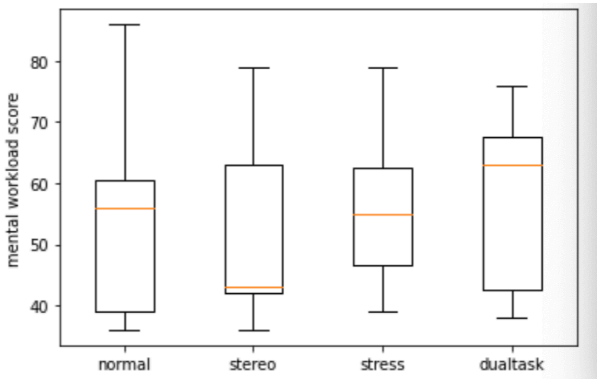
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

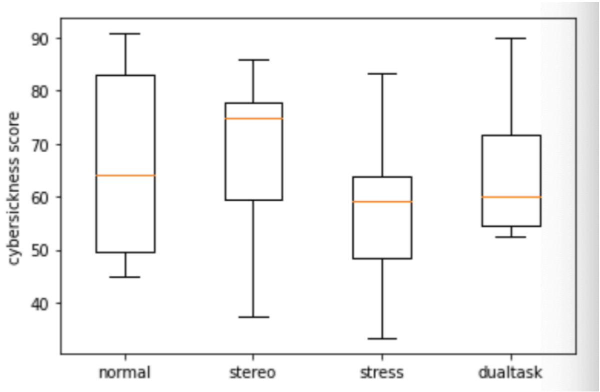
Résultats Pré-Tests Questionnaires

Scores Nasa-TLX Charge mentale



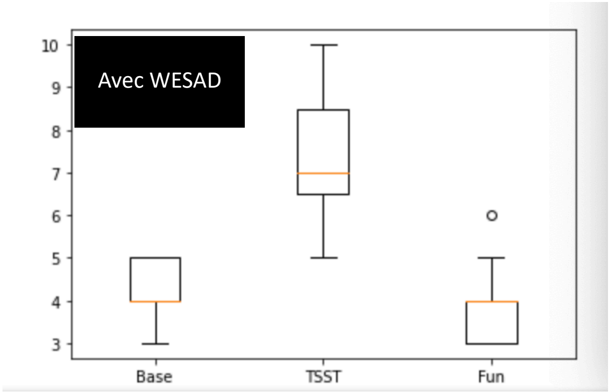
Chi square test
Dual task ≠ Control $p = 0.002$
Dual task ≠ Stressful $p = 6.5*10^{-6}$
Dual task ≠ Stereo $p = 0.001$

Scores VRSQ – Cybersickness (fatigue visuelle)



Chi square test
Stereo ≠ Control $p = 6.9*10^{-5}$
Stereo ≠ Stressful $p = 0.003$
Stereo ≠ Dual task $p = 0.0002$

Scores STAI-6 3 items – Stress



ANOVA
TSST ≠ Fun $p = 4*10^{-9}$
TSST ≠ Base $p = 7.8*10^{-9}$

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Résultats Pré-Tests Division binaire des scores questionnaires

Division binaire scores charge mentale Dell'Agnola et al. (2020) Nous avons également appliqué à Fatigue visuelle

Charge mentale

Faible < score Nasa-TLX 66 > Elevée

Charge mentale

Faible < score VRSQ 76 > Elevée

Stress (WESAD) Phillips-Wren and Adya (2020)

Somme des 3 items STAI-6_2 Je suis tendu(e), STAI-6_3 Je me sens bouleversé(e), STAI-6_6 Je suis inquiet(e)

Différence significative entre conditions stressée versus non stressée

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IEEE VR IEEE 2022

THE 29TH IEEE CONFERENCE ON VIRTUAL REALITY & 3D USER INTERFACES

Résultats Pré-Tests ML + Normalisation + Sélection features

Features pour détecter

Surcharge mentale

0. écart type du gaze point X (horizontal)
1. durée moyenne des saccades guidées visuellement
2. amplitude de la réponse de skin conductance
3. puissance spectrale de 0.045-025HZ du signal EDA
4. la densité de puissance spectrale de la bande haute fréquence, 0,15 à 0,4 Hz de l'ECG toutes les 30 secondes (écart type)
5. la moyenne de la durée RR (heart-beat)
6. l'écart type de la durée RR
7. la médiane de la durée RR

Fatigue visuelle

0. la moyenne de la taille de la pupille droite
1. la moyenne de la taille des deux pupilles
2. la moyen de la distance interpupillaire
3. le minmum de la distance interpupillaire
4. la distance interpupillaire minimale toutes les 30s (écart type)
5. la moyenne du temps de montée de la réponse de skin conductance chaque 30s (écart type)
6. l'écart type de la phase phasique (EDA)
7. le nombre de réponse de la skin conductance (EDA)
8. l'indice triangulaire HRV toutes les 30s (écart type)
9. nombre de beat par minute

Stress aigu

0. nombre de réponse total dans SCR
1. durée RR (moyen)
2. pNN20
3. pNN50

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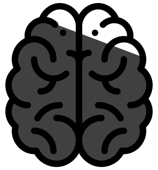
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Résultats Pré-Tests ML + Normalisation + Sélection features

Meilleures performances pour détecter

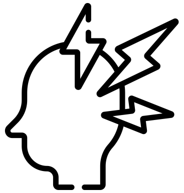


Surcharge mentale

Support Vector Machine – Linear (SVM-L)
+ Normalisation Z-score + Features selection ANOVA
Accuracy 93 %
Precision 95 %
Recall 91 %

Fatigue visuelle

Quadratic discriminant analysis (QDA)
+ Normalisation min-max + Feature selection Random Forest
Accuracy 91%
Precision 94%
Recall 91%



Stress aigu

Support Vector Machine – Linear (SVM-L)
+ Feature selection Pearson, normalisation pas meilleure performance
Accuracy 90 %
Precision 92 %
Recall 85 %

Avec WESAD

Souchet et al. IG-RV & AfIA - Collège Interaction avec l'Humain: journée "Environnements virtuels : adaptation du système à l'humain ou de l'humain au système ?« Mars 2022

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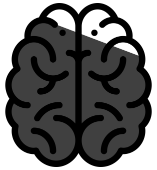
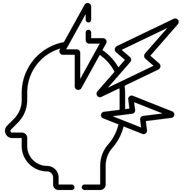
DÉTECTER LES EFFETS SECONDAIRES AVEC CAPTEURS PHYSIOLOGIQUES ET MACHINE LEARNING

Discussion

Effet secondaire	Nos résultats comparés aux précédents travaux
 Surcharge mentale	Ding *et al.* (2020) ont de meilleurs performances : accuracy 94.6 % Li *et al.* (2020) ont de moins bonnes performances : accuracy 85 % SVM aussi la meilleure technique ML pour détection
 Fatigue visuelle	Islam *et al.* (2020) ; Porcino *et al.* (2020) utilisent modèles non interprétables Dennison *et al.* (2016) ont de moins bonnes performances (accuracy 77.8 en moyenne avec les différentes techniques ML
 Stress aigu	Phillips-Wren and Adya (2020) difficile de comparer : utilisent fenêtres de 5 sec. Garcia-Agundez *et al.* (2019) ; Dell'Agnola *et al.* (2020) 3 classes de stress Classification plus fine que la binaire pour notre expérience

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Résultats Pré-Tests Hypothèses de travail

H1 Les informations physiologiques permettent de prédire les effets secondaires de VR — Soutenue

H2 Les informations physiologiques permettent de distinguer charge mentale et stress — Non Soutenue

H3 Les informations physiologiques permettent de distinguer cybersickness et stress — Non Soutenue

H4 Les informations physiologiques permettent de distinguer cybersickness et charge mentale — Non Soutenue

Mais features pour détecter différentes (pas testé dans pré-tests)

H5 Différentes variations des features des signaux physiologiques permettent de détecter les effets secondaires de la VR — Partiellement soutenue

Plus des données pour valider cette hypothèse sont nécessaires

Soutenue ... que SVM permet d'atteindre le meilleur niveau de dét[...] Non Soutenue secondaires de la VR comparés à d'autres

Charge mentale et Stress

Fatigue visuelle QDA meilleur

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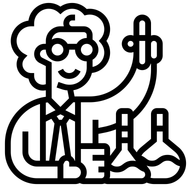
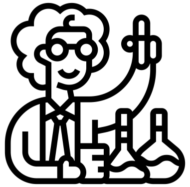
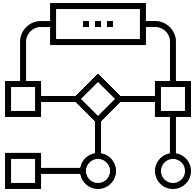
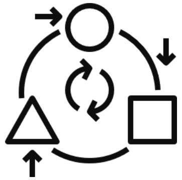
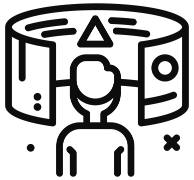
1  125 sujets
inter-sujet

2  30 sujets
intra-sujet



Création du modèle de détection
sur ces données (machine learning)





Adapter dynamiquement les contenus / interfaces
selon état et profil utilisateur
IA prise de décision, fonctions de croyance

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Environnements virtuels : adaptation du système à l’humain ou de l’humain au système ?

“*human first, technology second*”

Stone, 2016

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