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BOARD # 370: ERI: A Mixed-Methods Study of Statistical Thinking, Informed by Engineering Practice

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ERI: A Mixed-Methods Study of Statistical Thinking, Informed by Engineering Practice

This short report gives an update on the NSF-supported project "ERI: Towards Data-Capable Engineers with a Variability-Capable Mindset" (Grant No. 2138463).

Statistical variability is important, but under-emphasized in engineering. Variability is the phenomenon of non-identical behavior, which has important effects on designing systems for people (who are different), and on designing for safety (in the face of variable conditions). Our project seeks to better understand how people—engineers in particular—react to statistical variability, and to use these insights to improve undergraduate education.

Statistical variability is under-emphasized in engineering: A recent review of the education literature on mathematical practices in engineering found that only 2 out of 5,466 even discuss "uncertainty" or "error" [1]. A scoping review of textbooks actively used to teach engineering courses found that only 11% of textbooks mentioned "variability" [2]. Despite this neglect, variability remains important to engineering practice; for example, female automobile passengers in the U.S. experience 47% higher odds of injury than males [3], a disparity that the Government Accountability Office attributes to poor statistical modeling practices in crash testing [4].

This project is a mixed-methods study of statistical thinking, informed by engineering practice. The early (qualitative) phases of this project developed a novel taxonomy to describe a feature of statistical thinking that is of particular importance to engineering: *targeting variability* [5]. A decision with data is said to be *targeted* if the decision is made to address the potential consequences of variability. For instance, in the context of automobile crash testing, a targeted approach would be to use multiple crash test dummies that span the range of automobile passengers: both male and female, but also smaller (10%) and larger (90%) individuals in those groups. Our project also investigated factors that lead to *non* targeting, including engineers' perception of error in data [6].

This report focuses on results from the final (quantitative) phase of our project: The development of a survey instrument to measure decision-making under variability, and the deployment of the instrument with a large and representative sample. Piloting and refining of our quantitative instrument has been ongoing for over a year. Initial prototypes are reported in previous reports [7], [8]; the primary innovation in these works were survey items to measure a participant's perception of the consequences of variability.

However, by pairing our prototype survey with think-aloud interviews, we found that our prototype could identify instances where participants *attempt* to target variability, but make mistakes in *objectively* identifying the consequences of variability [7]. To overcome this issue, we refined our survey tasks to each have an objectively correct answer. This followed quality criteria developed in the psychophysics community (ground truth linkage [9]), and enabled more reliable measurement of targeting using a survey.

Our initial work with the updated survey suggests that U.S. adults target variability in everyday scenarios—such as driving to work with variable commute times—at a high rate (~70% of individuals). However, factors such as the presentation of data (e.g., as a bar graph) can decrease the rate of targeting. This result suggests that in engineering (and other) contexts involving variability, data should be presented in a way that clearly illustrates the variability (i.e., not just reporting the mean). More difficult tasks (e.g., evaluating a public policy proposal) can also lead to lower rates of targeting. This result suggests that specific training may be necessary for engineers to successfully target variability in more complex scenarios.

Acknowledgements

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