IMPROVING JOINT PROBABILITY REASONING

Nathalie Stegmüller, Karin Binder, and Patrick Wiesner
University of Regensburg, Germany
Ludwig-Maximilians-Universität München, Germany
nathalie.stegmueller@ur.de

In research on understanding situations with two binary events, joint probabilities are—in contrast to conditional probabilities—largely ignored in empirical studies. To enhance performance on conditional probability problems (e.g., concerning the famous Bayesian tasks), two main strategies have been proven to be successful: (a) using natural frequencies, e.g., "1 out of 100," rather than probabilities, e.g., "1%" (Gigerenzer & Hoffrage, 1995; McDowell & Jacobs, 2017) and (b) presenting visualizations (Binder et al., 2020; McDowell & Jacobs, 2017). The present study explores both strategies with respect to joint probability problems in order to find out whether these two strategies also work with joint probability problems.

In an empirical study, $N = 334$ German university students (from different fields of studies) were tested with a paper-and-pencil-test in a 2 × 5 experimental design. The first factor was information format (probabilities versus natural frequencies) and the second factor was visualization type (text only, tree diagram, double tree diagram, 2 × 2 table, net diagram). Each participant was given two different task contexts (one presenting information in probability and the other one presenting information in a natural frequency format) with two different visualization types. Thereby, the five types of visualization were systematically varied between all participants. For each context, the participants had to answer four questions concerning joint probabilities.

Results of the study show that there was no significant format effect across all visualization types—a result that stands in strong contrast to the research on Bayesian tasks, in which natural frequency tasks are solved more often compared to probability formats. Concerning the visualization type, the 2 × 2-table and the net diagram were most helpful. The best combination to understand joint probabilities was the 2 × 2-table filled with probabilities or the net diagram independent of information format.

The study yields two important results. First, the study indicates that joint probabilities are not well understood by university students. Second, evidence from the research on conditional probabilities (e.g., concerning format effects), however, cannot simply be transferred to joint probabilities.

REFERENCES

Binder, K., Krauss, S., & Wiesner, P. (2020). A new visualization for probabilistic situations containing two binary events: The frequency net. *Frontiers in Psychology*, *11*, Article 750. https://doi.org/10.3389/fpsyg.2020.00750

Gigerenzer, G., & Hoffrage, U. (1995). How to improve Bayesian reasoning without instruction: Frequency formats. *Psychological Review*, *102(*4), 684–704. https://doi.org/10.1037/0033-295X.102.4.684

McDowell, M., & Jacobs, P. (2017). Meta-analysis of the effect of natural frequencies on Bayesian reasoning. *Psychological Bulletin*, *143*(12), 1273–1312. https://doi.org/10.1037/bul0000126

In S. A. Peters, L. Zapata-Cardona, F. Bonafini, & A. Fan (Eds.), *Bridging the Gap: Empowering & Educating Today's Learners in Statistics. Proceedings of the 11th International Conference on Teaching Statistics (ICOTS11 2022), Rosario, Argentina.* International Association for Statistical Education. iase-web.org