Dynamic Ensembles versus Cones of Uncertainty: Visualizations to Support Understanding of Uncertainty in Hurricane Forecasts

Jessica K. Witt, Benjamin A. Clegg, Christopher D. Wickens, C.A.P. Smith, Emily L. Laitin, Amelia C. Warden
Department of Psychology, Colorado State University

Visualizations attempt to convey the uncertain track of an approaching hurricane. The current experiment contrasted decision characteristics that resulted from observing hurricane paths presented using cones of uncertainty versus a new form of dynamic ensemble. Participants made judgments about whether to evacuate a town at different eccentricities to the central predicted path of a storm. Results showed that dynamic ensembles have different properties to cone displays. Presentations of dynamic ensembles encouraged greater consideration of evacuation at locations further from the most probable path, but that were still at risk. However, dynamic ensembles resulted in lower evacuation rates at the center of the distribution, consistent with a probabilistic sense of the risk but nonetheless a potentially undesirable strategy. In addition, perceptions of the evacuation need with dynamic ensemble presentations were more strongly influenced by the amount of variability than with cones. The implications for use of dynamic ensembles are discussed.

Preparations for a potential hurricane landfall depend on two critical factors, the availability and accuracy of forecast models, and the decisions made based on that information (Regnier & Harr, 2006). While there are important human factors issues that can be addressed to improve the accuracy of forecasts (see Regnier & Kirlik, 2012), ultimately, forecasts for potential tracks that provide greater preparation time are inherently uncertain. Models used for predictions indicate some level of variability in the possible path of a hurricane. In order to maximize the level of preparation for an impending storm, one important challenge then is how to effectively convey the relevant information, that includes such variability, to individuals with no specialist knowledge (such as people living on property on a threatened coast) so that they make appropriate evacuation or preparation decisions.

When people are exposed to a distribution of uncertain spatial trajectories, they readily extract the "average" of the pattern they experienced but are poor at evaluating the variability (Herdener, Wickens, Clegg, & Smith, 2016, 2018).While a range of factors influence the estimation of variability that occurs (see Wickens et al., 2020), some modest gains in understanding of variability can be seen from the use of visualizations in the presentation of information (Pugh et al., 2018; Ruginski et al., 2016).

To provide information about uncertainty in the course of a hurricane, the National Weather Service employs National Hurricane Center Track Forecast Cones, colloquially known as "cones of uncertainty". This cone of uncertainty approach to convey the array of potential tracks for a storm is commonly mirrored in local weather forecasts presented to the general public (Broad, Leiserowitz, Weinkle, & Steketee, 2007; Ruginzki et al., 2016). Cones of uncertainty are built from the most probable path of the center of the storm, and variability around that path which captures two thirds of the forecast errors from a 5-year sample (NOAA, 2020).

One of the core problems with the cone of uncertainty is that people do not interpret it correctly. People focus too much on the central track of the storm, and of high concern is the belief that locations outside the cone boundaries are not impacted by the hurricane (Boone, Gulnap, & Heggerty, 2018; Broad et al., 2007). Some individuals also confuse the width of the cone as indicating a future larger size of the storm rather than an increased spatial uncertainty across time (Boone, Gulnap, & Heggerty, 2018).

There is also a range of issues with the use of cones as visualizations (Padilla, Creem-Regehr, Hegarty, & Stefanucci, 2018). These include the "containment effect" for which some forms of visualizations can induce artificial boundaries (see, for example, McKenzie, Hegarty, Barrett, & Goodchild, 2016). In cones this produces a large discontinuous drop off in perceived likelihood of paths outside the cone boundary compared to those inside, as if the cone contains all possible hurricane paths.

Hamill et al. (2012) outlined an interest in transition towards the use of ensemble techniques to convey uncertainty around tropical cyclones, including lagged ensemble track forecasts ("spaghetti plots"). An ensemble representation involves showing multiple, simultaneous individual paths that can illustrate the divergence over time. There has been research examining line, scatter, and heatmap based ensembles and their potential advantages versus various forms of cones of uncertainty (see, for example, Cox, House, & Lindell, 2013; Ruginski et al., 2016).

The visual system is tuned to extract properties of an ensemble of objects, quickly determining facets such as the mean, the variability, and outliers (for review, see Whitney & Leib 2018). Moreover, perceptual precision is similar when detecting properties of single objects as with ensembles. Visualizations can leverage this ability of the visual system. Rather than providing a visualization of the summary itself (as in the cone of uncertainty), ensemble visualizations can convey a range of potential outcomes and let the visual system do the work of summarizing this information. Doing so could avoid some of the biases associated with the cone of uncertainty as well as increase the amount of information that could be communicated.

In the current experiment, we built from prior work using ensembles to represent uncertainty in hurricane forecasts but implemented a dynamic display. One advantage of using an array of dynamic objects is the potential to shift understanding of uncertainty into the perceptual domain, rather that requiring abstract reasoning and extrapolation from the visualization (see Wickens et al., 2020). An effective visualization typically maximizes compatibility between visual features of the display and what they represent (Hegarty, 2014; Witt, 2019a). For example, displays are better understood when the size of the visual features correspond to the size of the concept being represented. For the cone of uncertainty, visual size represents uncertainty rather than the size of the storm, but as mentioned above this lack of compatibility contributes to the public's misunderstanding of the cone of uncertainty. An advantage of a dynamic display is to include compatibility between the storm's movement path and the visual features of the predicted storm's path.

Another possible advantage of a dynamic display is compatibility between the perceptual experience of uncertainty (see, for example, Witt, 2019b) that can enhance conceptual understanding of uncertainty. The uncertainty of the movement of a dynamic display carries with it an impression of uncertainty. This impression could carry into the conceptual understanding that predictions are uncertain and subsequently affect behavioral decisions.

In the current experiment, we employed a variant of the type of task used by Padilla, Ruginski and Creem-Regehr (2017). The central question for the study was how decisions about the potential course of an incoming storm would change as a function of the type of visualization offered about the variability possible in that track. The experiment compared decisions made when viewing a cone of uncertainty to convey the extent of the area under threat, versus a dynamic ensemble that demonstrated an array of possible paths. As outlined above, the specific predictions were that dynamic ensembles compared to cones would result in: (1) a generally increased perception of the variability presented, (2) a more calibrated, gradual sense of the decline in risk rather than the steep drop characterized by a containment effect.

METHOD

After seeing a hurricane forecast prediction approach a coastline, the participant was tasked with deciding whether to evacuate a town shown at a specific location. Forecast predictions came in the form of the cone of uncertainty or with a dynamic display of potential paths that we refer to as "zoomies".

Participants. Forty students enrolled in an introductory psychology course at Colorado State University volunteered in exchange for partial, optional course credit.

Stimuli and apparatus. The stimuli were viewed on a 19" computer monitor with 1280 x 1024 resolution. On the right side of the screen, a map of a coastline was presented.

Procedure. There were two types of trials: cones and zoomies. On cone trials, as shown in Figure 1, a cone (created as two lines and an arc connecting them) was presented to the left of the coastline. The left-right length of the cone was 18cm. The top-down width of the cone was set to 1 of 3 widths depending on the level of spread. For the narrow spread, the width was 4.7 cm at its widest point. For the medium and wide spreads, the widths were 7.1 and 9.4 cm, respectively. The center of the widest part of the cone was either at the center of the screen, 0.6 cm above the center, or 0.6 cm below the center of the screen. This corresponded to the manipulation of the angle of the storm (up, center, or down).

On the zoomie trials, 18 small squares (0.44 cm^2) originated from the center of the left side of the screen (1.5 cm from the left edge) and moved towards the coastline. The squares left no trails as they moved across the screen, disappeared once they reached the end of their path, and were only shown once per trial. As shown in Figure 1, their distribution approximated a normal distribution with 4 zoomies just above the center path, 4 just below, 2 each on either side of that, and 3 evenly spaced outside each of those. The 12 in the center (67%) would all have been inside the cone had the cone been present (cones and zoomies were never presented at the same time). As the spread increased, the spatial paths of the zoomies were more spread apart. The spatial paths were also manipulated to be up, center, or down depending on the angle of the storm. Each zoomie moved at a constant speed to which some random noise was added at the beginning of each trial. The speeds ranged from 120 to 190 cm/s. This created some variability in the distance of the tracks to their termination. It took approximately 150 ms (range = 126 – 186ms) for the zoomies to complete their movements.

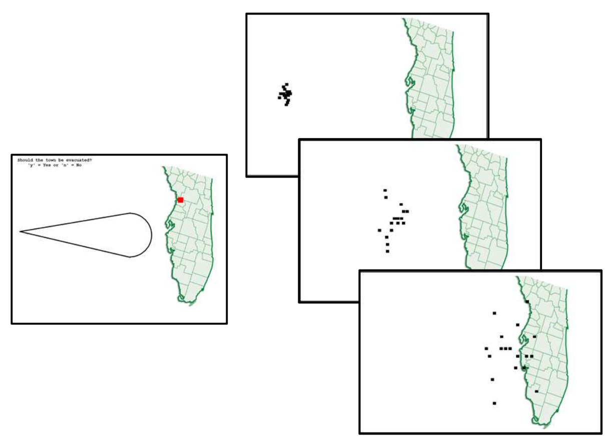

Figure 1. *The panel of the left shows a cone trial with the town for which the evacuate decision must be made depicted to the right of the upper edge of the cone. The 3 panels on the right show the progression of zoomies with a trial, with each instance in the dynamic ensemble moving smoothly and continuously across the screen.*

The town was a red square (0.88 cm^2) that was located either within the central region of the distribution or at the boundary for two thirds of the distribution (on cone trials that would be the top or bottom edge of the cone). Random noise of up to 1.46 cm was added to the town's location so that it did not appear to be the same town on every trial. Thus, when the town was located at the boundary, it could either be just inside the cone's boundary or just outside this boundary. On average, the town was located approximately 0.5cm on either side of the boundary.

Procedure. Participants provided informed consent; then the following instructions were provided on self-paced introductory screens: "You are in charge of evacuating a town when hurricanes approach. The town will be marked with a red square. If you choose not to evacuate the town and a hurricane hits, damage will be extensive and costly. If you choose to evacuate the town and the hurricane does not hit there, money will be spent on the evacuation for nothing. Thus, there are benefits and costs to evacuating the town. Towns must be evacuated 12 hours in advance of when the hurricane will hit. For each decision, a hurricane is hovering and is approximately 12 hours away, so it will be time to make your decision. You will see a model that shows the best predictions of the hurricane's anticipated path. *The models show a region that contains 67% of the predicted paths*. Hurricanes are unpredictable, so make your best guess of whether to evacuate the town." For the zoomies trials, the text shown in italics above was replaced with the following instruction: "The model shows animations of the most likely potential hurricane paths." None of the text shown to the participants was italicized.

The general flow of the trial was a fixation screen for 1000 ms, a display of the hurricane prediction (as a cone of uncertainty or as zoomies), and a decision about whether to evacuate the town. Participants indicated their decision by pressing "y" for yes to evacuate and "n" for no. The zoomies were only shown once. The cone remained on the screen until participants made their response.

There were small variations between participants based on when the town was shown relative to the prediction and the number of trials. For Experiment 1a (n = 22), the town was presented 500 ms after the cone was shown or immediately after all zoomies were shown. For these participants, each block contained 108 trials (3 spreads x 3 town positions x 3 angles x 4 repetitions), and they completed one block for each visualization condition. For 5 of these participants, there was sufficient time during their allotted slot that they were able to run through the experiment twice. To determine whether the timing of when the town was presented mattered, we started Experiment 1b (n = 7) for which the town was shown before the presentation of the cone or the zoomies, and there were 8 repetitions of each trial type for a total of 216 trials per block. To maximize data in the zoomies condition (given that the procedure did not change for the cones condition), we then conducted Experiment 1c (n = 11) for which we only ran the zoomies condition, presented the town in advance of the zoomies, and doubled the number of trials. Order within block was randomized, and starting visualization condition was counterbalanced across participants when both visualization conditions were included.

RESULTS

None of the variations across Experiments 1a-1c significantly affected the results, ps > .30, so all data were combined and analyzed together.

We first analyzed evacuation rate for towns located near the center of the cone (which also corresponds to the range for which 44% of the zoomies passed). As described in the Introduction, cones of uncertainty seem to convey a high likelihood that hurricane will progress along the central path of the cone. Our analyses explored whether that tendency was replicated in our experiment and the extent to which dynamic ensembles might exhibit the same effect. Mean evacuation rates from these trials were analyzed with a linear mixed model. The fixed effects were visualization condition (coded as -0.5 and 0.5 for zoomies and cone, respectively), prediction spread (coded as -0.5, 0, 0.5 for narrow, medium, and wide, respectively), and their interaction. Random effects for participant including intercepts and slopes for all fixed effects were also included.

Visualization condition had a significant effect on evacuation rate, estimate = 22%, SE = 4%, t = 6.08, p < .001. As shown in Figure 2, participants were more likely to evacuate towns located in the center when the visualization format was the cone (M = 94%, SD = 11%) than with the zoomies (M = 72%, SD = 24%). The high rate of evacuation for the cones for central locations is congruent with previous findings, but the lower rate for the dynamic ensembles shows a different property of these new visualizations.

Prediction spread affected evacuation rates, estimate = -6%, SE = 2%, t = -2.60, p = .013. The interaction between visualization format and prediction spread was significant, estimate = 18%, SE = 5%, t = 3.95, p< .001. As prediction spread increased, the difference in evacuation rates between the cone and zoomies conditions increased. Whereas the width of the cone did not impact the sense of a need for evacuation along its center, remaining consistently high, a greater width of the distribution resulted in a reduced rate of evacuation for the dynamic ensembles. Note that while the probability of the hurricane path occurring within this zone remains the same regardless of the width of the distribution, the true risk associated with any single location does decrease for a wider distribution of possible paths.

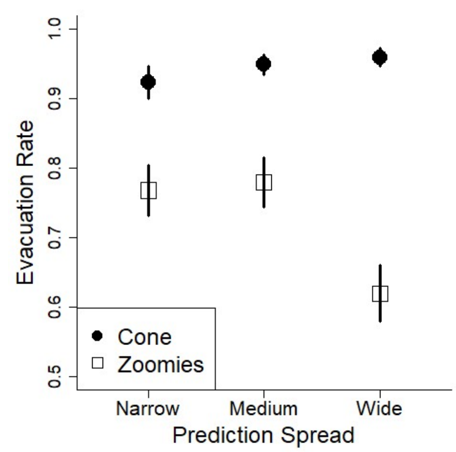

Figure 2. *Proportion of towns located in the center of the prediction zone that were evacuated (evacuation rate) as a function of the prediction spread and visualization condition. Error bars are 1 SEM calculated between subjects.*

Next, we analyzed evacuation rates at the edge of the cone, which corresponded to the edge for which 67% of zoomies passed through. Mean evacuation rates from these trials were analyzed with a linear mixed model. The fixed effects were visualization condition, prediction spread, whether the town was located within or outside the 67% zone (coded as -0.5 and 0.5), and the two-way interactions with visualization condition and each of the other factors. Random effects for participant including intercepts and slopes for each fixed effect were included. The model was singular unless town location was excluded from the random effects, but the estimates and significance for the fixed effects were nearly identical for both models, so we report the results from the full model.

Visualization condition had a small, marginally significant effect on evacuation rate, estimate = 6%, SE = 3%, t = 1.99, p = .055. Prediction uncertainty affected evacuation rate, estimate = -15%, SE = 2%, t = -8.84, $p < .001$. As the spread increased, the evacuation rate decreased (see Figure 3). Town location affected evacuation rates, with people evacuating towns located within the boundary at a higher rate compared with towns outside the boundary, estimate = -18%, SE = 2%, t = -10.32, $p < .001$. The interaction between visualization condition and prediction uncertainty was significant, estimate = -8%, SE = 3%, t = -2.73, p = .009. Critically, the interaction between visualization condition and town location was significant, estimate = 18%, SE = 4%, t = 4.72, $p < .001$. As shown in Figure 3, the visible boundary caused by the cone led to a steeper decrease in evacuation rates for towns just beyond the boundary compared with the zoomies condition. The dynamic ensembles led to evacuation rates across eccentricities that reduced far more gradually. While participants' choices reflect a high level of evacuation rates for points inside the 2/3 mark of the distribution for both forms of visualization, those just outside that zone show a strong drop off in evacuation rates with the cone but maintain a much higher level of readiness to evacuate for the zoomies. This increased drop in evacuation rates for the cone condition relative to the zoomies condition is present across all levels of prediction spread with the zoomies.

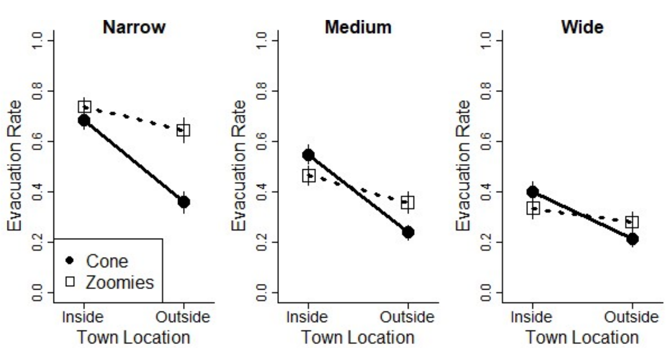

Figure 3. *Evacuation rates for towns located at the edge of the 67% prediction region are plotted as a function of whether the town was inside or outside the boundary, prediction spread, and visualization condition. Error bars are 1 SEM calculated between subjects.*

DISCUSSION

The current experiment explored differences in the understanding of the range of potential paths of a hurricane track based on two different types of visualizations. The findings suggest that there are different properties for dynamic ensembles compared to commonly used cones of uncertainty.

Results show that cones encouraged a strong sense that the central predicted path has at a very high risk (Figure 2), whereas dynamic ensembles suggest that locations at the center of the prediction do not always necessitate evacuation, particularly at the wide distribution (implying more uncertainty of the potential path). The study also illustrates a difference between the interpretation towards the edges of the distribution of possible paths. Consistent with previous findings (Boone et al., 2018; Broad et al., 2007), locations outside the cones showed a far lower rate of evacuation than those just inside the cones. Participants were explicitly informed that the cones showed the distribution for just two thirds of the paths and that one third of the time the actual path was likely to fall outside the radius of the cone. In contrast the dynamic ensembles showed a more gradual sense of the reduction in risk across the distribution of potential paths. Such findings imply dynamic ensembles offer another method to overcome the "containment effect", where some visualizations such as cones suggest artificial boundaries (see Padilla et al., 2018).

We hypothesized that the zoomies would be effective because of the compatibility between the visual presentation and the conceptual understanding. A next step is to directly compare zoomies to static ensemble visualizations. Another future direction is to leverage potential advantages for using a dynamic display, such as manipulating additional dimensions like the rate of approach of the individual hurricane paths. Showing different timings depending on the direction the hurricane takes would be difficult to do with static displays such as spaghetti plots.

Regardless of the mechanisms, the different properties of these visualizations have important potential real-world implications. Peripheral locations that were still at risk showed on average higher rates of endorsement of the need to evacuate with zoomies than with cones. This gain in willingness to evacuate, however, comes at the cost of lower rates of evacuation in the center of the distribution. The findings suggest an important trade-off from the use of dynamic ensembles versus cones of uncertainty, at least for this instantiation of the dynamic ensembles. One implication may be that at the earliest time points for supplying warnings to communities, dynamic ensembles might increase the area within which people begin making emergency preparations. As the time window narrows, moving to a cone of uncertainty may serve to better encourage those on the most likely path to begin evacuations.

The current findings also highlight the role that the spread of the distribution might play in the decisions that individuals are making. On the one hand, the decision to reduce the likelihood of evacuation at any one location because of a wider distribution of possible paths for the hurricane makes some rational sense. More uncertainty does imply lower risk for any specific location within that distribution. On the other hand, for many real-world forecasts with a long lead time, the area under threat will be large. The implication that individuals, including those still in locations with the strong possibility of being in the final actual path, may fail to begin to prepare presents an important challenge for developing more effective visualizations.

We note that this initial study with dynamic ensembles, while demonstrating they do have different properties from cones as a form of visualization for uncertainty, still leaves a range of important questions to be answered. This first experiment includes no parametric variations of number of items, speed of presentation, nor whether repetitions of the visualization (both identical repetitions, and further presentation that incorporate other variations of the possible paths) would influence the understanding of the variability, and the subsequent judgment based on that information. It also remains a question for future research how dynamic ensembles may differ from static one, or indeed from combinations of static and dynamic elements (such as would occur with instances leaving paths or trails). The study used only a decision to evacuate and did not directly probe people's understanding of the probabilities and uncertainty being conveyed. While this mirrors the actual decisions individuals in a potential hurricane path might have to make, it also introduces some interpretation for the participants in how they chose to weigh the costs and benefits of evacuation versus staying.

The current study used participants currently located in an area that is not at risk for hurricanes. Thus, although they may have been exposed to national hurricane warnings, overall the sample likely reflected very little personal experience with hurricane tracks. This has the advantage of reducing one potential confound around understanding of the visualizations presented. Previous research has shown that experience with natural disasters impacts future behavior and risk perception (see, for example, Demuth, Morss, & Lazo, 2016). People who had personal experience evacuating before were more likely to evacuate again, while other factors, such as extensive financial costs due to property damage, reduced chances of evacuating due to belief that they could better protect property from home. At the same time, an important question for future research is how the understanding of dynamic ensembles versus cones of uncertainty changes with populations with greater exposure to both the warnings and the variability in the paths of actual storms.

ACKNOWLEDGMENTS

JKW, ELL, and ACW were supported by the National Science Foundation (BCS-1632222). JKW was also supported by the School of Global Environmental Sustainability at Colorado State University. BAC, CDW, CAPS efforts on this paper were supported by Dr. Jeff Morrison and the Office of Naval Research under grant N00014-17-1-2825. Experiment scripts, data, and analysis scripts can be found at https://osf.io/2759k/.

REFERENCES

Boone, A. P., Gunalp, P., & Hegarty M. (2018). Explicit Versus Actionable Knowledge: The Influence of Explaining Graphical Conventions on Interpretation of Hurricane Forecast Visualizations. *Journal of Experimental Psychology: Applied, 24*(3): 275-295.https://doi.org/10.1037/xap0000166

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- 668. https://doi.org/10.1175/BAMS-88-5-651

Cox, J., House, D., & Lindell, M. (2013). Visualizing uncertainty in predicted hurricane tracks. *International Journal for Uncertainty Quantification, 3*(2), 143-156. https://doi.org/10.1615/Int.J.UncertaintyQuantification.2012003966

Demuth, J. L., Morss, R. E., & Lazo, J. K. (2016). The effects of past hurricane experiences on evacuation intentions through risk perception and efficacy beliefs: A mediation analysis. *Weather, Climate, and Society, 8*(4), 327-344. https://doi.org/10.1175/WCAS-D-15-0074.1

Hamill, T. M., Brennan, M. J., Brown, B., DeMaria, M., Rappaport, E. N., & Toth, Z. (2012). NOAA's future ensemble-based hurricane forecast products. Bulletin of the *American Meteorological Society, 93*, 209-220. https://dx.doi.org/10.1175/2011BAMS3106.1

Hegarty, M. (2014). Multimedia learning and the development of mental models. In R. E. Mayer (Ed.), *Cambridge handbooks in psychology. The Cambridge handbook of multimedia learning, 2*, 673-701. https://doi.org/10.1017/CBO9781139547369.033

Herdener, N., Wickens, C. D., Clegg, B. A., & Smith, C. A. P. (2016). Overconfidence in projecting uncertain spatial trajectories. *Human Factors, 58*(6), 899-914. https://doi.org/10.1177/0018720816645259

Herdener, N., Wickens, C. D., Clegg, B. A., & Smith, C. A. P. (2018). Attention does not improve impaired understanding of variability in spatial prediction. *Proceedings of the Human Factors and Ergonomics Society 2018 Annual Meeting*, 232-236. https://doi.org/10.1177/1541931218621054

McKenzie, G., Hegarty, M., Barrett, T., & Goodchild, M. (2016). Assessing the effectiveness of different visualizations for judgments of positional uncertainty. *International Journal of Geographical Information Science, 30*(2), 221-239. https://doi.org/10.1080/13658816.2015.1082566

National Oceanic and Atmospheric Administration (NOAA). National Hurricane Center and Central Pacific Hurricane Center: Definition of the NHC Track Forecast Cone. https://www.nhc.noaa.gov/aboutcone.shtml

Padilla, L. M., Ruginski, I. T., & Creem-Regehr, S. H. (2017). Effects of ensemble and summary displays on interpretations of geospatial uncertainty data. *Cognitive Research: Principles and Implications, 2*(40). https://doi.org/10.1186/s41235-017-0076-1

Padilla, L. M., Creem-Regehr, S. H., Hegarty, M., & Stefanucci, J. K. (2018). Decision making with visualizations: a cognitive framework across disciplines. *Cognitive Research: Principles and Impacts, 3*(29), 1-25. https://doi.org/10.1186/s41235-018-0120-9

Pugh, A. J., Wickens, C. D., Herdener, N., Clegg, B. A., & Smith, C. A. P. (2018). Effect of visualization training on uncertain spatial trajectory predictions. *Human Factors, 60*(3), 324-339. https://doi.org/10.1177/0018720818758770

Regnier, E., & Harr, P. A. (2006). A dynamic decision model applied to hurricane landfall. *Weather and Forecasting, 21*(5), 764-780. https://doi.org/10.1175/WAF958.1

Regnier, E., & Kirlik, A. (2012). Human factors in the joint typhoon warning center watch floor (NPS Publication No. NPS-OR-11003Rev). Monterey, CA: Naval Postgraduate School.

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 and Computation, 16*(2), 154-172. https://doi.org/10.1080/13875868.2015.1137577

Whitney, D., & Yamanashi Leib, A. (2018). Ensemble Perception. *Annual Review of Psychology, 69*, 105-129.

Wickens, C. D., Clegg, B. A., Witt, J. K., Smith, C.A.P., Herdener, N., & Spahr, K. S. (2020). Model of variability estimation (MOVE): Factors influencing human prediction and estimation of variance in continuous information. *Theoretical Issues in Ergonomics Science, 21*(2), 220-238.

Witt, J. K. (2019a). Graph construction: An empirical investigation on setting the range of the y-axis. *Meta-Psychology, 3*, MP.2018.895.

Witt, J. K. (2019b). The Perceptual Experience of Variability in Line Orientation is Greatly Exaggerated. *Journal of Experimental Psychology: Human Perception and Performance, 45*(8): 1083-1103. https://doi.org/10.1037/xhp0000648