

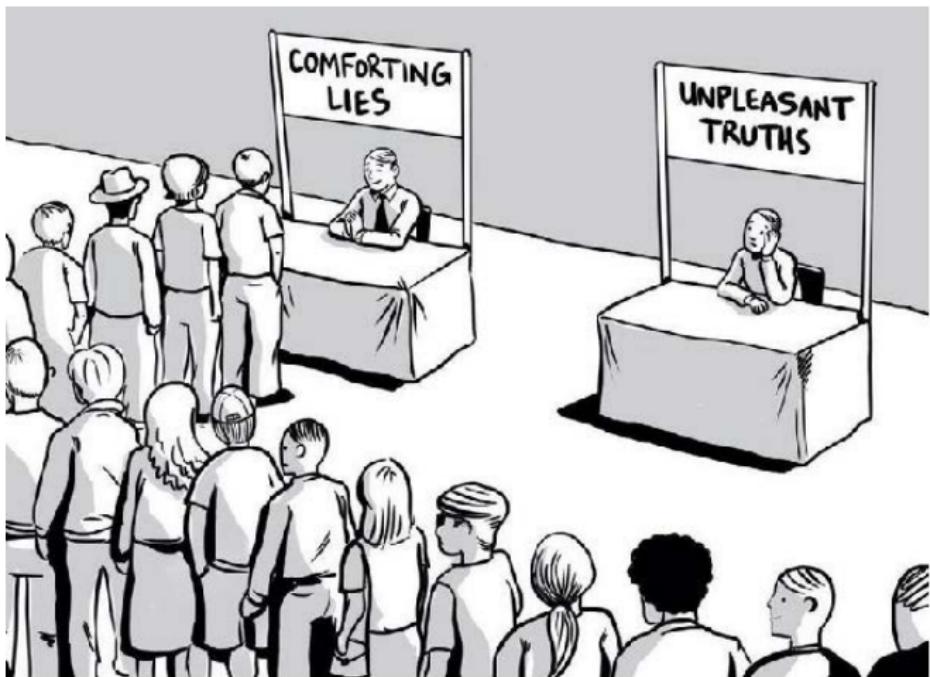
# Dealing with uncertainty in developmental psychology: the multiverse approach

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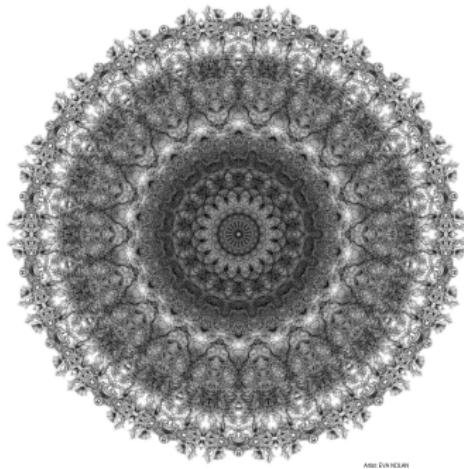
# Any datum is not for granted

## **data**

is the plural form of the Latin word *datum*,  
which means the 'thing given'

# The garden of forking paths

- Do we *find, collect, and observe data?*
- Or do we *build and shape dataset as a function of specific analysis?*



- when such sophisticated choices are not shared with the scientific community, it is impossible to reproduce the analysis pipeline and replicate results (Munafo et al., 2017).

# The garden of forking paths

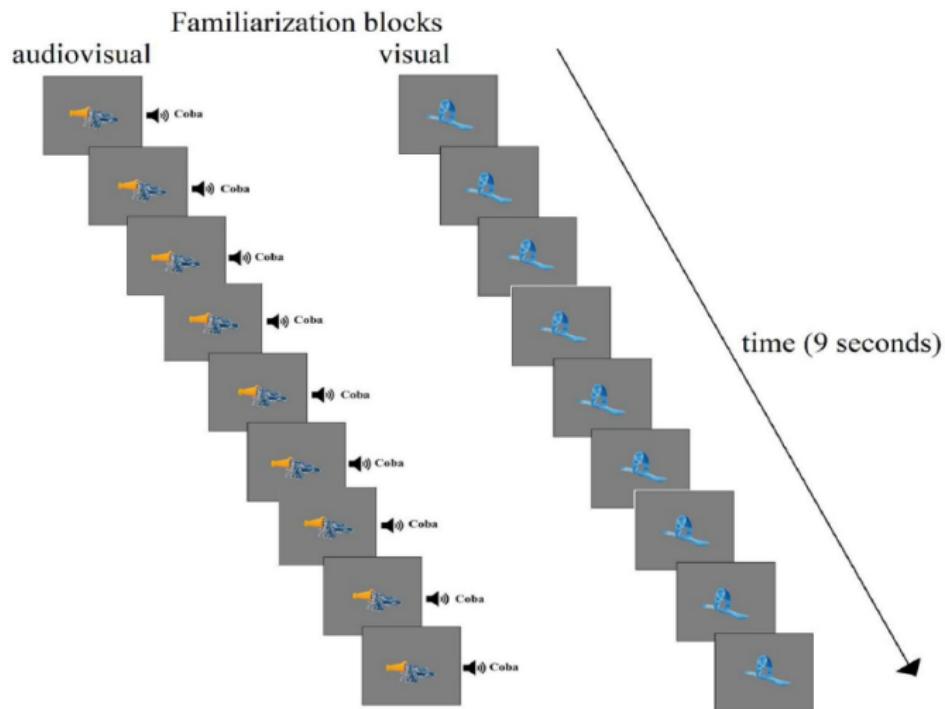
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## First steps into the pupillometry multiverse of developmental science

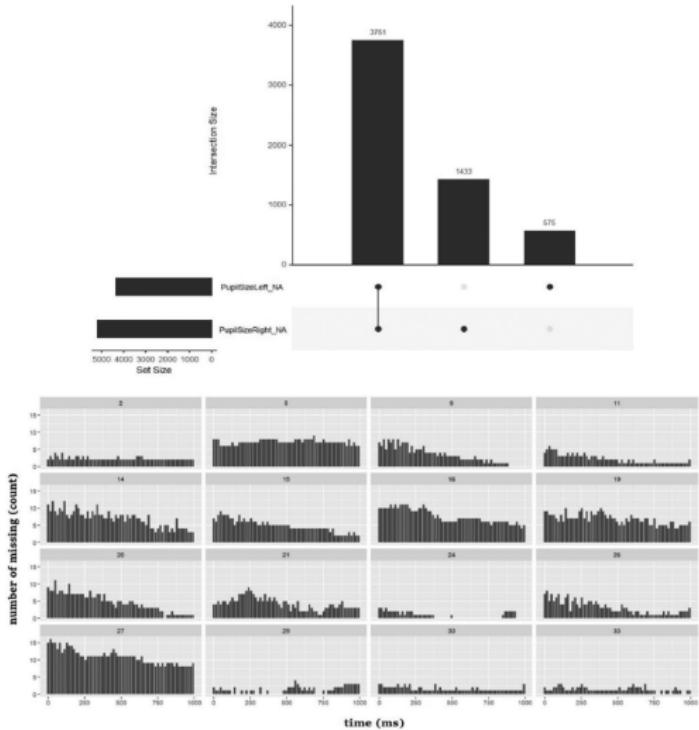
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[Giulia Calignano](#) , [Paolo Girardi](#) & [Gianmarco Altoè](#)

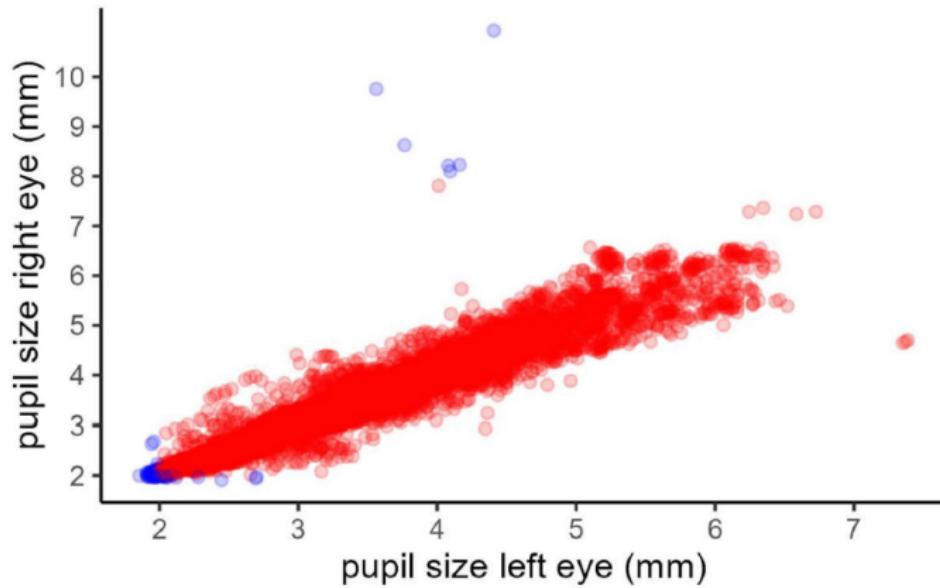
# An illustrative example



# Are missing... data?

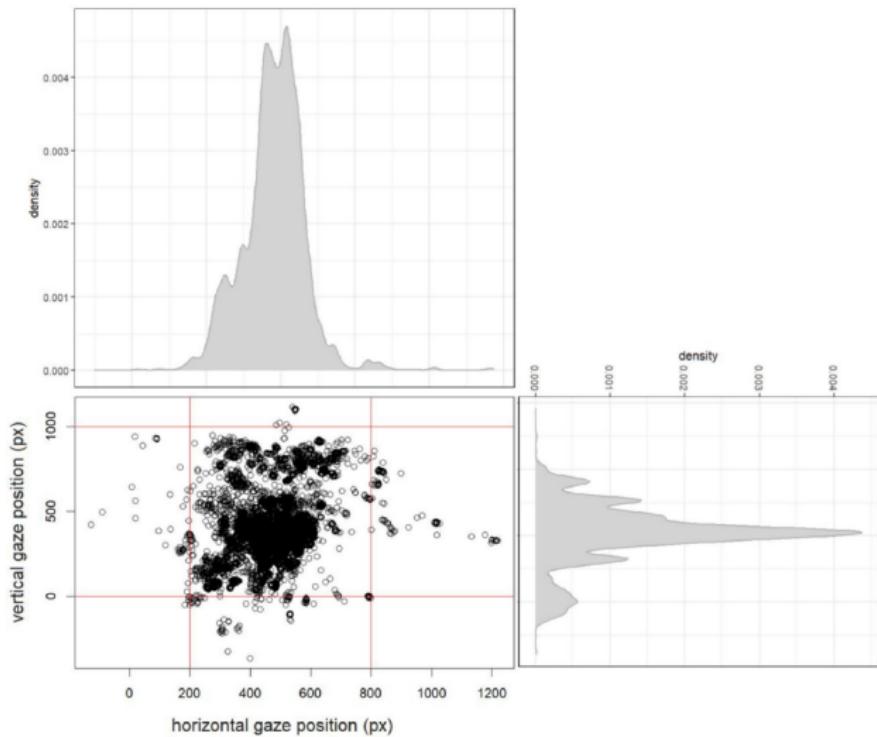


# Degrees of freedom (1) Data filtering



**Fig. 3** Scatter plot correlating left and right eye's pupil size. *Blue points* indicate the values excluded in the second filtered dataset (trimmed dataset)

## Degrees of freedom (2) Area of interest



# Degrees of freedom (3) Dealing with blinks

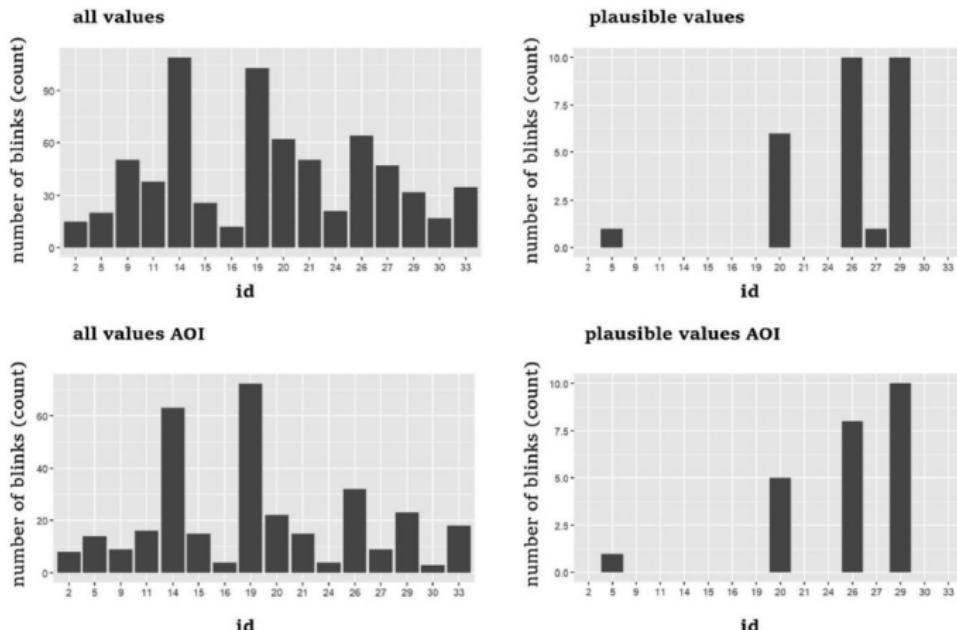
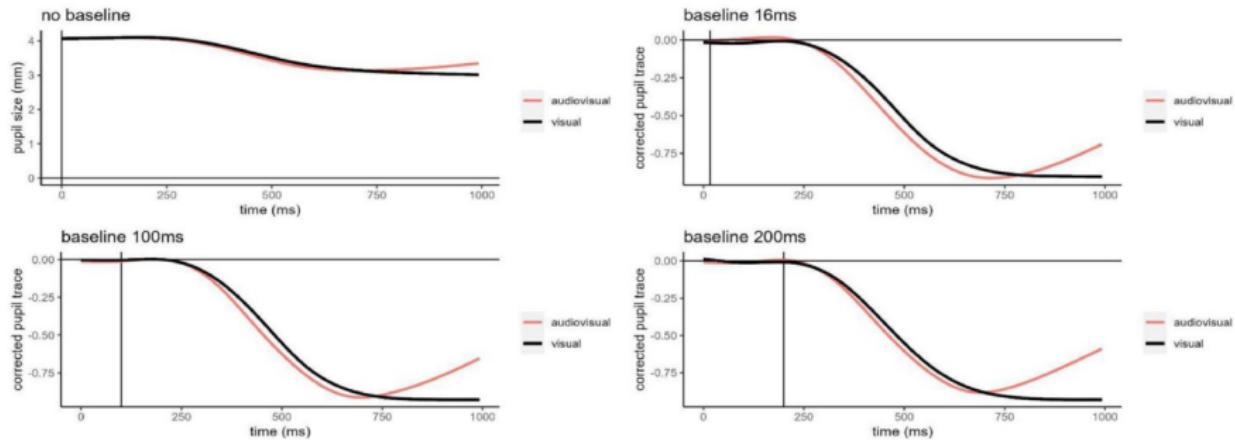


Fig. 5 Distribution of blink detected across the participants (id) in the four datasets, i.e., all values in the whole screen, plausible values in the whole screen, all values within the area of interest (AOI), plausible values within the AOI

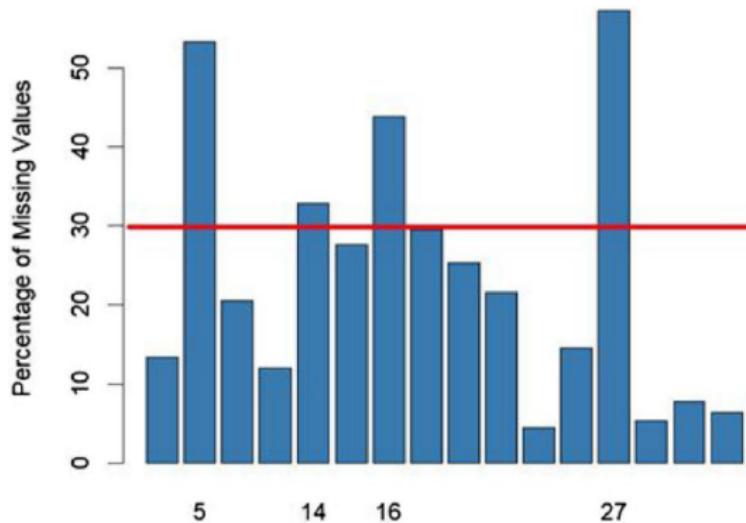
# Degrees of freedom (4) Baseline correction



**Fig. 6** Average pupil size variation (no baseline) and pupil changes relative to baseline (16, 100, and 200 ms) smoothed across time, we used the dataset with trimmed values filtered by the AoI and interpo-

lated blinks for illustrative purposes. The *red and black lines* represent the audiovisual and visual familiarization, respectively. The *vertical line* indicates the end of the baseline (when present)

## Degrees of freedom (5) Participants inclusion

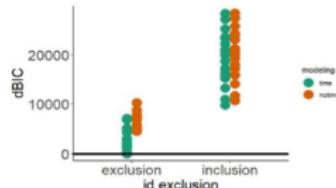
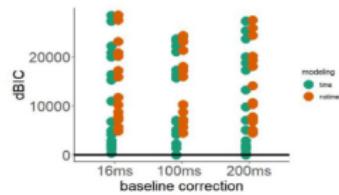
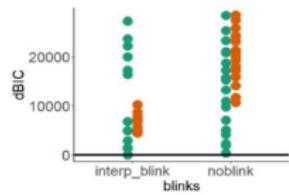
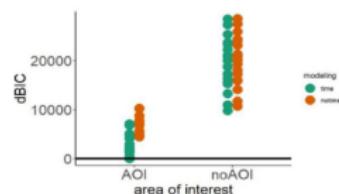
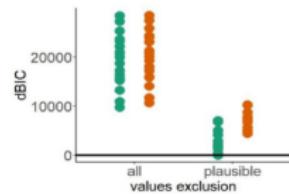


**Fig. 7** Percentage of missing values by subject (ID). The *red line* indicates the cut-off value. Note that all that only ID participants above the cut-off are shown in the x-axis

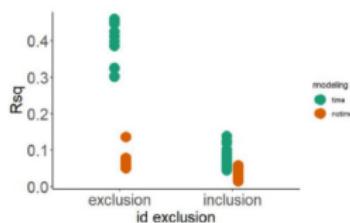
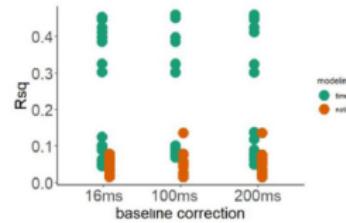
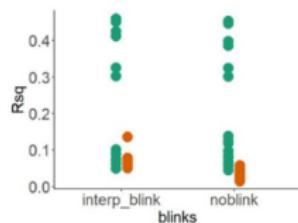
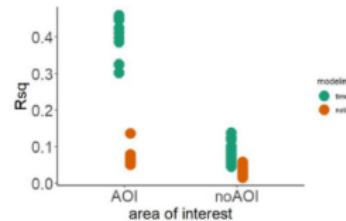
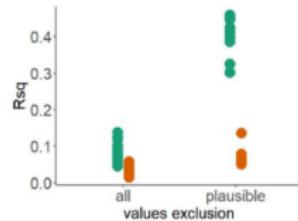
# Degrees of freedom (6) A multiverse of models

$$Y = \alpha + \beta X + g1(X, \text{id}) + \varepsilon$$

$$Y = \alpha + \beta X + g1(t, X) + g2(t, \text{id}) + \varepsilon$$

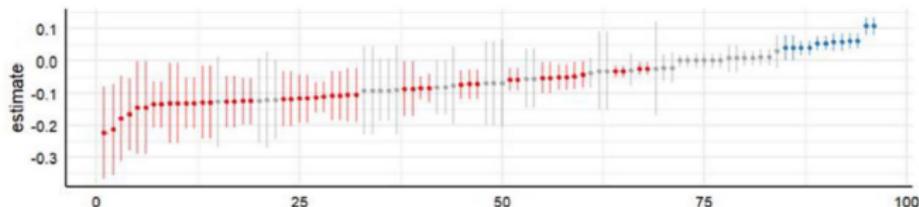


# Degrees of freedom (6) A multiverse of models

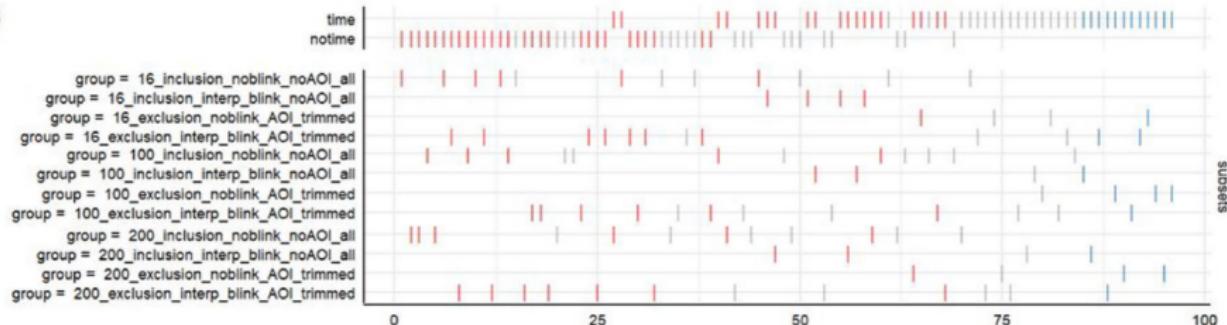


# Degrees of freedom (6) A multiverse of models

A



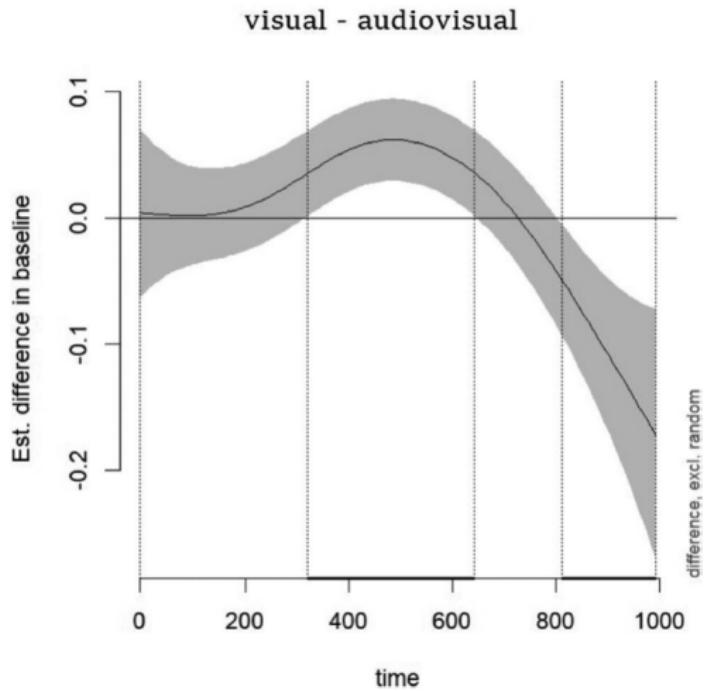
B



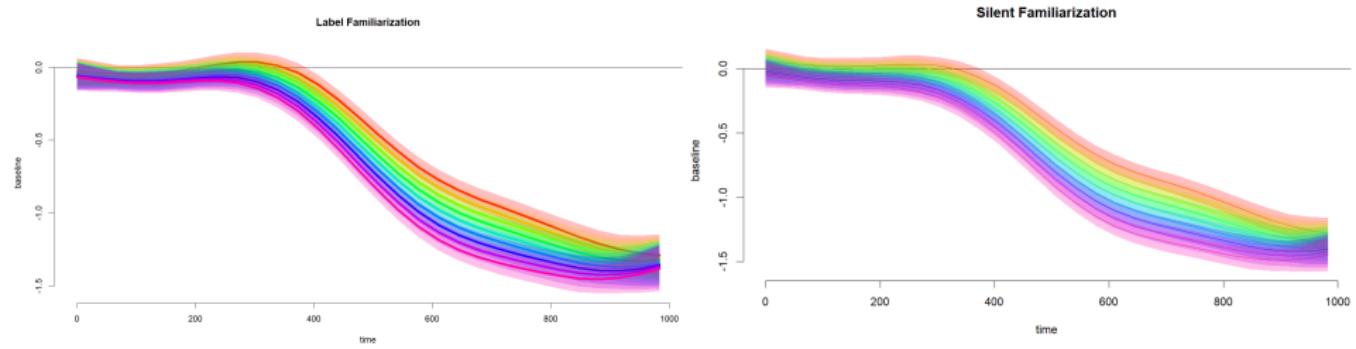
**Fig. 9** A The 96 coefficient's estimates and relative 95% CI related to the Visual vs. Audiovisual regressor. B Relative combinations by the six degrees of freedom of the multiverse analysis. The direction of the significant results are highlighted (negative = red, positive = blue, gray = non-significant). Note that positive estimates (in blue) indicate

higher pupil dilation for the Audiovisual condition and negative estimates (in red) indicate higher pupil dilation for the Visual condition. The x-axis represents the model number, while the y-axis represents the estimated coefficient

## Degrees of freedom (6) A multiverse of models



# Degrees of freedom (6) A multiverse of models



# Final considerations

- **No practice leads to perfectly clean data**, yet it is fundamental to show the impact of preprocessing on statistical results (Steegen et al., 2016; Dragicevic et al., 2019)
- Pupillometry is a useful indirect measure of **the time course** of attention since infancy (Blaser et al., 2014; Brisson et al., 2013; Sirois Jackson, 2012; Tamasi et al. 2016)
- Statistical models that allow to evaluate *how* and *when* an effect emerge is fundamental in cognitive development (more than p-value)
- Statistical significance **is not useful at all when taken alone**
- multiverse analysis address **robustness** and avoid p-hacking
- Embracing (rather than being afraid of) the inherent uncertainty of infant data **increase our understanding of individual differences in developmental pathways of attention, learning processes, and beyond.**

# Open data materials

The screenshot shows the OSF Storage interface for the project 'First steps into the pupillometry multiverse'. The top navigation bar includes 'OSF HOME', 'My Projects', 'Search', 'Support', 'Donate', and a user profile for 'Giulia Calignano'. Below the navigation is a toolbar with 'Edit', 'Make Private', 'Public', and other options. The main content area displays the project details: 'First steps into the pupillometry multiverse of developmental science' by Giulia Calignano, created on 2021-10-31 at 12:05 AM and last updated on 2023-04-29 at 05:29 PM. It has a DOI of 10.17605/OSF.IO/PBMH. The category is 'Methods and Measures'. A detailed description follows:

Abstract: This paper aims to introduce cognitive functioning in infancy. We more specifically studied the behavior of infants in the first theoretical levels of architecture before performing a pre-processing before statistical analysis. By means of an illustrative example, we checked the robustness of the results of a factorization procedure that compared the impact of additional and visual stimuli in 12-month-olds. We adopted a multivariate approach to pupillometry data analysis to explore the role of (i) the preprocessing phase, that is, handling of extreme values, selection of the areas of interest, management of outliers, baseline correction, participant inclusion/exclusion and (ii) the modeling invariance that is, the incorporation of intercepts, fixed and random effects structure, in guiding the parameter estimation. The equivalence of analyses shows how the preprocessing steps influenced the regression results, and when visual stimuli playfully predicted an increase of resource allocation compared with additional stimuli. Importantly, shrinking time in statistical models increased the plausibility of the results compared to those nested models that do not weigh the impact of time. Finally, we share theoretical and methodological tools to move the first steps into rather than being all off the interest uncertainty of infant pupillometry.

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The storage interface lists files under the project folder:

- First steps into the pupillometry multiverse of developmental science
- OSF Storage (Germany - Frankfurt)
- Code
  - figure\_paper\_multir.R (2023-06-28 05:54 PM)
  - Hierarchical\_structure\_multiverse.R (2023-06-28 05:54 PM)
  - pupillometry\_multiverse.R (2023-06-28 05:54 PM)
  - Specification\_Curve\_Multiverse.R (2023-06-28 05:54 PM)
- DATA
  - DATA\_dictionary.txt (2023-10-31 12:22 AM)
  - missing.csv (2023-05-13 04:59 PM)
  - multiverse.csv (2023-10-31 12:22 AM)
  - spec.csv (2023-09-31 04:54 PM)
  - README.txt (2023-06-28 05:27 PM)
- RESULTS

and we are working on an R package and a shiny app dedicated to developmental psychologist ;)



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