

# When randomness opens new possibilities: Acknowledging the stimulus sampling variability in Experimental Psychology

**Ottavia M. Epifania**<sup>1,2,3</sup>, Pasquale Anselmi <sup>1</sup>, Egidio Robusto <sup>1</sup>



<sup>1</sup> University of Padova, (IT)

<sup>2</sup> Psicostat Group, University of Padova, (IT)

<sup>3</sup> Università Cattolica del Sacro Cuore, Milano, (IT)

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Stimuli are fixed, respondents are random

## Respondents are random

Sampled from a larger population

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Need for acknowledging the sampling variability

Results can be generalized to other respondents belonging to the same population

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Taken to be entire population

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## Stimuli/item are fixed

Taken to be entire population

There is no sampling variability

There is no need to generalize the results because the stimuli are the population

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# However...

The stimuli can also represent a sample of a larger universe



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## Processing speed of positive and negative attributes

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## Processing speed of positive and negative attributes

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So... there must be a sampling variability!

What if the sampling variability is not acknowledged

## Generalizability

Generalizability is bounded to the specific set of stimuli used in the experiment

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## Robustness of the results

Random variability at the stimulus level might inflate the probability of committing Type I errors

Averaging across stimuli to obtain person-level scores results in biased estimates due to the noise in the data

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## Loss of information

Every stimulus is assumed to be equally informative

All the variability is not considered as well as all the information that can be obtained from it

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This contribution

Focus on the loss of information...the other side of the coin



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The information at the stimulus level that can be retrieved from the accuracy responses (correct vs. incorrect) from a typical experiment where the response times are usually employed for scoring the data

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# This contribution

Focus on the loss of information...the other side of the coin

The information at the stimulus level that can be retrieved from the accuracy responses (correct vs. incorrect) from a typical experiment where the response times are usually employed for scoring the data

It can actually help in disentangling what is known to be a shortcoming of the score usually employed for analyzing the data of this experiment

# Random effects and random factors

Linear combination of predictors in a Linear Model:

$$\eta = \beta X, \tag{1}$$

where  $\beta$  indicates the coefficients of the fixed intercept and slope(s), and  $X$  is the model-matrix.

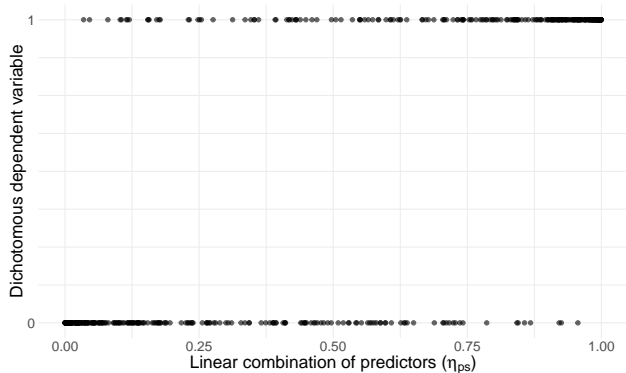
Linear combination of predictors in a Linear Mixed-Effects Model (GLMM):

$$\eta = \beta X Z d, \tag{2}$$

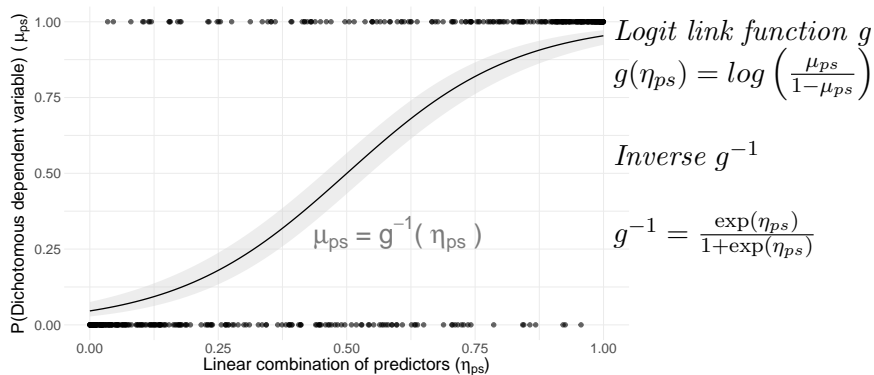
where  $Z$  is the matrix and  $d$  is the vector of the random effects (not parameters!)

*Best Linear Unbiased Predictors*

# Generalized linear model for dichotomous responses



# Generalized linear model for dichotomous responses



# The Rasch model

$$P(x_{ps} = 1 | \theta_p, b_s) = \frac{\exp(\theta_p - b_s)}{1 + \exp(\theta_p - b_s)}$$

where:

$\theta_p$ : ability of respondent  $p$  (i.e., latent trait level of respondent  $p$ )

$b_s$ : difficulty of stimulus  $s$  (i.e., “challenging” power of stimulus  $s$ )

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## GLM

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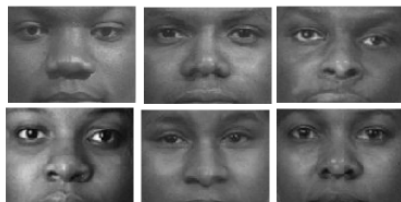


## 12 Object stimuli

White people faces



Black people faces



## 16 Attribute stimuli

Positive attributes

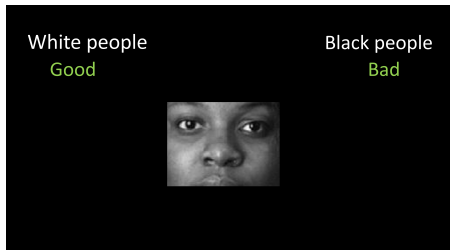
Good, laughter, pleasure, glory, peace,  
happy, joy, love

Negative attributes

Evil, bad, horrible, terrible, nasty,  
pain, failure, hate

## Two experimental conditions

**White-Good/Black-Bad**  
(WGBB): 60 trials



**Black-Good/White-Bad**  
(BGWB): 60 trials



$$D = \frac{M_{\text{BGWB}} - M_{\text{WGBB}}}{s_{\text{BGWB, WGBB}}}$$

Participants: 62 ( $F = 48.39\%$ , Age =  $24.92 \pm 2.11$  years)

The expected response  $y$  for the observation  $i = 1, \dots, I$  for respondent  $p = 1, \dots, P$  on stimulus  $s = 1, \dots, S$  in condition  $c = 1, \dots, C$ :

Model 1:

$$y_i = \text{logit}^{-1}(\alpha + \beta_c X_c + \alpha_{p[i]} + \alpha_{s[i]} + \varepsilon_i)$$

$$\alpha_p \sim \mathcal{N}(0, \sigma_p^2),$$

$$\alpha_s \sim \mathcal{N}(0, \sigma_s^2).$$

Model 2:

$$y_i = \text{logit}^{-1}(\alpha + \beta_c X_c + \alpha_{p[i]} + \beta_{s[i]} c_i + \varepsilon_i)$$

$$\alpha_p \sim \mathcal{N}(0, \sigma_p^2),$$

$$\beta_s \sim \mathcal{MVN}(0, \Sigma_{sc}).$$

Model 3:

$$y_i = \text{logit}^{-1}(\alpha + \beta_c X_c + \alpha_{s[i]} + \beta_{p[i]} c_i + \varepsilon_i)$$

$$\alpha_s \sim \mathcal{N}(0, \sigma_s^2),$$

$$\beta_p \sim \mathcal{MVN}(0, \Sigma_{pc}).$$

Accuracy:  $\epsilon \sim \text{Logistic}(0, \sigma^2)$

Model 1:

Model 2:

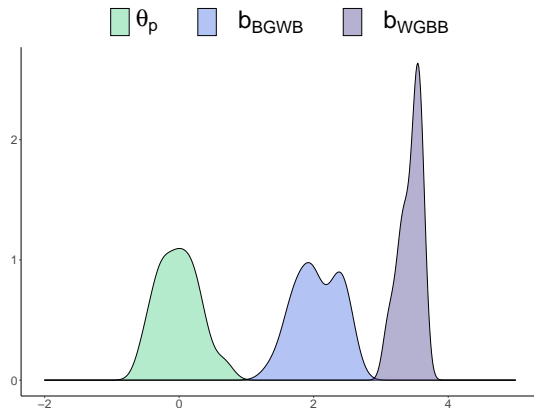
Model 3:

Accuracy:  $\epsilon \sim \text{Logistic}(0, \sigma^2)$

## Random structure

# Model 2 is the least wrong model

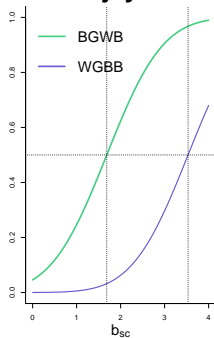
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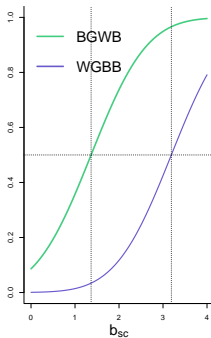
# Condition-specific easiness

## HIGHLY CONTRIBUTING STIMULI

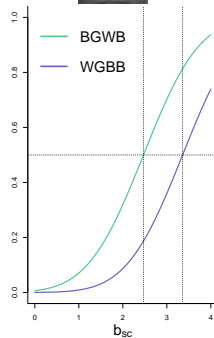
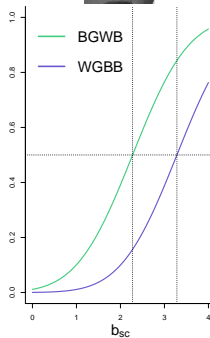
**joy**



**evil**



## LOWLY CONTRIBUTING STIMULI



- Acknowledge and gather the information at the stimulus level
- Improve generalizability of the results to other sets of stimuli
- Control for random variance in the data
- Allow for obtaining a Rasch-like parametrization of the data
- Possibility of extending the (linear) model to other dependent variables (e.g., response times)

# Thank you!

ottavia.epifania@unipd.it

