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Abstract

A cognitive task analysis (CTA) was used to determine the critical decisions and judgments of landing signal officers (LSOs) who are responsible for guiding in the aircraft who land on the U.S. Navy's aircraft carriers. Based on this CTA, a decision requirements table was constructed which outlined the critical decisions, the critical cues, any potential errors, why the decision is difficult, degrees of uncertainty, tools currently used, and conflicting goals and objectives. With the information, designs were generated for the LSO displays on the LSO platform of the aircraft carriers. Our approach is referred to as decision-centered design. Decision-centered design adopts the concept of using the critical decisions and judgments of the individuals as the basis for any system or design development with the goal of basing the designs on the decisions, rather than available data, sub-system configurations, or tasks. The recommendations were accepted by LSO instructors and a Phase II effort is underway to further revise the recommendations to encompass additional aircraft types and environmental conditions. This effort will be completed in early 2000.

Time-pressured decision making has traditionally presented a challenge to researchers, engineers, and designers alike. When these issues are examined within the context of true, naturalistic decision-making settings, they become even more complex (Beach, Chi, Klein, Smith, & Vicente, 1997). For example, the idea of supporting the urban fireground commander (FGC) as s/he makes decision after decision, all within a few minutes, can be very daunting (Klein, Calderwood, & Clinton-Cirocco, 1986). Lives often depend on these rapid, time-pressured decisions, even when they appear as simple as the FGC's initial decisions about how to place and reserve their resources when responding to the fire. While the decisions faced by the FGCs are definitely difficult and challenging, the decisions required of the Navy's Landing Signal Officers (LSOs) may possibly represent the extreme in time-pressured, high consequence decisions and judgments.

This presentation will describe recent work we conducted for the U.S. Navy under N68335-96-C-0250, where we examined the critical decisions and judgments of LSOs, who are the individuals who guide the aircraft back onto the aircraft carriers. This was a 6-month project during which we conducted a cognitive task analysis (CTA) on experienced LSOs, and extracted the data from the CTA so that we could begin making recommendations for the designs of displays on the equipment on the LSO platform. For a detailed examination of CTA refer to Gordon & Gill, 1997.

First we identified the way the LSOs conceptualize their overall job (i.e., by task, by segment, etc.) and then we identified the LSOs' "decision requirements" within each of these areas. Decision requirements are the critical decisions and judgments an LSO must be capable of making to be able to successfully accomplish their tasks. The next step involved examining each decision requirement closely to identify the critical cues, goals, uncertainty, potential errors, and the issues that make these decision requirements difficult and challenging. These decision requirements were represented in decision requirements tables (DRTs) with one DRT for each segment (as identified by the LSOs) of the approach and recovery. There is a row for each of the identified critical decisions and judgments with the additional columns containing the critical cues, challenges, uncertainty, etc. for each of these decisions and judgments.

These CTA data afford us several opportunities. First, we can approach the display or system design from the perspective of these critical decisions and judgments and, as such, employ *decision-centered* design. The advantage of decision-centered design is that the designs, rather than being based on equipment, available data, or system components, are constructed to directly support the individuals' decision making. Second, the *critical cues and expectancies* derived from the CTA provide us a clear picture of the information that is significant to the individual while they are trying to make these decisions, and possibly of more importance, it helps us to see what information *is not* needed at that time. In turn, this knowledge allows us to start defining what the displays should or should not be showing the operators within the context of the decisions and judgments. Third, data about the *potential errors, uncertainty,* and *"why it is difficult/challenging"* provide information about areas where the design should take extra steps in attempting to support and bolster the decision maker. These are flags that shout, "Look very closely here!". With regard to uncertainty, it may never be realistic to think we can remove it all, but there is a good chance that the design can help the individuals recognize the degree of uncertainty (what they *don't* know) and not let them be lulled into a false sense of security by what they *do* know. And finally, the potential errors information presents its own, often clearly articulated challenge for the designer: What can be done to reduce the probability that these errors will either occur, or if they do occur, go unnoticed.

As mentioned above, a decision-centered approach was employed in generating the recommendations for the LSO displays. In the following paragraphs, the Phase I results will briefly be described, including the LSO task itself, the identified decision requirements, one (out of several) conflicting priorities, and the display recommendations that were generated as a result of the above factors.

The LSOs serve as guides for the individuals piloting the aircraft aboard these "postage stamps" in every environmental condition imaginable. One interesting aspect of the LSO's job is that their decision times are consistently in the 3 to 10 second category. Often the critical decisions occur within 1½ to 3 seconds. The decisions that take place in these small windows are be repeated every 45-60 seconds, which represents the frequency at which aircraft land. An additional complication is that the LSOs have one overall mandate, the "*safe and expedient recovery of aircraft.*" This seems straightforward enough until one examines more closely the implication of these words: *Safe* implies that they do not take any risks with the aircraft and pilot. *Expedient* implies that they get them aboard as quickly as they can. These represent competing goals where accomplishment of one can often result in non-accomplishment of the second. Their overall goal is to improve both: determining better ways to move their waveoff windows in closer so they can recover more aircraft more efficiently, while simultaneously improving the safety factor.

Our challenge, as designers and researchers, is to help LSOs improve both safety and expediency. To do this we have to help them develop situation awareness even earlier and more accurately. In other words, help them improve their understanding of what the aircraft and pilot are doing *within* the context of all of the external and environmental factors (day, night, pitching deck, fog, etc.) so they can more readily determine where the waveoff window needs to be. And this must be done within the context of the particular decisions and for any particular pilot/aircraft.

The Phase I identified several primary decision requirements (Stottler & Thordsen, 1997). They all came into play to a greater or lesser extent depending upon where the aircraft was in the overall approach pattern. These included:

- Understanding the state and configuration of an aircraft
- Understanding the aircraft approach parameters
- Understanding the pattern and interval between aircraft on approach (sequencing)
- Knowledge of the pilot's trends and abilities
- Understanding the deck motion during recovery
- Determining the status of the deck during recovery
- Making sure that the pilot is making the appropriate corrections and adjustments
- Being able to log performance of each recovery
- Access to the information in the look-up tables
- Understanding the impact of external factors (wind, ship course, etc.)
- Understanding what has happened up to this point (history)
- Recognizing who has "charge" of the aircraft at any given point (handoffs)
- Understanding how big the waveoff window is, and where does it start/end
- Determining whether the LSOs and the pilots have the same understanding (SA)

Many of these involve perceptual judgments and as such, require that the LSOs have as clear and unobstructed view of the aircraft as possible. Because of this, they often move to the side of their platform displays so they can get a better, and unobstructed view. The result: the displays they do have are often not in their line of sight, and do them little good.

Based on these decision requirements, several design recommendations were made. First, because the LSOs need a clear view of the approaching aircraft, we recommended a monocular display with a clear area in the center so the LSOs could view the aircraft unobstructed. Second, because of their need to focus on the approaching aircraft, all display concepts had to be presented in the peripheral areas of their vision. Third, the displays had to impart information without further adding to their cognitive and attentional demands.

The specific display recommendations called for a combined ship turning/cross wind indicator, an indication that combined the tail number of the aircraft (i.e., type of aircraft and the pilot); an indicator that provided information about the status of the deck (foul/clear) and also emulated the loudness and cadence of the individuals who are yelling out deck status; a moving indication of the distance of the aircraft from the ramp that winds down from one mile inward; an indication of the rate of descent of the aircraft (on/off glide slope) and finally, an indication of both the roll and pitch of the deck. All of these display design recommendations can be traced back to the decision requirements and their respective critical cues, potential errors, challenges, and uncertainty.

Decision-centered design is a powerful tool, especially when it is used to help understand and support time-pressured, naturalistic decision making. This project is an example of how it can be used and the potential benefits of this approach.

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