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The Learning Strategies Program: Concluding Remarks

Gavan Lintern

University of Illinois

for

Contracting Officer's Representative
Michael Drillings

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The work of the Learning Strategies program reported in this paper marks a substantial advance in our knowledge about principles of training. Aspects of part training, adaptive training, task loading effects, specialized skills training, and generalized skills training are addressed. Some research in prediction of performance for complex tasks and analysis of tasks for training purposes is also presented. The Learning Strategies program has used an appropriately complex task to address basic questions. This effort has led to the development of principles at a level of abstraction that should permit effective exploitation of those principles in a wide range of operational training environments.

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THE LEARNING STRATEGIES PROGRAM: CONCLUDING REMARKS

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THE LEARNING STRATEGIES PROGRAM: CONCLUDING REMARKS

Introduction

Part training, adaptive training, augmented feedback, learning, and skill transfer are the focus of my own research program, and I welcome this opportunity to comment on what is by far the most substantive attack on these issues to date. The primary concerns are with skill learning and skill transfer, and with strategies to enhance both. The classification of "Learning Strategies" is appropriate.

My own focus is on training applications. How is it possible to enhance the instruction of operators in artifactual systems? How might we design training devices to support that instruction? Thus, I examine this literature from that perspective. Can it tell me anything useful for my own research program that is oriented around flight instruction? Are there lessons here that I can bring to the frequent discussions I have with those interested in training within other domains such as process control, ship control, or medical diagnosis? In short, can the research described in this volume offer anything to those of us whose mission it is to enhance the instruction of complex skills required of many specialists in our technological society?

An Orientation

In seeking guidance for the design of instructional systems, one might examine basic psychological research and

theory. Indeed, unless intuition or current practices are deemed satisfactory, there is no other option. While it would be foolish to ignore intuition and current practice entirely, one assumption of my own work is that there is more to know than can be gained from introspection or from casual observation, and that information gained from these informal procedures will often be misleading. At least in the absence of any trustworthy theory, there can be no substitute for controlled observation.

It was in this frame of mind that my colleagues and I have sought guidance within the basic psychological literature. We have reviewed the adaptive training literature (Lintern & Gopher, 1978) and the part-training literature (Wightman & Lintern, 1985) with the intent to be comprehensive and to integrate those data. We entered those projects with a spirit of optimism that was dashed by the limitations of the published research. In the case of adaptive training, there was a tone of religious fervour within the literature (McGrath & Harris, 1971) and it became clear to us that the case had been overstated. We concluded that there were no data which could be offered as conclusive support for the application of adaptive training and that the approach had been based on precarious assumptions.

The situation with part-training was only marginally better. There were at least some promising trends within a mass of otherwise uninspiring data. It seemed that a form of part-

training that Wightman and I characterized as segmented training, could enhance transfer. There was however, little evidence that other forms we characterized as fractionation and simplification could have any favorable impact.

There were significant problems with part-training research. Foremost among them was the lack of any principles for task decomposition. The supposed benefits of part-training were taken at face value, and investigators partitioned the task in a manner that either conformed to their intuitions or that were easily accomplished on their research apparatus. As a result, investigators were often left with null results and little possibility for offering anything but platitudes in their discussion of their own research.

Early work from the Learning Strategies program was available for our review (Mane, 1984, reported here by Mane, Adams, & Donchin) and it stood out as a piece of research that had important implications. A principled decomposition of a complex task had suggested a part training strategy that had then been shown to provide a substantial and persistent enhancement in transfer. It is now apparent that if Wightman and I had undertaken our review of part training these few years later, the bulk of the data we considered at that time would receive little more than a historical comment. The emphasis

would necessarily lie with the data that have come from the Learning Strategies program.

Basic Research for Applications

There may be a question about what we can expect from a research program that does not use a real-world task. The issue is well illustrated by reference to a nontraining experiment in which my colleagues and I tested a new display configuration for carrier landings (Lintern, Kaul, & Collyer, 1984). To land an aircraft on a carrier is a notoriously difficult and dangerous task. Although an on-carrier guidance system is available to assist pilots during their approach to the carrier, it provides only zero-order (displacement) information while control of the aircraft on glideslope is at least a second-order (acceleration) task.

Considerable data from the manual control literature led us to believe that the addition of rate information to the display would help, as indeed our experiment showed. Thus, our experiment was successful. Given the abundant data from the manual control literature in support of the point we wished to demonstrate, one might question the need for an experiment. There were, however, many possibilities for a null result. The carrier landing task is complex and is not well understood. The poor performance may have been due to limitations in motor coordination on which our information enhancement could have had

little impact. In addition, the principle could be correct, but the implementation incorrect. For example an inappropriate gain can eliminate the effect entirely. The general lessons to be drawn from this work is that basic research can establish a principle; applied research is needed to demonstrate the relevance of that principle to a specific domain, and to tune its implementation for that domain.

Principles

From this view of the relationship between basic and applied research, what might be gleaned from the Learning Strategies program that could be exploited in an operational training environment? A first principle is to know your task. Foss, Fabiani, Mane, and Donchin (1989) devoted considerable effort to exploring the Space Fortress game. We have always known of individual differences, and in training research they are most often viewed as a problem. Foss et al. have exploited individual differences to their advantage. With the aid of multivariate statistical procedures they were able to identify some sources of that variability. Differences in strategy (e.g., conservative versus aggressive) and in basic skills (e.g., ship control) distinguished subjects. There is an implication here that emphasis on modifying strategies or on enhancing basic skills may be rewarded with faster learning and with higher asymptotic levels of performance.

Some limited data indicate that part-training strategies will be of more benefit to low than to high aptitude subjects (Wightman & Sistrunk, 1987; also see Gopher, Weil, & Siegel, 1989). From the perspective provided by the analysis of Foss et al., it is likely that lower performing subjects will have more weaknesses in basic skills and will employ less effective strategies. Any reasonably useful part-training strategy should, on a purely probabilistic basis, have more chance of impacting the weaker subjects. However, the work of Foss et al. permits a more diagnostic extension of this thinking. Even the better subjects have something to learn. The identification of specific skills and strategies should permit the development of part-training schedules that can assist all subjects. The unfulfilled promise of adaptive training (Kelly, 1969) that instruction in complex skills could be individualized, could be realized through the task analytic procedures used by Foss et al.

Frederiksen and White (1989) articulate the need for generalizable skills. They are concerned with developing conceptual knowledge that would assist performance not only for Space Fortress but also for a range of other tasks. This is a potentially powerful goal that has motivated much of the skill transfer research in the past. The past research has, however, failed to achieve that goal (Wightman & Lintern, 1985). Most

data suggest that transfer is based on skills specific to the task under examination. The demonstration by Frederiksen and White that instruction on some skills (e.g., the dynamics of acceleration) could enhance performance on tasks other than Space Fortress is, to my knowledge, the only clear evidence from the psychomotor domain that generalized skills training is viable. This work suggests that the failures of the past are due to an incorrect conceptualization of what constitutes a generalizable skill. Furthermore, it points the way to an exciting new thrust in skill transfer research.

Gopher et al. (1989) address two problems. One is related to fixation on inefficient strategies. This can be a particular problem with strategies that allow some moderate level of success but that severely limit a student's potential to develop further. In particular, the switch to a more effective strategy may require a transitional period in which the student performs even more poorly than with the inefficient strategy. Thus, the student is discouraged, at least in the short term, from practicing the potentially more effective strategy. In the terms of the connectionist simulated annealing analogy (Hopfield & Tank, 1986), students are frozen in a state that is locally, but not globally optimum.

A common example of this is the problem faced by self-taught typists. The "hunt-and-peck" method accomplishes

something, but severely limits potential. Transition to a more efficient method requires an extended period of practice in which there is no useful output. An example relevant to military aviation is that of air combat maneuvering. With air combat flight time at a premium, and assignments and careers depending on the outcomes of single engagements, there is little motivation to explore and to refine complex strategies. Gopher et al. have demonstrated that carefully designed feedback can guide students through the transition from one strategy to another.

The second issue addressed by Gopher et al. is that of problems that may be created through partitioning a task. One criticism of previous part-training research is that the partitioning procedures may actually result in the disassembly of important task components such as critical integration skills. Additionally, components that offer no substantive learning challenge may be selected for intensive training. These problems can defeat the basic goals of part training. Efficient partitioning of the task will be a problem particularly where it is done without the support of task analysis such as that provided by Foss et al. (1989). The solution offered by Gopher et al. is to train students on the whole task but to direct their attention to critical dimensions with task-emphasis instructions. This type of procedure would

appear to be of particular value where limited resources do not permit the development of specialized part-task trainers and where knowledge about the task is limited.

The experiment reported by Mane, Adams, and Donchin (1989) provided the first demonstration that part training could be effective within the context of the Space Fortress task. An advantage due to 14 minutes of prior component training was maintained throughout 100 minutes of whole task practice. This was a powerful demonstration for part-training research where enhancements have been difficult to find and where those that are found are often weak and transient.

Mane et al. also examined two adaptive training manipulations. Had my advice been sought at the time I suspect I would have recommended against any interest in adaptive training. Nevertheless there is an intriguing result here. A less extreme form of adaptive training provided some benefit in relation to whole training while the more extreme form did not. This result clarifies some of the comments that Gopher and I made in our review of adaptive training (Lintern & Gopher, 1978). An adaptive manipulation can distort crucial dimensions of a task to such an extent that learning is impeded rather than facilitated. Nevertheless, there is some potential for enhancement if the manipulation encourages a focus on a critical learning challenge. It would appear that the manipulation used

by Mane et al. did both of these things, and that the less extreme form allowed the potential advantage to emerge, while the more extreme form severely disrupted some important task elements. It remains unclear whether adaptive training is merely a rather inefficient approach to part training or whether it has something unique and worthwhile to offer.

Newell, Carlton, Fisher, and Rutter (1989) demonstrated that the manner in which a component feature is isolated for intensive instruction can be important. In that some crucial elements of task coherence may be lost there is a danger in reducing the task to very small units. The particular danger evident in the data of Newell et al. is that these finer partitions of the task can produce some short term benefit. Practitioners may be seduced by an early benefits, and fail to track progress carefully enough to notice that they are not sustained. Although some part training may be good, more is not necessarily better. More may even be worse.

Another powerful demonstration from the work of Newell et al. relates to the effectiveness of preliminary instructions. Some of their subjects were advised of a particularly effective strategy. For applied training situations, this form of knowledge could be provided by subject-matter experts. In that it was their most powerful manipulation, Newell et al. showed that this sort of advice could be of considerable assistance.

Logie, Baddeley, Mane, Donchin, and Sheptak (1989) explored the effects of secondary loads on performance. This issue is relevant to performance with real-world tasks because operators may often be burdened with the additional loads of extra tasks or system failures. Logie et al. demonstrated that not all forms of loading are equal. With the Space Fortress task at least, loads that would seem to impact response timing are particularly significant. In addition, the pattern of effects may shift throughout learning. The subjects of Logie et al. became less susceptible to interference from a visual-spatial mental imaging task but more susceptible to interference from a requirement to generate paced responses. One important lesson to be drawn from this work is that high levels of skill do not always develop resistance to interference from additional loads. Highly skilled operators may be even more susceptible than novices to interference from some types of loads.

These suggestions are given solid support in the work of Fabiani, Buckley, Gratton, Coles, Donchin, and Logie (1989). Subjects, trained with procedures developed by Frederiksen and White (1989) and by Gopher et al. (1989), were transferred to various loadings of the whole task. As with the work of Logie et al., some secondary loads had strong effects while others did not. There are two other observations to be made from this work. The first is that performance in transfer to loaded

versions of the whole task was better following either form of part training than following whole-task control training. Thus, part training might not only speed skill acquisition but may also enhance performance under conditions of high workload.

The second observation is that the skills training procedure of Frederiksen and White (1989), while best for transfer to the unloaded whole task, was not as effective as the integrated approach of Gopher et al. (1989) for transfer to the loaded whole task. This is a useful observation for applied training where it is generally assumed that a training strategy shown to be more effective for one scenario will also be more effective with other scenarios.

Those who work with manual control tasks in which operators need to visually scan multiple sources of information would do well to pay particular attention to the work of Shapiro and Raymond (1989). Drills required to optimize scan patterns were shown to facilitate learning of the Space Fortress task. If any credence is to be accorded the opinions of expert pilots, this style of training could be of considerable value in the instruction of difficult tasks such as instrument flight and carrier landing.

One persistent problem in the applied training environment relates to the prediction of success. Substantial resources can be dissipated on the instruction of individuals who eventually

fail to perform adequately. While more attention to instructional strategies should reduce those losses, Rabbitt, Banerji, and Szemanski (1989) address the issue of how we might better predict success. They were able to demonstrate good correlations between scores on intelligence tests and practiced performance on Space Fortress. Rate of learning was also well predicted but initial performance was not. While a test that predicts rate of learning and final performance better than it predicts initial performance is desirable, it is not one that we normally search for or expect to find. This work of Rabbitt et al. suggests that such tests can be found if the appropriate research methodologies are employed. In addition, these data indicate that early, untrained performance on a complex task is not necessarily a good indicator of final success. This raises a serious concern for the common practice of cutting students from a course of instruction on the basis of their initial achievements.

Conclusions

Each of these experiments, taken in isolation, suggests at least one important principle. The integrated nature of this research program, built as it was around a basic experimental procedure and a common, relatively complex experimental task, adds a significant dimension to the effort. Those whose caution may demand support beyond that of a single experiment will find

it in the complementary research efforts and the mutually supportive data of the Learning Strategies program. Although much remains unaccomplished both in terms of basic research and in the translation of these results into procedures for applied instruction, the papers offered in this volume provide a substantive advance in this area of research which has typically provided fragmented results and has failed to live up to expectations.

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REFERENCES

Fabiani, M., Buckley, J., Gratton, G., Coles, M.G.H., Donchin, E., & Logie, R. (1989). The training of complex task performance. Acta Psychologica.

Foss, M.A., Fabiani, M., Mane, A.M., & Donchin, E. (1989). Unsupervised practice: The performance of the control group. Acta Psychologica.

Frederiksen, J.R., & White, B.Y. (1989). An approach to training based upon principled task decomposition. Acta Psychologica.

Gopher, D., Weil, M., & Siegel, D. (1989). Practice under changing priorities: An approach to the training of complex skills. Acta Psychologica.

Hopfield, J.J., & Tank, D.W. (1986). Computing with neural circuits: A model. Science, 233, 625-633.

Kelly, C.R. (1969). What is adaptive training? Human Factors, 11, 547-556.

Lintern, G., & Gopher, D. (1978). Adaptive training of perceptual-motor skills: Issues, results, and future directions. International Journal of Man-Machine Studies, 10, 521-551.

Lintern, G., Kaul, C.E., & Collyer, S.C. (1984). Glideslope descent-rate cuing to aid carrier landings. Human Factors, 26(6), 667-675.

Logie, R., Baddeley, A., Mane, A., Donchin, E., & Sheptak, R. (1989). Working memory in the acquisition of complex cognitive skills. Acta Psychologica.

Mane, A.M. (1984). Acquisition of perceptual-motor skill: Adaptive and part-whole training. In Proceedings of the 28th Annual Meeting of the Human Factors Society (pp. 522-526). Santa Monica, CA: Human Factors Society.

Mane, A.M., Adams, J.A., & Donchin, E. (1989). Adaptive and part-whole training in the acquisition of a complex perceptual-motor skill. Acta Psychologica.

McGrath, J.J., & Harris, D.H. (Eds.). (1971). Adaptive training. Aviation Research Monographs, 1(2). Savoy, IL: University of Illinois at Urbana-Champaign, Aviation Research Laboratory.

Newell, K.M., Carlton, M.J., Fisher, A.T., & Rutter, B.G. (1989). Whole-part training strategies for learning the response dynamics of microprocessor driven simulators. Acta Psychologica.

Rabbitt, P., Banerji, N., & Szemanski, A. (1989). Spacefortress as an IQ test? Predictions of learning and of practised performance in a complex interactive video-game. Acta Psychologica.

Shapiro, K.L., & Raymond, J.E. (1989). Training of efficient oculomotor strategies enhances skill acquisition. Acta Psychologica.

Wightman, D.C., & Lintern, G. (1985). Part-task training for tracking and manual control. Human Factors, 27(3), 267-283.

Wightman, D.C., & Sistrunk, F. (1987). Part-task training strategies in simulated carrier landing final-approach training. Human Factors, 29(3), 245-254.