Training Pilots' Pattern Recognition Skills: Perceptual Learning Modules (PLMs) in Instrument Flight Training

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Abstract

Many pilot skills develop over long periods of flight experience. Their development appears mysterious in that they do not arise from memorization of factual knowledge or execution of particular motor responses. One hypothesis about expert skills is that they depend heavily on *perceptual learning*, a process that increases the efficiency of information pick-up with experience. Basic research on perceptual learning indicates that specific training procedures can produce and accelerate it. Specifically, certain procedures lead to discovery of higher-order patterns, orders of magnitude improvement in discrimination of fine detail and automaticity in pattern detection.

There have been few attempts, however, to apply perceptual learning procedures to real-world training situations. Here we briefly summarize our efforts to apply perceptual learning technology to aviation training. Following up initial work by Kellman & Kaiser (1994), we have developed and tested several perceptual learning modules™ (PLMs)[1] designed for specific aspects of instrument flight training. These included an Instrument Relationships and Conflicts PLM, the Instrument Navigation PLM and the Approach Chart PLM. All three modules were tested on FA-250 Instrument Flight students in the Aeronautical Science Department at Embry-Riddle Aeronautical University.

Results showed that all modules produced substantial improvements in accuracy and speed. It appears that perceptual learning technology can substantially benefit aviation training. PLMs may offer an important complement to traditional in-flight, simulator and CBT training efforts.

INTRODUCTION

While flying in the clouds, the trainee in the left seat struggles as each gauge seems to have a mind of its own. One by one, he laboriously fixates each. After a few seconds on one gauge, he comprehends how it has strayed and corrects, perhaps with a jerk guaranteed to set up the next fluctuation. Yawning, the instructor in the right seat looks over at the panel and sees at a glance that the student has wandered off of the assigned altitude by 200 feet but at least has not yet turned the plane upside down.

Flying east past PDZ VOR on V388, the seasoned instrument pilot glances at the area chart and in only a few seconds sees that the airway up ahead bends at DEWAY intersection; the frequency for PSP VOR is 115.5; there is DME; and the 274 degree radial from PSP shown on the segment must be reversed to get his track (94 degrees) into Palm Springs. The novice pilot in the same situation will get the same information but will require repeated explorations of the chart, take a minute and a half, and hopefully he will not forget to reverse the radial.

These scenarios, although imaginary, remind us that expert pilot skills develop over long periods of time. Even a star student, completing a great training course, achieving a perfect score on all written tests, is not an expert pilot. What changes over time? Certainly the ease with which we pick up information, the ability to handle multiple overlapping tasks in the cockpit, and the ability to see patterns in the instruments, the charts and even out the window, e.g., the airport environment or weather patterns. We take this for granted: Besides the training we arrange and deliver, the student needs "seasoning" or experience. In the meantime there is no particular piece of information or advice that will quickly make the student an expert. Put another way, an instructor cannot tell the student exactly where and when to look at those countless things that would make him an expert at a task. Even if the instructor could do this, he would quickly overwhelm the student and either lose the student's interest or be out of a job!

The passage of time, then, is the last part of the curriculum. But this situation is not unique to aviation. It is just as true in teaching children to read English or training radiologists to read mammograms. In another vehicular context -- driving automobiles -- it is part of the reason for the dismal accident statistics of young drivers.

Cognitive Science and Expertise

From the standpoint of cognitive science (the study and simulation of intelligent systems), however, the passage of time is not very satisfying as an explanation of skill. We need more precise descriptions of human information processing and the changes in it brought about by learning. What is it that happens with the passage of time? If we could understand more precisely how information processing changes as the novice becomes the expert, we might be able to use this understanding to enhance training and perhaps reduce its time and cost.

Research in cognitive science suggests one hypothesis about the development of expert skills over time: These skill changes depend heavily on *perceptual learning*, a process that increases the efficiency of information pick-up with experience (Gibson, 1969). It appears to be a characteristic of the human attentional system that practice at any task leads to a progressive improvement in the extraction of particular informational features or relationships that make a difference for classifying objects, situations or events. (For a recent review, see Goldstone, 1997.)

Laboratory studies have documented dramatic effects of perceptual learning. A classic example involved the study of chess players (Chase & Simon, 1973). Chase and Simon compared grandmasters and less skilled players and found that the grandmasters' superior abilities depended on perceptual learning. Grandmasters had remarkable abilities to reconstruct the positions from brief glances at board positions, much better than novice or average players. Moreover, skilled performance depended on perceptual learning of complex patterns specific to the game of chess. The spatial and temporal orders in which grandmasters reconstructed patterns indicated use of meaningful "chunking" of chess relationships. When board positions were randomized, it was found that grandmasters and ordinary people had the same visual memory skills: there were no differences in performance. Chase & Simon concluded that the skills of grandmasters could be accounted for by perceptual learning of relationships specific to chess.

Perceptual learning has been a relatively neglected topic in learning, despite its promise for understanding expert performance. Recently, however, there has been a strong upsurge in research in perceptual learning. The research has documented remarkable improvements in both high-level pattern classification and even in low-level sensory discriminations (such as Vernier acuity), in which improvements of an order of magnitude or more have been found (e.g., Fahle, Edelman & Poggio, 1995; Karni & Sagi, 1993).

Especially relevant to aviation training is the fact that along with improvements in pattern classification, perceptual learning leads to *automaticity* (Bryan & Harter, 1899; Schneider & Shiffrin, 1977). Automaticity in information pick-up is the extraction of information with little or no effort and with little interference from concurrent tasks. Aviators are often in multitasking situations, i.e., adjusting one's altitude while listening to an incoming ATC transmission, or monitoring one's airspeed while lowering flaps. In aviation, training of information pick-up skills to automatic levels would be especially beneficial. Not only would it improve the quality of multitask operations, but it would also increase the threshold at which *task saturation* occurs.

Perceptual Learning and Aviation Training

So what do these concepts (and studies of chess players) have to do with aviation training? Simply this: From basic research, a great deal has been learned about specific training procedures that allow perceptual learning to occur. These procedures differ from most approaches used in ordinary ground school, typical computer-based training and even flight and simulator training. Proper application of these procedures, in conjunction with conventional training, might accelerate perceptual learning. We might take over from the passage of time the responsibility of teaching expert perceptual classification abilities.

Until recently, there have been few attempts to apply perceptual learning concepts to real-world training situations. Some recent work has attempted to apply perceptual learning to education and training in a variety of domains, including radiologic diagnosis (Mather, et al., 1995), science and mathematics learning (Silva & Kellman, 1999) and aviation training (Kellman & Kaiser, 1994).

Aviation training is fertile ground for the application of perceptual learning technology. Almost every flying task involves the pick-up of complex information. Some examples include interpretation of the primary flight instruments, pick-up of terrain and traffic information in visual conditions, interpretation of navigational displays and indicators, pick-up of information from VFR and IFR charts, pick-up of relevant information to guide visual approaches and the landing flare, and the interpretation of rapid-fire ATC instructions. Moreover, many of these tasks are relatively separable and may be usefully trained in modular form. In other words, becoming an expert at reading IFR Enroute charts is a separate skill from picking up relevant information necessary to complete a VFR landing or learning to check the engine instruments at a glance.

These considerations motivated initial studies of perceptual learning techniques in flight training. Working at NASA Ames Research Center, Kellman & Kaiser (1994) constructed two perceptual learning modules™ (PLMs), one for visual navigation and one for perception of relationships and conflicts among primary flight instruments. They found striking improvements in 1-2 hours of training in both novices and experienced pilots. Interestingly, they found that novices after training were faster and just as accurate as pilots (who averaged 1000 hours of civil aviation experience) had been at the beginning of training. These results suggested that direct training of perceptual classification skills may be useful in flight training.

In the present work, we undertook a larger trial, specifically geared to students undergoing instrument flight training. We constructed three perceptual learning modules for separable skills: the Instrument Relations and Conflicts PLM, the Visual Navigation PLM and the Approach Chart PLM. These were tested on instrument flight students at Embry-Riddle Aeronautical University. We hoped to find that relatively brief training interventions (an hour or less) could produce noticeable improvements in skill (speed and accuracy). We present here a short summary of the project.

METHOD

A full description of methods and results for the several modules is beyond the scope of this summary and will appear elsewhere. Here we give some general features and elaborate one specific example: the Approach Chart PLM.

Participants.-- Participants were FA-250 Instrument Flight students in the Aeronautical Science Department at Embry Riddle Aeronautical University.

General Procedure. -- Each module required an hour or less of training. Displays were presented and responses collected by computer. On each trial, subjects made a speeded classification of a display pattern (animated in the case of the Instrument Relationships PLM and static in the other cases) and received feedback. Speed and accuracy were assessed in 20-trial blocks; between 5 and 9 blocks were run, depending on the PLM.

Specific Procedure for the Approach Chart PLM.-- The Approach Chart PLM consisted of 5 blocks of 20 short trials, each consisting of 4 successive displays. First, a display appeared asking the the subject to extract a particular item of information, e.g., the altitude at the FAF. Next, a display containing a Jeppesen approach plate (© Jeppesen Sandersen, Inc.) appeared and a timer was started. Subjects indicated they knew the answer by pressing the spacebar on a keyboard; this response stopped the timer. A third screen appeared containing a box in which the subject typed the response. A fourth screen provided feedback to the subject. Incorrect answers led to a single retest of the same problem. If the answer was incorrect this second time, a feedback screen displayed the approach plate along with the correct answer. Twenty-eight pilot trainees contributed complete data sets and were counted in the results. The training took about 30 minutes to complete.

Dependent Measures and Data Analysis.-- Both speed and accuracy were measured for all trials, and block means (averaged over the 20 trials in each block) were used to assess learning at various points in the training. Separate one-way analyses of variance (ANOVA) for accuracy and reaction time were carried out with Trial Block as a within-subjects factor. An individual comparison of initial and final trial block performance was performed for both the reaction time and accuracy data.

RESULTS

Approach Chart PLM. Figure 1a shows accuracy data from the Approach Chart PLM, and response time data appear in Figure 1b. Although training averaged only 30 minutes in duration, pilots showed substantial performance gains. Pilots' accuracy averaged 80% at the beginning of training, reflecting their basic familiarity with the charts. Accuracy improved during training by about 14%.

The most dramatic results involved changes in the speed of information extraction. On average, pilots cut their response time over 60%. The time required to extract particular pieces of information from an approach plate dropped from an average of around 9.5 sec in the first block of trials to close to less than 4 sec in the final trial block.

These observations were confirmed by the statistical analyses, which showed reliable main effects of training for both accuracy and reaction time (both $ps < .001$). Differences between initial and final trial blocks were highly significant ($p < .001$) for both accuracy and reaction time.

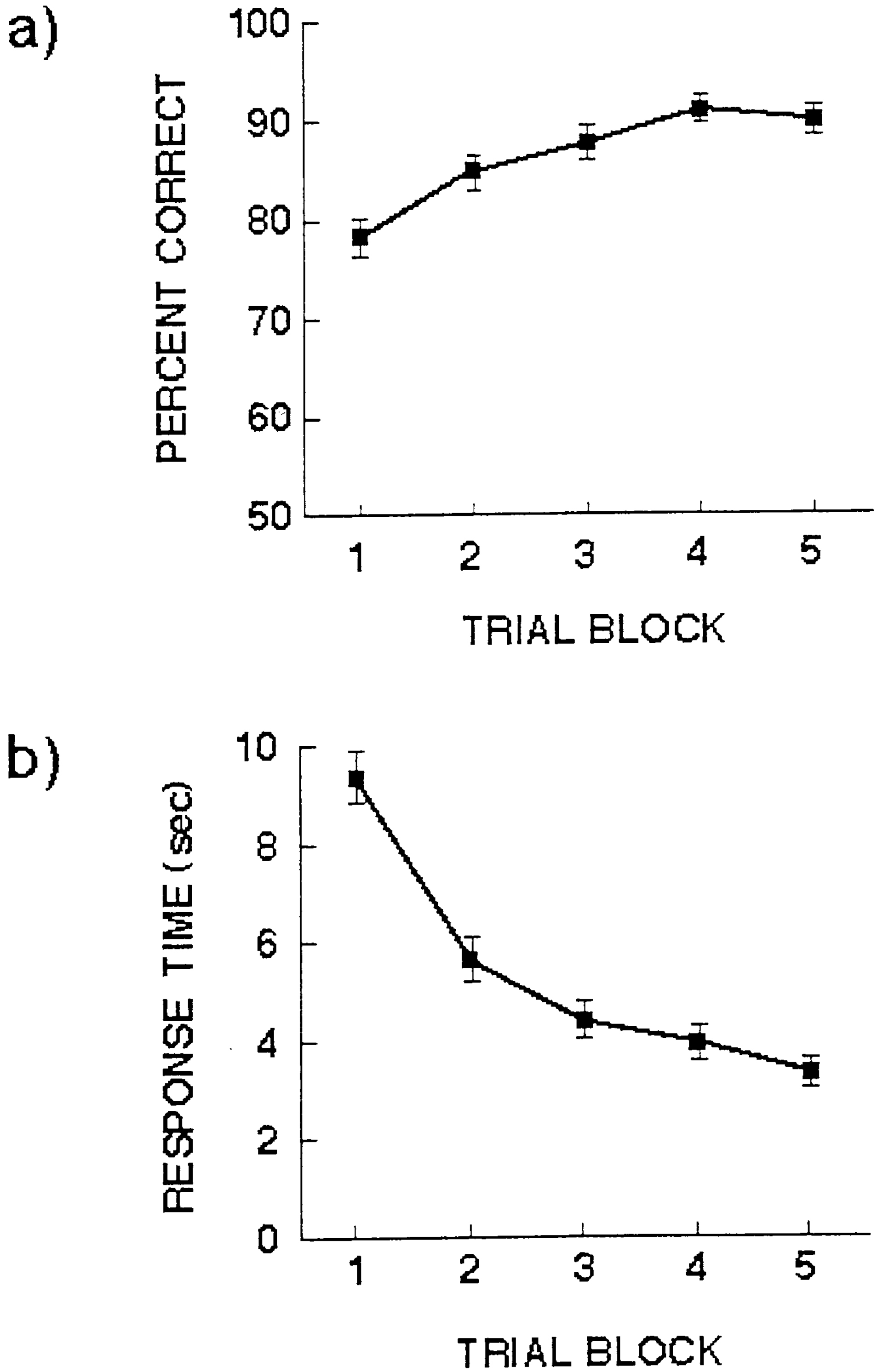

Figure 1. Performance Data for the Approach Chart PLM.
a) Accuracy by trial block. b) Response time (per trial) by tr
block. (Error bars indicate ±1 standard error of the mear

Instrument Relationships PLM and Instrument Navigation PLM. The other PLMs also led to substantial and highly statistically reliable improvements in performance. In the Instrument Relationships and Conflicts PLM, trainees at first required about 8 sec per trial to assess the depicted flight attitude but with training reduced their average recognition time to under 4 sec while increasing accuracy more than 10%. Recognition of instrument conflicts improved dramatically, from around 65% to nearly 90%, while recognition time was cut by more than half. The Instrument Navigation PLM produced roughly 25% improvements in accuracy with nearly 50% response time reductions.

DISCUSSION

Efforts to test PLMs on instrument flight trainees were most encouraging. Each module required a modest investment of training time and produced substantial gains in performance. For some skills, further validation of PLM training measured in actual instrument flying would be useful, but some of the results are already quite informative. Instrument flying consists of many component skills, used concurrently. To reduce by 60% the time required to extract information from flight instruments or from aeronautical charts while improving accuracy seems certain to be beneficial in the high-workload instrument flying environment.

In this brief summary of our work, we have highlighted the Approach Chart PLM. Extraction of information from information-rich aviation charts is a natural for a perceptual learning module. Explaining the layout of approach plates to students in ground school does not train efficient pick-up of information. Our results, in fact, showed that it does not even give near-perfect accuracy. With 30 minutes of PLM training, accuracy improved and the speed of information pick-up was enhanced greatly. It seems likely that further training along these lines could bring accuracy up to near-perfect levels. One concept we have developed but not implemented in the present work is the idea of adaptive PLM training, in which the sequencing of trials is adjusted to the learner to ensure extra practice on problem types that have high error rates for that student. We will report on the implementation and benefits of adaptive PLM training in future work.

In any case, the benefits suggested by the current results are clear. For a pilot in demanding instrument conditions to extract, confidently and accurately, crucial information in 3 sec rather than 10 sec is an improvement that can free up effort and attention for other flying tasks. Such skill can contribute to smoother and safer flying. Tests of a few highly experienced pilots indicate that even they could also benefit from the Approach Chart PLM. We expect our analogous Enroute Chart PLM to have similar effects.

PLMs may also help to address a difficult issue involved with chart *changes*. Approach plate and enroute charts are occasionally changed in format. For Jeppesen charts, some aspects of enroute charts recently changed, and we are in the midst of such a change for approach plates, with two different layouts still included in complete chart sets. Although format changes are intended to improve information pick-up, they pose a problem for experienced pilots accustomed to the old formats. These pilots will have developed, through perceptual learning, habits that lead them to seek information in the wrong places. These tendencies could cause delay or error in the pick-up of chart information even by these most seasoned pilots, especially under conditions of time pressure or stress. A promising strategy for combatting this type of problem would be to provide PLM training to give pilots new, automatized search skills geared to the revised approach plates and enroute charts.

As with the Approach Chart PLM, the results of the other PLMs are highly encouraging. To explicitly train improved extraction of patterns from flight instruments, navigational instruments, and other kinds of displays (e.g., weather displays) seems to be a desirable, and in light of our results, a feasible goal. We may never completely replace the passage of time as a contributor to expertise. By understanding more about what information processing activities over time produce perceptual learning and automatic detection, however, we can accelerate the acquisition of skill.

[1] *Perceptual Learning Modules* is a trademark of Kellman A.C.T. Services, Inc.

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