A Predictive Model of the Visual Demand Associated with In-Vehicle Touchscreens

David Large*, Gary Burnett*, Lizzie Crundall*, Editha van Loon*, Ayse Eren*, Lee Skrypchuk**

*Human Factors Research Group, University of Nottingham
** Jaguar LandRover HMI Research

gary.burnett@nottingham.ac.uk

Overview of talk

- Concerns over visual demand for in-vehicle HMIs
- Commonly used human factors methods for evaluating visual demand
- Modelling visual demand
  - The benefits
  - A novel approach with equations*
- Validating the approach
- Future work issues

* Large, D. R., Burnett, G., Crundall, E., van Loon, E., Skrypchuk, L. (2017, accepted) Developing Predictive Equations to Model the Visual Demand of In-Vehicle Touchscreen HMIs. *International Journal of Human Computer Interaction*

Defining Driver Distraction

- Driver distraction occurs when:
  - A driver is delayed in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task) (**Impact**)
  - Due to some event, activity, object or person, within or outside the vehicle (**Agent**)
  - That compels or tends to induce the driver's shifting attention away from fundamental driving tasks (**Mechanism**)
  - By compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof (**Type**).

* Pettitt, M.A., Burnett, G.E. and Stevens, A. (2005) Defining driver distraction. In Proceedings of *World Congress on Intelligent Transport Systems*. San Francisco, November 2005.

Some naturalistic driving data on secondary task distraction *

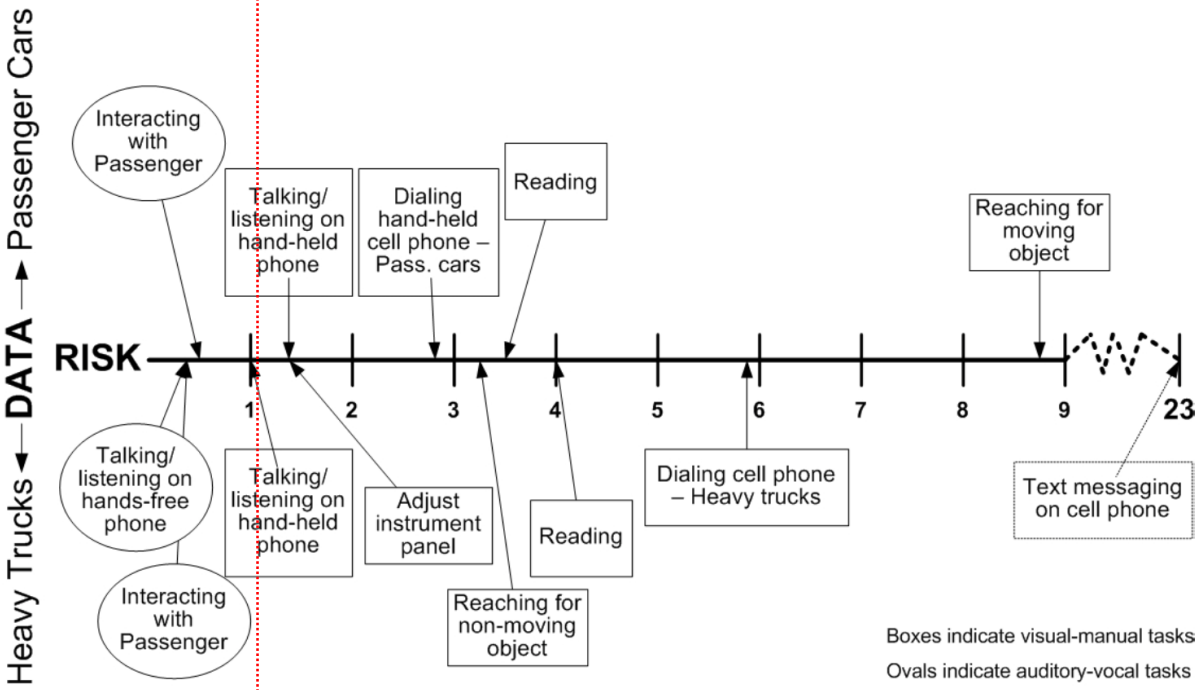
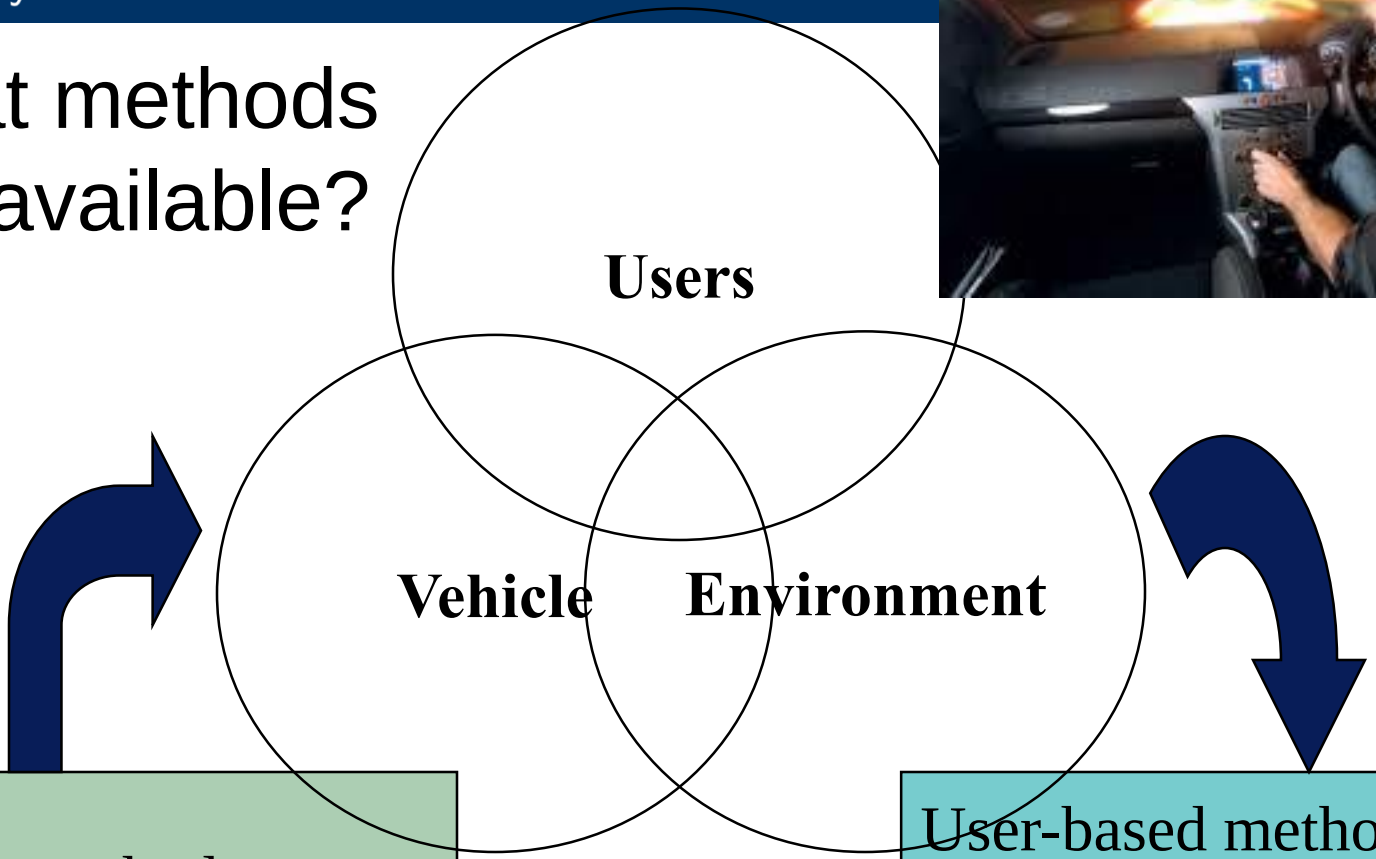


Figure 1: Risk Odds Ratios Determined by the 100-Car Study Analyses and Two Study FMCSA Analyses

* NHTSA. 2013. Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices. NHTSA-2010-0053

What methods are available?



Non-user methods, e.g.

- Guidelines/checklists
- Expert assessment
- **Modelling**

User-based methods, e.g.

- Focus groups
- Road trials
- **Simulator trials**
- **Occlusion**

Human Factors research with driving simulators

- Advantages:
  - Safe environment for research
  - Controlled environment for research (usually)
  - Cost-effective (usually)
- Issues:
  - Validity concerns (especially absolute)
  - Potential for ‘Simulator sickness’
  - Time to run studies/analyse data

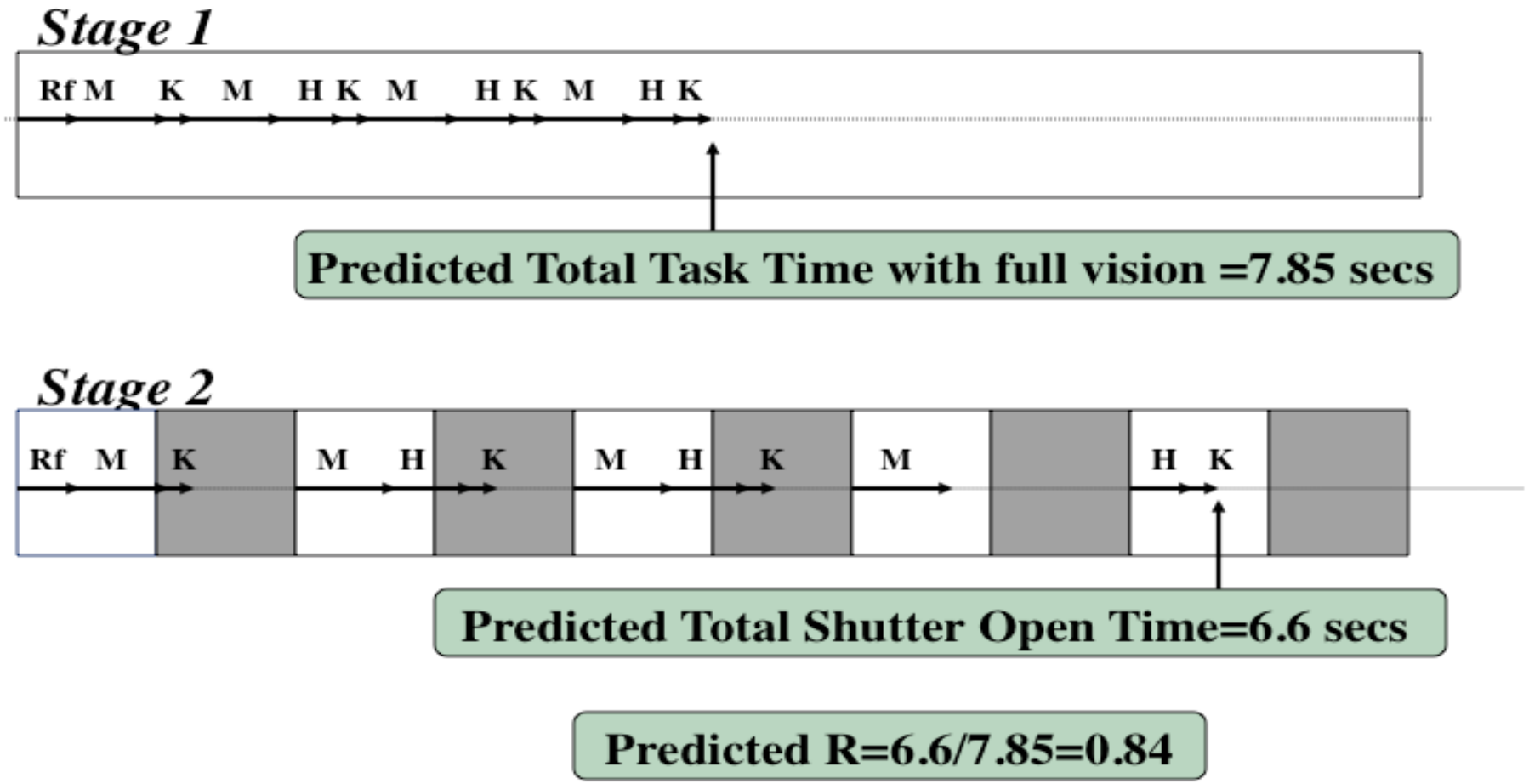
Occlusion method

- Method aims to assess visual-manual demand of user-interfaces
- Participant completes task with LCD goggles
- ISO standard (2007); also incorporated into NHTSA (2013) guidelines
  - Cycle of 1.5 secs open/1.5 secs closed
- Primary metric from method:
  - TSOT - Total Shutter Open Time
- Simpler approach than simulator studies, BUT
  - Still has validity issues
  - Still time-consuming to run studies
  - Needs robust prototypes for testing

An alternative way of understanding the visual demand of in-vehicle HMIs

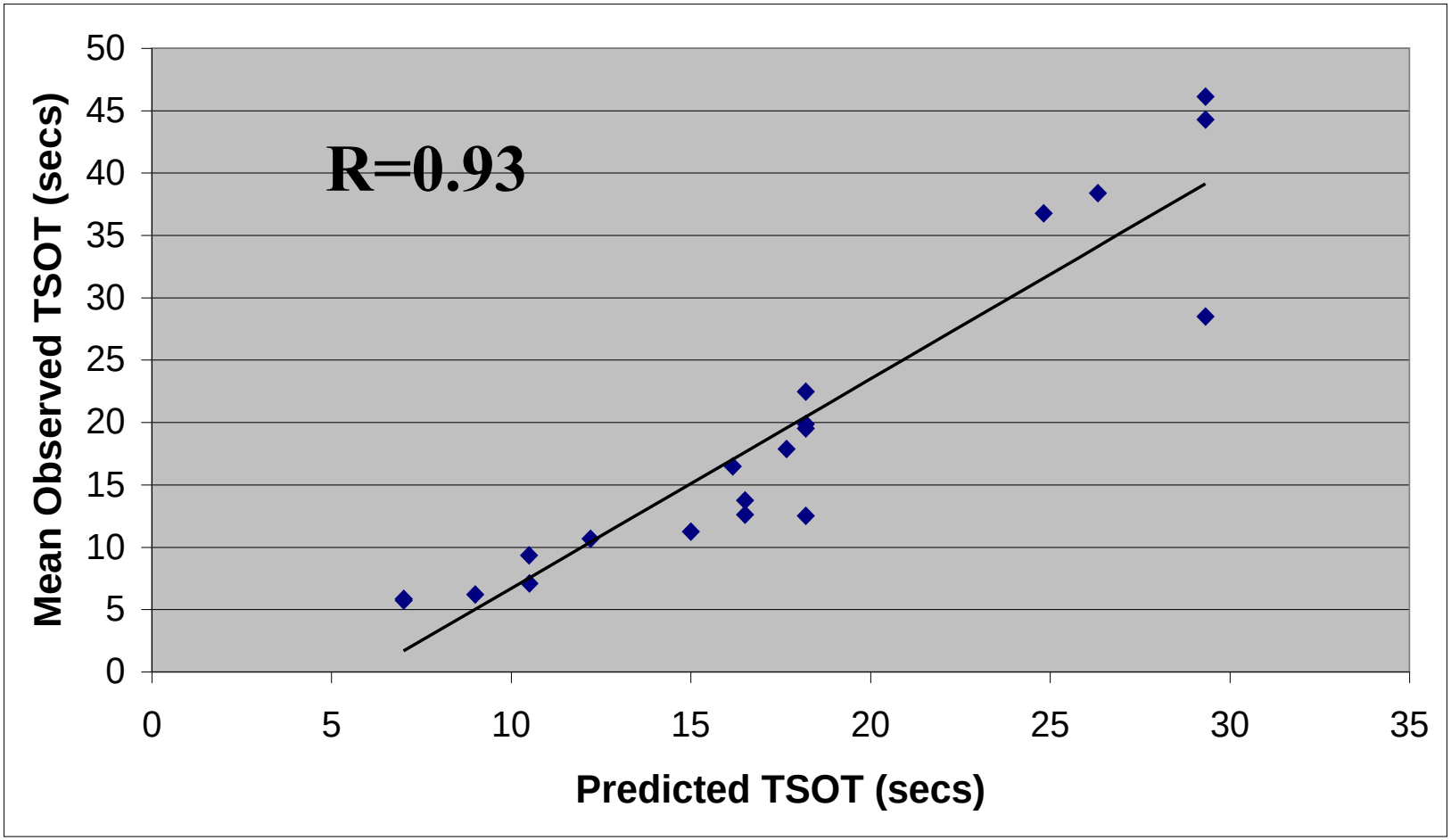
- Predictive/analytic modelling
  - *Cheap*!
  - Extremely useful for *rapid comparison* of designs *early* in design process
  - Can be used within *wireframe (lo-fidelity) prototyping* environments
  - "Reduce argument to *calculation*" (Raskin, 2000)
  - *Understanding* how a result has been reached is of benefit in its own right
  - Number of *different approaches* exist in the literature (e.g. CogTool, Distract-R, SEEV, CPA, **e-KLM,** etc.)

Earlier Approach - Modelling Occlusion using Keystroke Level Model*



* Burnett, G.E., Pettitt, M., Sharma, N., and Stevens, A (2011). Modelling and predicting the visual demand of in-vehicle information systems. *International Conference on Driver Distraction and Inattention*, Gothenburg

Some validity results - Observed and predicted TSOTs



A novel approach– Modelling visual demand when driving

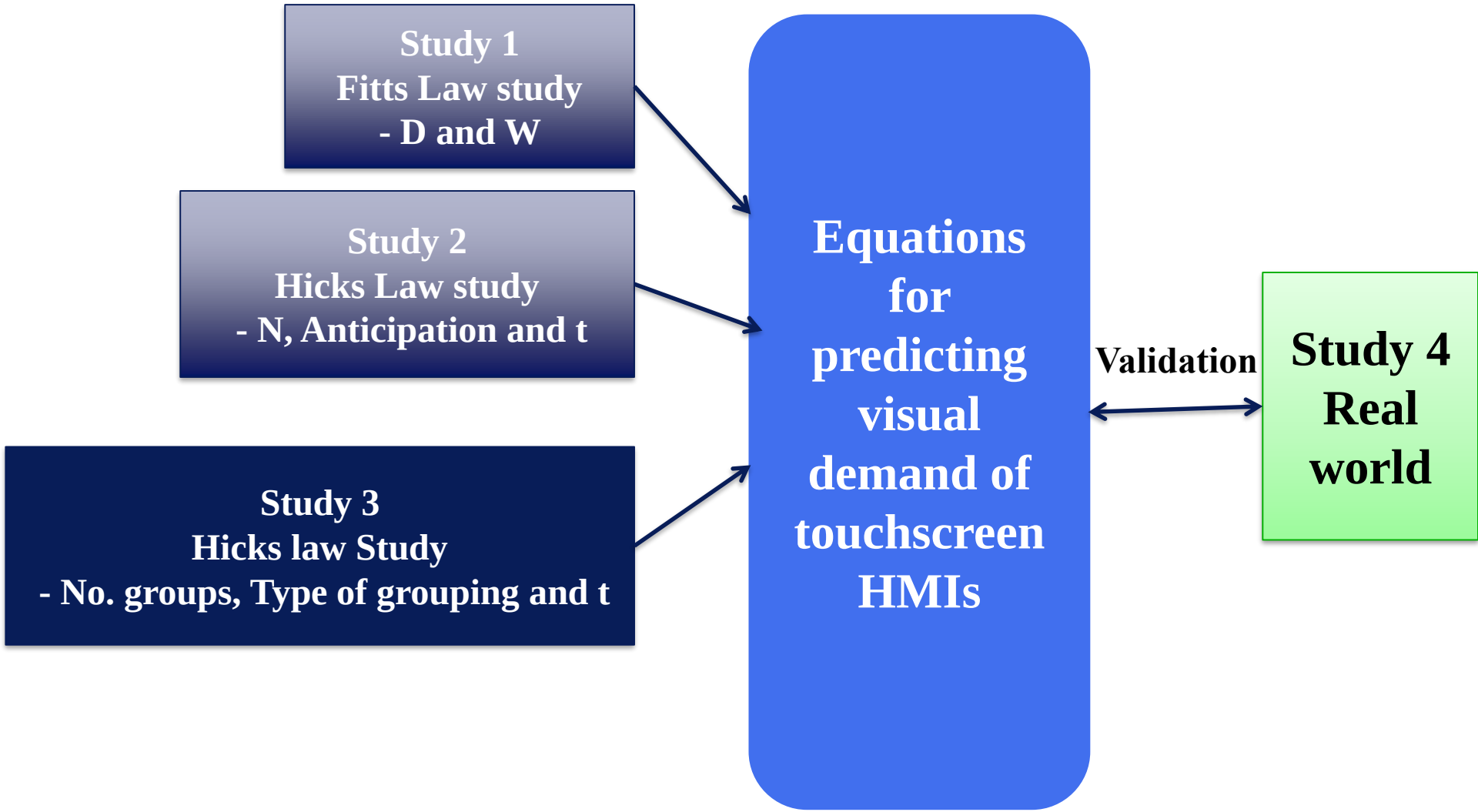
- Investigating relationships between different HMI/task variables….
  - Size of touchscreen targets
  - Number of potential touchscreen targets
  - Distance to target (from steering wheel)
  - Degree of anticipation possible in HMI
  - Exposure to HMI
- …..and commonly utilised visual demand metrics from simulator/road studies
  - Number of off-road glances
  - Duration of off-road glances
  - Total glance time to in-vehicle touchscreen

We draw upon influential study by Cockburn et al. (2007)* for predicting *static task time* with touchscreens

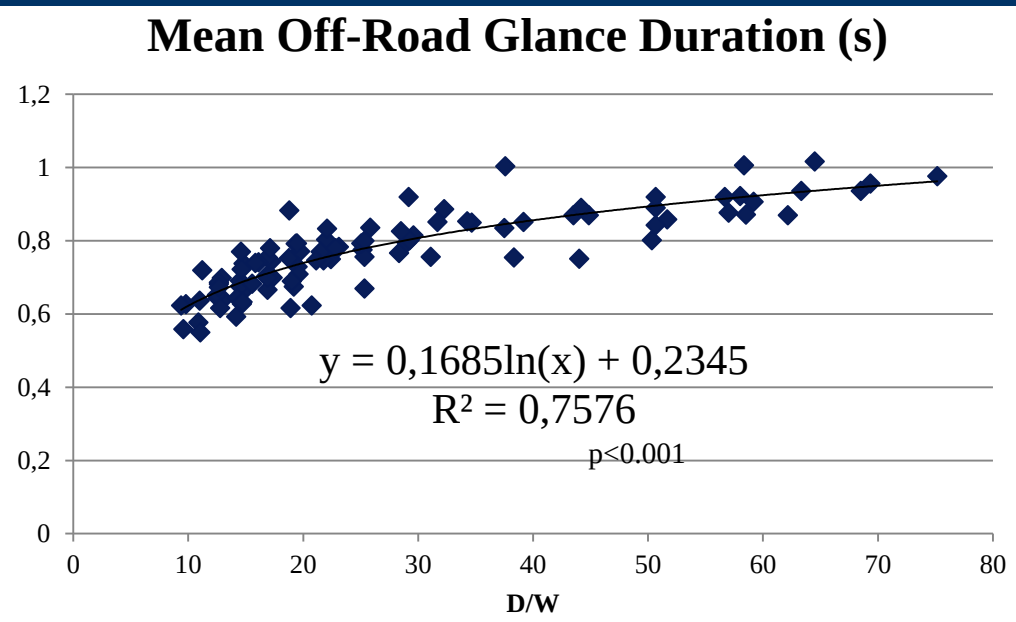
- Time to select target = $T_{decide} + T_{locate}$
- $T_{locate} = aLog_2 (D/W) + b$
- $T_{decide\text{-}anticipation} = cLog_2N + d$
- $T_{decide\text{-}nonanticipation} = eN + f$
- $T_{decide} = (1\text{-}E)\ T_{decide\text{-}nonanticipation} + (ExT_{decide\text{-}anticipation})$
- $E = L\ (1\text{-}1/t)$

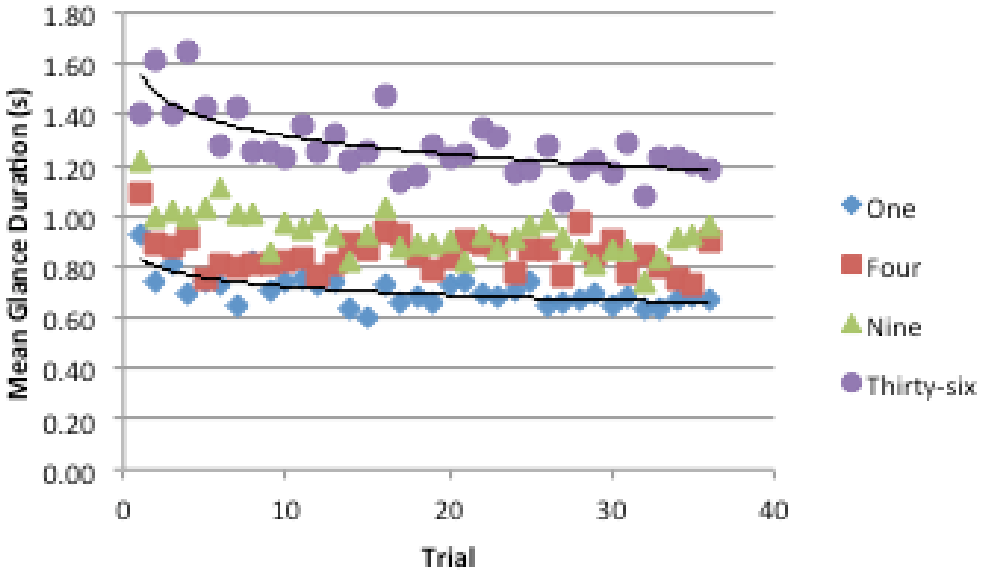
* Cockburn, A, Gutwin, C., Greenburg, S. 2007. A predictive model of menu performance, *Proceedings of SIGCHI conference*, ACM: NY.

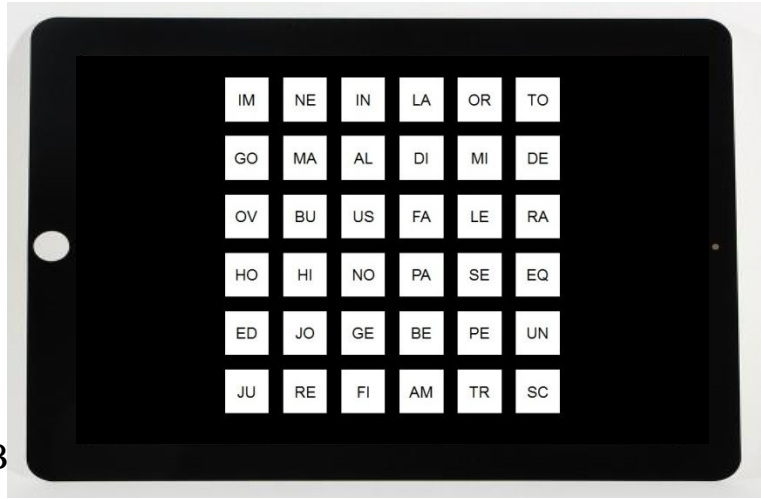
Process for developing equations

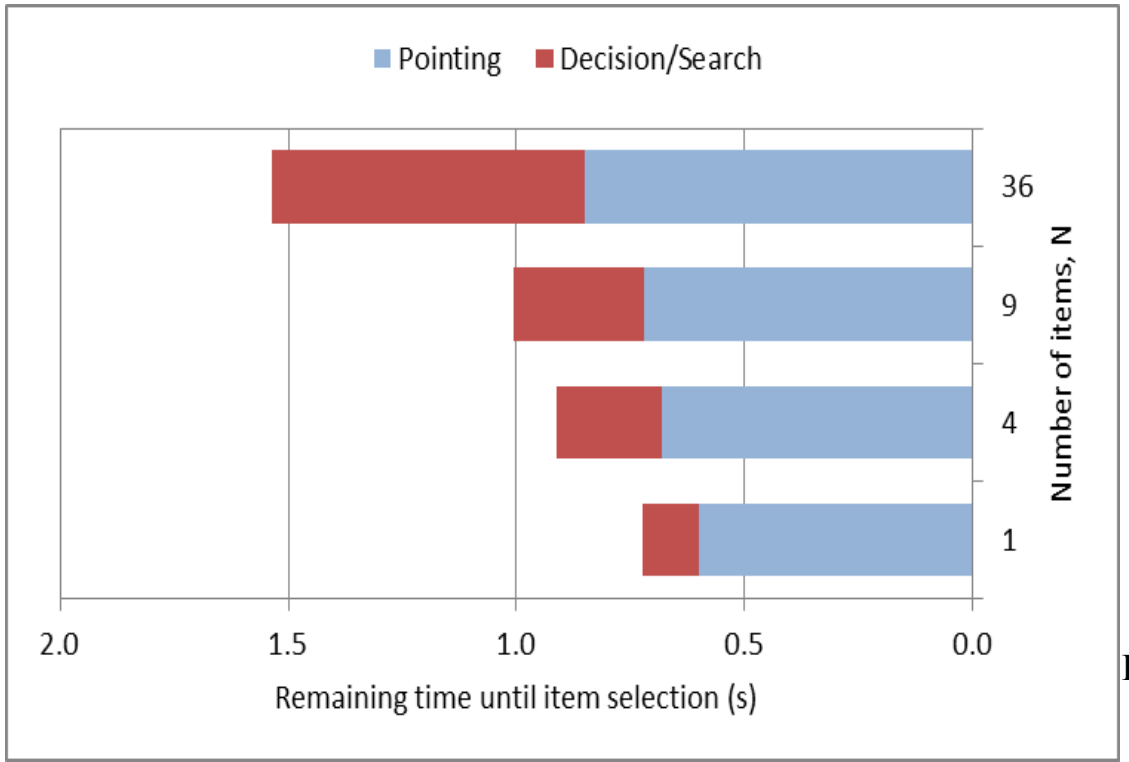


Development of predictive equations for visual demand









Visualisation of **final glance**, highlighting decision/search and locating/pointing components

Burnett, 2017

Final set of equations

$$TGT_{st} = \left(\frac{\log_2 N}{\log_2 (N+t)}\right).(0.029N + 0.44) + 0.11\log_2 N + 0.11\log_2 \frac{D}{W} + 0.35 \quad (22)$$

$$TGT_{un} = \left(\frac{\log_2 N}{\log_2 (N+t)}\right).(0.10N - 0.028) + 0.049N + 0.045\log_2 N + 0.11\log_2 \frac{D}{W} + 0.17 \quad (23)$$

$$NG_{st} = \left(\frac{\log_2 N}{\log_2 (N+t)}\right).(0.021N + 1.04) + 1 \quad (24)$$

$$NG_{un} = \left(\frac{\log_2 N}{\log_2 (N+t)}\right).(0.044N + 0.81) + 0.0071N + 1.96 \quad (25)$$

$$MGD_{st} = TGT_{st} \div NG_{st} \quad (26)$$

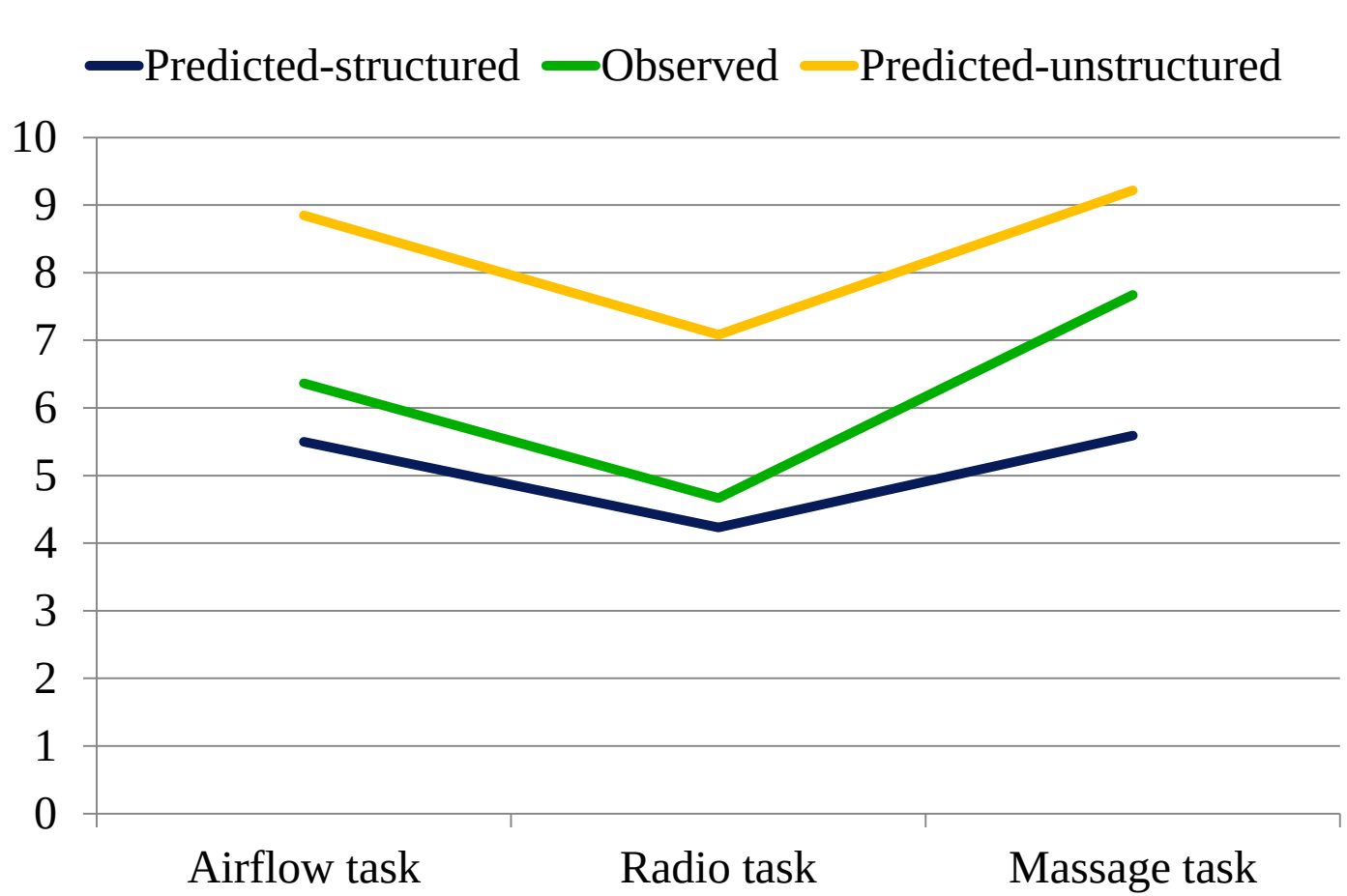
$$MGD_{un} = TGT_{un} \div NG_{un} \quad (27)$$

where:

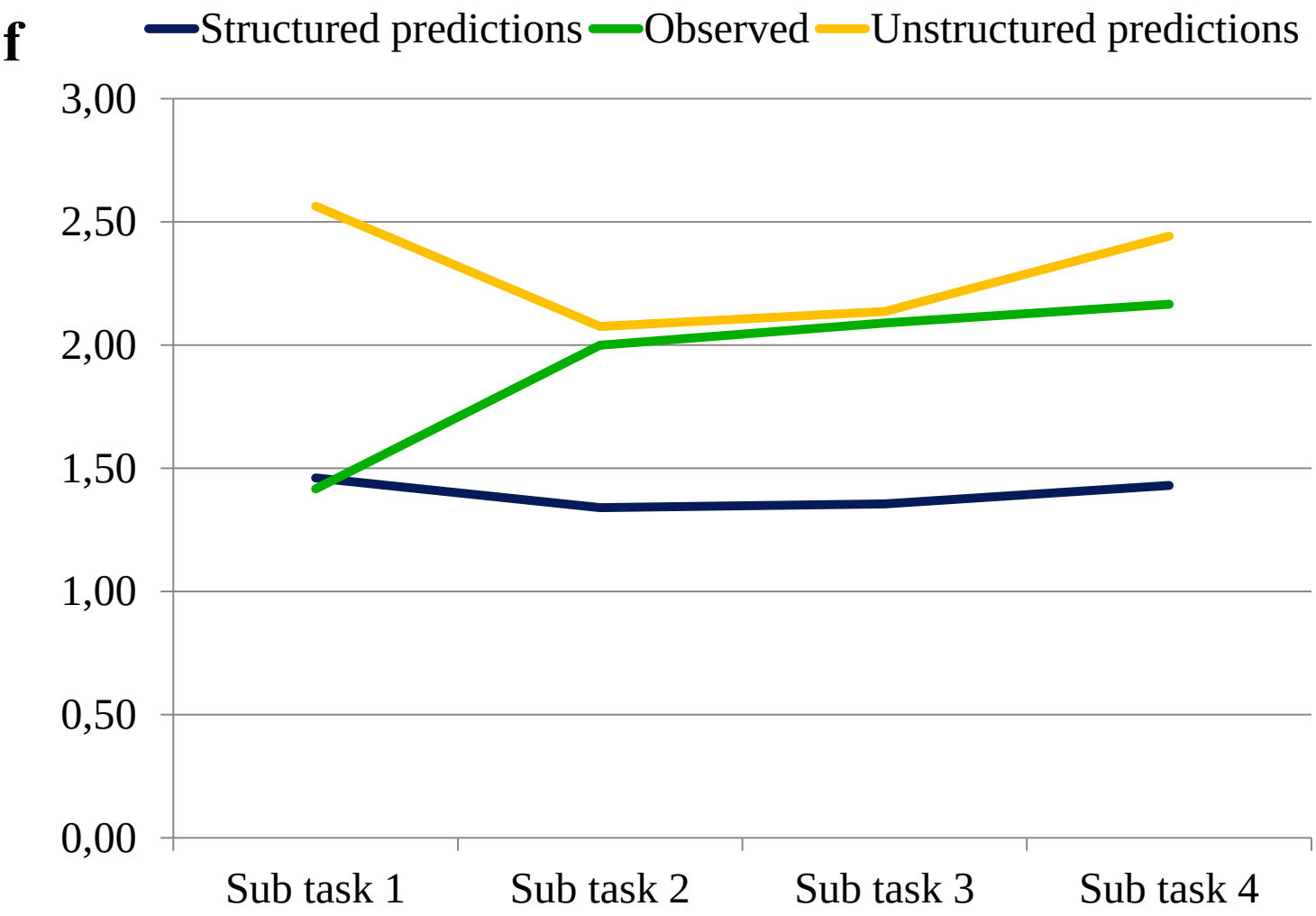
st	=	structured
un	=	unstructured
N	=	total number of selectable items on the screen
t	=	number of exposures to interface
D	=	distance to target from hand position on steering wheel
W	=	target width

and $N > 1$

Some **relative** validity data



Some **absolute** validity data



Summary/Future work

- Important to understand the visual demand implications of in-vehicle HMIs
- Various human factors methods (and associated measures) exist with various advantages/disadvantages
- Predictive modelling approaches have considerable potential as an extremely cost-effective means of analysing HMIs
- Future predictive modelling work needs to consider:
  - How to increase the *(face) validity/reliability/coverage* of predictive modelling
  - How to *implement* predictive approaches within the design process
  - Accounting for *individual variability* (spread of distribution)

- Thank you
- gary.burnett@nottingham.ac.uk