Hiding in Plain Parameters

Parametric Camouflage Optimization Through Synthetic Simulations

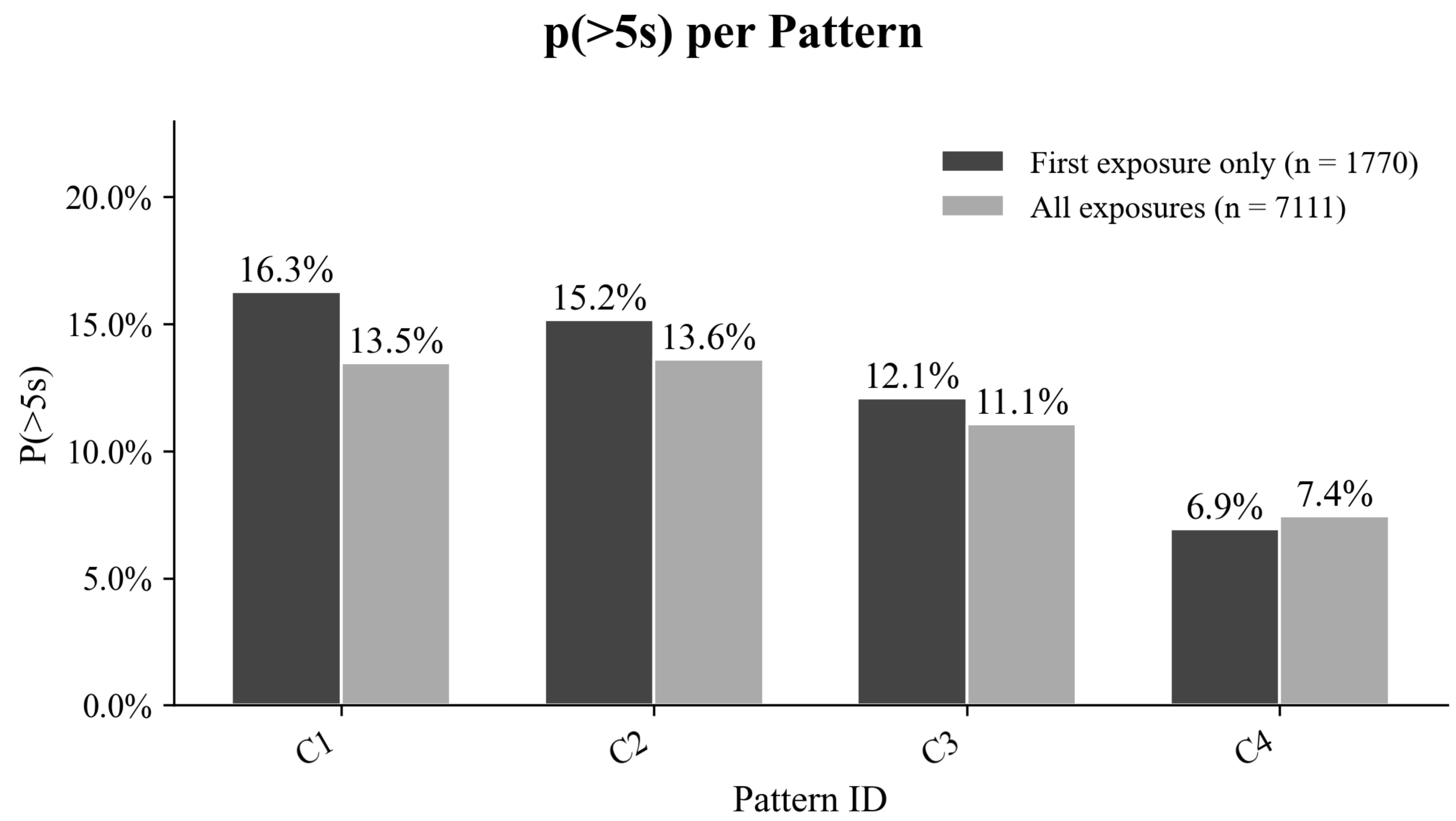
Why Synthetic Simulations?

Effective camouflage has a real impact on the survival chances of military assets. Yet camouflage development still relies on testing a small number of hand-picked patterns in human detection experiments, or on automated computer vision evaluations that may not reflect human perception. Neither approach enables systematic exploration of how design parameters interact across a continuous design space. This study introduces a method that samples a continuous four-dimensional parameter space, where each combination defines a unique parametric camouflage pattern rendered onto a vehicle in a fully synthetic environment using Blender. 18,000 unique stimuli were generated and evaluated by 32 participants in a visual search task, providing dense human-in-the-loop data across parameter space at a scale impossible with other methods.

Implications

The study shows that a machine learning model can map a camouflage parameter space and predict human detection performance, providing ordinally consistent findings despite noisy training data. Future work can build directly on these results: developing new camouflage patterns, assessing the impact of physical vehicle modifications on detectability, and allowing comprehensive benchmarking of vehicle detectability prior to acquisition.

Beyond camouflage, the results of this study show broader potential for an advanced design optimization method: any product or experience that can be parametrically defined and evaluated by a human metric could be systematically mapped and optimized using a similar approach.



Modelling the Parameter Space

Detection outcomes were modelled using a logistic regression classifier and a Gaussian Process model, mapping parameter combinations to detection difficulty. Each parameter combination corresponded to a unique camouflage pattern; covariates capturing target distance, occlusion, and orientation were included to isolate pattern effects. Both models achieved moderate discriminative performance (AUC: 0.79 and 0.77). A validation experiment confirmed the model's rank ordering held at the extremes: the predicted best-performing pattern was consistently harder to detect than the worst.

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