SYLLABUS

Visualizing Uncertainty

GPSY 6422
CRN 10804
Spring 2022

The New School
New School for Social Research/Parsons School of Design
Psychology Department/Data Visualization
Mondays 4-5:50 pm
LOCATION: 2 W 13th Street, 10th Floor, Room 1006
FIRST TWO WEEKS REMOTE VIA ZOOM

Instructors:
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Course Description

This seminar brings together data visualization and psychology graduate This seminar brings together data visualization and psychology graduate students to investigate new ways of representing and hypothesizing about data while rigorously questioning what conclusions can legitimately be drawn. How should we think about where the data came from and the methods by which they were generated? What sources of potential measurement error should psychologists and data scientists be concerned about? When can we trust that data collected from nonprobability samples generalize to a full population? When are patterns that emerge in exploratory data visualization trustworthy? How can skepticism and questions about data be communicated with the potential audiences for a visual representation of data? How can we better visualize measurement error and multivariate confidence intervals? Class sessions will combine discussion of academic articles with hands-on examination of existing data sets and practical examples. Psychology and data visualization students will be paired to carry out two hands-on projects during the semester, ideally using their own data from class or thesis projects (although having one's own data is not required). From

these projects, students will gain experience in communicating with collaborators with quite different backgrounds and expertise. *Students are only expected to have background knowledge from their own discipline; data visualization students are not expected to have any psychology expertise, and psychology students are not expected to have any coding or design expertise*. **Psychology students should already have taken a graduate-level Research Methods course, or Intro to Applied Psychology and Design, or Intro to Statistics and Research Design. Design and Data Visualization students should already have proficiency in interaction design.** The course counts as an elective and satisfies the seminar requirement for the Psychology PhD programs; it counts toward any of the umbrella courses for Data Visualization students.

Learning Goals

By the successful completion of this course, students will have gained the ability to:

1. Demonstrate their understanding of the elements and grammar of data visualizations
2. Question unexamined assumptions about certainty in data visualizations, articulate a range of different kinds of uncertainty in data sets of different kinds, and know about a range of existing options for representing that uncertainty
3. Understand how user experience needs affect graphics-creators' visualization choices and weigh the pros and cons of different choices for different audiences
4. Demonstrate their understanding of empirical methods for assessing user experience and comprehension of a visualization
5. Engage in cross-disciplinary discussion and project-based work that connects the terms and concepts of data visualization with the methods and understanding of cognition from psychology

Course Requirements/Graded Activities

Task/activity	Percent of final grade	Notes
Canvas postings	**50%**	10 posts over the course of the semester will be required. Thoughtful and on-time posts will receive full

		credit. Missing, less careful, and late responses/questions will not receive full credit. The expectation is that all students will be available for in-class discussion of their posts, unless they have an excused absence.
Final group project: (a) new visualization of a particular kind of uncertainty and (b) proposal for assessment of user experience of it	**50%**	Quality will be assessed not only based on the project itself but on how clearly the presentation articulates how the work is influenced by the course material and perspectives of the other discipline
TOTAL	100%	

Attendance

We see in-person attendance and participation in group discussion, to the extent possible given health and safety concerns, as central to the learning outcomes for this course. **Students are expected to attend in-person classes in person** and on time unless:
1. They are unable to enter a New School building because of entry issues.
2. They are unwell.
3. They have been told to isolate/quarantine because of Covid issues.

The majority of classes this semester will occur in person, but there will be a few (after the first two weeks) that will meet via Zoom by design, in order to best support that week's activities. This will be announced well in advance so that students can best prepare for participating via Zoom that week. Any Zoom meetings will be recorded and made available to class members. In person meetings will not be recorded.

If the instructors are both unable to attend a particular class, students will be notified in advance via Canvas, and also about what the makeup activities will

be.

Course Readings and Materials

All readings will be provided electronically in the Canvas course pages accessible through Canvas, under "Course Reserves" (A complete list of references is available at the end of this syllabus).

Reference readings and other resources for creating data visualization:

Books/Papers

Bohnacker, H., Gross, B., Laub, J., Lazzeroni, C., & Frohling, M. (2018). *Generative design: visualize, program, and create with JavaScript in p5.js.* Princeton Architectural Press.

Chang, W. (2018). *R graphics cookbook: practical recipes for visualizing data (Second edition).* O'Reilly.

Murray, S. (2017). *Interactive data visualization for the web: an introduction to designing with D3 (Second edition).* O'Reilly.

Wickham, H. (2010). A Layered Grammar of Graphics. *Journal of Computational and Graphical Statistics*, 19(1), 3–28. https://doi.org/10.1198/jcgs.2009.07098

Videos/Online Courses

Adobe Illustrator, LinkedIn Learning*

SVG, LinkedIn Learning*

** The University has a LinkedIn Learning account, offering all students access to all courses/content.*

Prototyping Environments

- Observable Notebooks for D3.js (and also P5.js, but it's better for D3)
- P5.js Editor for P5.js
- Glitch for D3.js and P5.js
- Kaggle Notebooks for R or Python

Resources

The university provides many resources to help students achieve academic and artistic excellence. These resources include:

- The University (and associated) Libraries: http://library.newschool.edu
- The University Learning Center: http://www.newschool.edu/learning-center

- University Disabilities Service: www.newschool.edu/student-disability-services/ In keeping with the university's policy of providing equal access for students with disabilities, any student with a disability who needs academic accommodations is welcome to meet with the instructor privately. All conversations will be kept confidential. Students requesting any accommodations will also need to contact Student Disability Service (SDS). SDS will conduct an intake and, if appropriate, the Director will provide an academic accommodation notification letter for you to bring to the instructor. At that point, the instructor will review the letter with you and discuss these accommodations in relation to this course.

Policies on Academic Honesty and Integrity

Compromising your academic integrity may lead to serious consequences, including (but not limited to) one or more of the following: failure of the assignment, failure of the course, academic warning, disciplinary probation, suspension from the university, or dismissal from the university.

Students are responsible for understanding the University's policy on academic honesty and integrity and must make use of proper citations of sources for writing papers, creating, presenting, and performing their work, taking examinations, and doing research. It is the responsibility of students to learn the procedures specific to their discipline for correctly and appropriately differentiating their own work from that of others. The full text of the policy, including adjudication procedures, is found at http://www.newschool.edu/provost/information-for-students/

Resources regarding what plagiarism is and how to avoid it can be found on the Learning Center's website: http://www.newschool.edu/learning-center/virtual-handout-drawer/

Course Policies

Responsibility

Students are responsible for all assignments, even if they are unable to attend a particular class meeting.

Late assignments
Late submission of assignments will lead to a reduction in the grade. Extra credit and make-up assignments will not be available.

Cellphones, laptops and other technology
Students are strongly encouraged to take notes during class, using whatever note-taking medium works best for them (paper and pencil, laptop, tablet, etc.). All devices must be silenced during class, and they should not be used in any way that distracts fellow classmates from attending to the class. (In other words, class time is not the appropriate time for online activities unrelated to the class).

Canvas
Use of Canvas is an essential resource for this class; all assignments are to be submitted through the Canvas course pages. Students should check Canvas for announcements before coming to class each week, and make sure to set up their preferences in Canvas to make sure that Canvas alerts reach them.

Additional Course Information

AMT Statement
As students, artists, designers, educators, and cultural producers, we must acknowledge the lineages of white supremacy, racial discrimination, and other forms of systemic oppression that exist within our society in the U.S. and abroad. In the School of Art, Media & Technology (AMT), we are committed to creating a more inclusive, equitable and anti-racist community. We aim to support and advocate for the needs of all AMT students, staff and faculty across all identities of race, gender, sexual orientation, disability, age, religion, culture, citizenship, or socio-economic status. We will stand in solidarity with marginalized communities who have been historically excluded from institutions, including Black, Indigenous, Latinx, AAPI (Asian, Asian American and Pacific Islander), People of Color, Queer, and Trans folks, and aim to center their narratives and practices within our learning environment. We recognize the limitations of language that can't envelop the breadth of all intersectional identities, and as such, we are committed to advancing equity, respect, and thoughtfulness within our teaching pedagogy, curriculum, classrooms and across AMT.

Student Course Evaluations
During the last two weeks of the semester, students are asked to provide feedback for each of their courses through an online survey and cannot view

grades until providing feedback or officially declining to do so. Instructors rely on course rating surveys for feedback on the course and teaching methods, so they can understand what aspects of the class are most successful in teaching students, and what aspects might be improved or changed in future. Without this information, it can be difficult for an instructor to reflect upon and improve teaching methods and course design. In addition, program/department chairs and other administrators review course surveys.

Course Outline

While we may take more or less time to cover various topics than this schedule suggests, and the exact readings and schedule may be adjusted over the course of the semester, you may rely on the project and assignment due dates. Readings are all available under "Course Reserves" in the course Canvas pages.

WEEK 1	Jan 24 VIA ZOOM	Introductions, syllabus review	Recommended: ▪ (Torres, 2016) ▪ (Leonhardt, 2017) ▪ (van der Bles et al., 2020)
WEEK 2	Jan 31 VIA ZOOM	Uncertainty in data visualization: a review and looking forward	Required: ▪ (Brodlie et al., 2012) ▪ (Hertwig et al., 2019), Ch. 1 Recommended: ▪ (Johnson & Sanderson, 2003) First Canvas post due (see Canvas)

WEEK 3	Feb 7	Graph grammars and visual languages	Required: ▪ (Wilkinson, 2005), Ch. 15 'Uncertainty", pp. 451-488 ▪ (Bertin, 1983), pp. 41 – 97 ▪ (Wartik, 2017) See syllabus section **"Reference readings and other resources for creating data visualization"** for a list of books and videos for various software that can be used to implement designed graphs. Recommended • (American Psychological Association, 2010), Ch. 5 "Displaying results" Second Canvas post due (see Canvas)

WEEK 4	Feb 14	Thinking like an applied psychologist: User comprehension and experience	Required: ▪ (Norman, 2013) Ch. 1 "The Psychology of Everyday Things" & Ch. 2 "The Psychology of Everyday Actions" from "The Design of Everyday Things". ▪ (Güss, 2018) Recommended: ▪ More chapters from "The Design of Everyday Things" (Norman 2013) ▪ (Norman, 2005) "Emotional Design: Why we love (or hate) everyday things" ▪ (Kieras, 2004) Ch. 4 "GOMS Models for Task Analysis" Third canvas post due (see Canvas)
	Feb 21	PRESIDENT'S DAY—NO CLASS MEETING	
WEEK 5	Feb 28	Thinking like an applied psychologist: Models of communicating uncertainty	Required: ▪ (van der Bles et al., 2019)

WEEK 6	Mar 7	Thinking like a designer	Required: ▪ (Drucker, 2014), pp. 125-129 ▪ (Dunne & Raby, 2013), Ch. 7 "Designing for Unreality" ▪ (Hill et al., 2018) **Demo: a quick tour of p5.js, D3.js, SVG/Adobe Illustrator, and ggplot in R and Python** See syllabus section **"Reference readings and other resources for creating data visualization"** for a list of books and videos for various software that can be used to implement designed graphs. **Final project groups assigned**
	Mar 14	SPRING BREAK—NO CLASS MEETING	
WEEK 7	Mar 21	Evaluating user comprehension of visualizations	Required: ▪ (Hullman et al., 2019) ▪ (Cleveland & McGill, 1984) ▪ (Broad et al., 2007) Recommended: ▪ (Padilla et al., 2015) ▪ (Ruginski et al., 2016)

WEEK 8	Mar 28	Evaluating user comprehension of visualizations II	Required: ▪ (Newman & Scholl, 2012) ▪ (Kale et al., 2019) ▪ (Boukhelifa et al., 2012) Recommended: ▪ (Zacks et al., 1998)
WEEK 9	Apr 4	Kinds of uncertainty: Measurement error	Required: ▪ (Wainer, 2013), Ch.13 "Depicting Error" ▪ (Belia et al., 2005) ▪ (Liu et al., 2017) ▪ (Han et al., 2009) ▪ (Goldstein & Rothschild, 2014)
WEEK 10	Apr 11	Kinds of uncertainty: Additional sources of error--Total Survey Error approach	Required: ▪ (Groves & Lyberg, 2010) ▪ (Cornesse et al., 2020) Recommended ▪ (Conrad et al., 2014)

WEEK 11	Apr 18	Kinds of uncertainty: Replication and questions about statistical methods	Required: ▪ (Open Science Collaboration, 2015) ▪ (Gilbert et al., 2016) ▪ (Wasserstein et al., 2019) ▪ (Clayton, 2019) Recommended: ▪ (Calin-Jageman & Cumming, 2019) ▪ (Mayo & Spanos, 2011)
WEEK 12	Apr 25	Kinds of uncertainty: Algorithms, data transformation, machine learning	Required: ▪ (Donoho, 2015) ▪ (Schober et al., 2016) ▪ (Fernandes et al., 2018)
WEEK 13	May 2 VIA ZOOM	Studio format with external critiques	Required: ▪ (Hullman, 2020) ▪ (Marx, 2013)
WEEK 14	May 9	Studio format	Present current draft of final project for review (Course evaluations)
WEEK 15 *Last class meeting*	May 16	Project presentations	**Final projects to be submitted by start of class**

COURSE READINGS:

American Psychological Association. (2010). *Publication manual of the American Psychological Association* (6th ed.). APA Books.

Belia, S., Fidler, F., Williams, J., & Cumming, G. (2005). Researchers misunderstand confidence intervals and standard error bars. *Psychological Methods*, *10*(4), 389–396. https://doi.org/10.1037/1082-989X.10.4.389

Bertin, J. (1983). *Semiology of graphics: Diagrams, networks, maps*. University of Wisconsin Press. https://doi.org/10.1037/023518

Boukhelifa, N., Bezerianos, A., Isenberg, T., & Fekete, J. D. (2012). Evaluating sketchiness as a visual variable for the depiction of qualitative uncertainty. *IEEE Transactions on Visualization and Computer Graphics*, *18*(12), 2769–2778. https://doi.org/10.1109/TVCG.2012.220

Broad, K., Leiserowitz, A., Weinkle, J., & Steketee, M. (2007). Misinterpretations of the "cone of uncertainty" in Florida during the 2004 hurricane season. *Bulletin of the American Meteorological Society*, *88*(5), 651–667. https://doi.org/10.1175/BAMS-88-5-651

Brodlie, K., Allendes Osorio, R., & Lopes, A. (2012). A review of uncertainty in data visualization. In *Expanding the frontiers of visual analytics and visualization* (pp. 81–109). Springer. https://doi.org/10.1007/978-1-4471-2804-5_6

Calin-Jageman, R. J., & Cumming, G. (2019). The new statistics for better science: Ask how much, how uncertain, and what else is known. *American Statistician*, *73*(sup1), 271–280. https://doi.org/10.1080/00031305.2018.1518266

Clayton, A. (2019). The flawed reasoning behind the replication crisis. *Nautilus*, *74*, 1–9.

Cleveland, W. S., & McGill, R. (1984). Graphical perception: Theory, experimentation, and application to the development of graphical methods. *Journal of the American Statistical Association*, *79*(387), 531–554. https://doi.org/10.2307/2288400

Conrad, F. G., Schober, M. F., & Schwarz, N. (2014). Pragmatic processes in survey interviewing. In T. Holtgraves (Ed.), *Oxford Handbook of Language and Social Psychology* (pp. 420–437). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199838639.013.005

Cornesse, C., Blom, A. G., Dutwin, D., Krosnick, J. A., De Leeuw, E. D., Legleye, S., Pasek, J., Pennay, D., Phillips, B., Sakshaug, J. W., Struminskaya, B., & Wenz, A. (2020). A review of conceptual approaches and empirical evidence on probability and nonprobability sample survey research. *Journal of Survey Statistics and Methodology*, 1–33. https://doi.org/10.1093/jssam/smz041

Donoho, D. (2015). 50 Years of Data Science. In *R Software*.

Drucker, J. (2014). *Graphesis: Visual forms of knowledge production*. Harvard University Press.
Dunne, A., & Raby, F. (2013). *Speculative everything: Design, fiction, and social dreaming*. MIT Press.
Fernandes, M., Walls, L., Munson, S., Hullman, J., & Kay, M. (2018). Uncertainty displays using quantile dotplots or CDFs improve transit decision-making. *Conference on Human Factors in Computing Systems - Proceedings*, *2018-April*. https://doi.org/10.1145/3173574.3173718
Gilbert, D. T., King, G., Pettigrew, S., & Wilson, T. D. (2016). Comment on: Estimating the reproducibility of psychological science. *Science*, *351*(6277), 4–6. https://doi.org/10.1126/science.aac4716
Goldstein, D. G., & Rothschild, D. (2014). Lay understanding of probability distributions. *Judgment and Decision Making*, *9*(1), 1–14.
Groves, R. M., & Lyberg, L. (2010). Total survey error: Past, present, and future. *Public Opinion Quarterly*, *74*(5), 849–879. https://doi.org/10.1093/poq/nfq065
Güss, C. D. (2018). What Is going through your mind? Thinking aloud as a method in cross-cultural psychology. *Frontiers in Psychology*, *9*(1292), 1–11. https://doi.org/10.3389/fpsyg.2018.01292
Han, P. K. J., Lehman, T. C., Massett, H., Lee, S. J. C., Klein, W. M. P., & Freedman, A. N. (2009). Conceptual problems in laypersons' understanding of individualized cancer risk: A qualitative study. *Health Expectations*, *12*(1), 4–17. https://doi.org/10.1111/j.1369-7625.2008.00524.x
Hertwig, R., Pleskac, T. J., & Pachur, T. (2019). *Taming uncertainty*. MIT Press.
Hill, A., Churchouse, C., & Schober, M. F. (2018). Seeking new ways to visually represent uncertainty in data: What we can learn from the fine arts. *2018 IEEE VIS Arts Program (VISAP)*, 1–8. https://doi.org/0.1109/VISAP45312.2018.9046052
Hullman, J. (2020). Why authors don't visualize uncertainty. *IEEE Transactions on Visualization and Computer Graphics*, *26*(1), 130–139. https://doi.org/10.1109/TVCG.2019.2934287
Hullman, J., Qiao, X., Correll, M., Kale, A., & Kay, M. (2019). In pursuit of error: A survey of uncertainty visualization evaluation. *IEEE Transactions on Visualization and Computer Graphics*, *25*(1), 903–913. https://doi.org/10.1109/TVCG.2018.2864889
Johnson, C. R., & Sanderson, A. R. (2003). A next step: Visualizing errors and uncertainty. *IEEE Computer Graphics and Applications*, *23*(5), 6–10. https://doi.org/10.1109/MCG.2003.1231171
Kale, A., Nguyen, F., Kay, M., & Hullman, J. (2019). Hypothetical outcome plots

help untrained observers judge trends in ambiguous data. *IEEE Transactions on Visualization and Computer Graphics*, *25*(1), 892–902. https://doi.org/10.1109/TVCG.2018.2864909

Kieras, D. (2004). GOMS models for task analysis. In D. Diaper & N. A. Stanton (Eds.), *The handbook of task analysis for human-computer interaction* (pp. 83–116). Lawrence Erlbaum Associates.

Leonhardt, D. (2017, December 24). What I was wrong about this year. *The New York Times*. https://nyti.ms/2DJWh2S

Liu, L., Boone, A. P., Ruginski, I. T., Padilla, L., Hegarty, M., Creem-Regehr, S. H., Thompson, W. B., Yuksel, C., & House, D. H. (2017). Uncertainty visualization by representative sampling from prediction ensembles. *IEEE Transactions on Visualization and Computer Graphics*, *23*(9), 2165–2178. https://doi.org/10.1109/TVCG.2016.2607204

Marx, V. (2013). Data visualization: Ambiguity as a fellow traveler. *Nature Methods*, *10*, 613–615. https://doi.org/10.1038/nmeth.2530

Mayo, D. G., & Spanos, A. (2011). Error statistics. In P. S. Bandyopadhyay, M. R. Forster, & D. M. Gabbay (Eds.), *Philosophy of statistics* (1. ed, pp. 153–198). Elsevier.

Newman, G. E., & Scholl, B. J. (2012). Bar graphs depicting averages are perceptually misinterpreted: The within-the-bar bias. *Psychonomic Bulletin & Review*, *19*, 601–607. https://doi.org/10.3758/s13423-012-0247-5

Norman, D. A. (2005). *Emotional design: why we love (or hate) everyday things*. Basic Books.

Norman, D. A. (2013). *Design of everyday things: Revised and expanded*. Basic Books.

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716–aac4716. https://doi.org/10.1126/science.aac4716

Padilla, L. M., Hansen, G., Ruginski, I. T., Kramer, H. S., Thompson, W. B., & Creem-Regehr, S. H. (2015). The influence of different graphical displays on nonexpert decision making under uncertainty. *Journal of Experimental Psychology: Applied*, *21*(1), 37–46. https://doi.org/10.1037/xap0000037

Ruginski, I. T., Boone, A. P., Padilla, L. M., Liu, L., Heydari, N., Kramer, H. S., Hegarty, M., Thompson, W. B., House, D. H., & Creem-Regehr, S. H. (2016). Non-expert interpretations of hurricane forecast uncertainty visualizations. *Spatial Cognition & Computation*, *16*(2), 154–172. https://doi.org/10.1080/13875868.2015.1137577

Schober, M. F., Pasek, J., Guggenheim, L., Lampe, C., & Conrad, F. G. (2016). Research synthesis: Social media analyses for social measurement. *Public*

Opinion Quarterly, *80*(1), 180–211. https://doi.org/10.1093/poq/nfv048
Torres, N. (2016, November). Why it's so hard for us to visualize uncertainty. *Harvard Business Review*. https://hbr.org/2016/11/why-its-so-hard-for-us-to-visualize-uncertainty
van der Bles, A. M., van der Linden, S., Freeman, A. L. J., Mitchell, J., Galvao, A. B., Zaval, L., & Spiegelhalter, D. J. (2019). Communicating uncertainty about facts, numbers and science. *Royal Society Open Science*, *6*(5), 181870. https://doi.org/10.1098/rsos.181870
van der Bles, A. M., van der Linden, S., Freeman, A. L. J., & Spiegelhalter, D. J. (2020). The effects of communicating uncertainty on public trust in facts and numbers. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(14), 7672–7683. https://doi.org/10.1073/pnas.1913678117
Wainer, H. (2013). *Picturing the uncertain world: How to understand, communicate, and control uncertainty through graphical display*. Princeton University Press.
Wartik, N. (2017, December 14). NYT needle returns to the spotlight. The internet notices. *The New York Times*.
Wasserstein, R. L., Schirm, A. L., & Lazar, N. A. (2019). Moving to a world beyond "p < 0.05." *American Statistician*, *73*(sup1), 1–19. https://doi.org/10.1080/00031305.2019.1583913
Wilkinson, L. (2005). *The grammar of graphics* (2nd ed.). Springer-Verlag. https://doi.org/10.1007/0-387-28695-0
Zacks, J., Levy, E., Tversky, B., & Schiano, D. J. (1998). Reading bar graphs: Effects of extraneous depth cues and graphical context. *Journal of Experimental Psychology: Applied*, *4*(2), 119–138. https://doi.org/10.1037/1076-898X.4.2.119