Towards a more robust, fast-moving, and resilient cognitive psychology.

In response to the COVID-19 crisis, laboratories around the world have ceased in-person human data collection. In principle, many of these labs could run their studies online. Most behavioral studies require no more than the technology that billions of people interact with every day and which powers Internet games, mobile apps, wearables, etc. With over 4,000,000 people online, most populations of interest are reachable [1]. Data quality compares favorably to that of lab studies [2-4].

In practice, the barrier to entry can be steep. Researchers must learn new paradigms, new tricks-of-the-trade, and new software -- if the needed software exists at all. Indeed, while there are good options for running keyboard-based studies over Amazon Mechanical Turk, many researchers require populations not available through Amazon (children or the elderly, speakers of specific languages, individuals with rare skills or deficits, etc.) or methods that go beyond key-presses (eyetracking, speech production, drawing, heart-rate monitoring, etc.). While some labs have solved these problems -- often with groundbreaking discoveries as a result -- it typically requires writing new software from scratch [3, 5-10].

We propose to lower the barrier, through training, support, and development. *Training*: we will produce documentation, tutorials, and Webinars, covering both technical issues (how to program online experiments) and design issues (best practices, tips-and-tricks). *Support*: we will provide online technical support to researchers trying to conduct online experiments. *Development*: we will extend existing software to meet the emerging needs of the community.

Specifically, we already do all of these things, and have done so for a decade. Our goal is to scale up and support more researchers. To keep scope manageable, we will focus on the following research areas: learning, memory, language, decision-making, categorization, concepts, and attention. We have implemented a plan to ensure access to and inclusion of students and researchers at teaching colleges and minority-serving institutions.

The timing of this proposal is motivated by the COVID-19 crisis. It is our goal to roll out as much support as quickly as possible, in order to help address current needs. But looking forward, pandemics will happen again, and regional disruptions are far from uncommon (Katrina, Maria, California wildfires, Australian wildfires, etc.). Better online infrastructure will make us more resilient to disruptions of our physical laboratories. Moreover, online studies have obvious scientific advantages, including larger samples, better statistical power, and access to non-WEIRD populations. As a result, some have argued that the field would benefit if most studies were done this way [11-13]. **Thus, improving the infrastructure for online studies will make our field more robust, faster-moving, and more resilient.**

Project Leads: *Joshua Hartshorne* (assistant professor, Department of Psychology & Neuroscience, Boston College) has conducted research through his online laboratory gameswithwords.org since 2006 [3, 6, 8, 12, 14-15]. He is the lead developer for Pushkin, an open-source software package for web-native experiments [12]. *Joshua de Leeuw* (assistant professor, Department of Cognitive Science, Vassar College) is the lead developer of jsPsych, an open-source software package for browser-based experiments [16]. jsPsych has 43 contributors and 9k downloads. Hartshorne & de Leeuw have run seven training workshops, including several in collaboration.

1. ITU Telecommunication Development Sector. Measuring digital development: Facts and figures, 2019. URL https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf

2. de Leeuw, J. R., & Motz, B. A. (2016). Psychophysics in a Web browser? Comparing response times collected with JavaScript and Psychophysics Toolbox in a visual search task. Behavior Research Methods, 48(1), 1-12.

3. Hartshorne, J. K., & Germine, L. T. (2015). When does cognitive functioning peak? The asynchronous rise and fall of different cognitive abilities across the life span. *Psychological Science*, 26(4), 433-443.

4. Germine, L., Nakayama, K., Duchaine, B. C., Chabris, C. F., Chatterjee, G., & Wilmer, J. B. (2012). Is the Web as good as the lab? Comparable performance from Web and lab in cognitive/perceptual experiments. *Psychonomic Bulletin & Review*, 19(5), 847-857.

5. Halberda, J., Ly, R., Wilmer, J. B., Naiman, D. Q., & Germine, L. (2012). Number sense across the lifespan as revealed by a massive Internet-based sample. *Proceedings of the National Academy of Sciences*, 109(28), 11116-11120.

6. Hartshorne, J. K., Tenenbaum, J. B., & Pinker, S. (2018). A critical period for second language acquisition: Evidence from 2/3 million English speakers. *Cognition*, 177, 263-277.

7. Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science*, 330(6006), 932-932.

8. Mehr, S. A., Singh, M., Knox, D., Ketter, D. M., Pickens-Jones, D., Atwood, S., Lucas, C., Jacoby, N., Egner, A. A., Hopkins, E. J., Howard, R. M., Hartshorne, J. K., Jennings, M. V., Simson, J., Bainbridge, C. M., Pinker, S., O'Donnell, T. J., Krasnow, M. M., & Glowacki, L. (2019). Universality and diversity in human song. *Science*, 366(6468).

9. Oller, D. K., Niyogi, P., Gray, S., Richards, J. A., Gilkerson, J., Xu, D., Yapanel, U., & Warren, S. F. (2010). Automated vocal analysis of naturalistic recordings from children with autism, language delay, and typical development. *Proceedings of the National Academy of Sciences*, 107(30), 13354-13359.

10. Salganik, M. J., Dodds, P. S., & Watts, D. J. (2006). Experimental study of inequality and unpredictability in an artificial cultural market. *Science*, 311(5762), 854-856.

11. Griffiths, T. L. (2015). Manifesto for a new (computational) cognitive revolution. Cognition, 135, 21-23.

12. Hartshorne, J. K., de Leeuw, J. R., Goodman, N. D., Jennings, M., & O'Donnell, T. J. (2019). A thousand studies for the price of one: Accelerating psychological science with Pushkin. Behavior research methods, 51(4), 1782-1803.

13. Miller, G. (2012). The smartphone psychology manifesto. Perspectives on psychological science, 7(3), 221-237.

14. Hartshorne, J. K. (2008). Visual working memory capacity and proactive interference. PLoS one, 3(7).

15. Hartshorne, J. K., & Snedeker, J. (2013). Verb argument structure predicts implicit causality: The advantages of finer-grained semantics. Language and Cognitive Processes, 28(10), 1474-1508.

16. de Leeuw, J. R. (2015). jsPsych: A JavaScript library for creating behavioral experiments in a Web browser. Behavior Research Methods, 47(1), 1–12.