Proceedings of the Human Factors and Ergonomics Society Annual Meeting
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Philip J. Kellman and Mary K. Kaiser

Proceedings of the Human Factors and Ergonomics Society Annual Meeting 1994 38: 1183
DOI: 10.1177/154193129403801808

PERCEPTUAL LEARNING MODULES IN FLIGHT TRAINING

Philip J. Kellman
University of California, Los Angeles
Los Angeles, CA

&

Mary K. Kaiser
NASA Ames Research Center
Moffett Field, CA

Differences between novices and experts in many piloting skills may be due to perceptual learning. Sufficient exposure to relevant stimulus variation produces more efficient information extraction, processing of higher-order patterns, and automaticity. Isolating and condensing relevant perceptual experience in part-task environments might accelerate training. Here we report initial studies of two prototype perceptual learning modules (PLMs) for flight training.

Subjects were either experienced (500-2500 hour) civil aviators or non-pilots. In the Visual Navigation PLM, subjects received brief instruction on aeronautical chart symbology and then viewed 20-second segments of terrain (videotaped from aircraft). Each trial required a speeded, forced choice of the aircraft's location from three possible grid locations on the aeronautical chart. A separate control group received only 20 pre- and 20 post-test trials. In the Instrument Relationships PLM, subjects viewed displays of primary flight instruments and performed a speeded response classifying the flight attitude depicted. In both PLMs, subjects' speed and accuracy were measured over 9 blocks of trials.

PLMs produced dramatic improvements in speed and accuracy for both non-pilots and pilots. Pilots initially outperformed non-pilots. Non-pilots after 1-2 hours of PLM training were as accurate and faster than pilots before training in both PLMs. The results suggest that PLMs have value for primary and recurrent training, both in aviation and other domains. Appropriately structured PLMs could condense perceptual learning processes that normally occur with extended experience. By fostering greater automaticity of pattern processing, PLMs might allow component skills to be more easily integrated in flight or other complex tasks.

INTRODUCTION

Many pilot skills develop over long periods of time from exposure to actual flying situations. Such skills include instrument scanning and cross-checking, visual navigation, approach plate interpretation, weather recognition, and others. Textbook instruction and even flight instruction make modest contributions toward developing expert performance.

An hypothesis about how such skills develop is that they involve perceptual learning (Gibson, 1969). Specifically, exposure to relevant stimulus variation changes the process of information pick-up: Features and dimensions pertinent to a given task come to be extracted rapidly and efficiently, while irrelevant aspects are selectively ignored. These changes have been characterized as a qualitative shift from *controlled* to *automatic* processing (Laberge & Samuels, 1974; Shiffrin & Schneider, 1977). Practiced subjects pick up information with little effort and little interference with other tasks. Moreover, they become sensitive to higher-order patterns in the input which are not available to the novice and which make possible superior performance (Bryan & Harter, 1899; Chase & Simon, 1973).

Although the mechanisms of perceptual learning are not understood in detail, the conditions for its occurrence are. The attentional selectivity characteristic of perceptual learning seems to occur from mere exposure to relevant variation, although in some cases feedback or reinforcement may also enhance learning.

Training in aviation and other domains might be improved if the conditions required to produce perceptual learning and resulting automatic processing are isolated and condensed. We are attempting to realize these benefits in a series of perceptual learning modules (PLMs) for aviation training. Here we report initial results involving two modules, addressing visual navigation and instrument relationships.

PLM I: Visual Navigation

Visual navigation is an important skill, learned primarily by experience, but not always well. Every year, some pilots get lost on cross-country flights, and a few air carrier pilots land at the wrong airports. In a search of the Aviation Safety Reporting System (ASRS) Database, it was not difficult to turn up 100 reports in which visual navigation errors seriously compromised safety. Although electronic navigation has supplanted visual navigation in much flying, visual navigation remains important to VFR flight, visual approaches under IFR and in the final phases of instrument approaches. Visual navigation comprises a rich informational domain in which to examine perceptual learning. Because navigational skill is acquired unsystematically after initial instruction, this domain is also ripe for improvements in training methods.

PLM II: Instrument Relationships & Cross-check

Casual observation suggests that expert instrument pilots extract information about aircraft attitude and situation from brief glances at an instrument panel. In contrast, novices undergo a slow, sequential, effortful search of separate instruments. These differences probably reflect qualitative changes in information pick-up brought about by perceptual learning, as has been demonstrated in other domains (e.g., Chase & Simon, 1973; Shiffrin & Schneider, 1977). Although such changes can result from hundreds of hours of aircraft or simulator experience, they may arrive more quickly through a PLM that isolates and trains the information extraction skills. A related goal is to provide better training on recognition of instrument failures/conflicts, since pilots ordinarily encounter too few instances of these situations to produce automatic pattern recognition skills.

METHOD

Visual Navigation PLM

Perceptual learning is involved in both terrain and map interpretation. To facilitate both, we used a task in which subjects viewed visual displays of real scenes, made judgments about their locations on a map, and received feedback.

Subjects. Four groups of four subjects each were tested. One group consisted of experienced pilots, with civil aviation experience ranging from 500 to 2500 hours. Three other groups consisted of naive subjects (no flight experience).

Displays and Apparatus. Charts used were VFR Sectional aeronautical charts of the San Francisco region. The relevant portions of the map involved parts of the San Joaquin Valley within a 40 NM radius of Stockton, CA, and more mountainous and coastal regions around Watsonville, CA. The map used by subjects was fastened onto a rigid cardboard backing with a transparent overlay containing a grid for specifying particular locations. Videotapes of selected terrain were made with a wide-angle, forward view from a Cessna 182 at an altitude of 2000 feet AGL, using a SONY Hi-8 videotape system. Particular segments were then edited onto laser discs. Display presentation was accomplished with a random access Pioneer Laser Disc Player (model LD-V6000A) and a SONY Trinitron monitor (model PVM1342Q) monitor.

Design and Procedure. On each trial, a subject viewed terrain visible in a 20-second animated segment of flight and chose the aircraft's location from among three possible grid locations. Speed and accuracy were measured, and feedback was given after each trial.

Subjects in the pilot group were familiar with Sectional charts and the basics of visual navigation. Naive subjects were assigned to *explicit* or *implicit* learning conditions. All subjects were given a minimal introduction to the sectional charts in which basic symbols were explained (e.g., markings used to depict roads, towns, bodies of water, power lines, etc.) In the implicit condition, as well as for experienced pilots, no further information about navigation was given. In the explicit condition, navigational advice similar to that taught in pilot training was given. For example, these subjects were told that bodies of water and interstate highways make good position-fixing references, whereas small local roads may be misleading, due to incomplete or inaccurate specification on the chart.

All subjects performed 3 warm-up trials to ensure that they understood the task. Subjects in the pilot, naive explicit and naive implicit groups received 9 blocks of 20 trials each, with speed and accuracy measured on each. Subjects in the control group received only pre- and post-tests of 20 trials each, and only their accuracy was measured. The 180 position-fixing problems spanned a range of difficulty and were presented exactly once to each subject. Specific problems appeared equally often as a pre-test or post-test problem in each group. Administration of the entire set took two 1.5 hour sessions for each subject. Subjects were tested in pairs.

Instrument Relationships PLM

A module was developed in which a view of an aircraft instrument panel (see Figure 1) was presented on a CRT screen on each trial, and the subject performed a speeded response classifying the flight situation depicted by pressing one of several keys on a keyboard.

Subjects. One group of 10 naive subjects and one group of four pilots were tested. Naive subjects were undergraduates at Swarthmore College and UCLA. Pilots had civil aviation experience ranging from 500 to 2500 hours.

Displays and Apparatus. Displays showing the 6 primary instruments in common general aviation aircraft were presented on an E-Machines TX-16 monitor connected to a Macintosh IIfx computer. Displays contained realistic looking gray scale images created in Adobe Illustrator. Each display depicted one of 7 possible flight situations: straight and level, straight climb, straight descent, level turn, climbing turn, descending turn, or instrument conflict (malfunction). Motion of instrument needles (e.g., VSI) or dials (e.g., DG) was depicted by large arrows. An example is shown in Figure 1.

Design and Procedure. Each trial was initiated by the subject pressing the space bar on the keyboard. When the display appeared, subjects pressed one of 7 response keys to indicate the flight situation depicted. Reaction time and accuracy were measured; feedback was given only at the end of each 24-trial block, in the form of number correct out of 24 and average response time.

Subjects in both groups were given a brief orientation (less than 5 minutes) to the aircraft instruments regarding what they should indicate in different flight situations, along with an illustration. All subjects were given 30 practice trials to become familiar with the 7 response keys. This practice consisted of trials in which

Figure 1. Example Display (climbing turn) from the Instrument Relationships PLM. Motion of needles or outer dials is depicted by arrows inside or outside the dials respectively.

subjects responded to auditory naming of flight situations (e.g., "climbing turn"). All subjects readily mastered the response keys, attaining average response times under 2 sec per trial by the end of practice. Subjects received 9 trial blocks in a single session that lasted about one hour.

RESULTS

Reaction time and accuracy were analyzed in separate two-way analyses of variance (ANOVAs), followed by planned comparisons. Flight experience (group) was the between subjects factor, and trial block was the within-subjects factor.

Visual Navigation PLM

Figures 2 and 3 show reaction time and accuracy data. Preliminary testing indicated no reliable differences between the naive explicit and naive implicit groups; their data were combined for the remaining analyses. Pilots were more accurate throughout, as shown by the main effect of group, $F(2, 13) = 7.26$, $p<.01$; accuracy improved for both groups across trial blocks, $F(8,83) = 9.00$, $p<.0001$. There was a reliable interaction of group and block, $F(9, 83) = 2.11$, $p<.05$, due to the control group showing no change between the pre- and post-test, $t(3) < 1$, n.s. Apart from the control group, there was no reliable interaction of group and trial block, $F(8,80) < 1$, n.s. Reaction time did not differ reliably across groups, $F(1,10) < 1$, n.s. There was a large improvement in reaction time across trial blocks, $F(8, 80) = 7.42$, $p < .001$, and there was no reliable interaction of group and block, $F(8, 80) <1$, n.s. Individual comparisons showed pilots were initially (block 1) more accurate than naive subjects, $t(10) = 1.85$, $p< .05$, but not faster, $t(10) = .58$, n.s. Non-pilots after training (block 9) were marginally faster, $t(10) = 1.52$, $p < .10$, and more accurate, $t(10) = 2.97$, $p< .01$, than pilots had been at the beginning (block 1).

Instrument Relationships PLM

Figures 4 and 5 show reaction time and accuracy data. Pilots responded faster than non-pilots, confirmed by a reliable main effect of group, $F(1, 12) = 6.29$, $p < .05$. Reaction time improved with training in both groups, indicated by the large main effect of trial block, $F(8, 96) = 40.51$, $p <.0001$, and no reliable interaction of group and block, $F(8, 96) = 1.23$, n.s. For accuracy there was no main effect of group, $F(1,12) = 1.22$, n.s. There was a reliable main effect of trial block, $F(8,96) = 4.00$, $p<.001$, and a marginally reliable interaction of group and block, $F(8, 96) = 2.00$, $p <.10$. The interaction reflects pilots' high accuracy in interpreting the instruments throughout training, while non-pilots improved from initially lower levels. Individual comparisons indicated pilots initially (block 1) performed better than naive subjects (reaction time: $t(12) = 3.46$, $p< .001$; accuracy: $t(12) = 2.97$, $p< .01$). Non-pilot subjects at the end of training (block 9) were faster, $t(12) = 4.69$, $p<.0001$, and no less accurate, $t(12) = .35$, n.s. than pilots at the beginning of training (block 1).

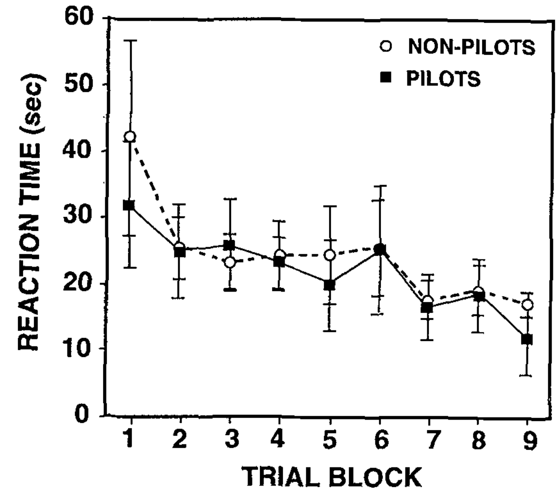

Figure 2. Reaction Time by Trial Block in the Visual Navigation PLM. Data for non-pilots in the implicit and explicit instructional conditions are combined.

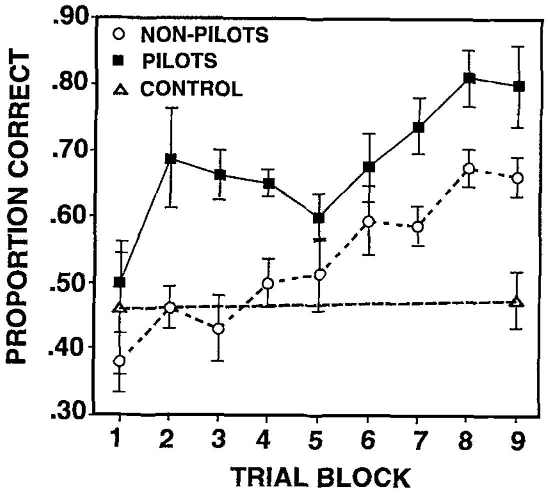

Figure 3. Proportion Correct by Trial Block in the Visual Navigation PLM. Data for non-pilots in the implicit and explicit instructional conditions are combined.

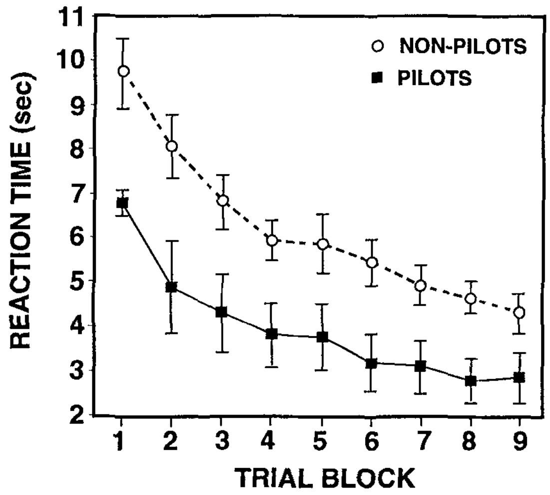

Figure 4. Reaction Time by Trial Block in the Instrument Relationships PLM.

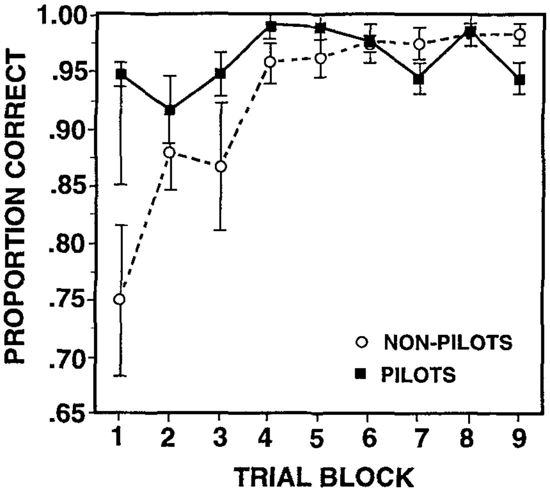

Figure 5. Proportion Correct by Trial Block in the Instrument Relationships PLM.

DISCUSSION

Both PLMs produced dramatic improvements in performance. Non-pilots reduced response time by 59% and 55% whereas pilots reduced response time by 61% and 58% in the Visual Navigation and Instrument Relationships modules, respectively. At the same time, accuracy rose markedly for both groups in the Visual Navigation Module and for non-pilots in the Instrument Relationships Module, while remaining at high levels for pilots in the latter module. These conspicuous changes in 1-2 training sessions suggests that perceptual learning occurs rapidly under these circumstances. They indicate great potential for PLMs as training technology.

A striking outcome of both PLMs is that naive subjects after training performed as accurately and reliably *faster* than pilots before training. This outcome occurred despite the fact that naive subjects had had no prior experience with sectional charts or aircraft instruments before training. Experienced pilots also improved substantially, suggesting that PLMs would benefit not only primary, but recurrent and advanced training.

Although in-flight validation of skills has not yet been carried out, both tasks involve information extraction demands similar to those required in actual flight environments. The validity of the tasks is also supported by the data. Experienced pilots performed substantially better than novices at the beginning of each module. In the Instrument Relationships Module, pilots' accuracy was nearly perfect from the start, and pilots' response times were initially about half as long as novices'. Pilots' initial superiority was also evident in the accuracy data for the the Visual Navigation Module. These results suggest that both tasks made contact with skills pilots have attained through flight training and experience. An important validation issue not addressed in these studies is whether individual pilot skills trained in modular fashion can be readily integrated into the multitasking environment of actual flying. There are reasons to suspect, however, that modular training might shorten the time required for trainees to achieve proficient multitask performance. The, results suggest that PLMs may speed up the development of automaticity for component skills. Research on divided attention and dual-task performance indicates that automatizing a task frees up attentional resources, allowing improved performance on concurrent tasks (Laberge & Samuels, 1974; Shiffrin & Schneider, 1977; Bryan & Harter, 1899). Flight training might be accelerated by interspersing PLMs with training sessions in aircraft and flight simulators.

These proof-of-concept studies of PLMs have broad implications for training in aviation and other domains. Expertise in many areas may depend on qualitative, domain-specific changes in information pick-up skills (Chase & Simon, 1973; Diamond & Carey, 1986; Gibson, 1969). These changes include discovery of relevant stimulus variables, use of higher-order relationships, parallel processing and automatic rather than controlled processing (Gibson, 1969; Shiffrin & Schneider, 1977). Such changes are not readily produced by classroom or textbook instruction. The pilot in the cockpit, the air traffic controller at the radar scope, the radiologist in the reading room and even the judge at a dog show (Diamond & Carey, 1986) employ expert information extraction skills that have originated in apparently mysterious fashion from long experience. The present research indicates that known characteristics of perceptual learning can be used to isolate and condense the experiences that produce skilled pattern processing. The large improvements attained after modest amounts of training in these aviation PLMs suggest that the approach has promise for accelerating the acquisition of skills in aviation and other training contexts.

ACKNOWLEDGEMENTS

Portions of this research were carried out while PJK was a National Research Council Senior Associate in the Aerospace Human Factors Division at NASA Ames Research Center. Additional support was provided by National Science Foundation Research Grant SBR-9496112 and a UCLA Academic Senate Grant to PJK.

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