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**Attention Based Display Design for
Terminal Area Operations**

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Our research on grant # NASA NAG 2-1120 entitled Attention Based Display Design for Terminal Area Operations has addressed a variety of themes related to pilot information processing. At the most global level, we have developed theories and principles of pilot attention that can help inform the design and layout of displays for 3D aircraft navigation through hazardous airspace, and can help the designer in harnessing the appropriate automation tools to support that navigation.

One way of parsing this work in more detail is to contrast the theoretical review articles that have been generated, with the empirical studies (whose data, in part, have contributed to those theoretical reviews). Lying between theoretical review and empirical data, are a smaller subset of articles that have focused explicitly on quantitative models of pilot information processing. A second way of parsing the work, is in terms of the kinds of pilot information processing activities that attention is designed to support, in a way that is related jointly to the kinds of pilot tasks (e.g., control/guidance versus hazard awareness, versus navigational planning) and the kinds of technology (e.g., HUDs, datalink displays, CDTIs). Below, we overview the separate studies, all attributed in part or in full to NASA support, that have addressed these different perspectives and highlight key findings.

Review Manuscripts

The grant has supported general reviews of the literature on issues related to: (1) display frame of reference and its influence on pilot performance and awareness (Wickens, 1999a, 2000a, 2000b, 2002a); (2) head up displays (Wickens, Ververs, & Fadden, in press), (3) issues of display clutter and data-base overlay (Wickens, 2000a), (4) multiple task performance (Wickens, 2002b), (5) automation (Wickens, 2000c), (6) issues of situation awareness, and its relation to attention and workload (Wickens, 1999b, 2000d, 2002c), and (7) more general reviews of aviation displays and pilot information processing (Wickens, 1999c, 1999d, 2002d).

Empirical Studies

Empirical studies, involving data collection from general aviation pilots in a series of experimental paradigms ranging from low to high fidelity flight simulation, can be classified in terms of five general issues:

1. Information processing characteristics (costs and benefits) of head up displays (Fadden, Wickens, & Ververs, 2000; Fadden, Ververs, & Wickens, 2001). The latter study is the first to fully evaluate the consequences of displaying a pathway display in a head up configuration, in which a range of ground and air-tasks (involving both expected and unexpected traffic detection) were imposed in visual meteorological conditions. The findings as to when the pathway HUD is more (ground operations) versus less (air operations) valuable relative to a head-down pathway, has important practical applications.
2. Pathway displays (Doherty & Wickens, 2001; Wickens, 2002d; Boeckman & Wickens, 2001). These studies examine the influence of pathway displays on pilot performance (independent of display location), and provide a foundation for future research on the pathway concept in synthetic imagery systems (SVS) displays. The studies provide further

validation of the great benefit offered by pathway displays, and the sources of those benefits (Doherty & Wickens, 2001).

3. Tactical displays for traffic awareness in free flight (Wickens, Gempler, & Morpew, 2000; Wickens, Helleberg, & Xu, in press; Alexander & Wickens, 2001, 2002; Wickens, Goh, Helleberg, & Talleur, 2002), and for traffic, weather and terrain representation in conventional flight planning (Podczerwinski, Wickens, & Alexander, 2002; Muthard & Wickens, 2001, 2002). These studies examine the optimal formatting of such displays, how that formatting influences a pilot's choice of maneuvers, and the cognitive processes and decision making biases that may be manifest in such choices. These studies have produced some of the most reliable data regarding the relationship between CDTI traffic depiction, and pilot's actual ability to locate traffic in the sky (e.g., visual callout of "traffic in sight").
4. Attentional issues of map configuration and display clutter, as produced by data-base overlay (Kroft & Wickens, 2001; Podczerwinski et al., 2002) and by HUD overlay (Fadden, Ververs, & Wickens, 2001). These studies provide data regarding the advantages, but also the limits of superimposing multiple data bases (e.g., traffic, weather) of the same geographic area, and offer some particular warnings about the dangers of automated "decluttering" tools.
5. Modality of information presentation (Helleberg & Wickens, in press; Wickens, Goh, Helleberg, & Talleur, 2002; Wickens, Dixon, & Seppelt, 2002). These studies have addressed when auditory display of information, via voice synthesis may provide a superior means of information transfer to more traditional visual displays. The work has significantly laid out some of the boundary conditions of this auditory display: While the au display may sometimes capitalize on separate resources from the visual display – an advantage, if the auditory display contains several items of information, or its arrival is unexpected, it can preempt ongoing visual processing of higher priority tasks.

Automation and Visual Attention

Overlaying the range of empirical studies described above, defined by the joint influence of task and display technology are two additional issues, related to automation and visual scanning. A theme emerging from this research (and from related research by others) is that many of the effects of automation on human performance, related to phenomena such as "complacency", over-reliance, and mistrust, can be attributed to the manner in which automation influences the allocation of visual attention.

1. In many of the empirical studies described above, we have examined the effects of different levels and kinds of automation (Wickens, 2000e) on pilot performance and automation reliance, particularly when that automation is not perfect (Wickens, Gempler, & Morpew, 2000; Wickens, Helleberg, & Xu, in press; Wickens, Helleberg, Goh, Xu, & Horrey, 2001; Wickens, 2000e; Wickens, Goh, Helleberg, & Talleur, 2002; Muthard & Wickens, 2001, 2002). Emerging from this research is the important concept of a "calibration" between system reliability level, and pilot attention allocation.

2. In several of these studies we have also measured visual scanning, across various channels of information in the full cockpit environment (Helleberg & Wickens, in press; Wickens, Helleberg, & Xu, in press; Wickens, Goh, Helleberg, & Talleur, 2002; Wickens, Xu, Helleberg, & Marsh, 2001; Wickens, Helleberg, Goh, Xu, & Horrey, 2001). Part of this effort is designed to understand the implications of new cockpit technology on the allocation of visual attention to the outside world. Another part of the effort is designed to better understand how automation drives visual attention, in a way that can mediate performance when automation fails (i.e., is imperfect). This latter issue is particularly relevant for understanding the consequences of imperfect CDTI traffic data bases on pilots' traffic awareness.

Attention Modeling

We have used the data obtained from our empirical studies to develop and validate two attentional models that we believe are relatively unique in their applicability to complex large scale environments. First, we have developed a model called "SEEV" whose components (saliency, effort, expectancy and value) are purported to drive the pilots' allocation of attention to flight relevant information channels. (Wickens, Helleberg, Goh, Xu, & Horrey, 2001). What is unique about this model is its linkage of visual attention to models of cockpit task management. That is, how does attention allocated to various sources of visual information support cockpit tasks of varying levels of priority. Second, we are working to develop models of multiple task performance based upon multiple resources (Wickens, 2002b; Wickens, Goh, Helleberg, & Talleur, 2002; Wickens, Dixon, & Seppelt, 2002), with the ultimate goal of linking these to the SEEV model in a comprehensive model of pilot attention.

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