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Thinking Things Through

FIRST OF TWO PARTS

BY CLARENCE E. RASH AND SHARON D. MANNING

A pilot's cognitive processes — thinking and decision-making skills — often are the key to successfully overcoming in-flight safety risks.

On the chilly afternoon of Jan. 15, 2009, having lost power from both engines of their Airbus A320 minutes after takeoff from New York's LaGuardia Airport, the crew of US Airways Flight 1549 landed the aircraft in the Hudson River.[1] Although the A320 was destroyed, all 155 people inside survived.

There is little doubt as to the role that the training and experience of the flight crew played in the successful emergency landing, but ultimately, it was their decision-making skill that turned a potential tragedy into a triumph.

When faced with a challenging situation, pilots must use their skills, abilities and knowledge to overcome the immediate circumstances. Cognitive psychologists consider decision making as the interaction between a *problem* needing to be solved and a *person* who wishes to solve it within a specific environment and set of circumstances.[2] Although making the right decisions does not always lead to success, making the wrong decisions makes success considerably less likely.

When the crew is faced with a threatening situation in the cockpit, the outcome is largely determined by three groups of factors:

- External factors, such as weather, runway conditions, takeoff weight and presence of birds;
- Aircraft and flight deck design factors, such as the structural limits of the aircraft and the human factors engineering design of flight deck displays and input controls that affect the workload; and,
- Factors related to human capabilities, such as those that influence a pilot's level of cognitive processing and his or her decision-making capability.

The first two groups are largely predetermined and beyond the immediate control of the pilots. However, the third group of factors centers around the human performance of the pilots and is within their direct control.[3] This group includes high-profile factors that are recognized as important enough to be regulated, such as the amount of rest time provided and alcohol consumed within a specified preceding time period, as well as factors that frequently are overlooked, such as nutrition state, hydration level, smoking rate and ambient noise level. These and other seemingly unimportant factors can significantly degrade pilot performance by impairing cognition, and, as a result, problem-solving and decision-making capabilities.

Cognitive Capacity

Although philosophers have been interested in human thought for thousands of years, the field of cognitive science — the scientific study of the human mind or of intelligence — is barely more than 100 years old. Despite tremendous advances in the understanding of how the mind works, it remains difficult, even for cognitive specialists, to predict the cognitive capabilities of an individual in most sets of circumstances.

When cognitive demands exceed an individual's capacity — a condition referred to as cognitive saturation — newly presented information may not be perceived or understood.[4] This implies that individuals have a set amount of cognitive resources — a term that refers to information-processing capabilities and knowledge that can be used to perform mental tasks. Different cognitive tasks appear to involve different information-processing systems, and the resources and limits of these systems determine the cognitive capability to perform a given set of tasks. One of the main goals of cognitive science is to identify the properties of these systems and characterize their limits.

Scientists have explored human cognition by studying its fundamental processes and how they are affected by internal and external factors called stressors.

Cognitive Processes

To make decisions that lead to doing the "right thing" at the "right time" requires pilots to acquire, process and act on information available within the immediate situation. This information is acquired through the five basic human senses — sight, hearing, smell, taste and touch — and the so-called sixth sense of proprioception, or the ability to sense the position and movement of the body and its parts (see "How Humans Obtain Information").

On the flight deck, there is an unusually broad unitization of the senses to continually update pilot information. For example, vision is used to monitor panel displays and to detect airspace and runway incursions. Hearing is used to detect aural warning signals and in communication. Smell — and in some cases, taste — can help detect the presence of fire, fuel leaks or chemicals. Proprioception supplies not only the sensations associated with "seat of the pants" flying but also a range of other signals from sensors in the skin, muscles, tendons and joints that aid in establishing awareness of the position of the body relative to the Earth.

As information is provided by the senses, it is interpreted by the respective cognitive processes of perception, attention, memory, knowledge, problem solving and decision making, after which a course of action is implemented. This defines just one cycle in the decision-action sequence, which is a continuous feedback loop of acquisition, processing, decision and action.

Perception

Perception is a series of conscious sensory experiences. It is a combination of the information from the stimuli, or sources of information, in the world around us producing sensations in the sense organs — via sensory receptors — and cognitive processes that interpret those sensations. Perception deals with the psychological awareness of objects in the world, based

on the effect of those objects on the sensory systems. It often is defined as the mental organization and interpretation of the visual sensory information with the intent of attaining awareness and understanding of the objects and events in the immediate environment.

Because perception is an interpretation by the cognitive processes of the information obtained by the senses, it is possible for an interpretation to be wrong. These misperceptions are called "illusions" and are attributed to all of the senses. The flight environment is known for inducing a host of sensory illusions in pilots. When not recognized as incorrect interpretations of the current state of the aircraft, these illusions impair situational awareness and frequently lead to incorrect decisions and courses of action, often with disastrous consequences.

How Humans Obtain Information

Humans obtain information via a number of senses. Although most cognitive scientists have moved away from the historical concepts of physiological senses and their resultant sensations and toward the psychological concept of perception — the understanding of sensory information — these older concepts are useful in understanding how we obtain information to make decisions.

Our senses acquire information using specialized receptors (Table 1). The most basic sense modes are sight, hearing, touch, taste and smell.

Along with the sense of balance (equilibrioception, or vestibular sense), these senses sometimes are referred to as exteroceptive senses, because they relate to our perceptions of the world around us. However, scientists have identified a second group of senses called interoceptive senses that pertain to our sense of self. This group includes thermoception, or temperature; nociception, or pain; and proprioception, the sense of the orientation and position of oneself in space. Proprioception does not result from any specific sense organ but from the nervous system as a whole.

— CER, SDM

Human Senses

Human Sense	Receptors	Sensations/Perceptions
Sight (Vision)	Photoreceptors (Cones and rods)	Brightness and color
Hearing (Audition)	Hair cells (Vibration receptors)	Sound
Touch (Tactility)	Touch receptors (Mechanoreceptors)	Touch and pressure
Smell (Olfaction)	Chemoreceptors (Odor receptors)	Smell (Odor)
Taste	Taste buds	Salty, sour, sweet, bitter and umami[1]
Thermoception (Temperature)	Thermoceptors (Heat receptors in the skin)	Temperature (Heat and cold)
Proprioception	Muscle spindles, Golgi tendon organs, and joint receptors	Self orientation and position
Nociception (Pain)	Nocioptors (Pain receptors)	Pain
Equilibrioception (Vestibular sense)	Otolith organs	Balance (Direction of gravity)

Note:

1. Umami, the lesser-known "fifth taste," is described as savory or "meaty."

Source: Clarence E. Rash and Sharon D. Manning

Table 1

Attention

Because humans have limited cognitive processing capability, there is a distinction between the total information provided by the real world and the amount of this information that actually is processed. The mental process that is involved in producing this distinction is referred to as "attention." A stimulus can be processed very differently when attended to, compared with when it is unattended. For example, if someone is asked a question while he is busy attending to something else, he may not even hear the question.

Generally, attention involves a voluntary or intended focusing of concentration. It is believed that attention can be directed to different aspects of the environment. In reality, attention is not based on a single mechanism but involves the properties of many different cognitive systems.

Cognitive scientists distinguish between voluntary and involuntary attention.[5] Voluntary attention occurs when a person makes an obvious cognitive effort to remain focused on a particular task. Involuntary attention often is related to environmental stimuli, such as warning signals, that seem to automatically draw attention.

One attention condition that has been the subject of considerable interest in aviation is "cognitive tunneling." Cognitive tunneling refers to a difficulty in dividing attention between two superimposed fields of information — for example, head-up display (HUD) symbology as one field and see-through images as another field. It sometimes is referred to as "attentional tunneling" or "cognitive capture." In the aviation environment, such difficulty can lead to serious problems. Studies have found that pilots sometimes have failed to detect an airplane on a runway when they are landing while using a HUD system.[6,7] Cognitive tunneling is an extreme form of a trade-off between attending to displays and attending to the outside world. Several studies have shown that a HUD improves monitoring of altitude information in a simulated flight but at the expense of maintaining the flight path.[8,9]

Memory

Memory interacts with attention and perception. Indeed, many failures of attention are described as breakdowns in memory of recent events. Cognitive scientists have identified various components of memory, such as short-term memory, working memory and long-term memory.[10]

Short-term memory deals with memory of items for several seconds and generally has a relatively small capacity, holding only a few items before forgetting takes place. Working memory, which typically involves the manipulation of a piece of information — such as the mental comparison of two remembered airspeeds — is broken down into subsystems that process information in a variety of ways.[11]

Long-term memory refers to the important memories that are stored for long-term use. For example, training information, information about rules for behavior in specific situations and other developed forms of knowledge are stored in long-term memory. Closely related to this type of knowledge is a sort of mental model, a cognitive structure called a "schema," that helps interpret information about how particular situations typically play out; for example, of how a specific aircraft will behave under stall conditions. Schemas allow people to adapt to new situations by using knowledge about other similar situations.

The cognitive process of problem solving refers to an immediate distinction between the present state of circumstances and a goal for which there is no immediately obvious path to attainment.[12] The ability to solve a problem is interrelated with the previously discussed cognitive processes. Some problems are difficult because their solution requires retaining more information than can be held by working memory, and others are difficult because individuals lack the appropriate schemas to characterize and analyze the important issues of a problem.

One important aspect of problem solving is to identify the differences between expert and novice problem solvers. Pilots are specially trained for their duties and are thus experts at solving some aviation-related problems. As a result of their training, experts in a particular field solve problems faster and with a higher success rate than novices. The primary difference between expert and novice problem solvers seems to be that experts have more specific schemas for solving problems.

Experts also generally have more knowledge about their field of specialization than novices. Their knowledge is organized differently than novices' knowledge. In particular, experts often organize their knowledge in a way that reflects the fundamental aspects of solving a class of problems.

Decision Making

The culmination of the other cognitive processes is the decision-making process.

The major elements of decision making are: outcome selection, certainty and uncertainty, and risk. An outcome is what will happen if a particular course of action is selected. Training helps identify the list of possible outcomes and the courses of action that may lead to each outcome. Knowledge of possible outcomes is important when multiple courses of action are available. Certainty implies that decision makers have complete and accurate knowledge of the possible outcomes for each possible course of action, and that there is only one outcome for each course of action. This last condition is not always met.

Risk becomes a factor when there are multiple outcomes for one or more courses of action. Risk can be managed if a probability can be assigned to each outcome when a specific course of action is taken. Uncertainty is present when the probabilities cannot be assigned; such a decision situation is referred to as "decision under uncertainty."

Researchers at the U.S. National Aeronautics and Space Administration (NASA) Ames Research Center examined decision-making errors in aviation[13] and found most errors to be intentional — that is, they resulted from a positive selection of an incorrect course of action (a mistake) and not from a failure to take action (a lapse) or because an intended action was carried out incorrectly (a slip).[14]

However, as has been described, the decision-making process is the culmination of the other cognitive processes; if the other processes are degraded or go awry, then the decision-making process and the resulting selected course of action will be incorrect. The consequences can be disastrous.

To assist pilots with their decision-making skills, the U.S. Federal Aviation Administration (FAA) developed a six-step model for use in teaching the elements of decision making. Known by the acronym "DECIDE," the six elements are:[15,16]

- *Detect* that a change has occurred;
- *Estimate* the need to counter or react to the change;
- *Choose* a desirable outcome;
- *Identify* actions that could successfully control the change;
- *Do* take the necessary action to adapt to the change; and,
- *Evaluate* the effect(s) of the action.

Decision making is a skill. Pilots, like other professionals, must learn to become better decision makers. The DECIDE model — one of many human factors approaches to teaching decision-making skills — has proved to be a successful resource for learning the crucial components of making more effective decisions.

Developing good decision-making skills is not just an academic exercise for pilots; it is a necessity. With lives at stake, making the right decision at the right time is imperative. From 1990 through 2002, decision errors were identified as a contributing factor in 30 to 40 percent of commercial and general aviation accidents.[17,18]

Clarence E. Rash is a research physicist with 30 years experience in military aviation research and development and the author of more than 200 papers on aviation display, human factors and protection topics. His latest book is Helmet-Mounted Displays: Sensation, Perception and Cognition Issues*, U.S. Army Aeromedical Research Laboratory, 2009.*

Sharon D. Manning is a safety and occupational health specialist at the Aviation Branch Safety Office at Fort Rucker, Alabama, U.S., and has more than 20 years experience in aviation safety.

Notes

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