1.5 OBSERVED HEURISTICS AND BIASES IN AIR TRAFFIC MANAGEMENT DECISION MAKING USING CONVECTIVE WEATHER UNCERTAINTY*

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1. INTRODUCTION

General Dynamics Information Technology (GDIT), under contract to the Federal Aviation Administration (FAA), performed a research study to assess how convective weather uncertainty information is used in today's national airspace system (NAS) to support air traffic management (ATM) decisions. As part of the study the FAA asked GDIT to consider how human factors influence the communication and use of convective weather uncertainty information in ATM decisions.

GDIT's primary data came from interviews with Traffic Management Unit (TMU) personnel that included Traffic Management Officers; Supervisors, Traffic Management Coordinators (STMCs); and Traffic Management Coordinators (TMCs) at air route traffic control centers (ARTCCs), terminal radar approach control (TRACON) facilities, and air traffic control towers (Towers). GDIT also interviewed personnel at the Air Traffic Control System Command Center (ATCSCC), Center Weather Service Unit (CWSU) meteorologists, weather information providers, airline personnel, and weather researchers.

The study found that while NAS users generally understand that all convective weather observations and forecasts contain uncertainty, they don't fully understand how to use convective weather information that includes uncertainty for decision making in the NAS. In particular, these discussions identified several heuristics and resulting biases in decision making by TMU personnel when using convective weather uncertainty information. Specifically, the heuristics of availability, confirmation, overconfidence, anchoring and adjustment, and representativeness were observed. These heuristics must be taken into account in future next generation air transportation system (NextGen) decision support tools (DSTs) since humans will make the final ATM decisions.

2. RESEARCH STUDY

A summary of sites visited during the research study is shown in Table 1.

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Table 1. Summary of GDIT Site Visits for Stakeholder Outreach

Stakeholder Category	Facility Type	Facility Location
Air Traffic Management	ATCSCC	Warrenton, VA
	ARTCC	New York, Chicago, Washington DC, Kansas City, Fort Worth, Atlanta, Boston, and Oakland
	TRACON	New York, Chicago, Potomac, Fort Worth, and Atlanta
	Tower	Baltimore, MD
Weather Providers – NOAA	Aviation Weather Center	Kansas City, MO
	CWSU	New York, Chicago, Washington DC, Kansas City, Fort Worth, Atlanta, Boston, and Oakland
	NWS Aviation Weather Services Branch	Silver Spring, MD
Airlines	Airline Operations Center	JetBlue, American, Southwest, and Jet Aviation
Weather Researchers	FAA/NASA North Texas Research Station	Fort Worth, TX
	NASA Ames Research Center	Moffett Field, CA
	Mosaic ATM	Leesburg, VA
	MIT Lincoln Laboratory	Lexington, MA

3. OBSERVED HEURISTICS AND BIASES

In assessing how convective weather information is currently used by ATM personnel, it was useful to consider the impact that human decision making may have on the ATM system. Not only is it important to ascertain how ATM personnel interpret uncertainty and which tools they use to make decisions, but also to examine the existing cognitive psychological literature to determine how human judgment may play a role in decision making during convective weather events.

A large body of psychological research has demonstrated that how individuals reason about uncertainty depends to a great extent on how the problem is presented. In dealing with uncertainty, people use a number of heuristic principles, or rules-of-thumb, designed to simplify their information processing. While these heuristics are generally accurate for everyday tasks, they can result in systemic errors, known as biases.

Commonly used heuristics and some of the observed biases discovered during the discussions with ATM personnel are described in the sections that follow.

3.1 Availability Heuristic

Availability is one of the most common heuristics employed in decision making. The availability heuristic is a mental shortcut that relies on immediate examples that come to mind. Events which come to mind more readily are perceived as more likely.

In one of the most cited studies addressing this phenomenon, Tversky and Kahneman (1973) asked subjects to judge whether the letter “r” was more likely to appear in the first or third letter position of a word. Over 65% of subjects judged the first letter position to be more likely. This result was obtained even though English words with “r” as the third letter are much more frequent. The authors attributed this to the ease with which category instances came to mind, i.e., it is easier to think of words that start with a given letter than words having that letter in the third position. Furthermore, subjects had extensive experience with dictionaries in looking up words by their first letter and not their third, so the number of words individuals could recollect beginning with an “r” was much greater than the number of words with an “r” as the third letter.

A disproportionate amount of convective weather exposure may reinforce a STMC’s or TMC’s perception of comparable situations occurring in the future. To the extent that one’s experiences are biased, one’s perceptions are likely to be inaccurate. A STMC or TMC who has just had a week of non-stop convective weather exposure on the job will find it easier to conceive of such events occurring in the future. Thus, they will be more able to retrieve convective weather information from memory when they see a forecast for convective weather. This may result in the STMC or TMC giving too much weight to a low or moderate probability forecast of convection or, alternatively, increasing their subjective probability estimate for the convective event. Conversely, a STMC or TMC who has not encountered much convection recently may not give an equivalent level of attention to a convective weather forecast. One STMC nicely summarized the availability heuristic when he stated, “If it [convection] did not happen on your forecast shift [then] that event is not likely to play as much a role in your decision making in comparison to someone who actually worked the case.”

3.2 Confirmation Heuristic

A confirmation bias is found when individuals favor data which supports their belief or hypothesis. Stated another way, don’t confuse me with the facts, my mind is already made up. Thus, there is selectivity in acquiring and using evidence. Therefore, if a STMC or TMC expects convective weather to occur, a STMC or TMC may give excess weight to a high probability convective weather forecast while ignoring data suggesting that the convective weather will not materialize. Conversely, a STMC or TMC may believe that convective weather is unlikely and ignore data that suggests convective weather development. A more balanced approach is for STMCs and TMCs to be aware of the convective forecasts in conjunction with the strengths and weaknesses of the various forecast products. Furthermore, if meteorologists provide alternative probabilities, this forces STMCs and TMCs to explicitly consider those events. As one TMC stated, “I'd rather they [the meteorologists] do a 60% probability event A is going to happen and a 30% probability event B is going to happen and a 10% probability that nothing is going to happen.” The explicit analysis of scenarios having different probabilities helps to reduce the possibility that data may be selectively chosen for analysis and requires the STMC or TMC to evaluate different event outcomes.

3.3 Overconfidence Heuristic

Overconfidence is the tendency of people to overestimate their knowledge or abilities. Research has shown that individuals tend to show overconfidence across a wide variety of tasks ranging from clinical/medical (Oskamp, 1962); visual perception and identification (Adams and Adams, 1958); to general knowledge items (Philips and Wright, 1977; Fischhoff, Slovic and Lichtenstein, 1977; Lichtenstein and Fischhoff, 1977).

An excellent example of overconfidence from the GDIT site visits is a STMC who used the Consolidated Storm Prediction for Aviation (CoSPA) for convective weather decisions and, when asked about the product's accuracy, stated, "CoSPA has never let me down." Needless to say, no single convective weather forecast product will ever be accurate all of the time. The STMC's extreme confidence in CoSPA was based on her recollected experiences with the product which were all positive.

A STMC or TMC who receives a convective forecast and gives it a subjective estimate higher than the forecast probability is said to be overconfident. This could happen if he or she pays attention to a specific convective weather product and that product's forecasts have recently been extremely accurate leading the person to believe that the product's accuracy is higher than that dictated by the probability estimates associated with the convective weather forecasts.

3.4 Anchoring and Adjustment Heuristic

One method humans employ in estimating uncertain quantities is to begin with an initial piece of information (known as the anchor) and make adjustments until an acceptable estimate is reached. Tversky and Kahneman (1974) referred to this as anchoring and adjustment.

Unfortunately, the initial estimate can often be incorrect and adjustments are usually inadequate to match the true final condition. In the original experiments exploring this phenomenon, subjects were asked to make comparative assessments involving a given value. For example, is the population of Chicago more or less than 200,000? Subjects would be asked to provide an absolute estimate following their comparison judgment. A large number of studies have demonstrated that individual absolute estimates are biased by the number used in the comparison task. For example, individuals believe that Chicago has fewer residents if they have judged the population as being "more or less than 200,000" versus those who have judged the population as "more or less than 5 million" (Jacowitz and Kahneman, 1995). Anchoring has been used to explain why judgments tend to be heavily influenced by an initial value, estimate, impression, or perspective.

Anchoring of probabilities or uncertainty occurs based on an initial perception a person has of the situation. Assume that a STMC has already received a low probability Collaborative Convective Forecast Product (CCFP) forecast. STMCs contacted during the GDIT site visits indicated that they liked the CCFP and they used it as part of a structured forecast methodology; it was often the first piece of information they would turn to at the start of their shift. This could result in a bias for their use of other convective weather information. Assume that a new forecast is now presented to the STMC stating that there is a high probability of convective weather. The anchoring heuristic argues that the initial CCFP will result in the STMC maintaining a lower convective weather probability than warranted and the adjustment bias holds that the new forecast will result in an insufficient adjustment in probability for convection by the STMC. This could be a particularly relevant heuristic given NextGen's goal of providing fully probabilistic forecasts. An initial probability forecast could "anchor" a STMC's estimate with new forecasts of higher convective probability resulting in a STMC having a lower probability estimate than dictated by the official forecasts.

3.5 Representativeness Heuristic

The representativeness heuristic occurs when people estimate the likelihood of an event by comparing it to an existing model in their minds. Meteorologists do this by looking for patterns (i.e., pattern recognition) when making a weather forecast.

People have mental models for many concepts; consider the concept of "randomness". Consider observing a roulette wheel in Las Vegas and you are asked which of the following color sequences is the most likely to occur: RBRBRB; RRRBBB; or RBBBBB (R = Red and B = Black). If you are like most people, you will select the first sequence of colors. People have a strong idea about how 50-50 items should appear and the first sequence is closest to our notion of "randomness." The fact that a majority of individuals say that the first color sequence is more random to occur indicates that humans have an internal cognitive representation for what is most representative of a random process. However, all three of these sequences are equally likely to occur; 1.5625% assuming a fair roulette wheel with only red and black spaces.

The representativeness heuristic argues that the degree to which a convective weather forecast corresponds to a STMC's mental model of "convection" will affect their response to forecasts. For example, a STMC using this heuristic probably believes that cold weather and snow will not be associated with convection. However, during the winter, there are snow thunderstorms or thunder snow conditions. Conversely, hot and humid conditions are considered representative for convective storm development and thus, if these are present, a thunderstorm forecast will be judged more likely by the STMC than if they are absent. Furthermore, when a convective storm is predicted to occur, STMCs stated that they expected to see indications on their weather products; many STMCs paid attention to the system's movement and growth. If what they observe corresponds to their mental model of convection, this makes it more likely they will accept the convective weather forecast.

4. Conclusions

The current use of convective weather uncertainty data by TMU personnel shows that heuristics are being used at times and biases can result from this. In the ATM environment, these biases can result in non-optimal decisions relative to traffic flow. These less-than-optimal decisions can also affect a controller's workload as well as air traffic efficiency. As NAS ATM systems move from a human-centric to a machine-to-machine transfer of data, NextGen users must be cognizant that humans will still make final operational decisions and, based on the findings reported here, heuristics must be taken into account during system development.

Convective weather researchers, weather product producers, and DST developers all need to be aware of these human cognitive factors and their effect their decision making. Training individuals about these heuristics combined with operationally relevant examples of their biasing effects is a first step in helping to bridge the forecast-decision making gap. Research has shown that education and training can have a significant effect on tasks involving analytical probabilistic type reasoning along with judgments based on more abstract mental models of the system under consideration (Hammond, 1996). Further, strategies designed to reduce the impact of heuristics have been studied and proven to be useful. For example, in attempting to minimize the effects of the confirmation heuristic on individuals, forcing users to explicitly consider alternatives to the decision they are predisposed to has been found to be effective. The example used in this paper provides a clear illustration of this—that is, by providing the decision maker with all forecast outcomes and their expected probabilities forces individuals to consider all possible events. Finally, as DSTs become more available to end-users, these cognitive factors should be considered early in the DST development stage.

Research is continuing in cognitive psychology to make human-based decisions as rational as possible. As Doswell (2004) has noted "[a] consistent collaboration between meteorologists, cognitive psychologists and others involved in decision-making research will be necessary if the goal of improving human weather forecasting is to be achieved" (p. 1125). The same is true for any organization using probabilistic forecasts (such as NAS ATM) to make operational decisions.

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