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A Breakdown in Simultaneous Information Processing*

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INTRODUCTION

The ability to detect accurately, recognize, and extract useful information from two superimposed sources of visual information at the same time is of both theoretical and practical interest. The scientific literature in such areas as the psychology of attentional processes, cognitive processing, sensory channel capacity, and other fields contains numerous such studies. Among them are the early auditory perception research of Broadbent (1952, 1958) in which he proposed a single-channel filter theory of information processing, Treisman's (1960) modified sequential processing model involving a two-stage filter, and Deutsch and Deutsch's (1963) preattentive parallel processing model. Most past visual research employed simple stimuli (point light sources, simple geometric shapes, etc.). Nevertheless, the effectiveness of information transfer using more complex, real-life stimulus fields demanded further study from the standpoint of helping to design modern instrumentation for commercial turbojet airplane flight. This study combined both basic and applied objectives, as will be seen.

A pilot landing an airplane is concerned with two principal fields of information, his external view through the windshield and the instrument panel. They differ in their location within the pilot's field of view, their angular extent, range of brightness and color, dynamic characteristics, and various other sensory and cognitive dimensions. All the pilot needs to do is to shift his gaze back and forth from one to the other sequentially and keep them both in sufficient optical focus (Weintraub *et al.*, 1985) to be able to extract the required flight guidance and control information they contain. It is my belief that the very process of nodding the head up and down (during this information gathering), of rotating the eyeballs within the bony sockets, and of the image translation across the retina associated with these saccades (each) acts to add significant coded "bits" in the afferent information stream to the central nervous system to signify a change in information source by way of previous associations.

The main purpose of this investigation was to find out how well pilots could accurately and rapidly extract information from either one or both of two superimposed sources of flight guidance and control information.

METHOD

Procedure and Experimental Design

Each pilot was given extensive familiarization in the control of a NASA Ames Research Center fixed-base (no cockpit motion) flight simulator, which was programmed to fly like a Boeing model 272 turbojet airplane. They were given a battery of vision tests (all possessed a Class A medical certificate) and shown a 20-min video tape explaining and demonstrating the various features of the head-up display (HUD) in flight. They were not told about the possibility of runway obstruction but only that

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the purpose of the study ". . . was to test the HUD under various environmental conditions."

Flight training consisted of flying five increasingly difficult approaches without HUD; HUD training followed, using simple maneuvers in clear visibility and calm winds. The difficulty of the flight conditions was continually increased by adding turbulence, crosswind, wind shear, and low visibility (simulated fog). The author sat in the right seat serving as the First Officer during all training and data runs; I operated flaps, landing gear, and verbalized whatever landing-related information the pilot asked for (e.g., altitude and distance to go). A colleague (E. Fischer) was also present to ensure that all experimental conditions were accurately preset and that the pilot fully understood what was required prior to each run. This pretest training averaged about 3 hr, about 2 hr of which were devoted to flying with the HUD.

Each trial began with the simulator's flight being controlled by an autopilot (to ensure uniform initial conditions for all runs and all pilots) in level flight at 1500-ft altitude and 8 miles from the runway. The First Officer kept looking outside; he pressed a button and called out the words "ground in sight" and, later, "runway in sight" at the earliest possible moment during the low-visibility runs. During the no-HUD trials the pilot remained looking down at the instrument panel until he heard the words "ground in sight" and then looked up quickly toward the outside scene. He would look up and down several more times before making the decision to land or go around (Haines *et al.*, 1980). The pilot was instructed to say "decision" when he felt he had enough real-world information to decide whether to land or to go around. The runway obstruction was not mentioned in advance except on two occasions by the First Officer by mistake. During the HUD runs the pilot looked at the HUD symbology and external scene at the same time throughout the entire approach to landing.

Four of the eight pilots were presented the runway obstruction condition with the HUD first, and the other four encountered it with the standard instrument panel first. Each also received a second obstruction trial from 13 to 21 runs later but with the opposite HUD-present or HUD-absent condition to counterbalance the presentation order.

An unobtrusive infrared (Honeywell) oculometer was installed inside the cockpit to monitor the pilot's eye movements during the trials (approx. 1° accuracy). The output from this system was a small white dot, which was accurately superimposed on a videotape record of what the pilot was seeing through the windshield. In addition, another camera was aimed at the pilot's head; its image was inlaid into a corner of the main scene for later analysis.

HUD Symbology Information

The computer-generated HUD symbols were seen at the pilot's normal eye position by reflection off of a semitransparent glass. Both the HUD and the external scene were collimated to apparent optical infinity (Od). A three-sided trapezoidal outline of a runway was seen on the HUD. It always remained in proper registration with the image of the "real" (external scene) runway, as is shown in Fig. 17-1. This photograph was taken from the pilot's eye position at an altitude of 72 feet and airspeed of 131 knots.

Other HUD-presented information included a digital airspeed, altitude, heading, vertical rate, angle of attack, etc. We will not be concerned with the other available information except to say that the symbology was carefully designed to provide all the information a pilot usually requires to make these approaches (Bray, 1980).

Simulator

The scene presented outside the simulator's forward windows was obtained from a full-color, 900:1 scale model with accurate runway, approach lights, surrounding terrain, terminal building, etc. The flight control inputs made by the pilot controlled the movement of a small, medium-resolution color TV camera relative to this model and its runway. It provided a realistic scene, which was displayed on large-raster color monitors located behind large-diameter collimating lenses mounted to the simulator. Electronically generated "fog" was produced by a white raster overlay, which effectively reduced the scene's contrast over a wide range. This fog effect can be seen at the top of Fig. 17-1. The cockpit forward windows each subtended 45° arc in width.

Test Subjects

Eight commercial pilots currently certified to fly Boeing model 727 aircraft from two domestic airlines were tested. All possessed 20:20 distance acuity, normal color and depth perception, and no dysfunctions that may have influenced their performance. They were paid for their services and were also highly motivated because of their interest in