# Human-machine relationships in automated driving: active vs passive driving.

Jordan Navarro, Lyon, France

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## Humain-Machine relationships in cognitive sciences

2

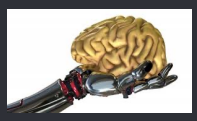
## *Homo Sapiens* VS tools/technology

Phase 1

*Homo Sapiens*

Tools/technology

Phase 2



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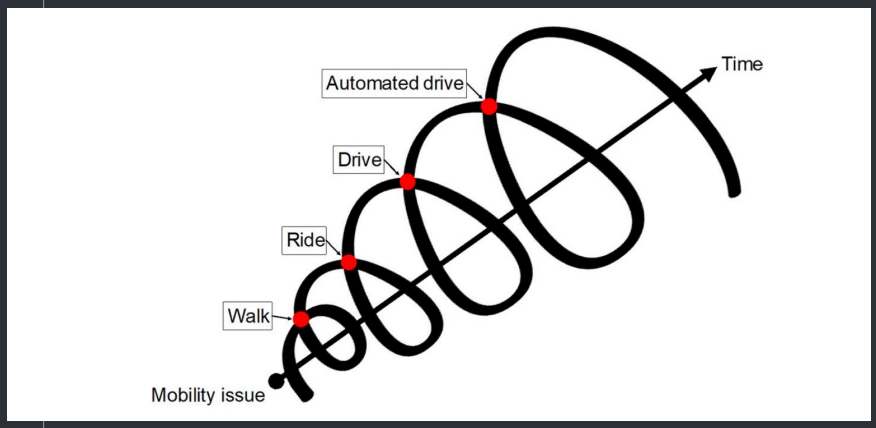


Navarro, J. & Hancock, P.A. (2023). Did Tools Create Humans? *Theoretical Issues in ergonomics science.*

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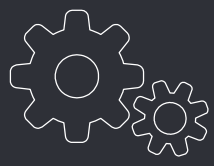
# Cognitive ergonomics - Human Factors



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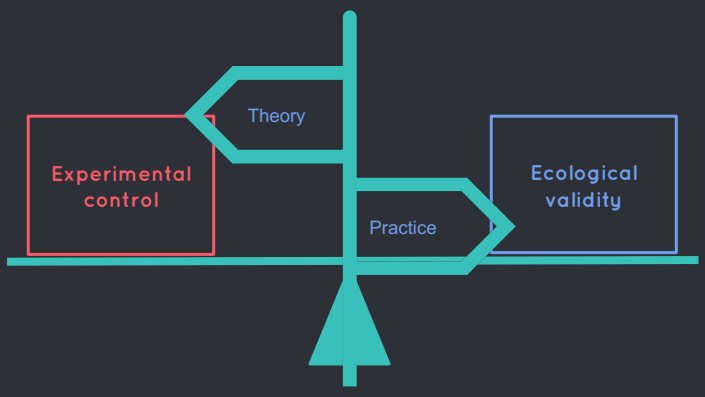


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# Driving

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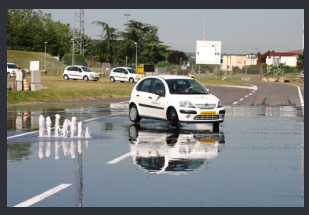

Steering | Hazard perception | Navigation

- A brief Hierarchical Task Analysis (Stanton et al., 2001)

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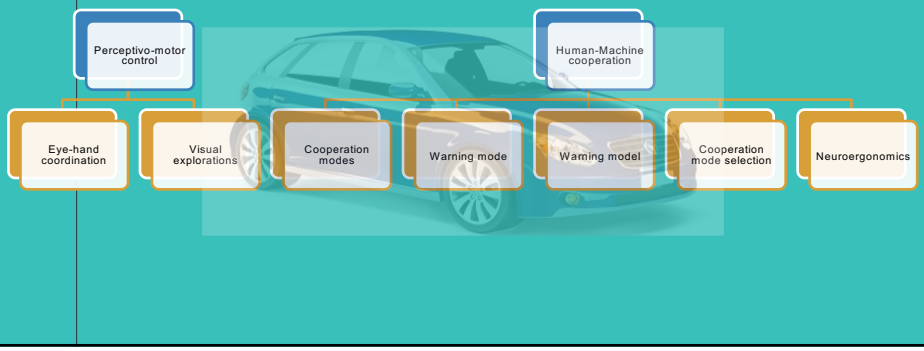
# Human Machine cooperation

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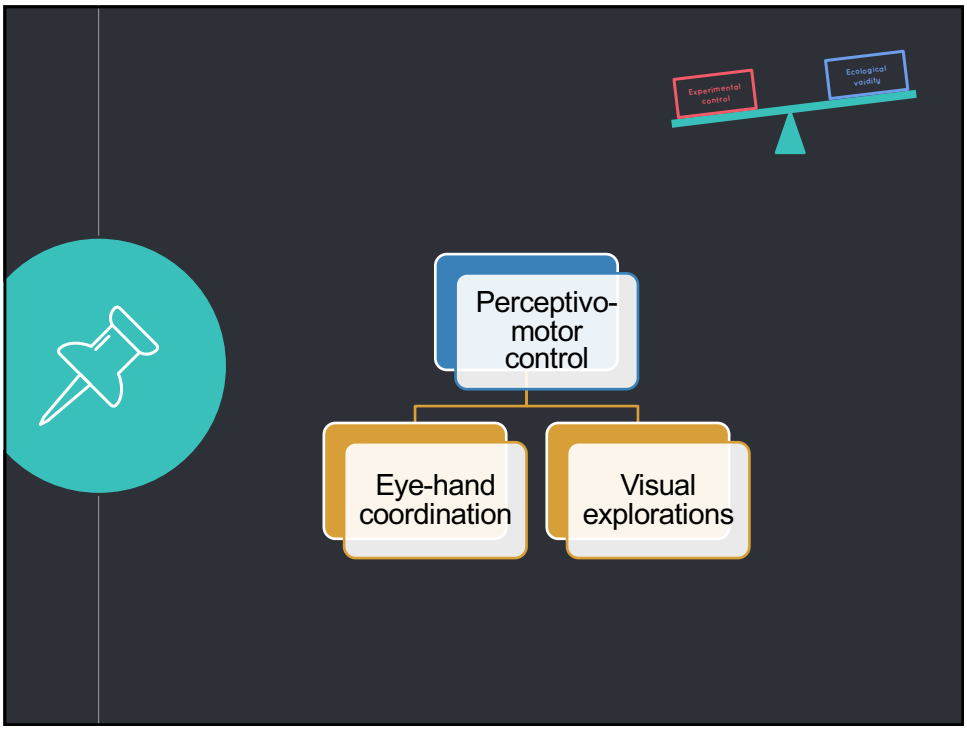


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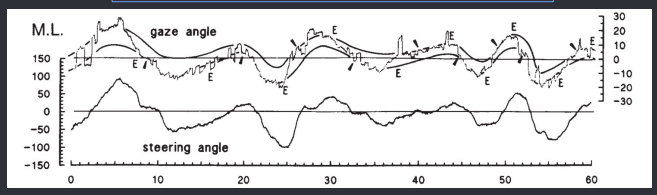
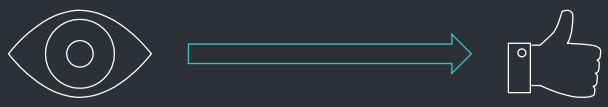
Eye-hands coordinations

Steering



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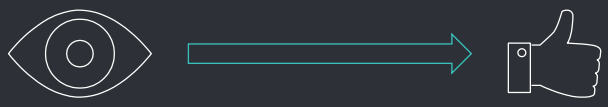
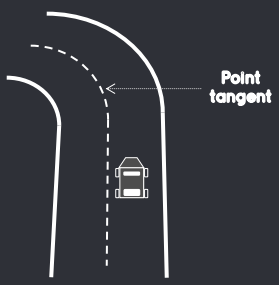
Goal 1 : eye-hands relationship



Goal 2: tangent point role




Hyp 1: Geometric relationship with bend curvature **(Land & Lee, 1994)**

Hyp 2: Direction of the point in the environment where to pass **(Wann & Swapp, 2000; Wilkie & Wann, 2003)**

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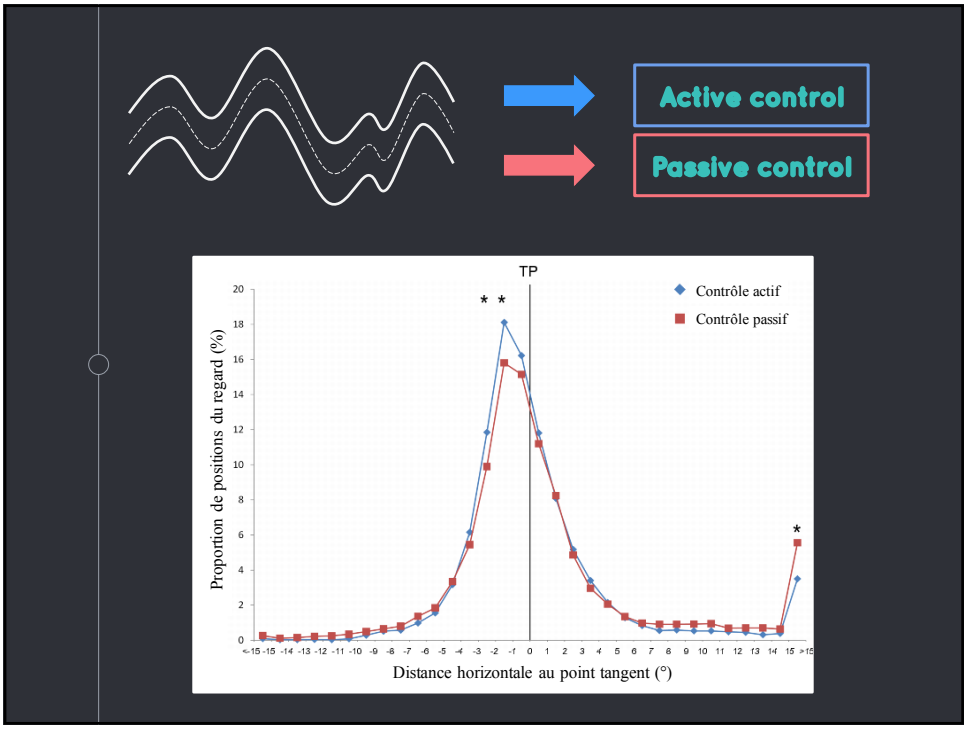
Active control
Passive control
TP
Contrôle actif
Contrôle passif
Proportion de positions du regard (%)
Distance horizontale au point tangent (°)

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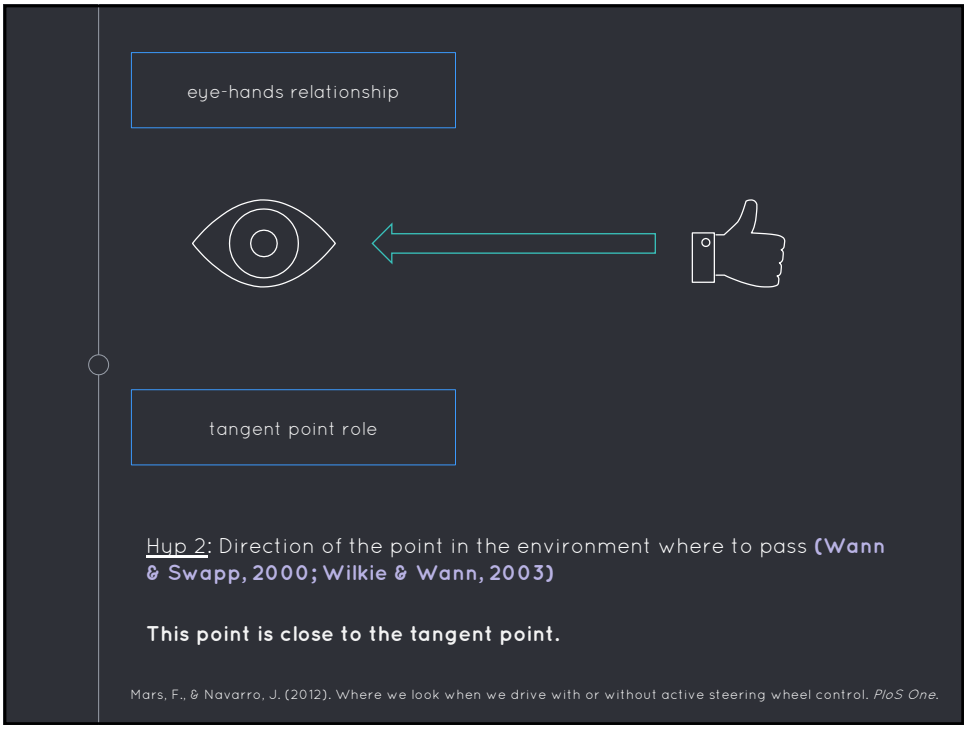
eye-hands relationship
tangent point role
Hyp 2: Direction of the point in the environment where to pass (Wann & Swapp, 2000; Wilkie & Wann, 2003)
This point is close to the tangent point.
Mars, F., & Navarro, J. (2012). Where we look when we drive with or without active steering wheel control. PloS One.

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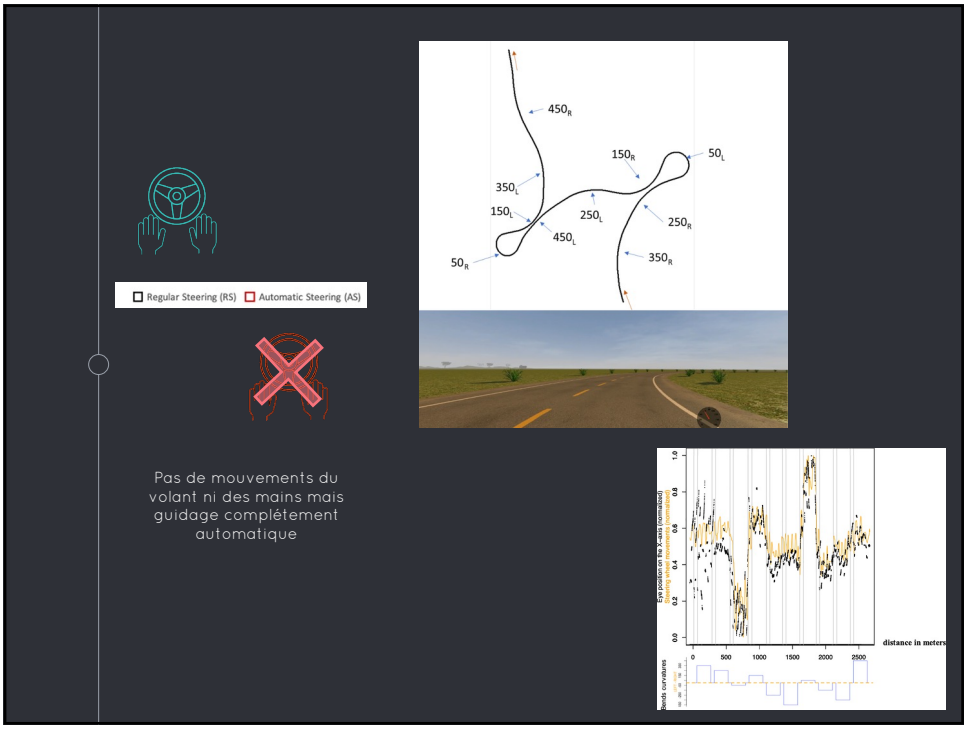
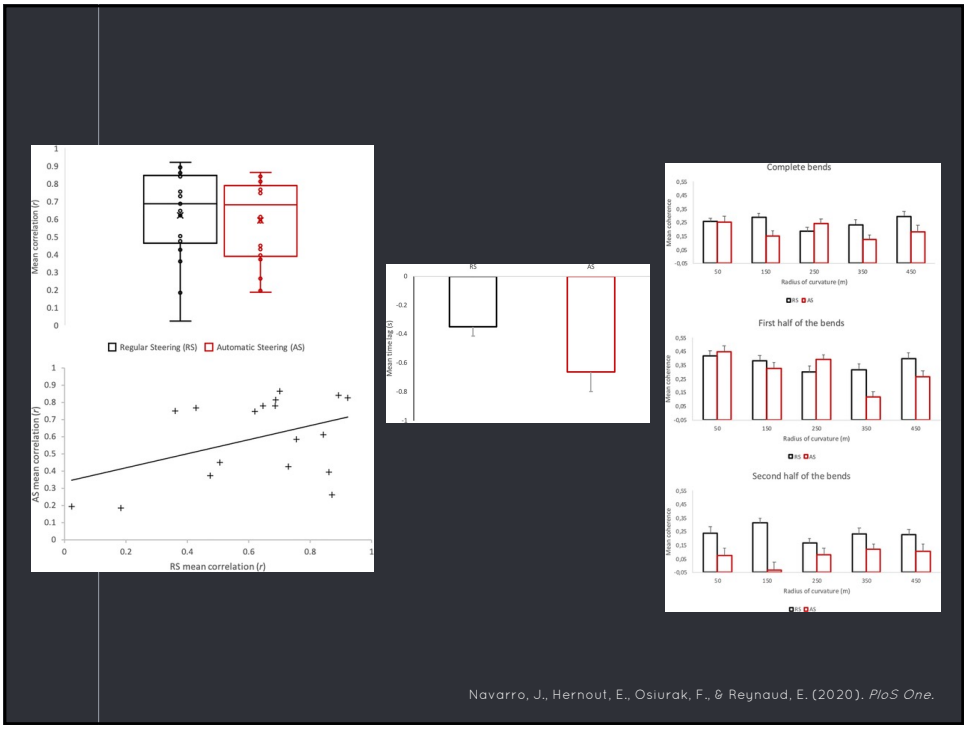

Regular Steering (RS)
Automatic Steering (AS)
Pas de mouvements du volant ni des mains mais guidage complétement automatique
distance in meters

15


Regular Steering (RS)
Automatic Steering (AS)
Mean correlation (r)
AS mean correlation (r)
RS mean correlation (r)
Mean time lag (s)
Complete bends
First half of the bends
Second half of the bends
Radius of curvature (m)
Navarro, J., Hernout, E., Osiurak, F., & Reynaud, E. (2020). PloS One.

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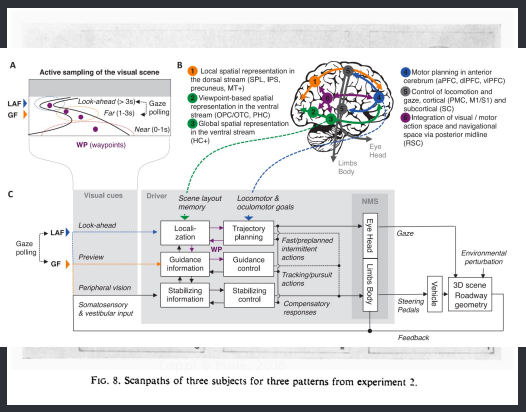


FIG. 8. Scanpaths of three subjects for three patterns from experiment 2.

Noton & Stark, 1971

- Conduite manuelle (MD)
- Conduite hautement automatisée (HAD)

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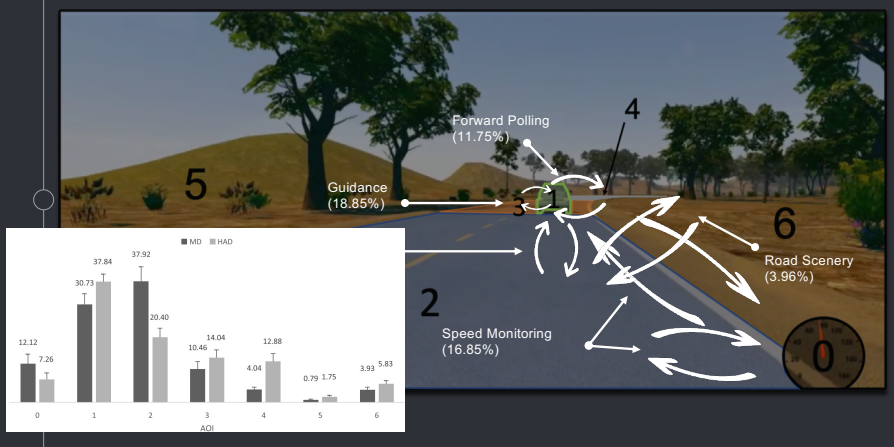
En conduite manuelle (longueur scanpath 4 AOIs)

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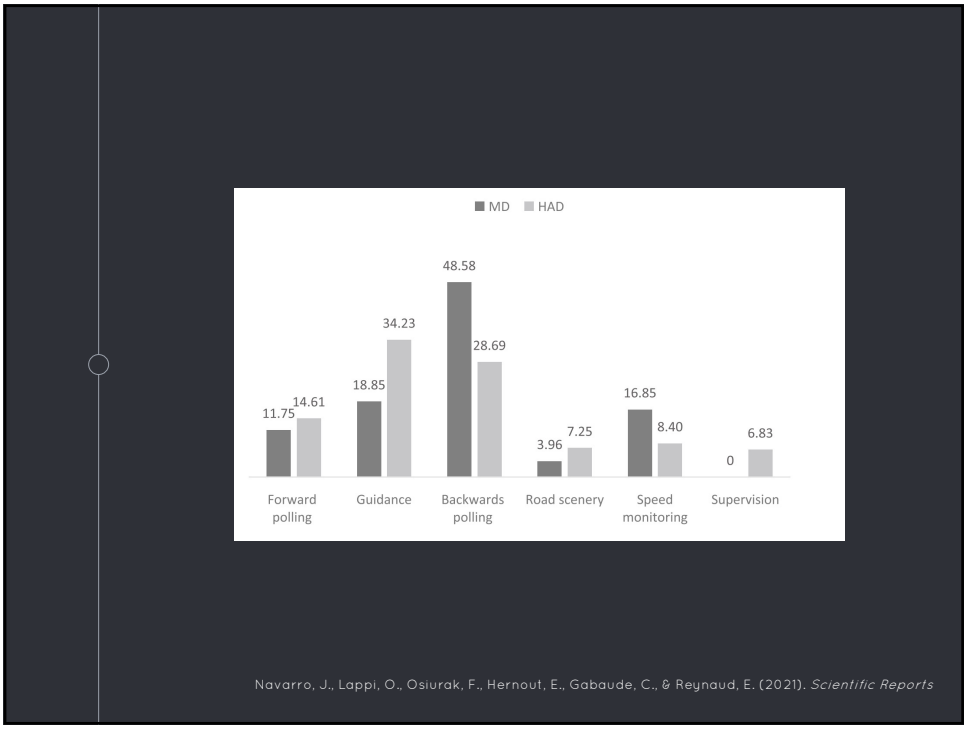
MD
HAD
48.58
34.23
28.69
18.85
16.85
14.61
11.75
8.40
7.25
6.83
3.96
0
Forward polling
Guidance
Backwards polling
Road scenery
Speed monitoring
Supervision
Navarro, J., Lappi, O., Osiurak, F., Hernout, E., Gabaude, C., & Reynaud, E. (2021). Scientific Reports

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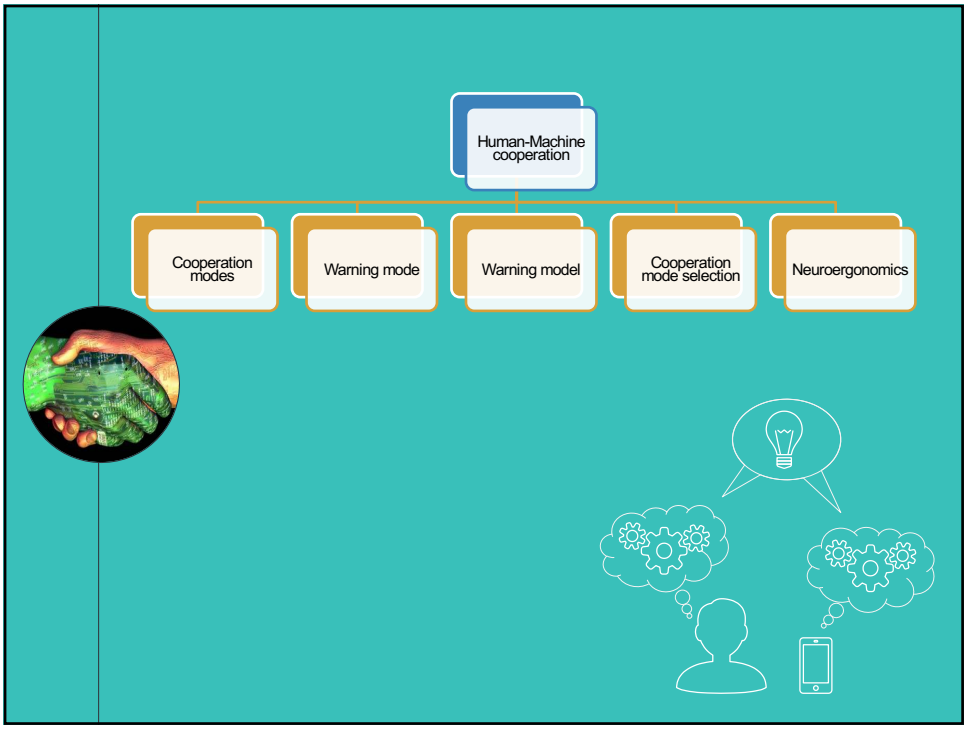
Human-Machine cooperation
Cooperation modes
Warning mode
Warning model
Cooperation mode selection
Neuroergonomics

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# Neuroergonomics in driving

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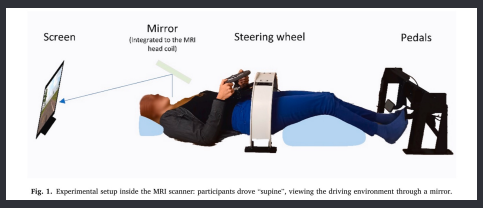
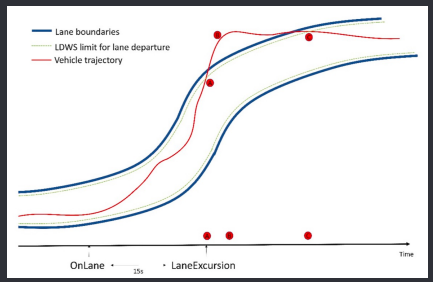



Fig. 1. Experimental setup inside the MRI scanner: participants drove "supine", viewing the driving environment through a mirror.




## Active driving with unprovoked lane departures

Schnebelen, D., Reynaud, E., Ouimet, M. C., Seguin, P., & Navarro, J. (2024). A neuroergonomics approach to driver's cooperation with Lane Departure Warning Systems. Behavioural Brain Research, 456, 114699.

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**Table 1**
Characteristics of lane excursions observed during the experimental drive for experienced and novice drivers. The values represent the mean and the standard error calculated for each group of drivers.

| Driving Experience | Number of Lane Excursions | Mean Duration of Lane Excursion (s) | Mean Steering Reaction Time during Lane Excursion (ms) |
|---|---|---|---|
| Experienced Drivers | 52,89 (+- 6,03) | 1,63 (+- 0,09) | 520 (+- 50) |
| Novice Drivers | 70,86 (+- 5,95) | 1,8 (+- 0,27) | 490 (+- 50) |

LaneExcursion > OnLane

**Table 2**
Foci of activations (FDR-corrected *p*-value of 0.001; minimum cluster size of 100) and matching brain areas in the LaneExcursion > OnLane condition.

| Cluster | Volume (voxels) | x | y | z | Hemisphere | Brain Areas | Brodmann Areas |
|---|---|---|---|---|---|---|---|
| 1 | 1486 | -34 | -14 | 64 | L | PostCentral / Precentral Gyrus | BA 6/4/2/3 |
| 2 | 3249 | 3 | -12 | 48 | R | PostCentral / Precentral Gyrus / Inferior Parietal Lobule | BA 6/40/4/2/3 |
| 3 | 601 | 37 | -7 | -10 | R | Insula / Inferior Frontal Gyrus / Superior Temporal Gyrus | BA 13 |
| 4 | 421 | 10 | -21 | -5 | L/R | Midbrain / Thalamus | |
| 5 | 178 | 5 | 9 | 41 | R | Cingulate Gyrus / Anterior Cingulate Gyrus | BA 32 |
| 6 | 2023 | -6 | -48 | -10 | L/R | Cerebellum Anterior / Posterior Lobe | |
| 7 | 121 | -59 | -25 | 8 | L | Superior Temporal Gyrus | BA 41 |
| 8 | 118 | 28 | 48 | 20 | R | Superior Frontal Gyrus | BA 10 |

Schnebelen, D., Reynaud, E., Ouimet, M. C., Seguin, P., & Navarro, J. (2024). A neuroergonomics approach to driver's cooperation with Lane Departure Warning Systems. Behavioural Brain Research, 456, 114699.

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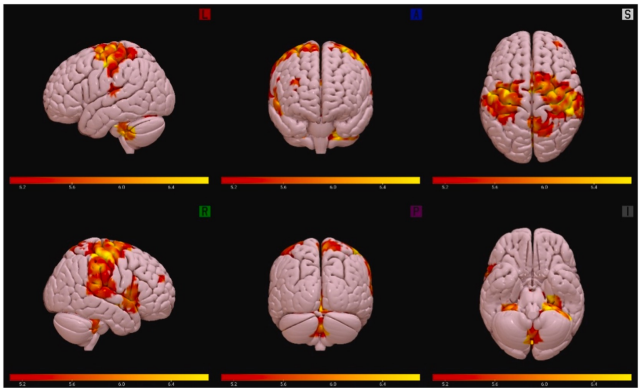


**Fig. 4.** 3D representations of the cerebral areas activated (FDR-corrected *p*-value of 0.001; minimum cluster size of 100) in the LaneExcursion > OnLane condition on inflated brains. From top to bottom, Left part: left and right hemispheres, middle part: anterior and posterior views, bottom part: dorsal and ventral views.

Schnebelen, D., Reynaud, E., Ouimet, M. C., Seguin, P., & Navarro, J. (2024). A neuroergonomics approach to driver's cooperation with Lane Departure Warning Systems. Behavioural Brain Research, 456, 114699.

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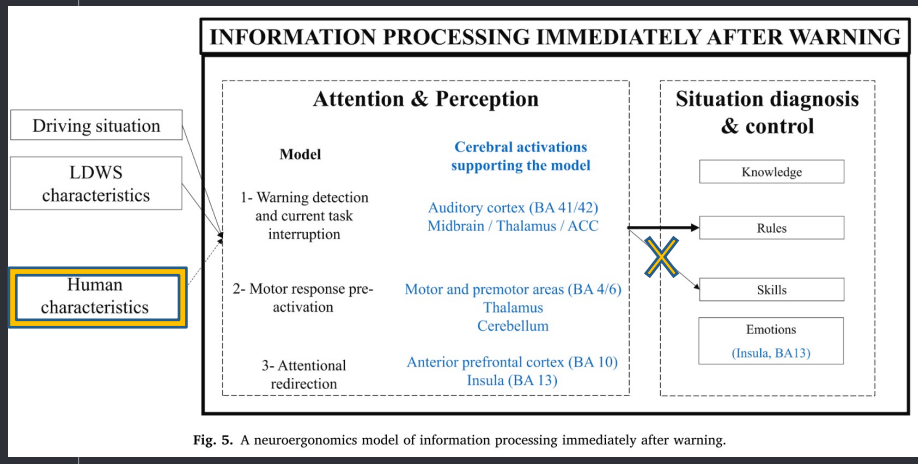


**Fig. 5.** A neuroergonomics model of information processing immediately after warning.

Schnebelen, D., Reynaud, E., Ouimet, M. C., Seguin, P., & Navarro, J. (2024). A neuroergonomics approach to driver's cooperation with Lane Departure Warning Systems. Behavioural Brain Research, 456, 114699.

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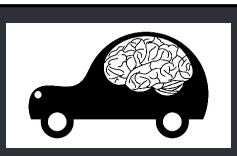

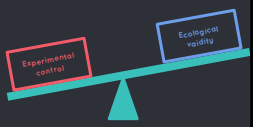


# A Meta-analysis in neuroergonomics

Received: 26 April 2023 | Revised: 21 September 2023 | Accepted: 23 September 2023
DOI: 10.1002/hbm3.3272
REVIEW
Brain and Behavior
WILEY

**Hands off, brain off? A meta-analysis of neuroimaging data during active and passive driving**

Navarro Jordan[1,2] | Reynaud Emanuelle[1]

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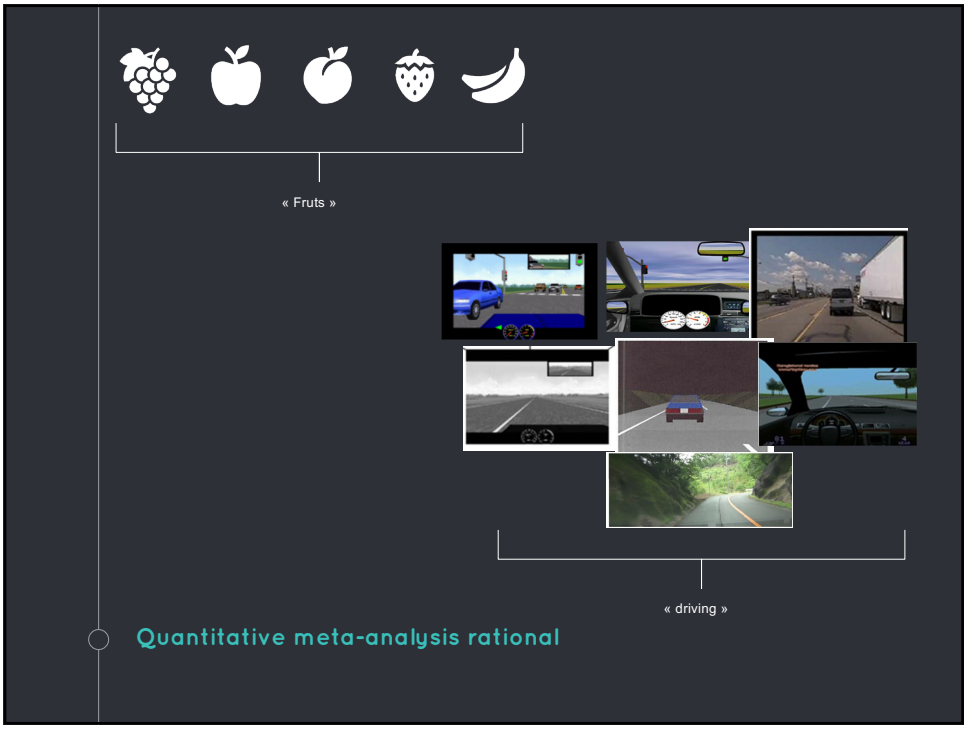


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## ALE Meta-analysis

Coordinate Based Meta Analysis, quantitative analysis

1- a single experimental = a table of brain coordinates + a number of participants

2- ALE map with activation gaussians centered on peaks and standard deviation function of the sample size

3- combinaison of individual ALE maps → transformed in a *p* values map of activation peaks consistency

4- Contrats between maps possible

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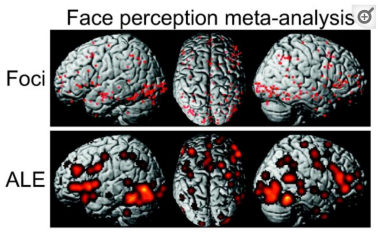
## ALE Meta-analysis

Neuroimage. Author manuscript; available in PMC 2013 Feb 1.
*Published in final edited form as:*
Neuroimage. 2012 Feb 1; 59(3): 2349–2361.
Published online 2011 Sep 22. doi: 10.1016/j.neuroimage.2011.09.017



<< Prev Figure 2 Next >>

Figure 2




A real dataset was analysed in order to exemplify the new algorithms. This dataset consisted of 19 papers reporting 20 individual experiments (305 subjects) and a total of 183 activation foci on the brain activity evoked by visually presented faces. The figure shows the distribution of individual foci (upper row) as well as the (un-thresholded) ALE map (lower row) for the exemplary dataset.

Activation Likelihood Estimation meta-analysis revisited

Simon B. Eickhoff,[1,2,3,*] Danilo Bzdok,[1,2,3] Angela R. Laird,[4] Florian Kurth,[5] and Peter T. Fox[4]



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## What happens in the human brain of a drivenger?


Drivenger. In real life conditions TOR and associated difficulties

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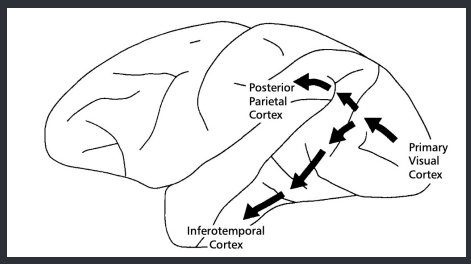
## Distinct visual pathways




**'What' and 'where' in the human brain**

Leslie G Ungerleider and James V Haxby

National Institute of Mental Health, Bethesda, USA

Multiple visual areas in the cortex of nonhuman primates are organized into two hierarchically organized and functionally specialized processing pathways, a 'ventral stream' for object vision and a 'dorsal stream' for spatial vision. Recent findings from positron emission tomography activation studies have localized these pathways within the human brain, yielding insights into cortical hierarchies, specialization of function, and attentional mechanisms.

Current Opinion in Neurobiology 1994, 4:157–165

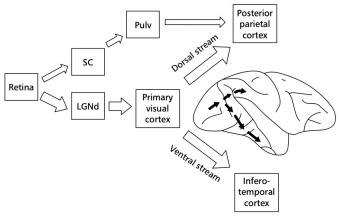
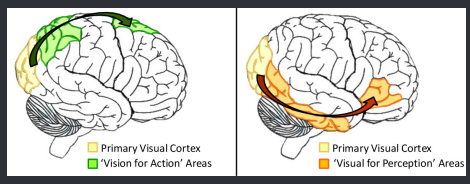



**Fig. 3.1** Schematic diagram showing major routes whereby retinal input reaches the dorsal and ventral streams. The inset shows the cortical projections on the right hemisphere of a macaque brain. LGNd, lateral geniculate nucleus, pars dorsalis; Pulv, pulvinar nucleus; SC, superior colliculus.

## What & How




Milner & Goodale, 2006

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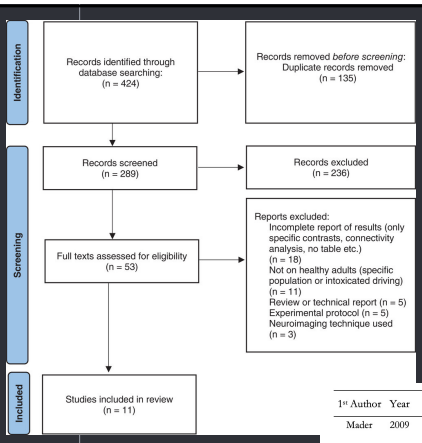


Brain coordinates available reexamined through the passive/active lens

| 1st Author | Year | Journal | Original contrast in the given study | Table number | N | Driving category |
|---|---|---|---|---|---|---|
| Mader | 2009 | Neuroscience Letters | Unfamiliar route | Table 1 | 16 | Passive |
| | | | Familiar route | Table 1 | 16 | Passive |
| Jeong | 2006 | Annals of Nuclear Medecine | Active driving > control | Table 1 | 10 | Active |
| | | | Passive driving > control | Table 1 | 10 | Passive |
| Schweizer | 2013 | Frontiers in Human Neuroscience | Right and left turns | Table 1 | 16 | Active |
| | | | Straight driving | Table 1 | 16 | Active |
| | | | Left turns +traffic and left turns + traffic + audio | Table 1 | 16 | Active |
| Graydon | 2004 | Transportation Research Part F | Visual detection > fixation baseline | Table 2 | 6 | Passive |
| Horikawa | 2005 | Brain and Cognition | Driving > rest | Table 1 | 15 | Active |
| | | | Passive > rest | Table 1 | 15 | Passive |
| Kan | 2013 | Medical Physics | Driving > fixation | Table 4 | 16 | Active |
| Walter | 2001 | Neuroreport | Driving > visual scene | Table 1 | 12 | Active |
| | | | Passive driving > visual scene | Table 1 | 12 | Passive |
| Uchiyama | 2012 | Transportation Research Part F | Driving > rest | Table 1 | 18 | Active |
| Choi | 2017 | Journal of Physiological Anthropology | Driving only > control | Table 2 | 15 | Active |
| Sakai | 2018 | Scientific Reports | Passive driving > control | Supp. Mat. | 34 | Passive |
| Just | 2008 | Brain Research | Driving alone > fixation baseline | Section 2.2 | 29 | Active |

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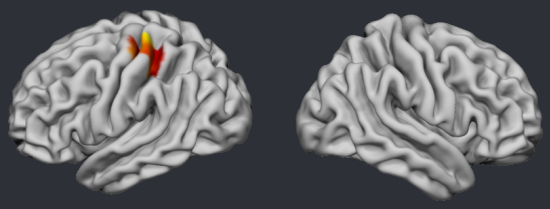
## Active driving > passive driving



Somatosensory area
Motor area
Gesture, motor coordination and grasping

| cluster | size | x | y | z | p value | Z score | Hemisphere | Region | Brodmann Area |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 512 mm3 | -32 | -33 | 58 | 0.024 | 1.98 | Left | Parietal / Frontal lobe | |
| | | -33 | -23 | 57 | | | | Precentral gyrus | BA4 |
| | | -33 | -31 | 62 | | | | Postcentral gyrus | BA3 / BA40 |
| 2 | 368 mm3 | -30 | -32 | 72 | 0.006 | 2.51 | Left | Frontal / Parietal lobe | |
| | | -28 | -23 | 73 | | | | Postcentral gyrus | BA3 |
| | | -33 | -16 | 69 | | | | Precentral gyrus | BA4 |
| | | -37 | -26 | 70 | | | | Postcentral gyrus | BA3 |

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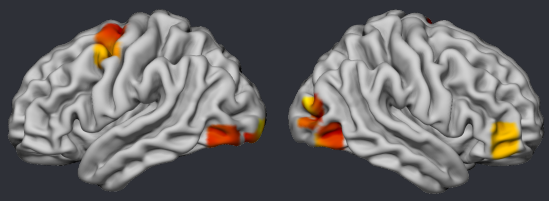
## Passive driving > active driving



| cluster | size | x | y | z | p value | Z score | Hemisphere | Region | Brodmann Area |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1672 mm3 | -27 | -8 | 59 | 0.018 | 2.1 | Left | Middle Frontal Gyrus | BA6 |
| | | -28 | 2 | 53 | | | | | |
| | | -31 | 9 | 61 | | | | | |
| | | -23 | 4 | 65 | | | | | |
| 2 | 1424 mm3 | 28 | -44 | -22 | 0.008 | 2.41 | Right | Cerebellum - Anterior lobe | |
| | | 28 | -42 | -22 | | | | Fusiform Gyrus | BA37 |
| 3 | 1032 mm3 | 15 | -23 | 6 | 0.018 | 2.1 | Right | Pulvinar / Medial dorsal nucleus of Thalamus | |
| | | 16 | -24 | 9 | | | | | |
| | | 17 | -20 | 6 | | | | | |
| | | 23 | -24 | 4 | | | | | |
| 4 | 776 mm3 | -30 | -56 | -18 | 0.002 | 2.88 | Left | Cerebellum - Posterior lobe | |
| | | -29 | -59 | -12 | | | | | |
| | | -29 | -66 | -9 | | | | | |
| 5 | 680 mm3 | 44 | 47 | -8 | 0.018 | 2.1 | Right | Inferior Frontal Gyrus | BA10 |
| 6 | 488 mm3 | 40 | -71 | -11 | 0.01 | 2.33 | Right | Inferior Occipital Gyrus | BA19 |
| | | 44 | -78 | -7 | | | | Inferior Occipital Gyrus | BA19 |
| | | 48 | -71 | -3 | | | | Inferior Temporal Gyrus | BA37 |
| | | 47 | -75 | 1 | | | | Inferior Occipital Gyrus | BA19 |
| 7 | 480 mm3 | 37 | -89 | 11 | 0.006 | 2.51 | Right | Middle Occipital Gyrus | BA18/19 |
| | | 41 | -91 | 22 | | | | | |
| | | 45 | -90 | 16 | | | | | |
| 8 | 416 mm3 | -43 | -76 | -12 | 0.03 | 1.88 | Left | Inferior Occipital Gyrus | BA18/19 |
| 9 | 288 mm3 | -42 | -1 | 54 | 0.018 | 2.1 | Left | Middle Frontal Gyrus | BA6 |
| | | -42 | 2 | 51 | | | | | |

Areas V1, V2, V5, MT & IT: vision, objects recognition
Frontal area (BA10): supervision, transition between tasks
Frontal area (BA6): action observation (reaching/grasping)
Cerebellum: movement perception

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## Discussion

A single source of visual information: two processes
action / identification

Active driving: dorsal stream, vision for action
Passive driving: ventral stream, vision for identification

During passive driving, the vision for action is no longer used:
the drivenger is no longer a driver

Automatic switch from active to passive:

« Driving control » & « driving monitoring »: two different tasks

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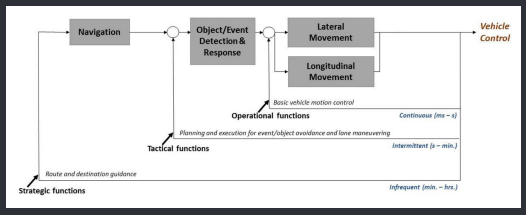
## Human factors perspective




Active driving

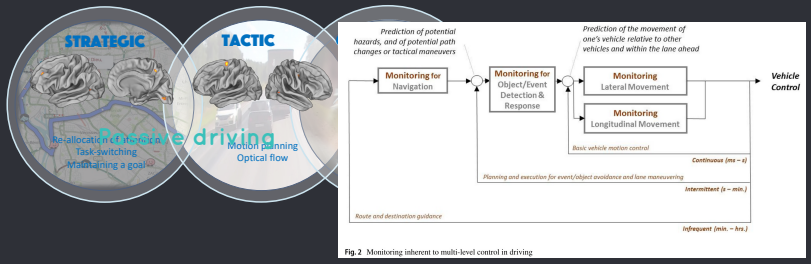



Fig. 2 Monitoring inherent to multi-level control in driving

Merat, N., Seppelt, B., Louw, T., Engström, J., Lee, J. D., Johansson, E., Green, C. A., Katazaki, S., Monk, C., Itoh, M., McGehee, D., Sunda, T., Unoura, K., Victor, T., Schieben, A., & Keinath, A. (2019). The "Out-of-the-Loop" concept in automated driving: proposed definition, measures and implications. *Cognition, Technology & Work*.

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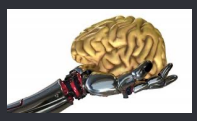
## *Homo Sapiens* VS tools/technology

Phase 1

*Homo Sapiens*

Tools/technology



Phase 2

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## Thanks


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