Evaluation of a Bayesian cognitive model for adolescent risky decision making in the Yellow Light Game

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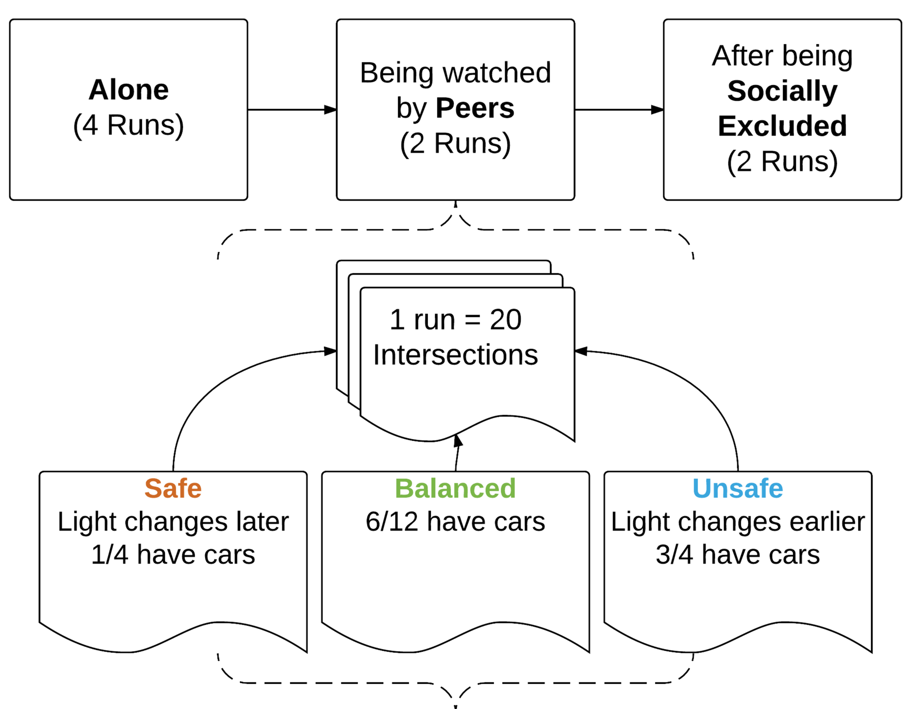
Background

Developmental cognitive neuroscience is at the forefront of research on adolescent risk taking. However, commonly used tasks have relatively low ecological validity (like the Balloon Analogue Risk Task), or confound risky and adaptive responding (some iterations of the original Stoplight Driving Game).

To address this, we developed the Yellow Light Game (YLG). It is also a simple driving simulation with a series of intersections, but with more flexibility to set various parameters. The goal is to reach the finish line as quickly as possible.

Method

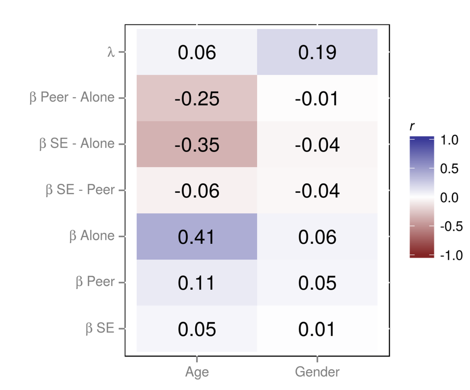


Participants:

N=55 (28 boys), ages 11-17 (M=13.9, SD=1.7), from a mid-sized city in the Pacific Northwest , USA

Task:

Participants played eight (8) runs of the Yellow Light Game across three (3) conditions, and filled out numerous self-report questionnaires.

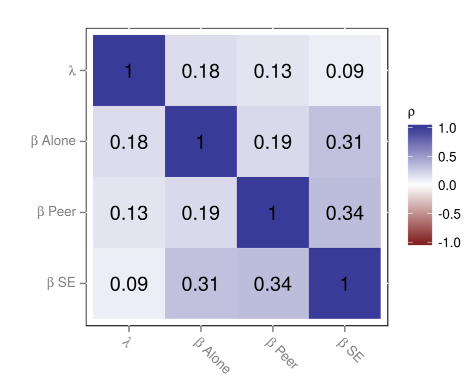


At each intersection, the participant chooses to Stop (certain) or Go (risky), with the following 'payouts':

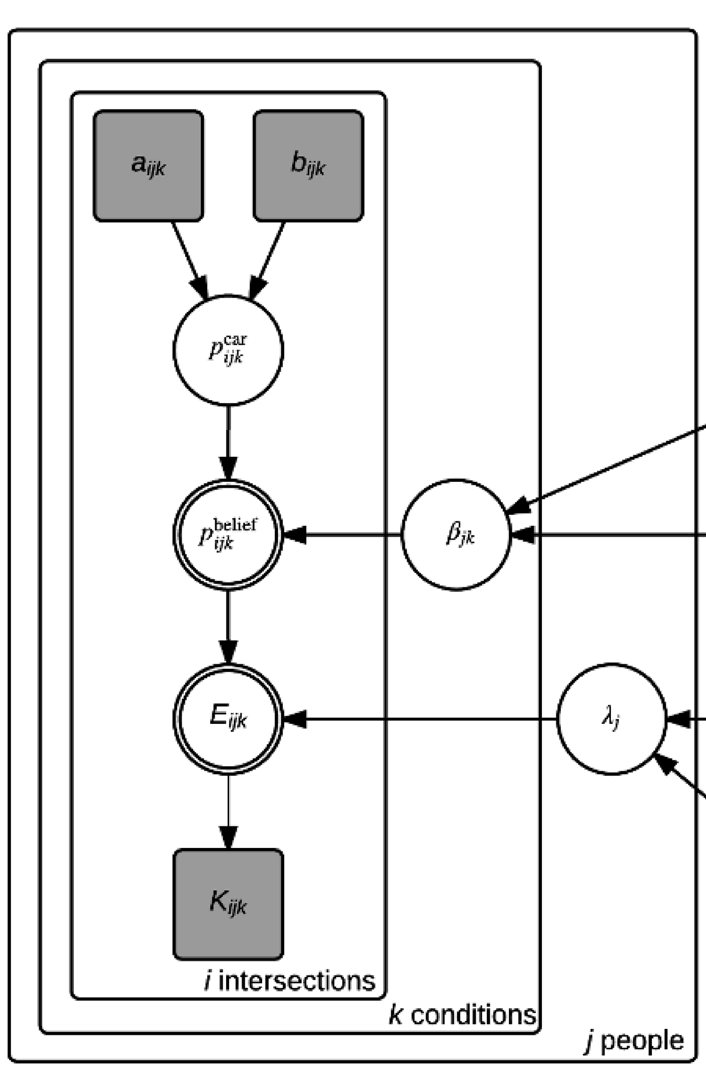
Stop: 0 s

Go (no car): + 2.5 s

Go (crash): - 2.5 s



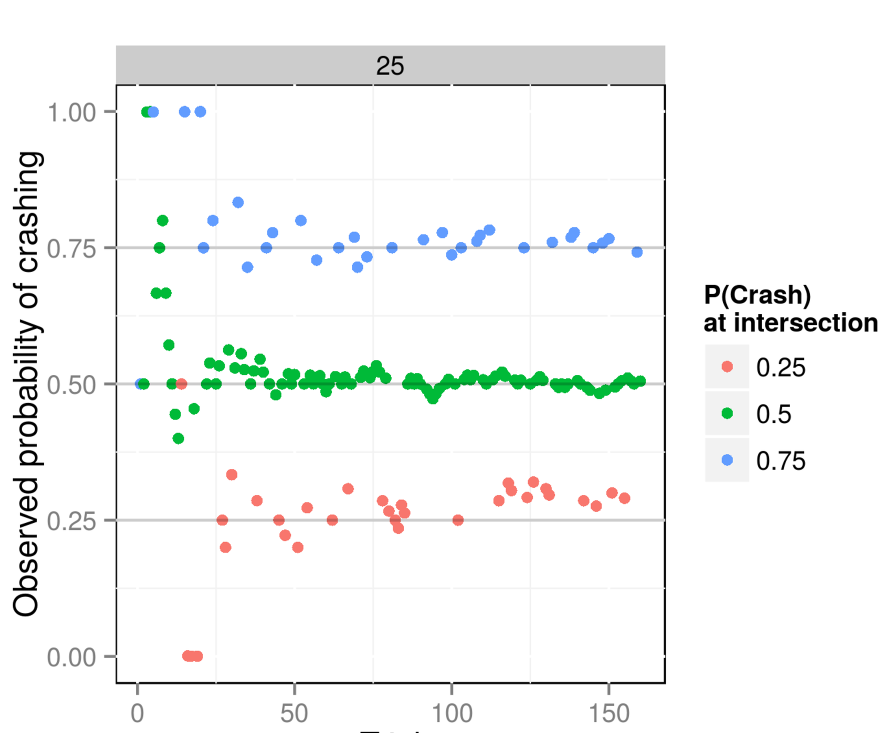
In addition, there are three types of intersection with different cross-car (crash) probabilities that are distinguishable by how soon the light changes from green to yellow.



$$\mu_\beta \sim \text{normal}(0, 10)$$
$$\sigma^2_\beta \sim \text{cauchy}(0, 10)T[0,]$$
$$\mu_\lambda \sim \text{uniform}(0, 10)$$
$$\sigma^2_\lambda \sim \text{cauchy}(0, 10)T[0,]$$
$$\beta_{jk} \sim \text{normal}(\mu_\beta, \sigma^2_\beta)$$
$$\lambda_j \sim \text{normal}(\mu_\lambda, \sigma^2_\lambda)$$
$$p^{car}_{ijk} \sim \text{beta}(a_{ijk}, b_{ijk})$$
$$p^{belief}_{ijk} \leftarrow 1 \Big/ \left(1 + \exp\left(-\beta_{jk} \log\left(\frac{p^{car}_{ijk}}{1-p^{car}_{ijk}}\right)\right)\right)$$
$$E_{ijk} \leftarrow (1 - p^{belief}_{ijk}) \cdot 2.5 - \lambda_j p^{belief}_{ijk} \cdot 2.5$$
$$k \sim \text{bernoulli}\left(\frac{1}{1+\exp(-E_{ijk})}\right)$$

Cognitive model:

Explicitly modeling the theoretical cognitive process is an approach that has been fruitful in describing several latent parameters in BART behavior (e.g., Plescak, 2008; van Ravenzwaaij et al., 2011). We take a similar approach, estimating the parameters using a hierarchical Bayesian model fit in Stan (Stan Development Team, 2015).



In the YLG, participants gradually gain information about the probability of crashing (p^{car}). Differences in sensitivity to this information is estimated by **Beta**, which can vary between conditions. Greater weight given to losses is estimated by **Lambda**. These can be combined into an function mapping the expected value of a 'Go' decision to how likely the participant is to press go.

Results & Discussion

Bayesian model diagnostics:

6 chains of 10,000 HMC iterations (thinned by 4) had acceptable autocorrelation and visual profiles.

Posterior Predictions:

Comparison of expected value for go decisions with rates of actual go decisions reveals that the model captures important aspects of the data, with some room for improvement.

Correlations with Self Report:

Affect

Higher levels of depression, anxiety, fear of negative evaluation (FNE), and expectation of rejection were associated with greater use of available information during the peer run.

Similarly, higher levels of depression, FNE, and likelihood of anger in reaction to rejection were associated with greater decrease in use of information following social exclusion.

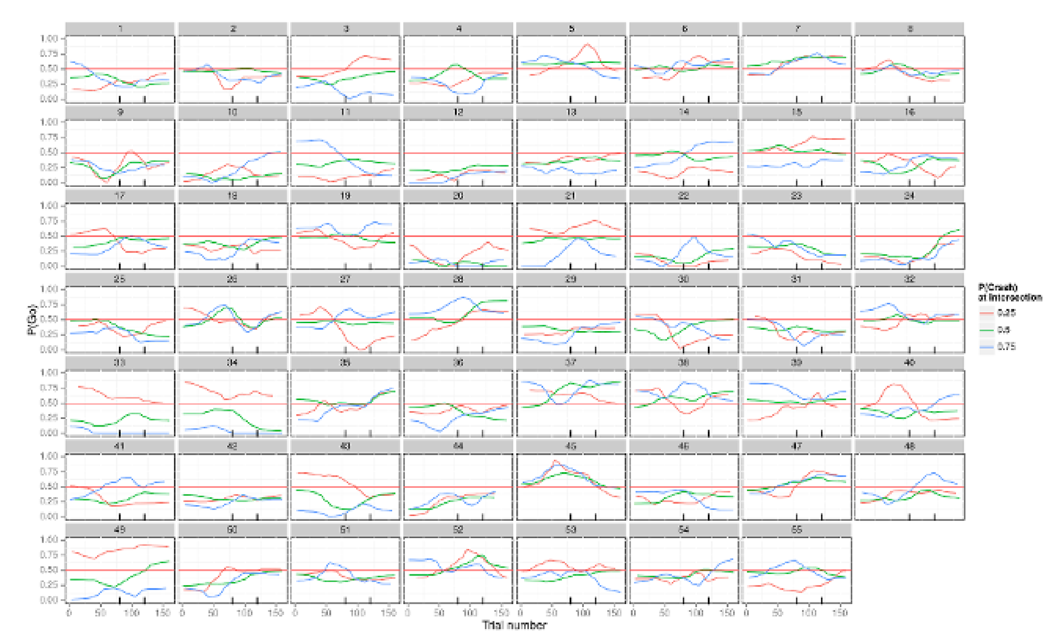
RTB, impulsivity, and aggression

Sensation seeking, disinhibition, relational aggression, and appraisal of certain risky events were all variously associated with information sensitivity.

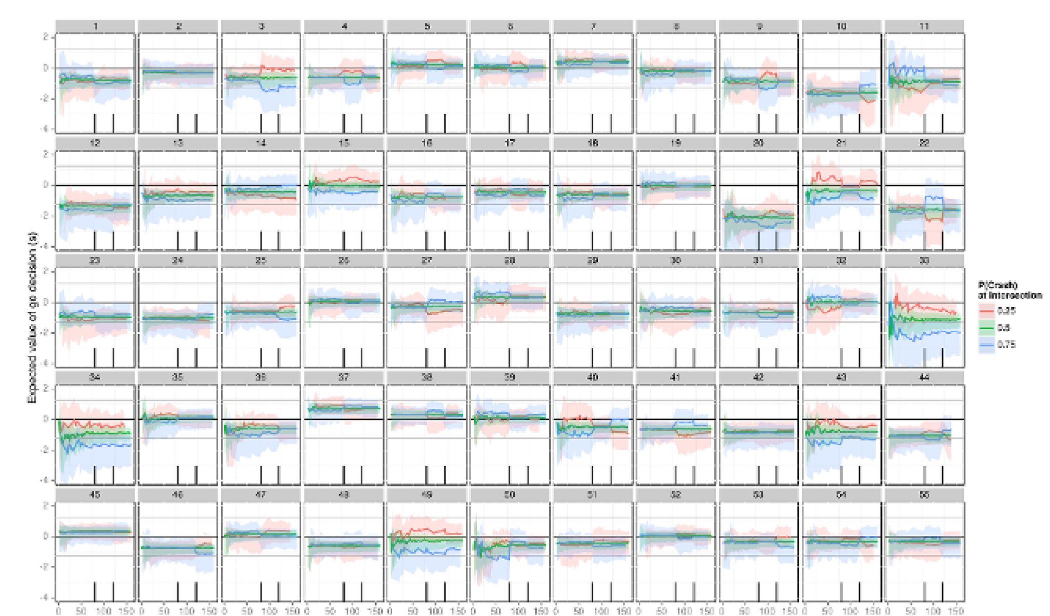
Future Directions:

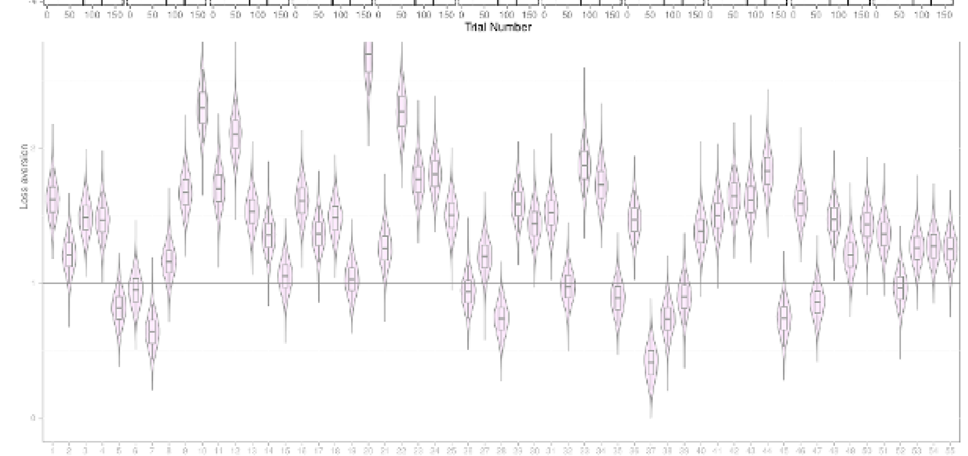
- Model comparison using alternative learning strategies
- Functional neural correlates
- Prediction of behavior at Wave 2

Observed proportion of go decisions



Modeled expected value of go decision





Zero-order | **Partial (Age and Gender)**