DESIGN OF INSTRUMENT APPROACH PROCEDURE CHARTS: COMPREHENDING MISSED APPROACH INSTRUCTIONS CODED IN TEXT OR ICONS

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The objectives of this experiment were to determine whether coding missed approach instructions in text or icons would result in more efficient information transfer, and if the information transfer efficiency for either coding technique was dependent upon the level of information content. Twelve pilots currently licensed for instrument (IFR) flight participated as subjects. Text instructions were either taken directly or developed from instructions found on National Ocean Service (NOS) instrument approach procedure charts. These instructions possessed one of three levels of information content: low, medium, and high. Across the range of information content levels, iconic missed approach instructions were comprehended more quickly and as accurately as instructions coded in text of the font style and size used by NOS. Regardless of coding technique, report accuracy was significantly worse for instructions with a high information content level. Pilots indicated that in single pilot IFR conditions, they would rather have the iconic than the text version of the missed approach instructions.

INTRODUCTION

The missed approach procedure is one of the most hazardous aspects of an instrument approach, and typically one in which pilots have the least experience. Pilots will execute a missed approach when, upon reaching the missed approach point, prevailing factors (e.g., visibility conditions, obstructions on the runway) preclude landing on the intended runway.

The missed approach instructions must be coded to allow the most efficient transfer of information possible because the number and complexity of tasks in terminal operations reduce pilots' spare attention. Based on the findings of previous research, (Ells and Dewar, 1979; Whitaker and Stacey, 1981), iconic encoding of missed approach instructions would be expected to result in faster comprehension without degrading accuracy. However, using icons to convey missed approach instructions would differ from their applications in these studies in several ways: the information content of a set of missed approach instructions is higher than that of a single highway traffic message; a sequence of activities need to be conveyed, rather than one activity; the instructions are given for movement in three dimensions rather than two; and, alphanumerics must be included with the icons (e.g., altitudes, headings, and radials).

The objectives of this research were to determine whether coding missed approach instructions in text or icons would result in more efficient information transfer, and if the information transfer efficiency for either coding technique was dependent upon the level of information content. The present study was conducted as part of a continuing effort at the Volpe National Transportation Systems Center Human Performance Laboratory to develop human performance-based design guidelines for instrument approach procedure (IAP) charts.

METHOD

Subjects

Twelve pilots (eleven males) currently licensed for instrument (IFR) flight and having at least 20/20 visual acuity (normal or corrected) participated as subjects (Ss) in this experiment. Subjects who were employees of the Volpe Center were given an account number to which they charged their time, and Ss unaffiliated with the Volpe Center were paid $50.00.

Apparatus

Instructions were either taken directly or developed from instructions found on National Ocean Service (NOS) IAP charts. Because of formatting inconsistencies in current NOS missed approach instructions, a standard format was developed. All stimuli adhered to this standard formatting. Missed approach instructions possessed one of three levels of information content (low: 6 items; medium: 9 items, and high: 17 - 19 items). These levels were chosen to approximate the range of information content found in current NOS missed approach instructions.

Text stimuli were created by using *WordPerfect* (Wordperfect Corporation) and *Ventura Publisher* (Xerox Corporation) installed on an IBM compatible 386 computer. All text stimuli (iconic stimuli also incorporated text) were printed in a 14 point Helvetica font closely matched to the font used by NOS for its IAP charts. Iconic stimuli were created by using *DrawPerfect* (WordPerfect Corporation) installed on the same computer. Current NOS symbols were recreated, and new icons were developed. All stimuli were printed using *Freedom of the Press* (Custom Applications Incorporated) post-script language interpreter installed on a Hewlett-Packard Laser Jet 3 with 300 dots per inch resolution. Printouts were reduced photographically and produced as pin-registered slides.

All slides were displayed at a contrast ratio of 11.88:1.91 candelas/meter^2 by adjusting the transmissivity of polarizing filters mounted on the tachistoscopic slide projectors' lenses. The contrast ratios were measured using a Soligor (Spot Sensor II) spot photometer and a calibration slide with the same darkness as the experimental slides. Ambient room illumination was 4 footcandles at the subjects' eye point as measured by a Sylvania light meter (model DS-2050). Visual acuity was measured using a Graham-Field eye test chart (model 2867-1264).

A Gerbrands tachistoscopic projector system presented all stimuli and was controlled by a Solutions (IBM compatible 286) computer and by Ss using two pushbuttons (see Figure 1). Stimuli (see Figure 2) were projected at a size which allowed all alphanumerics to subtend the same visual angle as the alphanumerics in missed approach instructions on actual NOS IAP charts at the same viewing distance. To maintain a constant viewing distance of 50 cm (20 inches) from the Da-Lite 41.25 x 45 cm (16.5 x 18 inch) back projection screen, Ss placed their chins in a chin rest. Subjects' verbal reports were given to the experimenter (E) using a Realistic (model 33984 B) microphone and recorded on TDK (model D120 IECI/Type I) cassette tapes using a Marantz (model PMD420) cassette recorder.

Procedure

After successfully completing visual acuity testing, each S was seated at a table and read an informed consent form summarizing the purpose and general procedures of the experiment. Ss then completed a questionnaire concerning their flight experience and preferences for IAP chart manufacturers. The order in which Ss were exposed to both coding techniques (text and iconic) was pseudorandomly counterbalanced. Subjects completed training and both practice and experimental trials for one coding technique before exposure to the other.

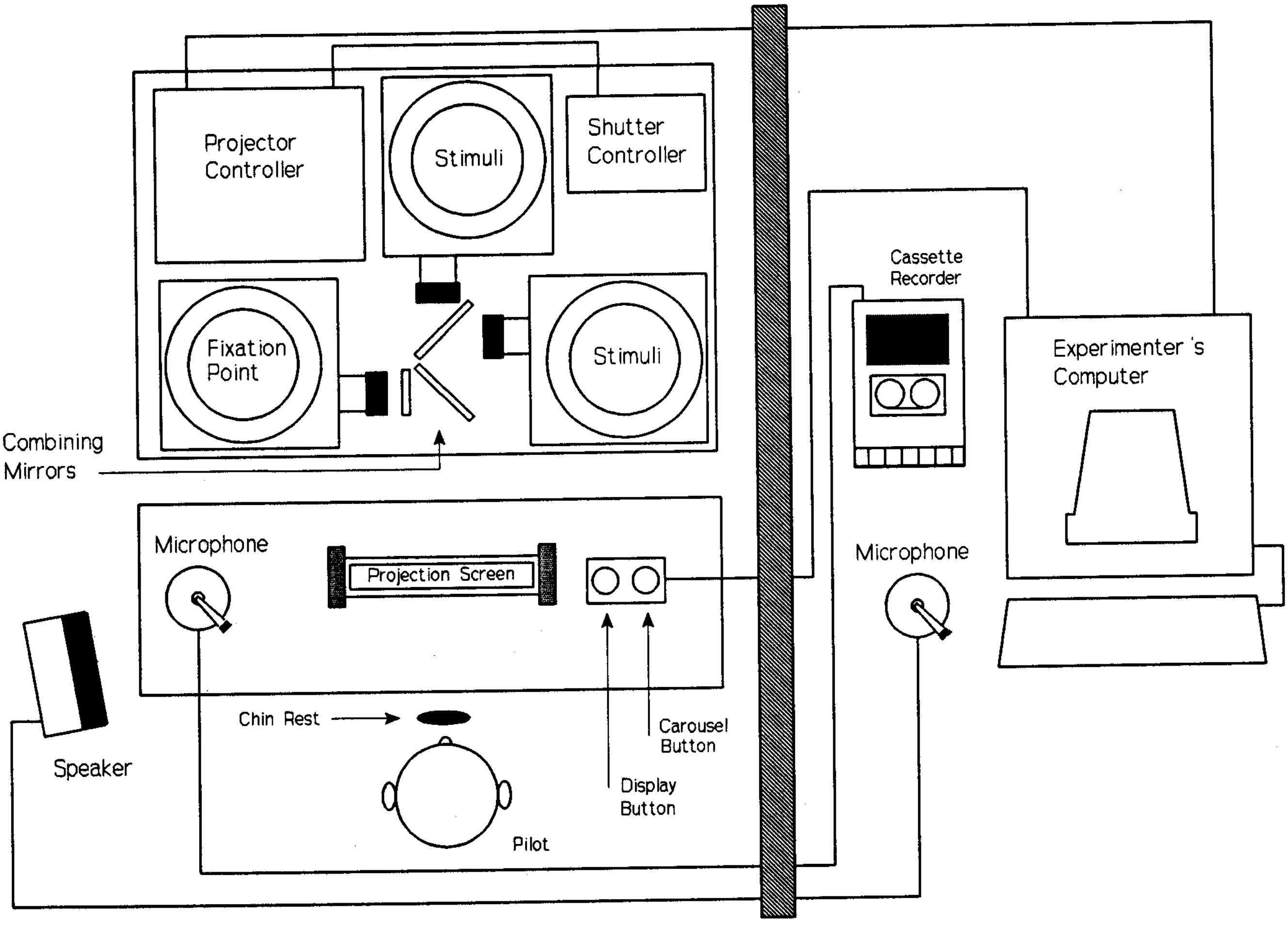

Figure 1. Schematic diagram of the experimental apparatus.

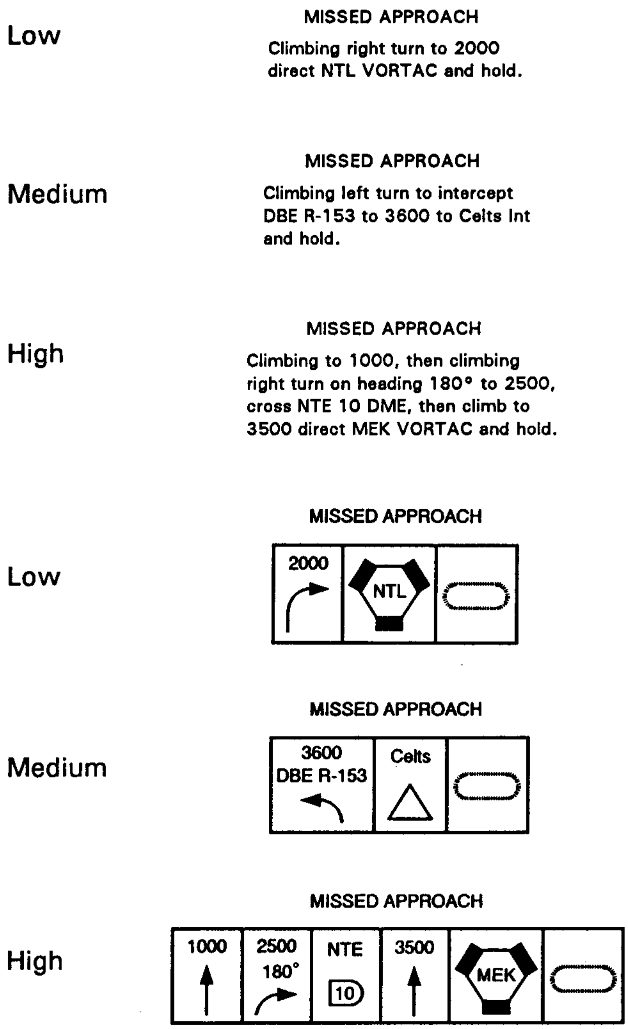

Figure 2. Examples of text and iconic missed approach instructions in each information content level.

Training for the text and iconic instructions began with Ss studying examples. Unlike the text instructions, Ss were required to learn a new "vocabulary" of icons. Subsequently, a self-test was provided to Ss which allowed them to assess their competency. Examples depicted instructions of all information content conditions. Ss had as much time as they wished to study the instructions, and the E was available to answer questions. After completing the self-test on their own, the E reviewed the items in a pseudorandom order, and the Ss were required to demonstrate 100% accuracy in order to proceed.

Upon completion of training, Ss were seated in front of the projection screen. The E then adjusted the chin rest and introduced the response procedure. The procedure began with the display of a fixation point with the same contrast ratio as the instructions. Subjects pressed the *display* button to remove the fixation point and display the instruction slide for one second. The fixation point then returned. Subjects read the instructions and verbally reported them through their microphone to the E.

Subjects repeated this procedure until they believed that either they had reported the complete instruction correctly, or they had reported as well as they could and wished to proceed to the next instruction. Subjects then pressed the *carousel* button to prepare the system for displaying the next instruction. The computer recorded the number of button presses for each instruction, and the E scored the Ss' reporting accuracy.

Subjects who performed the procedure correctly for the final 10 trials (trials 18-27) were judged as understanding the response procedure and were allowed to proceed to the experimental trials. Both during the practice trials and before the experimental trials began, the E verbally instructed Ss to minimize the number of stimulus presentations while reporting the instructions as accurately as possible.

In the practice trials, within each coding technique, the 27 instructions (three instruction information content sets - 9 instructions per set) were randomized in 3 blocks of 9 instructions, with each information content level appearing 3 times per block. Ss were exposed to the same 27 instructions in two forms, text and iconic, for a total of 54 practice trials.

During and after the practice trials, the E answered Ss' questions. After Ss had completed the practice trials, they indicated when they were ready to begin experimental trials. In the experimental trials, within each coding technique, the 90 instructions (three sets - 30 instructions per set) were randomized in 15 blocks of six instructions, with each information content level appearing twice per block. Ss were exposed to the same 90 instructions in two forms, text and iconic, for a total of 180 experimental trials.

After Ss had completed the second session of experimental trials, they completed a questionnaire which asked for their subjective ratings of the coding techniques. They were also asked to recall difficulties they have encountered with IAP charts while flying to help identify other problem areas in chart design.

Performance Measures

This study employed mean number of glances (MG) as a measure of comprehension speed. A glance was measured as one *display* button press (one stimulus presentation).

Report accuracy was measured as either correct (1) or incorrect (0). Because the correct execution of a missed approach instruction depends upon performing all steps in their proper order, errors resulting from misidentification or omission of information, or transpositions in the perceived order of execution necessitated a binary report accuracy scoring system.

Both MG and the mean number of errors (ME) were computed for both coding techniques (text and iconic), and each information content level (low, medium, and high).

Experimental Design

The within-subjects independent variables were coding technique (text and iconic), and information content level (low, medium, and high). Analyses of variance and the necessary post hoc tests were conducted on the data.

RESULTS

Pilot Flight Experience and IAP Chart Usage

Subjects' ages ranged from 24 to 61 years, with a median age of 45.5 years. Total flight hours ranged from 330 to 21000 hours, with a median of 948.5 hours. The range of actual IFR flight hours was from 3 to 1750 hours, with a median of 62 hours. Simulated IFR flight hours (accomplished with foggles, a hood, or a flight simulator) ranged from 0 to 200 hours, with a median of 95.5 hours. Twelve, three, and one of the Ss had general aviation, Part 121, and Part 135 experience, respectively. Two Ss, including a helicopter pilot, had military flight experience.

All 12 Ss stated that they used NOS IAP charts, eight of which used them *always* or *frequently*. Instrument approach procedure charts manufactured by Jeppesen-Sanderson were used *always* or *frequently* by six Ss, while four other Ss *never* used them. Denoting their preference for either manufacturers' IAP charts by assigning each a rank of 1 (most preferred) or 2 (least preferred), the eight Ss who used both the Jeppesen-Sanderson and NOS IAP charts ranked them at 1.25 and 1.75, respectively. This difference was not significant ($p > .28$) as shown by the Binomial Test (Siegel, 1956).

Mean Glances for Correct Trials

Both main effects, coding technique and information content level, were significant ($p < .05$). The MG for iconic coding was significantly lower than that for text. All pairwise contrasts between MG for each information content level were then conducted with the Tukey-Kramer procedure (Kirk, 1982), and all were significant. From lowest to highest MG, the information content levels were: low, medium, and high. The MG data are depicted in Figure 3.

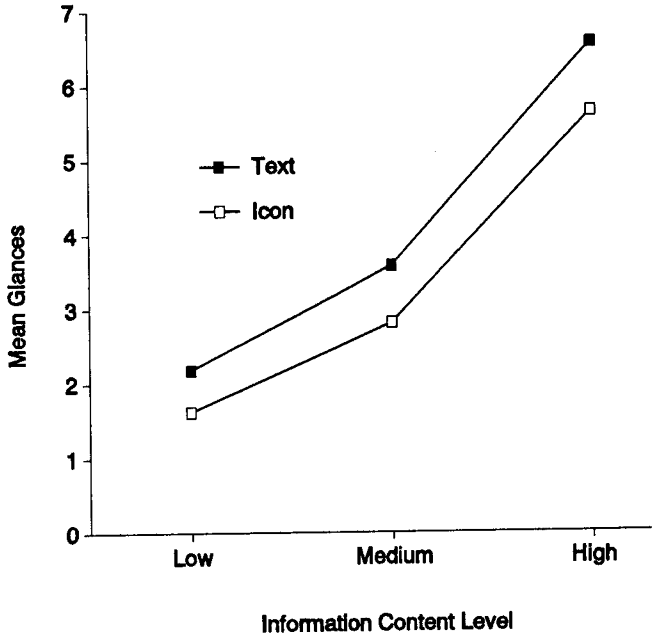

Figure 3. Mean glances for each coding condition in each information content level (correct trials only).

Mean Errors

The main effect for information content level was significant ($p < .05$). The Tukey-Kramer procedure (Kirk, 1982) was used to conduct all pairwise contrasts between ME for each information content level. The ME for the high information content level was significantly higher than those for both the low and medium levels. Figure 4 presents the ME data.

Questionnaire Responses

Eleven of the 12 pilots indicated that in single pilot IFR conditions, they would rather have the iconic than the text version of the missed approach instructions. The Binomial Test (Siegel, 1956) of this difference was significant ($p < .01$).

The most common reason given for this preference rating was that icons were perceived as being easier to comprehend, although they were more difficult to verbalize than text. Four subjects reported icons which incorporated radial information as being very difficult to read. Whether "read" in this case refers to "comprehend" and/or "verbalize" is unclear. Perhaps related to these comments were the statements of two Ss who reported that they would prefer the text version when flying in a two-person crew. Instructions conveyed in text may be easier to verbally brief to another crewmember in preparation for the approach.

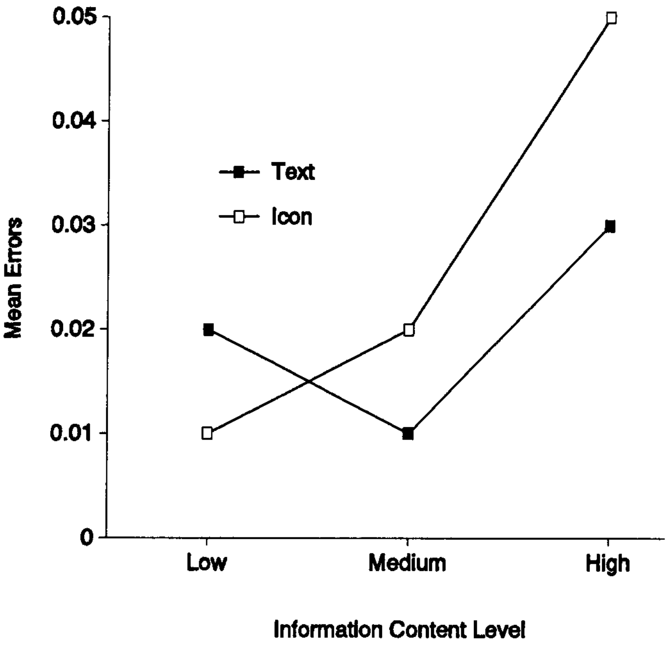

Figure 4. Mean errors for each coding condition in each information content level.

DISCUSSION

Mean Glances and a Paradigm Bias

Subjects required significantly fewer glances to read and verbally report iconically coded instructions across all information content levels ($p < .05$). Mean glances for icons was expected to vary less than MG for text as a function of information content level, however, the coding technique * information content level interaction was not significant ($p > .05$). This differential effect was expected for two reasons. First, although a set of instructions coded in icons conveys the same information as when coded in text, iconic coding uses fewer figures and takes advantage of redundancies in relationships between instructions. Therefore, more information was expected to be conveyed per glance for icons than for text. Second, icons integrated the instructions such that each step was more holistically conveyed.

These two factors were expected to partially compensate for increases in information content for iconic instructions, producing correspondingly more divergent MG values between coding techniques. The data did not support this expectation. The absence of a differential effect for coding technique as a function of information content level may have been due to a bias in the experimental paradigm. In order to verbally report iconic instructions, subjects were required to interpret and then translate the pictorial/alphanumeric information into words. Accurate interpretation of the icons was essential to subsequent translation into verbal reporting, whereas verbal reporting of text instructions did not require the translation step, nor did it even necessitate understanding the instructions to accurately verbally report them. This difference in information processing requirements was the rationale for using MG as the measure of comprehension speed. It was expected that comprehension speed could be measured independently of the information processing requirements imposed by verbal reporting by measuring the number of one second presentations subjects required to view the stimulus in order to report it. However, the iconic - verbal translation step may have attenuated the amount of information conveyed during verbal reporting.

Mean Errors

All instructions were either taken directly or developed from instructions found on NOS IAP charts. In actual IAP charts, as the information content level of the instructions increases, the complexity of the information typically increases concurrently. The stimuli reflected this relationship. Whether the significant increase in errors is due to the greater amount of information and/or the accompanying increase in complexity is unknown.

Design Recommendations

The iconic missed approach instructions evaluated in this experiment were comprehended more quickly and as accurately as instructions coded in text of the font style and size used by NOS. Pilots indicated a strong preference for using icons in single pilot IFR conditions. However, further research must be conducted before implementation of iconic missed approach instructions on NOS IAP charts can be recommended as a full replacement for the current text. In the interim, it is recommended that both text and icons be included on NOS IAP charts.

ACKNOWLEDGMENTS

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