

Validation of an evidence accumulation model for driver readiness in assisted driving using driver ocular metrics

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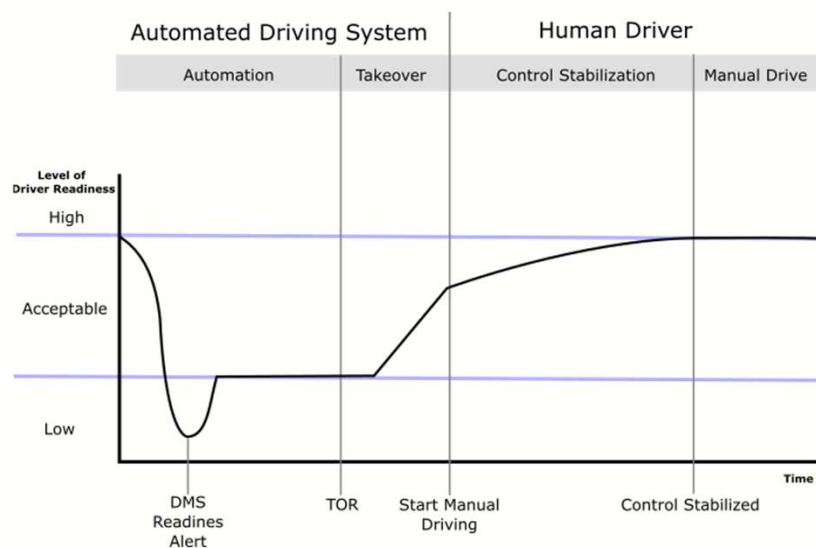
**seeing
machines**

DMS and readiness



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By using a DMS, OEMs can mitigate misuse, and somewhat ensure drivers are in a desirable state to perform a reaction with a high probability of a timely, and safe resolution of a potential hazardous situation (Mariajoseph, 2020).



Kim et al., 2021



“An **abstract** concept that represents the cognitive and motoric **resources** available to drivers for **resuming control** of the driving task” (Kim et al, 2021)

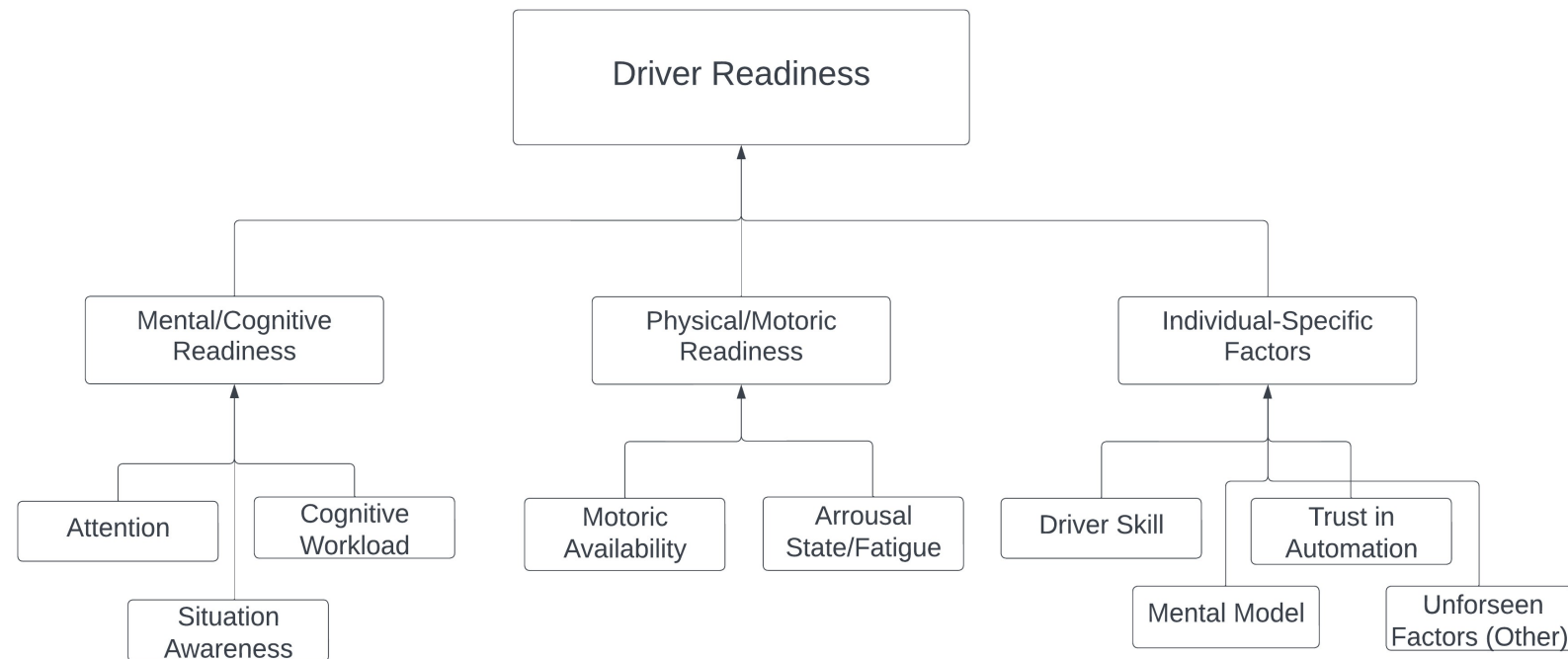
Issues with readiness estimation



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Readiness is a complex combination of several constructs interacting together

Not directly observable, nor experimentally controllable



Goncalves et al., 2024 (Adapted from Mioch et al., 2017)

Different people in an experimental setup won't ever have the same level of readiness, so we need to model performance based on inter-trial variability.

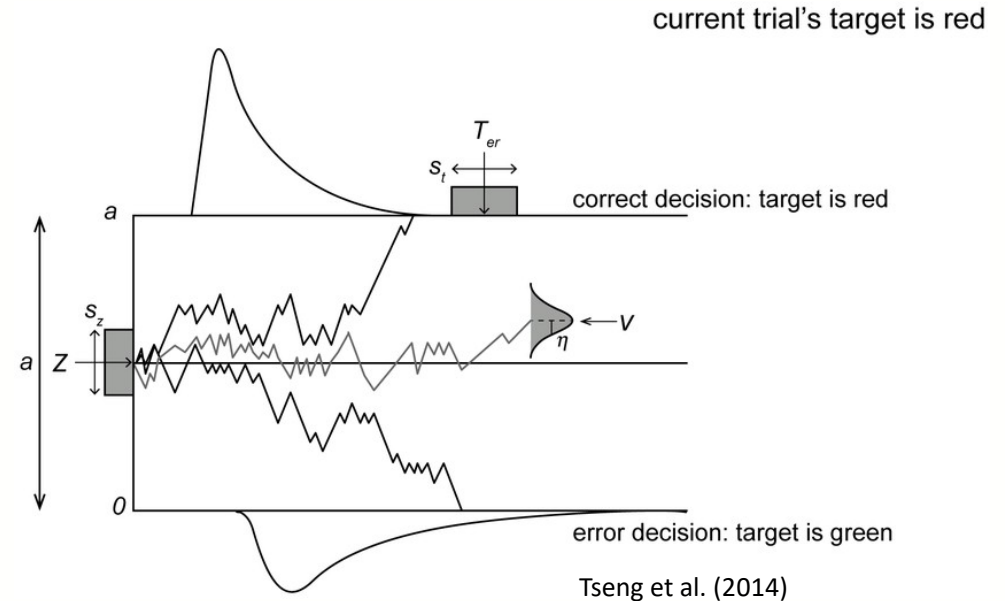
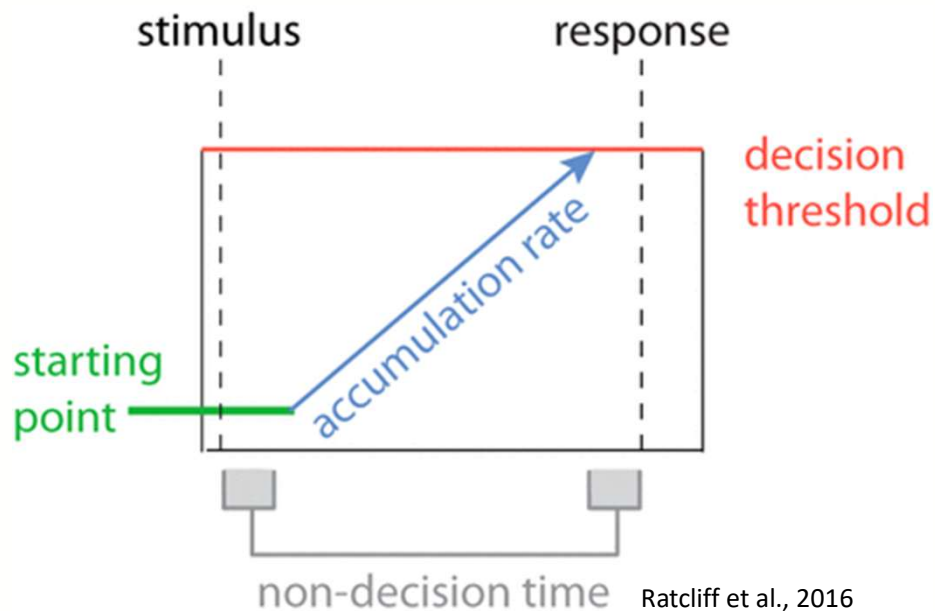
Modelling driver readiness



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EAMs assume that every decision has a **threshold of Evidence** that needs to be gathered, to trigger a response (Ratcliff, 2008).

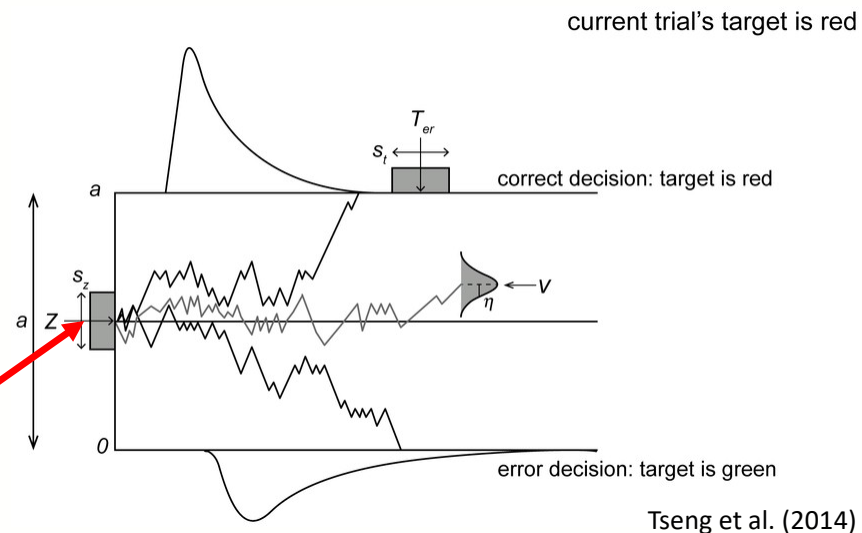
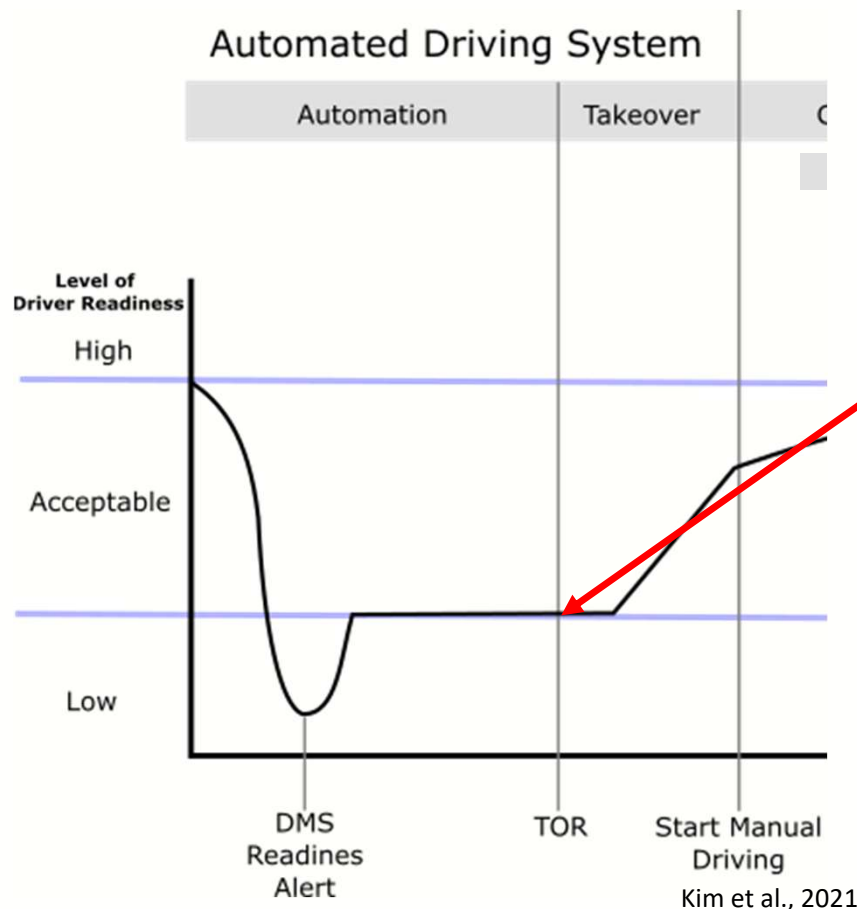
This evidence accumulation process **is noisy** and may explain **inter-trial variability**.



Modelling driver readiness



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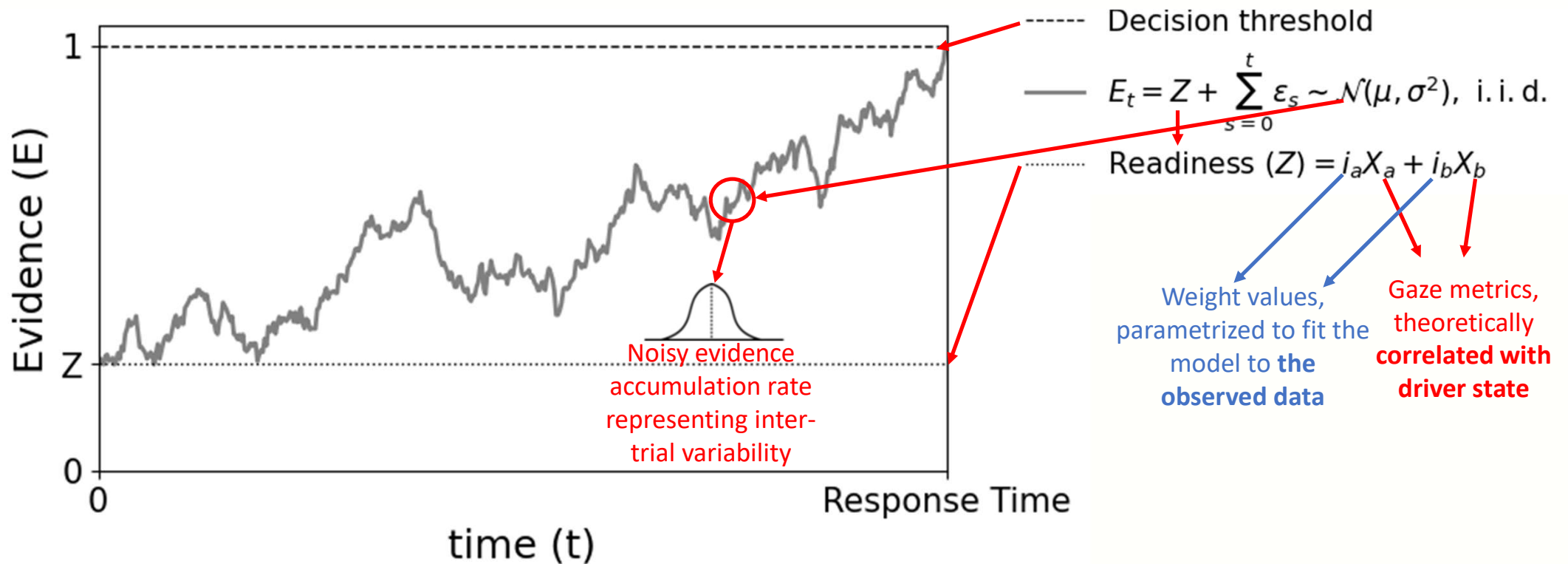


If we understand readiness as the **evidence accumulated by the time of the criticality**, we can use **inter-trial variability** to understand the relationship between readiness **indicators** and reaction **performance**.

Modelling driver readiness



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Initial Proof of concept



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Cognition, Technology & Work
<https://doi.org/10.1007/s10111-024-00777-3>

ORIGINAL ARTICLE



Using driver monitoring to estimate readiness in automation: a conceptual model based on simulator experimental data

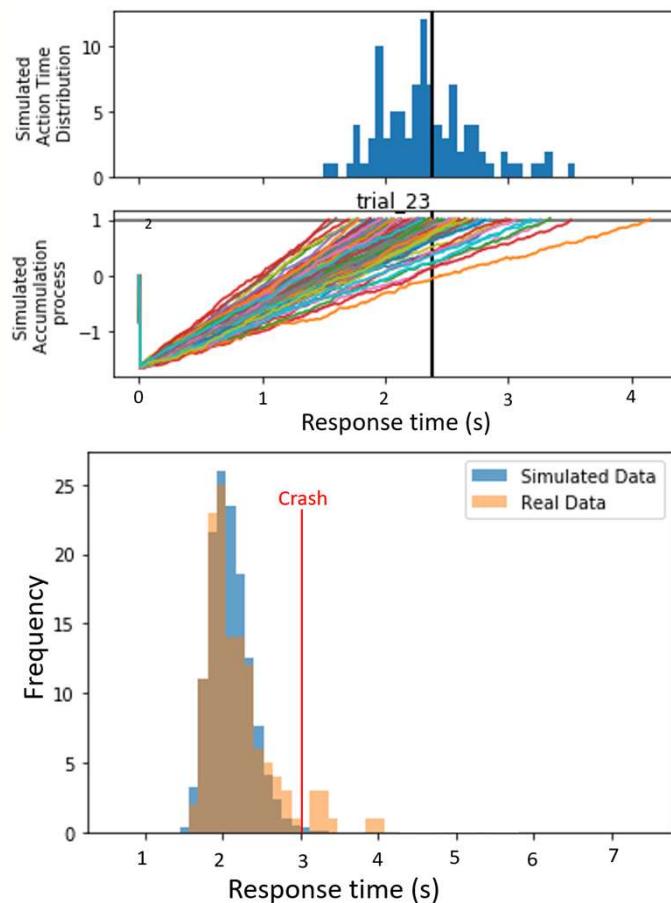
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Abstract

This paper provides a theoretical overview of how the concept of driver readiness can be objectively measured, using controlled experimental data. First, a literature review regarding the concept of driver readiness is provided. Then, it highlights challenges for a standardized readiness estimation model. A conceptual readiness estimation model is presented, and a methodology is proposed for defining readiness thresholds for use by Driver State Monitoring (DSM) systems. The paper then explores how this model can be used to estimate readiness thresholds. A proof of concept for the model application is presented, using previously collected experimental involving SAE Level 2 automation. This paper contributes to the state of the art in DSM-development, by providing a methodology for estimating driver readiness, while considering variabilities across individual drivers. The model also allows readiness thresholds to be defined with data from driving simulator experiments, without relying on subjective assessment of readiness as its ground truth.

Keywords Vehicle automation · Driver readiness · Computational modelling · Evidence accumulation · Driver state monitoring



Research overview



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The objective of the present study was to test the validity of the concept of readiness as an accumulation of resources towards a resumption of control from assisted driving, for drivers under different driver states, and its association with different DMS-based ocular metrics.

- Can the level of driver readiness, as an accumulation of resources, be associated with their capability to safely resume control of the driving task?
- What metrics of a DMS are correlated with drivers' readiness?

To achieve this goal, the model was fit to a driving simulator dataset, containing responses to safety-critical transitions of control under different controlled variations of driver state impairment.

Experimental Design



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3X2X2 Mixed design (N = 32):



2-Back



3/6 occlusion



Both



Night-shift



TTC=3



TTC=4



General pop



5.....

Data Analysis: Ocular Metric Selection



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The DMS ocular metrics used for readiness calculation were those previously associated with one of our driver state manipulations.

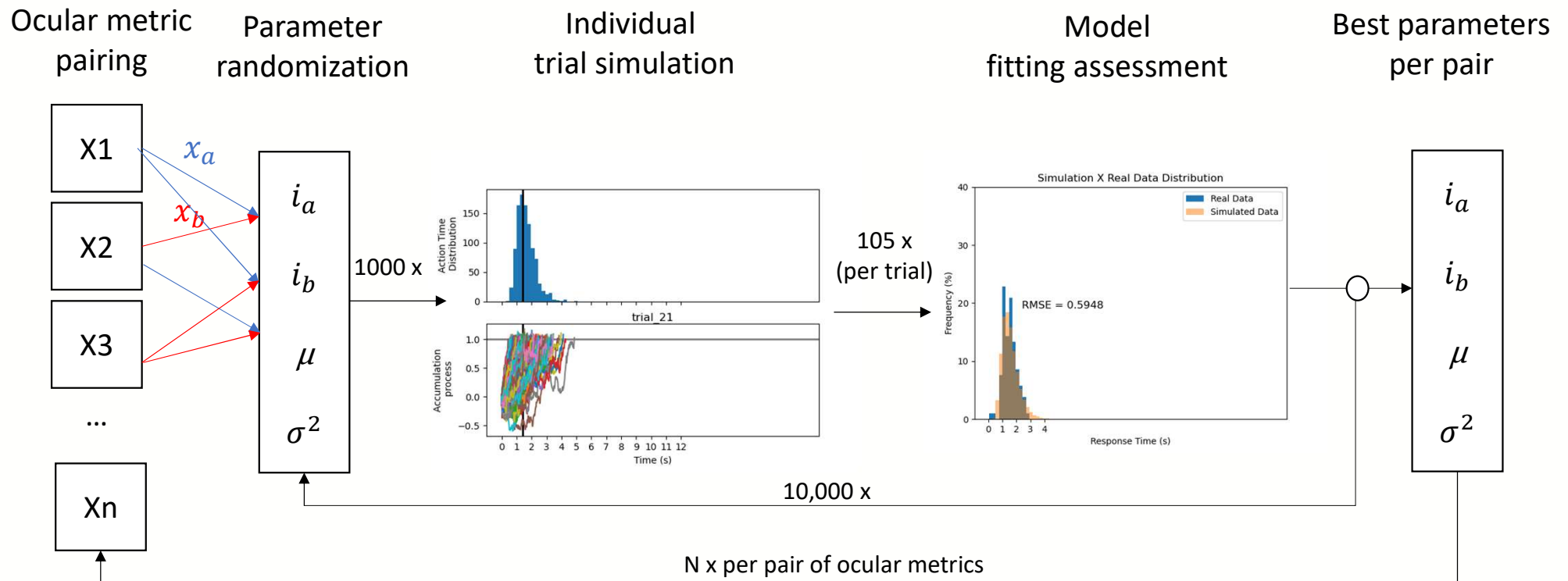
This presentation will only focus on data of the best-fitting model, but a full comprehensive list of fitted models will be available on an online repository.

DMS Ocular Metric	Reference	Proxy
Dwell time on road (s)	Euro NCAP (2023)	Visual distraction
Dwell time driver mirror (s)	Euro NCAP (2023)	Visual distraction
Dwell time off road (s)	Euro NCAP (2023)	Visual distraction
Dwell time instrument cluster (s)	Euro NCAP (2023)	Visual distraction
Gaze transition rate towards on road (percentage)	Schenebelen et al. (2019)	Situation awareness
Gaze transition rate towards driver mirror (percentage)	Schenebelen et al. (2019)	Situation awareness
Gaze transition rate towards off road (percentage)	Schenebelen et al. (2019)	Situation awareness
Gaze transition rate towards instrument cluster (percentage)	Schenebelen et al. (2019)	Situation awareness
Vertical gaze dispersion (degrees)	Engström et al. (2017)	Visual distraction, cognitive load, situation awareness
Horizontal gaze dispersion (degrees)	Engström et al. (2017)	Visual distraction, cognitive load, situation awareness
PERCLOS (percentage)	Kuo et al. (2019)	Fatigue
Blink amplitude/velocity ratio (AVR, ms)	Johns (2003)	Fatigue
Gaze stationary entropy (percentage)	Shifferaw et al. (2019)	Cognitive load

Data Analysis: Model Fitting



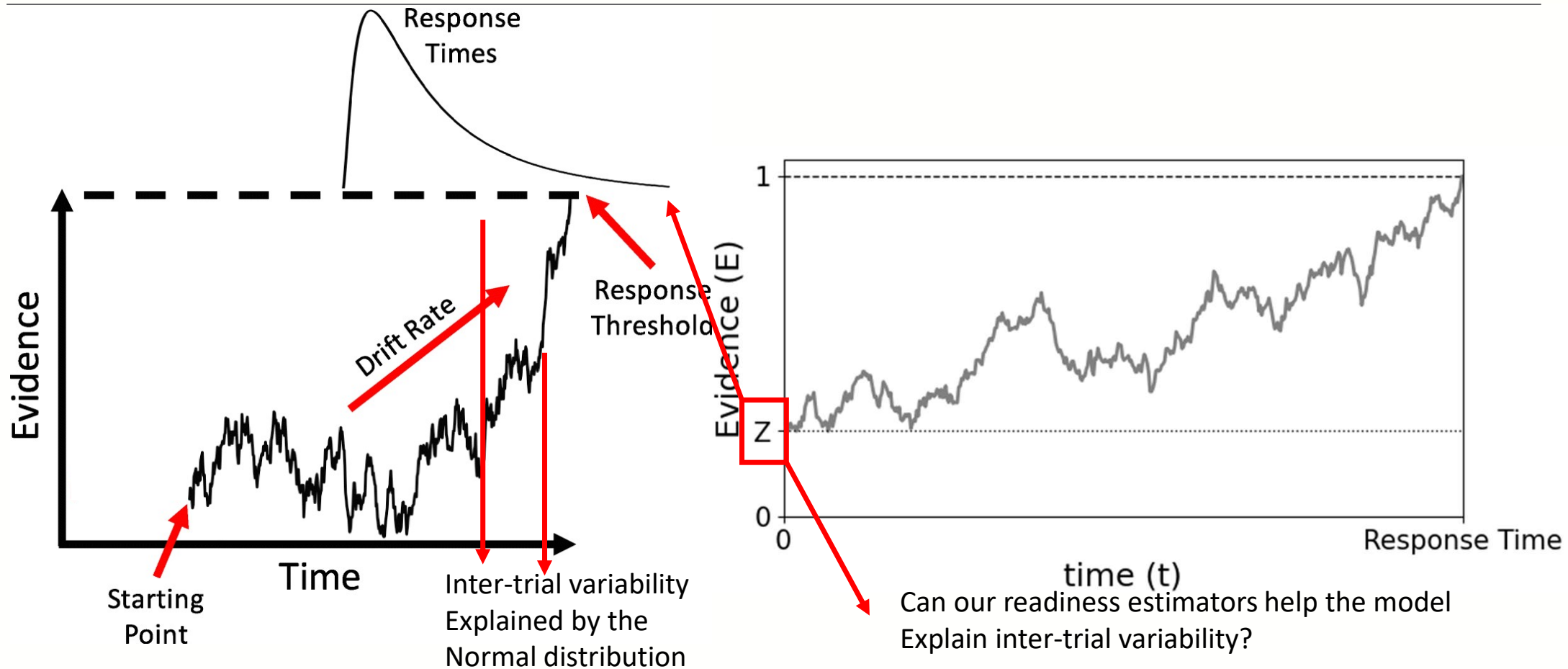
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Data Analysis: Model Validation



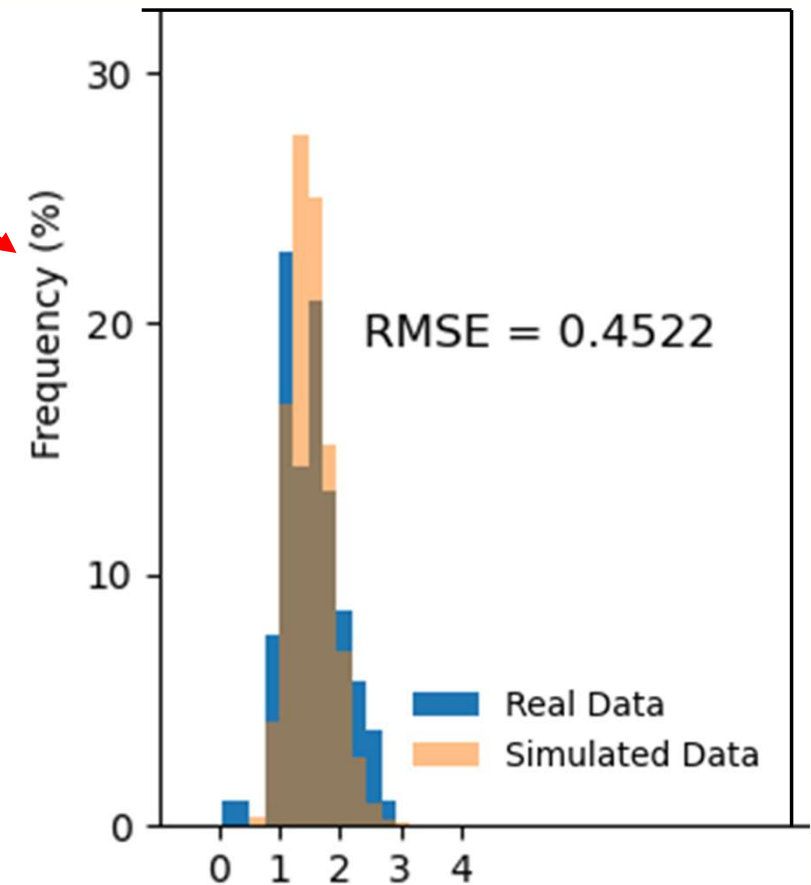
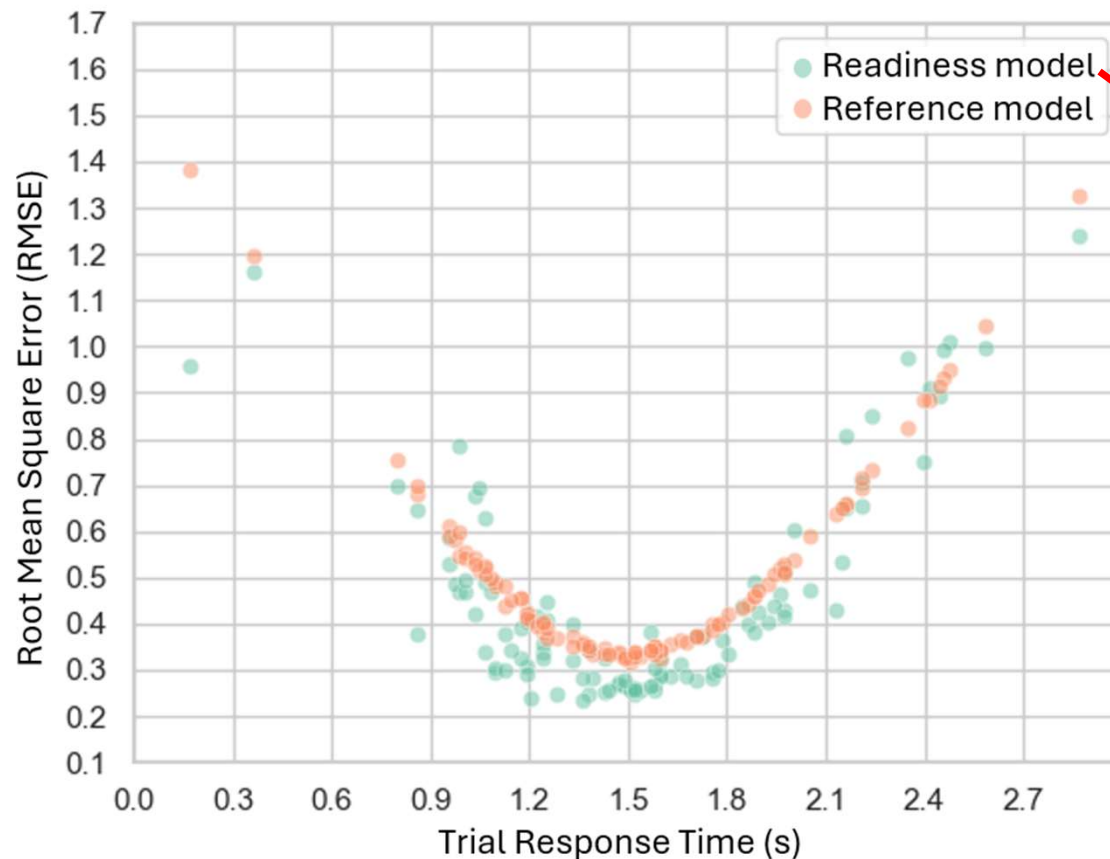
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Dwell Time Off Road + Gaze Entropy



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Dwell Time Off Road + Gaze Entropy

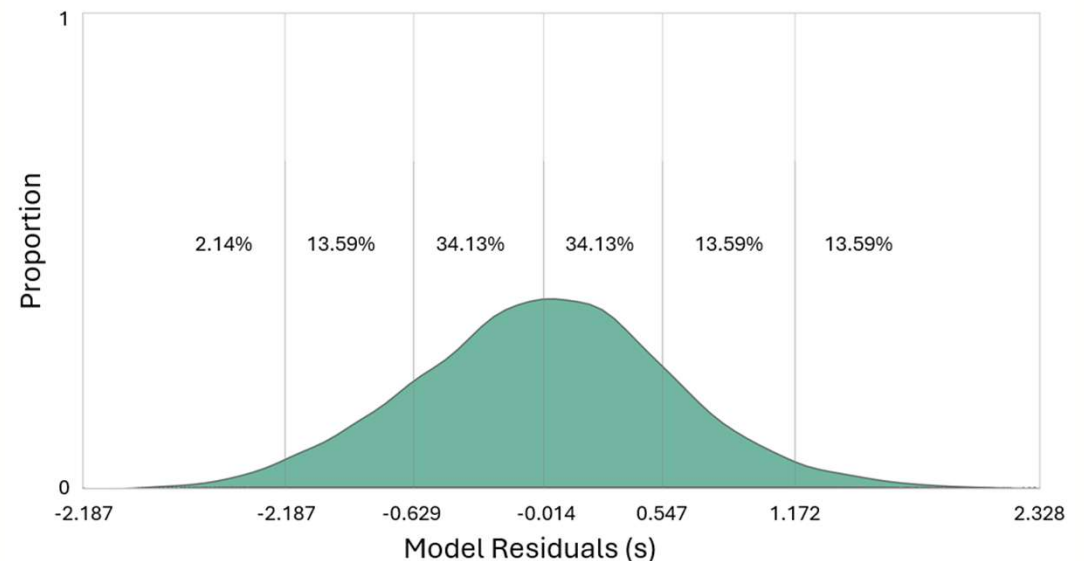


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- **Comparative Performance:**
 - Residual reduction: 0.053s (10.495%)
 - AIC-C (delta = 7.717, p = 0.021)
- **Practical application considerations:**
 - Residual improvements suggests that readiness estimators seem to explain a small, but significant part of the phenomenon. With slightly negative skew in the residual distribution.
 - Majority of the residuals floating ~ -.62 to 0.55 s, and improvements are not significant, on an applied safety point of view.

Mean = 0.0126, SD = **0.237**

Gaze entropy = -0.0365, Dwell time off road = -0.0817



Significant comparative improvements in the model suggest theoretical value of those indicators. But on a practical point of view, those indicators are not enough to provide an accurate prediction of safety outcomes.

Conclusion



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- Can the level of driver readiness, as an accumulation of resources, be associated with their capability to safely resume control of the driving task?

The relationship seems to be minor, but the model can explain safety outcomes, to a certain degree. This proves that readiness is indeed **theoretically related to performance** but **may not be the only factor affecting ones' performance**.

- What metrics of a DMS are correlated with drivers' readiness?

It seems like **offroad-glance metrics** are promising readiness indicators in a linear way. However, other metrics generally associated with **cognitive load** also seem to be significant.



Thank you

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