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Simulation and Training in Work Settings

Training is a set of activities planned to bring about learning in order to achieve goals often established using a training needs analysis. Methods of training include: behavior modeling, based on video or real activities; action training, which provides an opportunity to learn from errors; rule- and exemplar-based approaches that differ in terms of the extent to which theory is covered; and methods that aim to develop learning skills, the skills needed to learn in new situations. Simulation involves using a computer-based or other form of model for training, providing an opportunity for systematic exposure to a variety of experiences. Simulations are often used in training complex skills such as flying or command and control. Issues in training highlight the differing emphasis that can be placed on goals related to the process of learning or performance outcomes; motivation and self-management in training; and the transfer dilemma where effortful methods of training that enhance transfer may be less motivational. Finally organizational issues and training evaluation are discussed with a particular emphasis on the role of the environment and follow-up enhancing transfer of skills learned during training to the workplace.

1. Overview

Training is a set of planned activities organised to bring about learning needed to achieve organizational goals. Organizations undertake training as part of the socialization of newcomers. Even with the best selection systems a gap frequently remains between the knowledge, skills, and abilities (KSAs) required in a job, and those possessed by the individual. Training is used by organizations to improve the fit between what an individual has to offer and what is required. Training is also used when job requirements change such as with the introduction of new technology. Because of the frequency with which job requirements change, a major aim of training is to develop specific skills while also ensuring their transferability and adaptability. An ultimate aim is to increase learning skills where the emphasis in training is on learning to learn. Many methods of training are available (e.g. behavioral modeling, action, computer-based training), with an increasing trend toward incorporating evaluation as part of the training. Although simulations have been used in training for decades, the reduced cost and increased sophistication of simulations now make them more readily available for a wide range of situations. Simulations provide increased opportunities to train for transferable and adaptable skills because trainees can experiment, make errors, and learn from feedback on complex and dynamic real-time tasks. Evaluation of training programmes remains an important component of the training plan, and can be used to enhance transfer.

2. Training Needs Analysis

Most training starts with a training needs analysis, where the present and future tasks and jobs that people do are analyzed to determine the task and job requirements. The identified requirements are then compared with what the individual has to offer. This is done within a broader organizational context. Many different methods of job, task, and organizational analysis can be used, including observation, questionnaires, key people consultation, interviews, group discussion, using records, and work samples (that is, letting people perform a certain activity and checking what they need to know to perform well). A transfer of training needs analysis (Hesketh 1997a), places a particular emphasis on identifying the cognitive processes that must be practised during learning to ensure that the skills can be transferred to contexts and tasks beyond the learning environment.

3. The Training Plan and Methods

There has been an increase in the methods of training that can be used within a broader training plan that includes transfer and evaluation (Quinones and Ehrenstein 1997). The training plan provides a way of combining the illustrative methods discussed below to ensure that the training needs identified in the analysis can be met.

3.1 Behavior Modeling

Behavior modeling is often combined with role-playing in training. A model is presented on video or in real life, and the rationale for the special behaviors of the model are discussed with the trainees. Trainees then role play the action or interaction, and receive feedback from the trainers and fellow trainees. This type of training is very effective as it provides an opportunity for practice with feedback (e.g. Latham and Saari 1979).

3.2 Action Training

Action training follows from action theory (Frese and Zapf 1994) and exploratory learning. Key aspects of action training involve active learning and exploration, often while doing a task. Action learning is particularly effective as a method of training (Smith et al. 1997). Another important aspect of action training involves obtaining a good mental model of the task and how it should be approached. A mental model is an abstraction or representation of the task or function. Trainees can be helped to acquire a mental model through the use of 'orientation posters' or advanced organizers, or through the provision of heuristic rules (rules of thumb) (Volpert et al. 1984). One of the advantages of action training is the opportunity to learn from feedback and errors. Feedback is particularly important in the early stages of learning, but fading the feedback at later stages of learning helps ensure that trainees develop their own self-assessment skills (Schmidt and Bjork 1992). Errors are central in action training since systematic exposure to errors during learning provides opportunities to correct faulty mental models while providing direct negative feedback. Although earlier learning theory approaches argued that there should be only positive feedback, active error training helps trainees develop a positive attitude toward errors because of their value in learning (Frese et al. 1991).

3.3 Rules versus Examples in Training

Although it has traditionally been assumed that rule-based training provides a sound basis for longer term transfer, recent research suggests that for complex nonlinear problems, exemplar training may be superior. Optimizing the combination of rules and examples may be critical. In order to facilitate transfer, examples should be chosen carefully to cover the typical areas of the problem. With only a few examples, the rule and the example are often confused. However, individual instances are difficult to recall if trainees are provided with too many examples (DeLosh et al. 1997), suggesting that care needs to be taken when deciding how many examples will be presented in training.

3.4 Developing Learning Skills: Learning to Learn

Downs and Perry (1984) offer a practical way of helping trainees develop learning skills such as knowing that there are different ways of learning (e.g., learning by Memorizing, Understanding and Doing, the MUD categories). Facts need to be memorized, concepts need to be understood and tasks such as driving a motor car need to be learned by doing. The approach stresses the importance of selecting the most appropriate method for the material to be learned so that learning skills can be trained while also developing content skills. Methods that typically encourage learning skills as well as content skills involve action learning, active questioning and discovery learning, rather than direct lecturing and instruction. The ideas in the learning to learn literature lead to issues such as developing self-management techniques and focusing on learning.

3.5 Simulation Training

Simulation involves developing a model of an on-the-job situation that can be used for training and other purposes. The advantages of using simulation for training include reduced cost, opportunity to learn from errors, and the potential to reduce complexity during the early stages of learning. Historically simulators have been used for training in military, industrial and transport industries, and in management training where business games are widespread.

Pilot training on simulators is well developed, to the extent that many pilots can transfer directly from a flight simulator to a real aircraft (Salas et al. 1998). Within the aviation industry, crew cockpit resource management training has also been undertaken using simulators. Driving simulators are not as well developed, and the transfer of skills learned on a driving simulator to the actual road remains to be established. Nevertheless, there is a view that attitudes and driving decisions can be trained on a simulator. Simulations of management decision situations and command and control in the military, police, and emergency personnel are well developed, and widely used for training. These simulations provide a miniaturized version of real crises, with key decision points extracted and shrunk in time. They provide an opportunity for the trainee to experiment with decisions, make mistakes, and learn from these errors (Alluisi 1991). Simulation training has also been used to facilitate the acquisition of cross-cultural skills.

4. *Issues in Training*

4.1 *Learning vs. Performance Goals*

Whether the emphasis during learning is on performance or learning goals is used to explain differences in how people conceptualize their ability. Dweck and Leggett (1988) argue that some people conceptualize ability as increasing with learning (learning orientation), while others see ability as fixed (performance orientation). People with a learning orientation learn from mistakes and challenges. However, individuals with a performance orientation view mistakes as examples of poor performance and learn less from errors. Performance oriented people also tend to demonstrate a helpless response to problems and are therefore less likely to overcome challenges. Martocchio (1994) showed that ability self-conceptualization was related to computer anxiety and self-efficacy.

Motivation plays a key role in transfer of training (Baldwin and Ford 1988). Numerous motivation issues have been studied, the most important ones being self-efficacy, relapse prevention, perceived payoffs, goals, and the training contract. Self-efficacy is critical to transfer in that people will use a skill only if they believe that they can actually perform the appropriate behavior. Relapse prevention focuses on teaching solutions to those situations in which it may prove difficult to use the newly learned skills (Marx 1982). Trainees who receive relapse prevention training have been found to use their skills more often and perform their job better.

4.2 *Self-management in Training*

Self-management implies that one acquires the skills to deal with difficulties, reward oneself, and increase self-efficacy. Metacognitive strategies showing evidence of self-management and self-reward during training related to training performance. Furthermore, self-efficacy is related to increased post-training knowledge (Martocchio 1994) and transfer performance. Thus, self-efficacy functions as a predictor of both training and transfer performance.

4.3 *Transfer Dilemma*

Transfer is important to ensure that the skills learned in one context or on one task can be applied in a range of different contexts and tasks. For example fire fighters may learn how to fight fires in urban areas, but their skills must also transfer to the bush or rural areas where they are frequently required to work in emergencies. In the field of technology, training, in the use of one spreadsheet or database should lead to transfer to different spreadsheets and databases and a range of other software packages. Baldwin and Ford (1988) provide a model that highlights several factors that influence transfer, including the similarity of the training and transfer situation, the nature of the training methods used, and the extent to which environmental factors reinforce transfer. Annett and Sparrow (1986) explained that transfer would be best if the stimulus situations and behaviors trained shared identical elements with stimuli in the work environment and the behaviors required there. Because these are seldom identical it is important to use methods of training that encourage learners to bridge the gap and transfer their skills (Hesketh 1997b), and to create an environment that reinforces them for doing so. A transfer of training needs analysis can be used to discover how best to design training to increase transfer knowledge and skill (Hesketh 1997a). For example, a transfer of training needs analysis for a team leader in fire fighting would highlight the types of decisions that needed to be made in different fire incidents and the specific cues used in making the decisions. This information would be used to design training that emphasized practice of these decision processes in a range of systematically chosen contexts to facilitate transfer. This approach ensures that the cognitive skills required for transfer are practised during training, and that knowledge about transfer and likely barriers are discovered during training (Von Papstein and Frese 1988).

Druckman and Bjork (1992) has highlighted a dilemma in that the methods of training that trainees enjoy, and that often lead to better performance on the training task, are not necessarily the ones that enhance long term retention and transfer. Trainees enjoy methods of training that require less effortful cognitive processing. Yet to facilitate transfer, trainees need to engage in the problem solving and active processes that they will be required to do on transfer. This may create motivational difficulties. Designing the training to provide an appropriate level of challenge is important for both motivation and transfer.

4.4 *Simulation and Transfer*

Early debate about the appropriate level of physical and psychological fidelity of simulation for training remains important, but has been incorporated into the more general issue of transfer and generalization. A high fidelity simulation may facilitate transfer to a single context, but lower fidelity simulators may be more appropriate if transfer is required to a range of situations. Current research issues are addressing the best ways of integrating simulation with other forms of training, and how to optimize the level of fidelity for the particular purpose and type of simulation. The debate is being informed by research on the best way of combining rules and examples for training. Simulators provide an ideal opportunity to structure systematic exposure to a carefully chosen set of exemplar situations.

Simulators have traditionally been used for training, but their potential use is much more widespread. Simulation may provide a more realistic selection task for situations that require dynamic decision-making. Simulations are also being used as a way of signing off competency levels. Questions remain about how to deal with re-testing with a simulator, e.g., whether the trainee should be given an opportunity to perform again on exactly the same sequence as used during an initial test or a transfer problem. Here the research on transfer of training is critical, and may be of use in resolving the reassessment debate. This illustrates the ways in which selection, assessment, and training are strongly related areas of research and practice.

4.5 Organizational Issues

Organizational characteristics often influence transfer success. Trainees develop expectations about whether or not it will pay off when they use what they have learned in training. Often, companies teach one thing and reward a completely different behavior. For example, trainees may learn to be cooperative in a training course, but may then be paid for their individual contribution in a highly competitive environment. In such situations there is no transfer. Trainees need to be reinforced for what they have learned, and to practise skills in circumstances where errors can be made without serious consequences. For example a practice niche can be created where a bank clerk who has learned a new program to calculate mortgages is provided with an opportunity to practise it first while answering written requests. Thus, the customer does not see all the mistakes the bank clerk makes when using the new program.

4.6 Evaluating Training

The importance of evaluation has always been emphasized in training, although until recently approaches were somewhat traditional and limited. The importance of training evaluation has been recognized because intuitive guesses about what works are often wrong. Druckman and Bjork (1991) concluded that many companies in the USA continue to use methods of training known to be suboptimal for transfer because they rely on short term reactions evaluation, rather than examining the longer term retention and transfer of skills. Training evaluation can also be used as a way of indicating the importance of the skills learned, and of providing an opportunity to practise. Integrating training evaluation into the training plan is the best way of achieving this. The more detailed understanding of ways in which knowledge structures change with skill acquisition has also provided a basis for evaluating training. For example, experts tend to have hierarchically organized knowledge structures, and are able to read off solutions to problems far more quickly. These ideas can be used to suggest innovative ways of evaluating training programs.

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Simultaneous Equation Estimates (Exact and Approximate), Distribution of

A simple example of a system of linear simultaneous equations may consist of production and consumption functions of a nation: $Y = a + bK + cL + \text{error}$, and $C = d + eY + \text{error}$. The variables Y, K, L, and C represent the gross domestic product (GDP), the capital equipment, the labor input, and the consumption, respectively.

These variables are measures of the level of economic activity of a nation. In the production function, Y increases if the inputs K and/or L increase. C increases if Y increases in the consumption equation. Each equation is modeled to explain the variation in the left-hand side 'explained' variable by the variation in the right-hand side 'explanatory' variables. Error terms are added to analyze numerically the effect of the neglected factors from the right-hand side of the equation. These equations are different from the regression equations since the 'explained' variable Y is the 'explanatory' variable in the C equation, and Y and C are simultaneously determined by the two equations. Estimation of unknown coefficients and the properties of estimation methods are not straightforward compared with the ordinary least squares estimator.

In practice, this kind of simultaneous equation system is extended to include more than 100 equations, and regularly updated to measure the economic activities of a nation. It is indispensable to analyze numerically the effect of policy changes and public investments.

In this article, the statistical model and the estimation methods of all the equations are first explained, followed by the estimation methods of a single equation and their asymptotic distributions. Explained next are the exact distributions, the asymptotic expansions, and the higher order efficiency of the estimators.

1. The System of Simultaneous Equations and Identification of the System

We write the structural form of a system consisting of G simultaneous equations as

$$y_i = Y_i\,\beta_i + Z_i\,\gamma_i + u_i \equiv (\,Y_i\;Z_i\,)\delta_i + u_i, \qquad i = 1,\ldots, G \quad (1)$$

where y_i and Y_i are 1 and G_i subcolumns in the $T \times G$ matrix of whole endogenous variables $Y = (y_i, Y_i, Y_{ei})$, Z_i consists of K_i subcolumns in the $T \times K$ matrix of whole exogenous variables Z, β_i and γ_i are $G_i \times 1$ and $K_i \times 1$ column vectors of unknown coefficients, $\delta_i = (\beta_i', \gamma_i')'$, and u_i is the $T \times 1$ error term. This system of G equations with T observations is frequently summarized in a simple form

$$YB + Z\Gamma = U \quad (2)$$

the ith column of which is $y_i - Y_i\beta_i - Z_i\gamma_i = u_i$, i.e., Eqn. (1). The ith columns of B and Γ may be denoted as b_i and c_i where $(G - G_i - 1)$ and $(K - K_i)$ elements are zero so that $y_i - Y_i\beta_i - Z_i\gamma_i = Yb_i + Zc_i$. Zero elements are called zero restrictions. It is assumed that each row of U is independently distributed as $N(0, \Sigma)$. The reduced form of Eqn. (2) is

$$Y = Z\Pi + V \quad (3)$$

where the $K \times G$ reduced form coefficient matrix is $\Pi = -\Gamma B^{-1}$, and the $T \times G$ reduced form error term is $V = UB^{-1}$. Each row of V is assumed to be independently distributed as $N(0, \Omega)$, and then $\Sigma = B^{-1}, \Omega B^{-1}$.

The definition $\Pi = -\Gamma B^{-1}$, or $-\Pi B = \Gamma$ is the key to identify structural coefficients. Coefficients in β_i are identified if they can be uniquely determined by the equation $-\Pi b_i = c_i$ given Π. This equation is reduced to $-\Pi_0(1, \beta_i')' = 0$ denoting the $(K - K_i) \times (1 + G_i)$ submatrix in Π as Π_0. (Rows and columns are selected according to the zero elements in c_i and non-zero elements in b_i, respectively.) Given Π_0, this includes $(K - K_i)$ linear equations and G_i unknowns, and β_i is solvable if rank $(\Pi_0) = G_i$. This means $(K - K_i)$ must be at least G_i, or $L = K - K_i - G_i$ must be at least 0. If $L = 0$, β_i is uniquely determined. For the positive L, there are L linearly dependent rows in Π_0 since only G_i rows are necessary to determine β_i uniquely. Once β_i is determined, γ_i is determined by other K_i equations through $-\Pi b_i = c_i$. L is called the number of the degrees of overidentifiability of the ith equation.

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