Visual demands of traffic signs in control drivers and drivers with reading impairment

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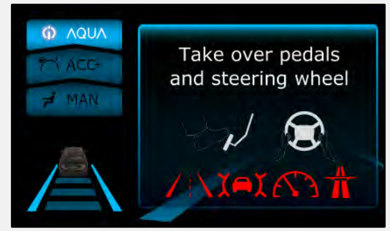
Daily living involves many reading activities,

even for those who define themselves as “non-frequent readers”.



Quick and accurate reading of traffic signs can be critical

and performance depends on a variety of visual and cognitive factors.

Perceptual factors
Lexical factors
Syntactic factors
Attention
Cognitive load
Individual differences
...

(Fortunately)
infrequent traffic situations

Daily traffic situations

Reading impairment in the adult life

Dyslexia is considered a persistent disorder (DSM-5; APA, 2013):

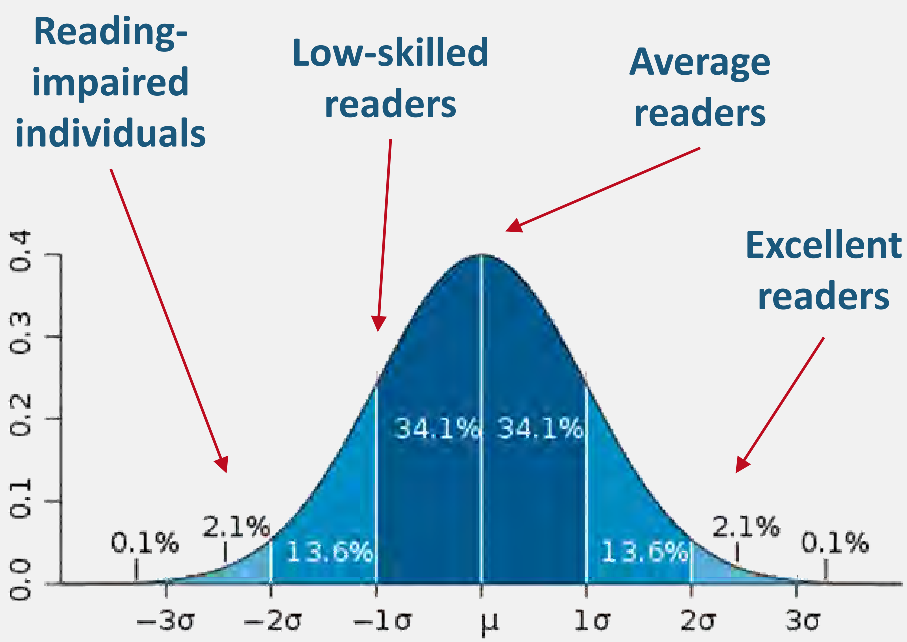
- Difficulties generally **start during the childhood** (elementary school).

- As adults, there is evidence of partial **neurocognitive compensation** and the deployment of **higher-order strategies** (e.g. Shaywitz et al., 2003; Temple et al., 2003).

- Still, some difficulties **endure during adult life** (e.g., Bruck, 1990; Nilssen-Nergård & Hulme, 2014; Suárez-Coalla & Cuetos, 2015):
    - **Slow, effortful reading** (e.g. low fluency and delayed word recognition)
    - **Reading errors** (more or less frequent depending on language)
    - **Impaired reading comprehension**

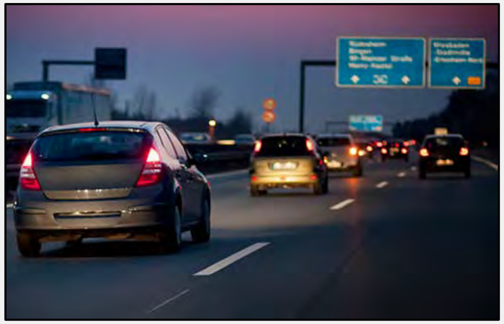
Reading impairment in the adult life

- **Prevalence of dyslexia**: 4% - 8% of general population



- **Measures to facilitate reading of traffic signs would potentially help any driver**:
  - Low-skilled and impaired readers, but also
  - Good readers in cognitively demanding conditions
    (e.g., dense traffic flow, visual clutter, night driving, reduced visibility…)

Reading traffic signs is a visually demanding task
competing with other driving and non-driving operations.



Night driving

Traffic density

Driver behaviour
& condition

Visual clutter

Motivation of the current project

(1) Which reading performance factors can be generalised to driving situations (e.g. are lexical factors also relevant on the road)?

(2) Do adults with dyslexia struggle to read while driving a vehicle?

(3) Are their reading difficulties affecting driving basic operations (e.g. speed control)?

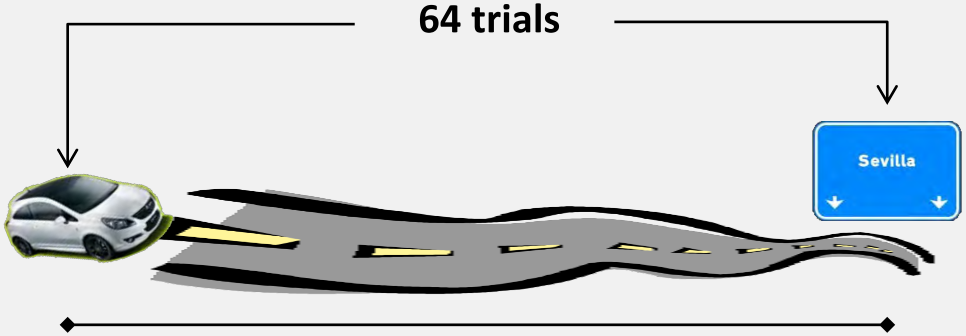
Methods

Experiment 1

- ✓ **Objective**: To evaluate the difficulties of adults with and without dyslexia in reading **single words displayed on direction signs**, while they are driving in a simulator
- ✓ **Stimuli**: 64 signs with names of cities varying in **length** (short/long) and **frequency** (frequent/infrequent)

PC-based driving simulator

Motorway route



350 m　　0 m


Gear
Eco
Automatic
Nav

Methods

Participants:

- **Experiment 1**:
  21 adults with dyslexia, and
  21 matched controls.

> ✓ **Adults with dyslexia**:
> DSM-5 criteria, impaired nonword reading
>
> ✓ **Matched controls**: similar age, sex, IQ and level of education
>
> ✓ **All of them**: normal or corrected-to-normal vision.

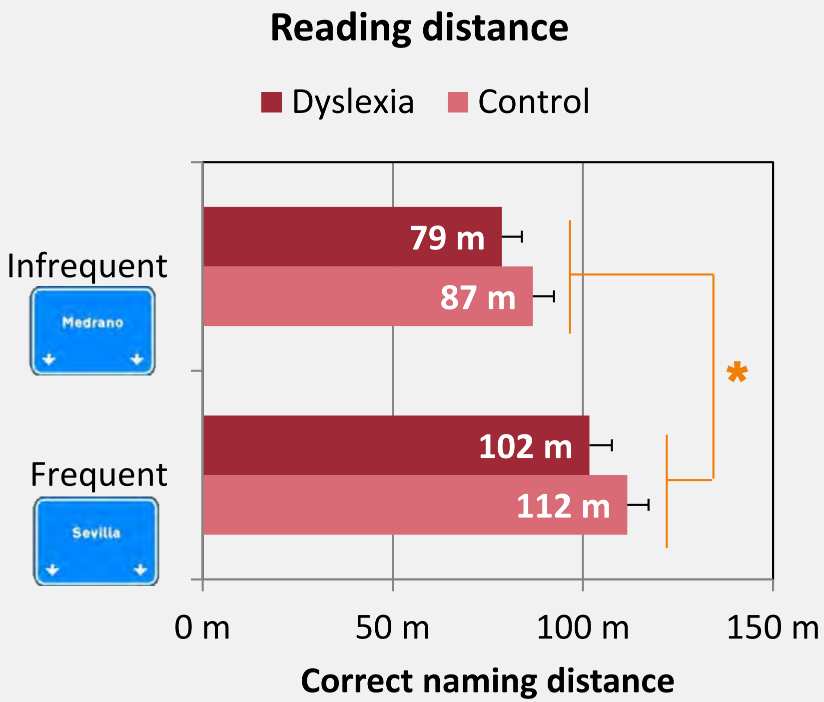
The driving task:

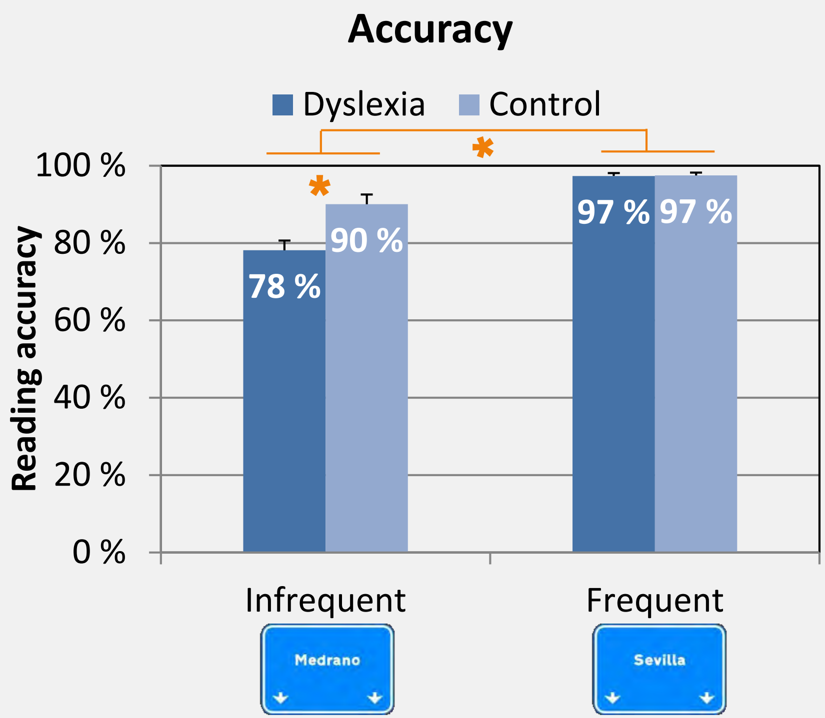
- *"You have to drive at a constant speed of 120 km/h and read aloud the content of the direction signs that you will encounter, as soon as you can correctly do it"*.

Measures:

- **Reading distance** (i.e. meters from the traffic sign where correct reading begins).
- **Reading accuracy** (i.e. correct or incorrect word reading).
- **Eye tracking data** (i.e., number of gazes and percentage of time gazing each sign, using SMI-Eye Tracking Glasses).
- **Vehicle control indicators** (i.e. variability of speed inside and outside trial sections).

Word frequency

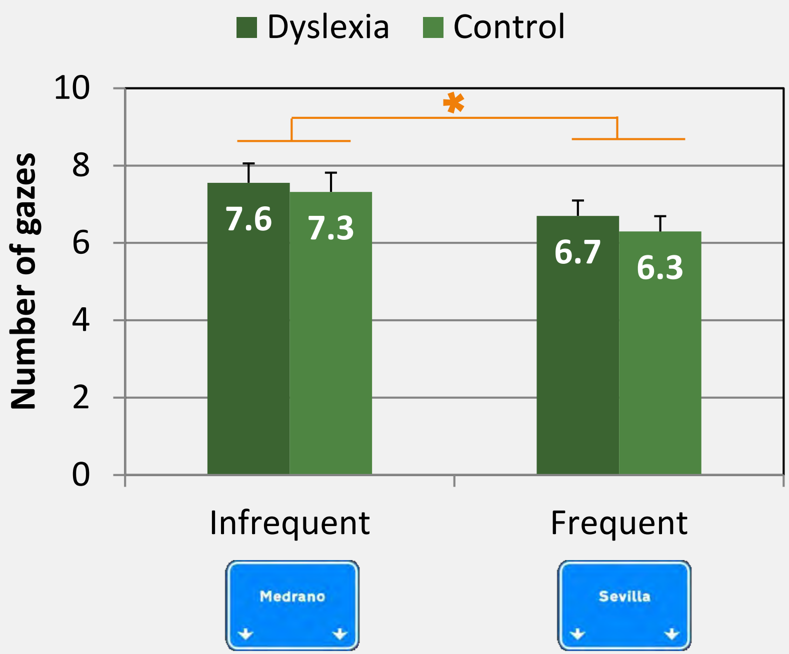




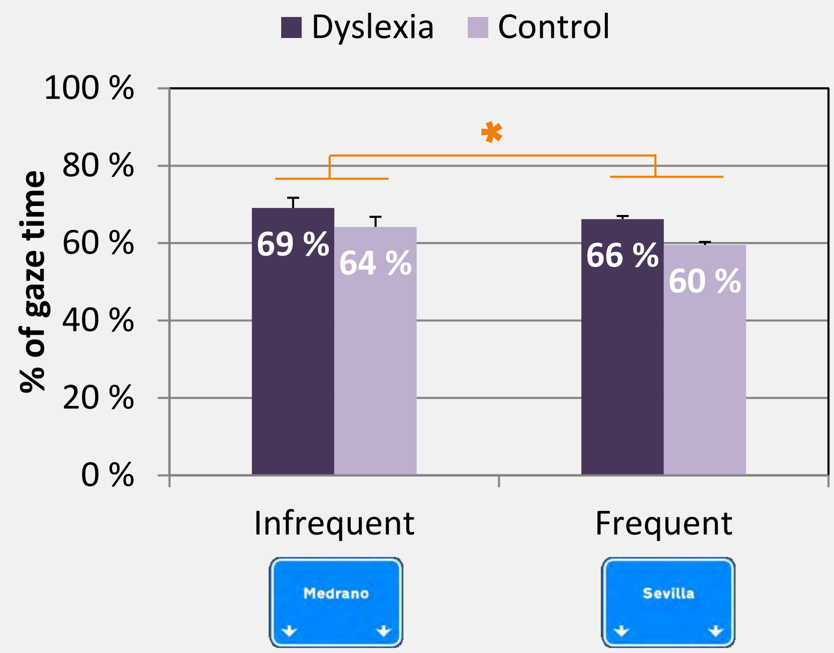
- Overall, drivers could read from a **farther distance** ($p < .001$) and **made fewer reading errors** ($p < .001$) with **frequent words**.
- **Drivers with dyslexia** generally made more reading errors than matched controls ($p = .007$), in particular when reading **infrequent words** ($p = .002$).

Word frequency

Number of gazes

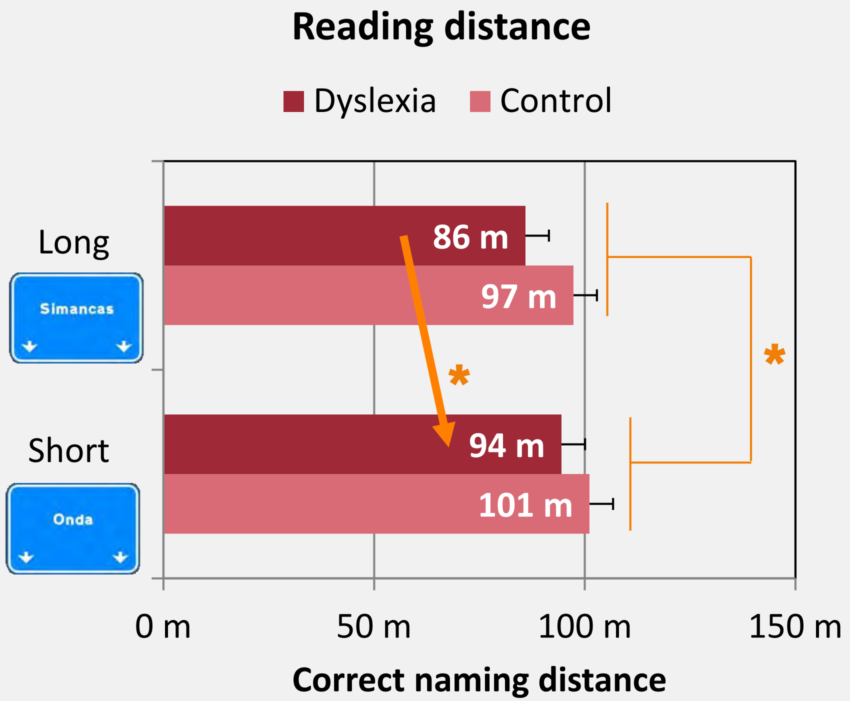


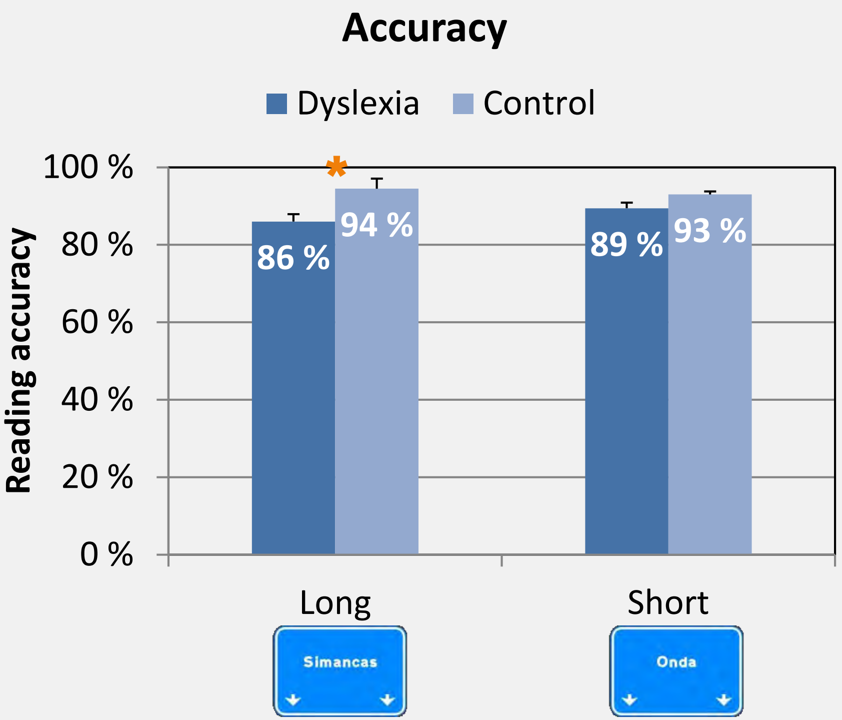
% of time gazing at the sign



- Overall, drivers dedicated **more gazes** ($p < .001$) and a **higher percentage of time** ($p < .001$) gazing at the **infrequent words**.
- **Drivers with dyslexia** dedicated a **similar number of gazes and gaze time percentage** as control participants.

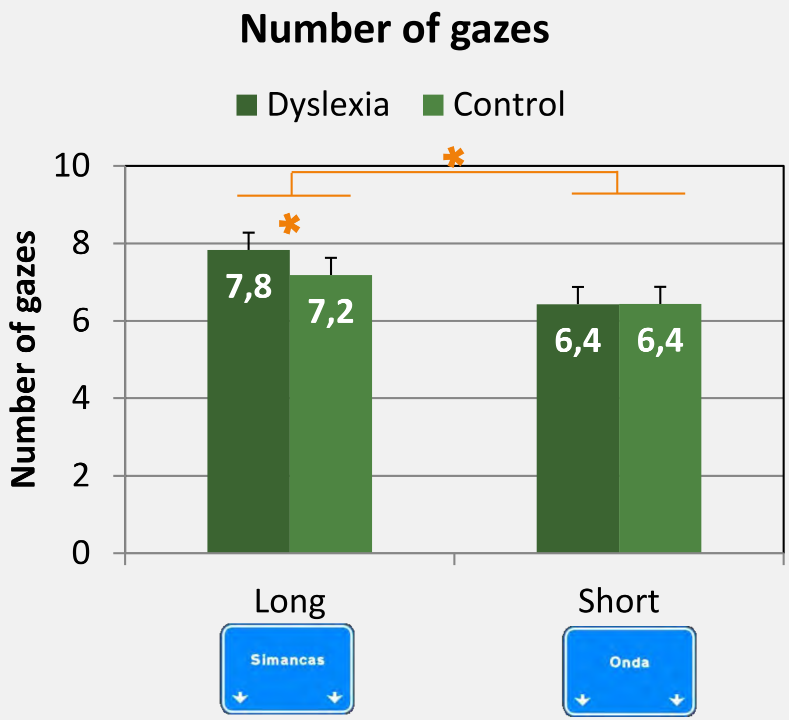
Word length

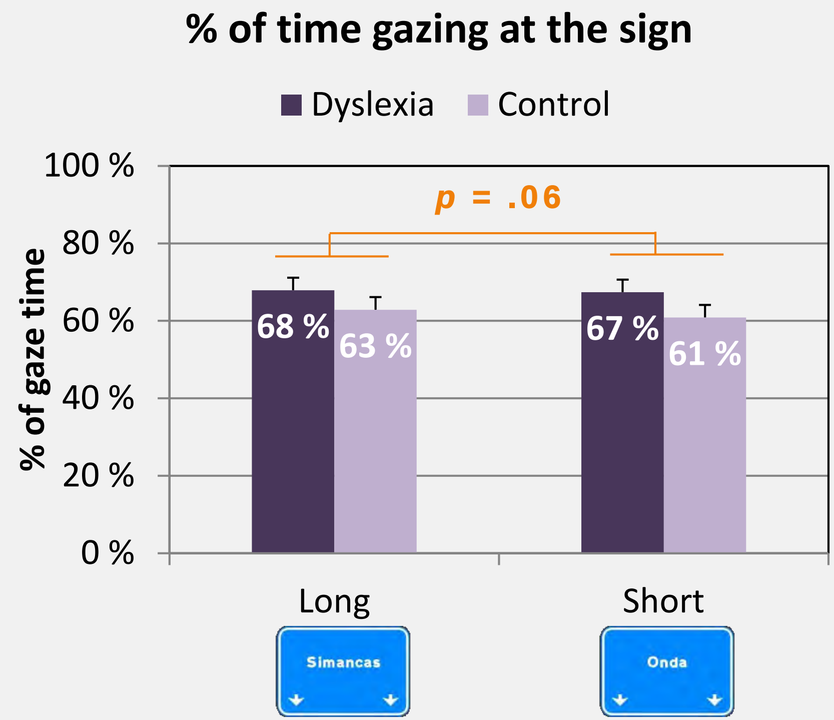




- Overall, drivers could read from a farther distance **short words** ($p < .001$).
- **Drivers with dyslexia** had to be even closer to correctly read a **long than a short word** ($p < .001$) and they made more errors with **long words** ($p = .003$).

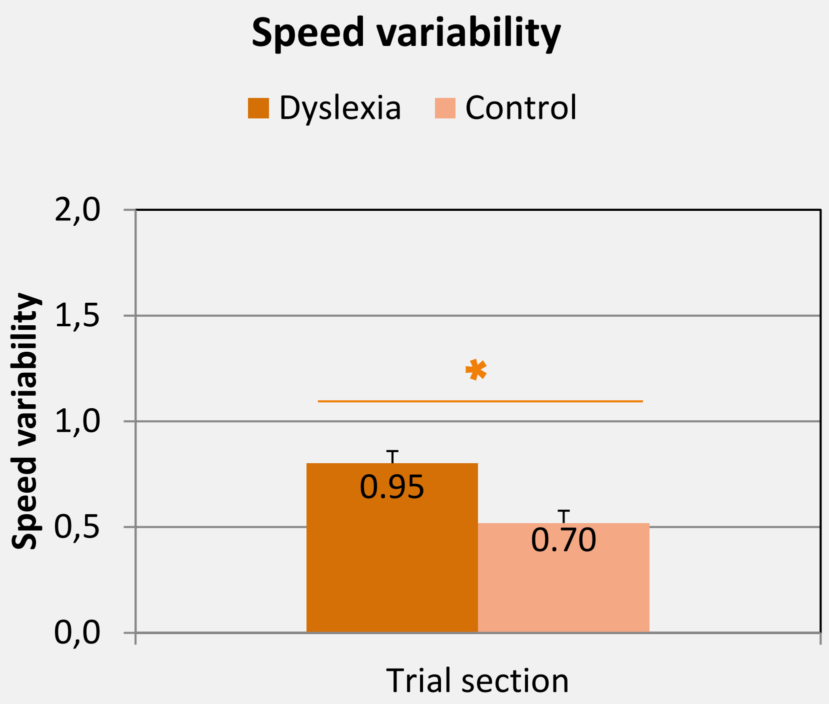
Word length





- Overall, drivers dedicated **more gazes** ($p < .001$) at the **long words.** They only tended to dedicate higher percentage of time ($p = .06$) at long words.
- **Drivers with dyslexia dedicated more gazes** at long words than control participants ($p = .03$), but a similar percentage of time.

Driving performance

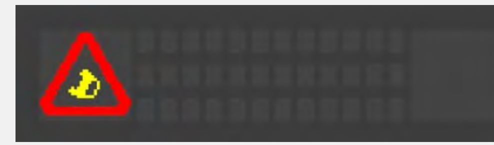


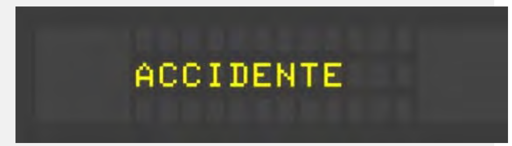
- Adults with dyslexia found **more difficult to keep a constant speed (p < .001) inside the trial sections**, i.e. where they were approaching a traffic sign and were trying to read the content.
- The ability to keep a constant speed is **similar in both groups (p > .10) outside the trial sections**, i.e. when drivers were not required to read.

Methods

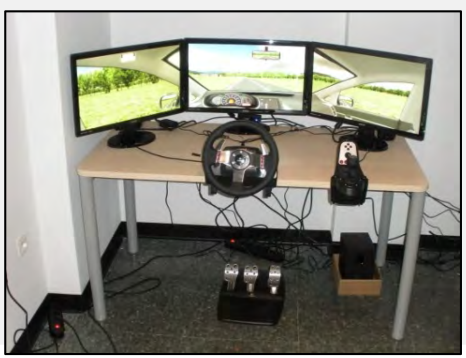
Experiment 2

- **Objective:** To evaluate the difficulties of adults with and without dyslexia in recognizing **single words and pictograms** displayed **on variable message signs**, while they are driving in a simulator.
- **Stimuli** : 36 variable message signs showing 1 of 6 **words** (e.g. congestion, accident, fog) or 1 of the 6 **pictograms**, which were **previously trained, and repeatedly presented**.

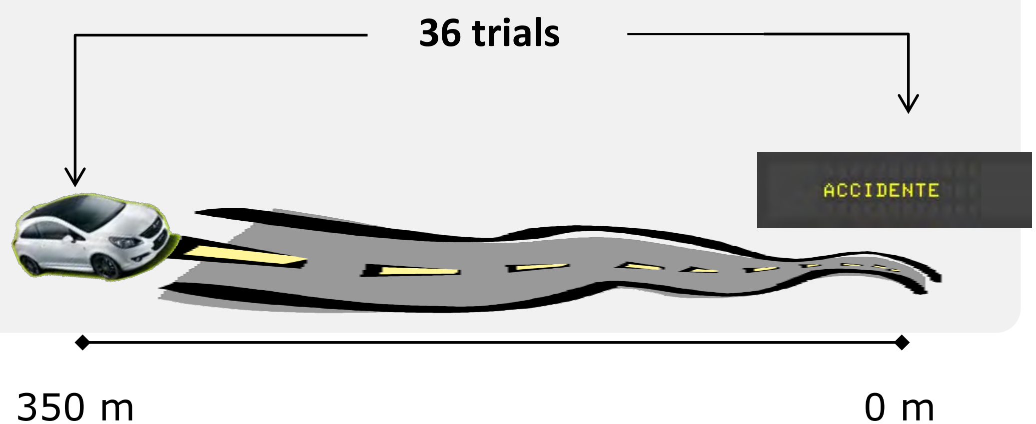




PC-based driving simulator



Experiment 2



Methods

Participants:

- **Experiment 2**:
  22 adults with dyslexia and
  22 matched controls.

✓ **Adults with dyslexia**: DSM-5 criteria, impaired nonword reading
✓ **Matched controls**: similar age, sex, IQ and level of education
✓ **All of them**: normal or corrected-to-normal vision.

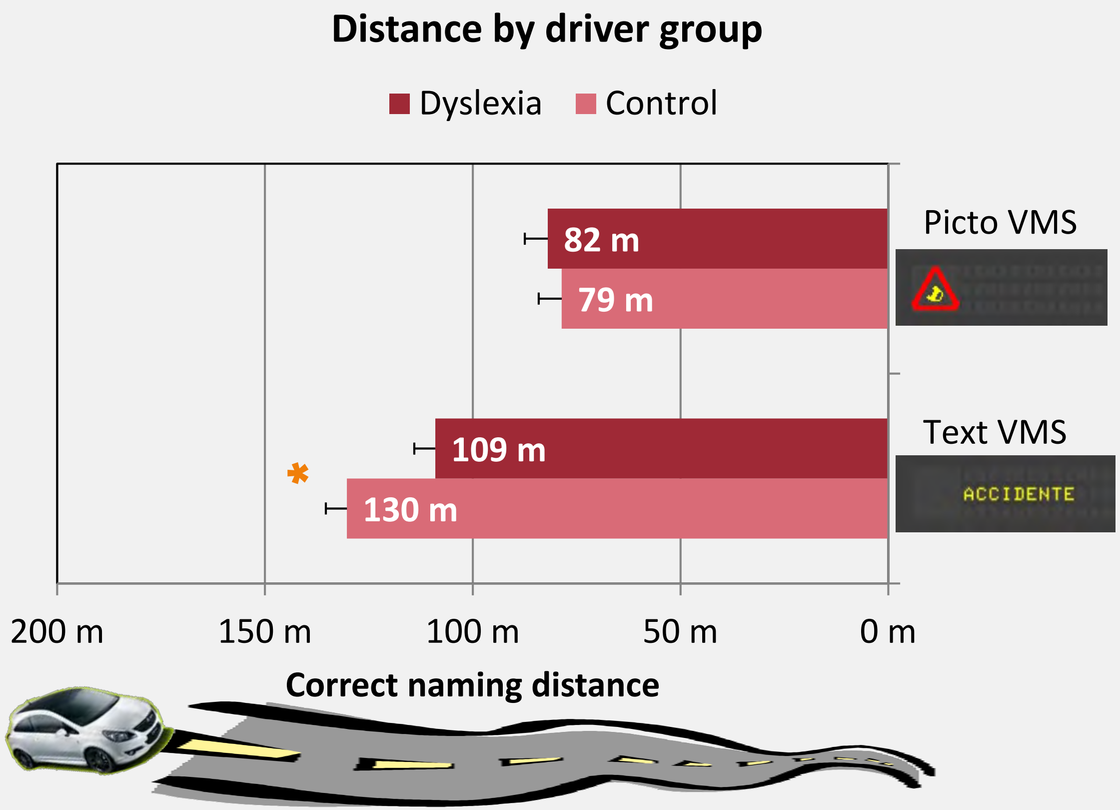
The driving task:

- *“You have to drive at a constant speed of 120 km/h and read aloud the content of the variable message signs that you will encounter, as soon as you can correctly do it*”.

Measures:

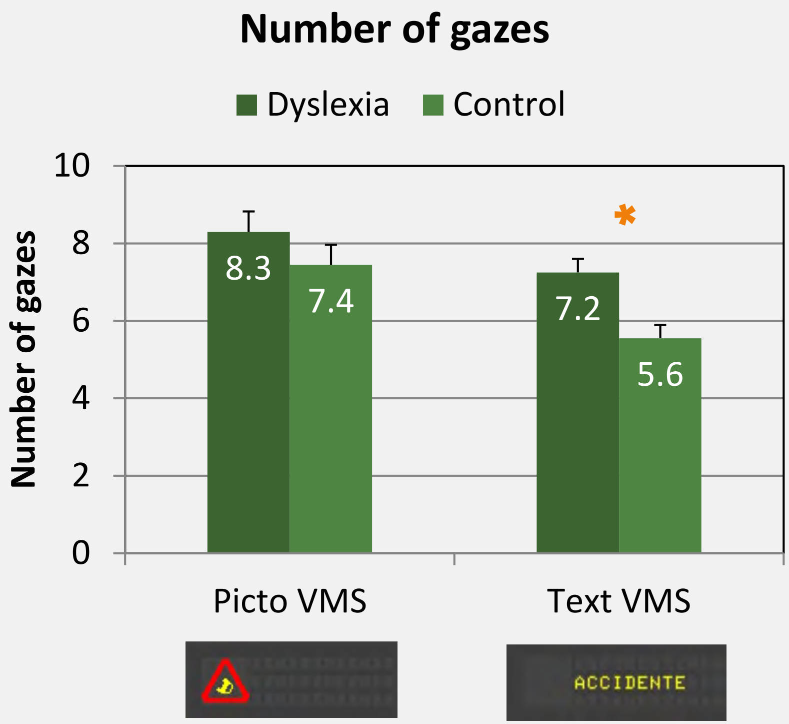
- **Reading distance** (i.e. meters from the traffic sign where correct reading begins).
- **Reading accuracy** (i.e. correct or incorrect word reading).
- **Eye tracking data** (i.e., number of gazes and percentage of time gazing each sign, using SMI-Eye Tracking Glasses).
- **Vehicle control indicators** (i.e. variability of speed inside and outside trial sections).

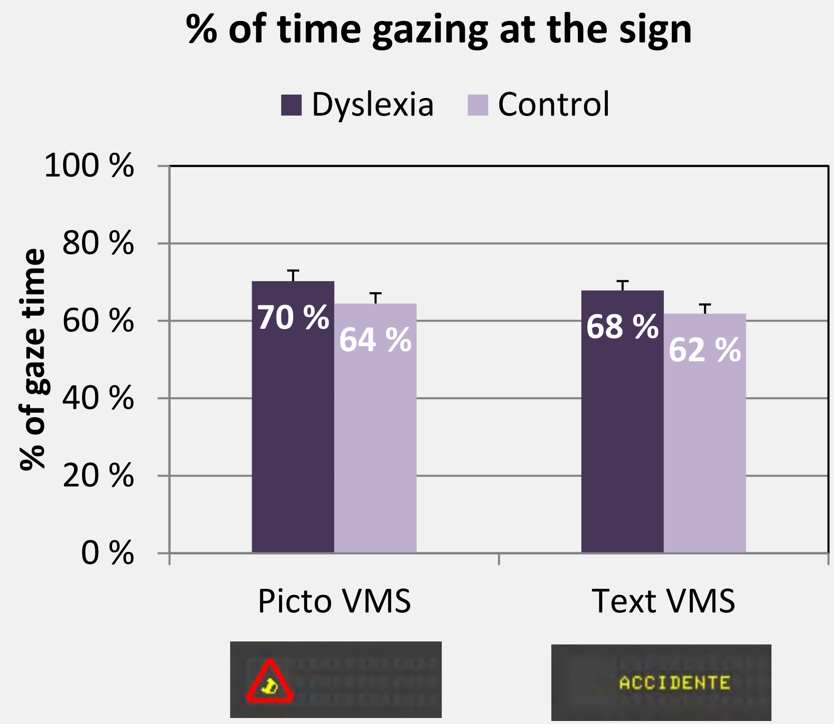
Reading performance measures



- Drivers with dyslexia **had to be closer to the variable message sign** to correctly read the previously trained, repeatedly presented words (*p* = .005).
- **Accuracy was high for both groups** (>95%) and no significant differences were reported between them.

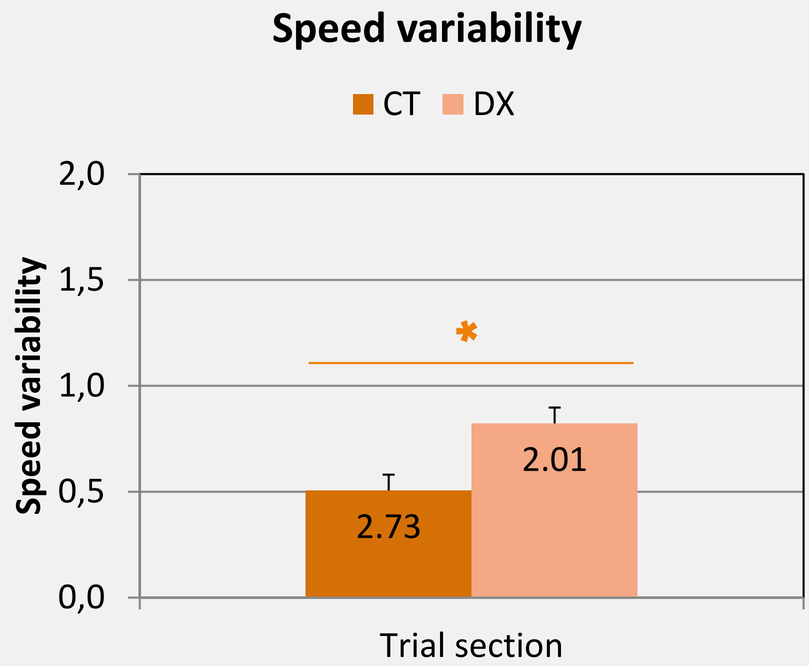
Eye-tracking measures





- **Drivers with dyslexia** dedicated a **more gazes to the text VMS** ($p < .001$) **and gaze time percentage** tended to be higher ($p = .09$).

Driving performance measures



- Adults with dyslexia found **more difficult to keep a constant speed (*p* = .005) inside the trial sections**, i.e. where they were approaching a traffic sign and were trying to read the content.
- The ability to keep a constant speed is **similar in both groups (*p* > .10) outside the trial sections**, i.e. when drivers were not required to read.

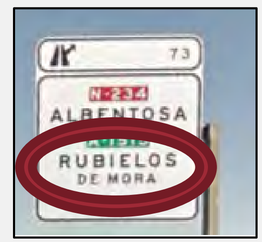
Conclusions

- **Which factors are influencing reading performance on the road (e.g. lexical factors)?**
  - **Word frequency** significantly affects reading distance, accuracy, gaze number, and gaze percentage in drivers with and without reading impairment.
  - The influence of **word length** is also significant and it affects reading distance and the number of gazes, but not the accuracy (except in dyslexia) nor the gaze time percentage
- **Do adults with dyslexia struggle to read while driving a vehicle?**
  - Adults with dyslexia **seem to be in disadvantage** when they have to read traffic signs, as compared to control drivers:
    - They make **more errors,** particularly with infrequent and long words, and
    - They **have to be closer** to read correctly long words.
- **Are their reading difficulties impairing their driving ability?**
  - They show **impaired speed control** when they are approaching a traffic sign and trying to read it, **which suggest increased cognitive load**.

Conclusions

- And **how can we help drivers with dyslexia?**
    - **Cognitive ergonomics measures to achieve a more inclusive design of traffic signs** (e.g., there are many examples in which word length and frequency were not carefully considered to decide the content of traffic signs).

    - **Recommendation of specific cognitive strategies while driving** (e.g. getting familiar with the route in advance)



    - **In-vehicle devices to advance or complement the information provided by traffic signs,** including variable message signs.

    - **Automated driving** as a measure to reduce cognitive overload.

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