90

Computer-based Testing and Training with Scenarios from Complex Problem-solving Research: Advantages and Disadvantages

Joachim Funke*

The use of PC-based simulations for selection and training for jobs which require complex problem solving skills is ever-increasing. This paper gives a short review of such simulations along with a list of advantages and disadvantages of their use. Possible future developments are sketched.

Key words: Complex problem-solving, computer-based testing.

The growing number of stand-alone computers (PCs) which have become available in research labs since the mid-seventies has led to a new area of psychological research: the analysis of how people deal with complex computer-simulated systems. This approach has spread quickly from the research lab to applications in personnel selection and training. This trend is discussed within four major perspectives. First, a short historical sketch of different developments in North America and in Europe regarding research paradigms in this area will be given. Second, examples of computer simulations used in selection as well as in training will be discussed. Third, advantages and disadvantages of using PC-based simulations for both selection and training will be enumerated. Last, emerging developments in this R&D area will be presented.

1 Emergence of complex problem solving (CPS) research

The emergence of complex problem solving (CPS) research has its roots in a deep disillusion with theories and results on simple problem solving, as represented by tasks like anagrams, concept identification, puzzles, etc. (for a review see Bourne and Dominowski 1972). The main reason for this can be found in the assumed low validity of simple laboratory tasks with respect to the complexity of problems solved in everyday life.

In North America, initiated by the work of Herbert Simon on learning by doing in semantically rich domains (e.g., Anzai and Simon 1979; Bhaskar and Simon 1977), researchers began to investigate problem solving in specific knowledge domains (e.g., physics, writing, chess playing). Frequently, such research focused on trying to understand the development of problem solving within a certain domain, that is, on the development of specialized expertise (e.g., Anderson *et al.* 1985; Chase and Simon 1973; Chi *et al.* 1981). Domains that have attracted extensive attention in North America include such diverse fields as reading, writing, calculation, political decision making, managerial problem solving, lawyers' reasoning, mechanical problem solving, problem solving in electronics, computer skills, and game playing.

In Europe, two main approaches have surfaced during the past two decades, one initiated by Donald Broadbent (1977; see Berry and Broadbent 1995) in Great Britain and the other by Dietrich Dörner (1975; see Dörner and Wearing 1995) in Germany. The two approaches have in common an emphasis on relatively complex, semantically rich, computerized laboratory tasks that are constructed to be similar to real-life problems. PC-based simulations have been seen both by Broadbent and Dörner as being central to our understanding of CPS.

Their two approaches, however, differ somewhat regarding theoretical goals and methodology. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem solving processes that operate under awareness versus outside of awareness, and typically employs mathe-

*Address for correspondence: Joachim Funke, Department of Psychology, Heidelberg University, Hauptstr. 47-51, D-69117 Heidelberg, Germany. Email: Joachim.Funke@urz.uni-heidelberg.de

matically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, is interested in the interplay of the cognitive, motivational, and social components of problem solving, and utilizes very complex computerized scenarios that contain up to 2,000 highly interconnected variables.

Buchner (1995) has classified the Dörner approach as a search for individual differences, which has needed semantically rich scenarios without giving much notice to the mathematical properties of the systems. The tradition founded by Broadbent was labeled by him as one which is more interested in basic research on the psychological processes of learning to control complex systems and which needed simple and mathematically well-defined systems. The detection of a dissociation between verbalizable knowledge about a system and the ability to control that system has led to an impressive body of research on what we call now 'implicit learning and memory' (for an overview, see Berry and Broadbent 1995).

North American research on CPS has typically concentrated on examining the development of expertise in separate, natural knowledge domains. Most of the European research, in contrast, has focused on novel, complex problems, and has been performed with computerized and sometimes highly artificial tasks. Much of the North American work has been summarized in a volume edited by Sternberg and Frensch (1991). The European research has been systematically and extensively summarized in a recent volume edited by Frensch and Funke (1995).

Whereas North-American psychologists seem to be reluctant in using complex scenarios in assessment situations, European psychologists are not. In training situations, especially within the area of flight training for pilots, psychologists from both continents are equally interested in using these new instruments.

Of the two European approaches mentioned above the one initiated by Dörner has mainly influenced the European practitioner's work in assessment and training. The reason for this may be the surface or face validity of the scenarios which, naturally, is higher if not restricted for purely methodological reasons.

2 Prevalence of computer-based testing with CPS scenarios

Especially in the German-speaking countries, many CPS scenarios are offered for use within the area of personnel selection and training (for a review, see U. Funke 1995). Two recently published German editions (Geilhardt and Mühlbradt 1995; Strauß and Kleinmann 1995) reveal this increased interest in the topic from the practitioner's view.

The distinction of the following two sections between PC-based scenarios used for selection and those used for training is somewhat arbitrary because some systems can be used for both purposes. The major reason for making such a distinction lies in respect to the different goals of the systems.

2.1 Scenarios used for assessment purposes

Within the context of the Assessment Center philosophy in Germany, a set of quality standards has been established (Arbeitskreis Assessment Center 1996). One of the nine principles is called the "Simulation principle" (see also Guion 1991). It requires the psychologist (who sets up the instruments used within an assessment center) to simulate situations in as many and as different ways as they will be found in the target position. It is explicitly *not* recommended to only *think* of these situations (instructions like "please imagine ..."); instead one should try to simulate a situation as realistically as possible.

There is one simple reason why PC-based simulations are so attractive to use in the assessment context: they allow for the design of highly complex scenarios which behave dynamically over time and respond directly to subjects' decisions.

Space restrictions preclude an exhaustive listing of all simulations used for assessment purposes. This would be a very difficult task because many systems are applied for which no documentation or references exist. Instead two examples which illustrate the approach will be offered.

TEXTILFABRIK ("textile factory"; Hasselmann 1993) is the name of a scenario developed from basic research in the Dörner school. It has been subject to many evaluation studies and represents the type of scenario in which subjects have to maximize the profits of the small enterprise. The system operates on 30 variables and behaves dynamically depending on subjects' interventions. On half of these variables, subjects can determine their values according to their decisions. Also, background information about the importance of the variables and their role in the scenario can be accessed by the subject. For a total period of 20 simulated months, subjects receive monthly information about the actual state of the factory.

Dependent variables in TEXTILFABRIK are the total value of the company at the end of the simulation period, the relative amount of months with an increase in raw capital, or an index summing up the increase from four selected important areas of the system. Analyses concerning reliability and validity of these indices are presented in Hasselmann (1993). Test-retest reliability as well as prediction of external criteria of job performance (salary; job position 0, 1, or 5 years after testing, etc.) with the indices yield acceptable values in the range between 0.40 and 0.60.

AIRPORT (Obermann 1991, 1995) requires management of an airport for eight periods distributed over a restricted amount of total time (about 2 hours). All information about the four different departments in this simulated airport has to be collected by the subject. Also, subjects are free to decide on many of topics related to that business. By this procedure, one can see according to the author how people gather information, set priorities, and make a decision.

In the current version, about 30 variables can be manipulated directly by the subject, about 150 dependent variables play a role in this dynamic scenario. At the end of the game, an automatic evaluation occurs showing about 20 measures which can be condensed to three main result variables reflecting analytic behavior, decision making, and logical and deductive abilities. According to Obermann (1995), more than 1000 subjects have worked with this scenario. Published data on reliability and validity (Obermann 1991) refer only to 150 subjects. A clear indication of the reliability and validity for each of the 20 measures is missing.

2.2 Scenarios used for training purposes

A slightly different perspective is involved if scenarios are not used for selection but for training purposes. In this case, the question of reliability and validity of the measurement instrument is not as important as in the selection case because the impact of any measurement error upon a selectee is normally greater than upon a trainee who always gets a 'second chance'. Nevertheless, reliable and valid indicators are also needed in the training situation. Most important regarding the training perspective is the question of transfer and generalizability to real-world situations: for good scenarios, one should be able to demonstrate the effectiveness of the training with respect to a list of training goals.

As mentioned, there also exist many PC-simulations for training purposes, most of which were not subject to psychometric or other scientific analyses. In an overview about PC simulations for practical applications published by Graf (1992), 139 scenarios are listed – most of them developed for training purposes.

As an example of PC-simulations used for training we look at the "Strategic Flight Management Simulators" developed by the MIT group of systems thinking. Morecroft (1988), Bakken *et al.* (1992) as well as Graham *et al.* (1992) give reports on this approach which requires participants to develop their own models about certain domains of reality. Training is done in this approach not with a ready-made simulation but with the construction of the simulation model itself. The rationale behind this strategy is the detection that learning effects with simulation scenarios are maximal for the persons who construct these systems and not as high for the ones who play with them.

Bakken *et al.* (1992) report the results of a transfer evaluation study comparing 17 MBA students (participating individually) with 32 professionals from major corporations (participating in teams of two). The players were confronted with one of two structurally identical decision making games (oil tanker transportation and office real estate), for two trials consisting of 40 periods each with the task of maximizing profits. After a break, they received information about the other game and had to play it for one trial. It turned out that during the first game, students went bankrupt twice as often as professionals. But with respect to transfer, students show markedly better performance than professionals. Training success in professionals was low because they felt much more restricted than students who learned a lot from their experienced bankruptcies. The consequence for designing effective training settings is according to the authors to produce non-threatening learning laboratories which foster experimentation and a game playing strategy which uses "the information available in the game as a springboard for investigation into causal dynamics" (Bakken *et al.* 1992, p. 180).

3 Advantages and disadvantages of computer-based testing and training with CPS scenarios

In what follows, some of the major advantages as well as disadvantages of using PC-based simulations in the context of assessment and/or training are discussed. The summarized evaluations rely largely upon trends discerned from the relevant literature.

3.1 Advantages

In general, the advantages of PC-based simulations can be summarized as follows:

(1) PC-based simulations allow the construction of highly complex scenarios which behave dynamically over time and, thus, pose new requirements to subjects.
(2) PC-based simulations allow for an economic presentation of complex scenarios as well as

for a process-oriented data registration.

(3) PC-based simulations allow for a quick computing of results – and at least in part – for an 'automatic' interpretation of these results.

(4) PC-based simulations make it possible to have complex scenarios presented in a standardized manner.

(5) PC-based simulations have high acceptance from the testee's point of view.

In a training context, PC-based methods have some specific advantages. According to Funke (1995, p. 228), these advantages are:

(6) The opportunity for practice: trainees can experiment with a complex system and thus, learn by doing, without risk and cost. They can actively discover and explore an unknown scenario and acquire declarative as well as procedural knowledge about a certain domain of reality.

(7) Augmented feedback: due to the time compression which is inherent in most PC-based simulations, feedback about the long-term consequences and side-effects of decisions appears quickly and can be related to one's own behavior.

(8) Increased motivation: most PC-based simulations provoke challenge and curiosity. This is related to affective processes which enable not only acquisition of knowledge but also the change of attitudes.

(9) Adaptability to training objectives: depending on the actual training goals, the complexity of many simulations can be changed and adjusted to the trainee's needs.

These advantages are also reported in the above-mentioned American literature (e.g., Bakken *et al.* 1992; Graham *et al.* 1992).

The realization of certain training goals (e.g., increased understanding of interdependent systems, intensified reflections about own decision strategies) depends not only on the learner but also much on the activities of the trainer: to present an environment in which learning *can* occur is not enough – to increase the learning potential of such situations, the controlled "explication of implicit information" seems to be a very important step (see Leutner, 1995). This can be done by adaptive hints and requests which require the active discussion of a topic related to the learner's decision or to the state of the system, presented either by a human trainer or by a system-implemented intelligent tutor.

3.2 *Disadvantages*

Besides their advantages, computer-based scenarios have serious disadvantages (see also Funke and Geilhardt 1996). Some are presented here together with proposals for their solution.

(1) PC-based simulations are often so complex that even the developer of the system does not know what the correct or best solution will be for a given problem constellation.

This situation poses a problem for the comparison of individual results. If the maximum of a scale cannot be determined (as is often not possible in scenarios with non-linear equations), only *relative* rankings between scores are possible.

Possible solution: use of scenarios with known features and with the existence of a best solution.

(2) PC-based simulations produce a lot of behavioral data for most of which the psychological interpretation may be unclear.

Some simulations produce log-files containing all of the subjects' interventions and decisions. Even if this huge amount of data are compressed to some measures and indices this reduction does not guarantee useful and sensible indicators.

Possible solution: use only those measures and indices in a selection situation for which validity data are available. This proposal does not prohibit the inclusion of measures and indices which have not yet been validated to evaluate their eventual validity. But they should have no impact on the selection decision.

(3) PC-based simulations cannot easily be evaluated with respect to their simulated domain validity.

Simulations often promise to reflect the structure of a certain domain of reality with a high degree of fidelity. Most often, such promises cannot be verified because details about the internal structure of the system will not be published. For systems with published equations (e.g., TAILORSHOP; see Funke 1983) it turns out that there exist relations which don't make much sense (e.g., increase in number of vans does increase requests and orders in an unlimited way) as well as that reasonable and realistic factors (e.g., market competitors) are not realized at all.

Possible solution: use only those simulations for which domain validity has been proven. This proof can be done best by looking into details of the simulation equations. Because structural equation models for larger domains of reality are not known exactly, a plausibility check may be the only possible evaluation.

(4) Results from PC-based simulations cannot easily be compared from one subject to another because the dynamic situations differ between subjects due to their different interventions.

This argument reflects the fact that shortly after start of a simulation, the further course of action in a simulated environment for one person may differ drastically from that in the same environment but played by another person. As Streufert *et al.* (1988, p. 539) put it: "Participants in free simulations make decisions that can drastically modify their subsequent task environment. As a result, comparisons among different individuals (or groups) *after* they have participated in a free simulation for some amount of time can be difficult or impossible."

Possible solution: use of systems which do not differ with respect to the simulated course of action (see Streufert *et al.* 1988, for this quasi-experimental simulation technique). The disadvantage of this solution is the renouncement of the simulation principle; thus, this proposal would not be compatible with the scenario concept which is realized in nearly all of the systems.

(5) PC-based simulations are low on the social dimension.

This argument points to the fact that most simulations require decisions made by a single subject faced with the system. In real life, complex situations often involve other people. The social dimension of an interaction between different people cannot be easily reconstructed in a simulation.

Possible solution: use of simulations which allow for group decision making. This could be realized, for example, by use of interconnected computers. Especially in the area of distributed decision making, these interconnections between different problem solvers have been analyzed successfully (see, e.g., Rasmussen, Brehmer and Leplat 1991; Rogalski and Samurcay 1993). Even formal models for communication in these situations already exist (Billard and Pasquale 1995).

(6) PC-based training applications need more data to demonstrate their usefulness in the practice of management.

Up to now, there is weak empirical evidence on the usefulness of PC-based scenario training with respect to the practice of management. As in the case of scenarios for assessment where empirical data about reliability and validity of the indices are important, it is also necessary in the case of scenarios for training purposes to have empirical indicators for the quality of the training. Strong evaluation of such training under practical aspects is urgently required.

4 Future developments

Some remarks about potential future developments in this area will be offered:

(1) PC-based simulations will not replace other diagnostic instruments. Rather, they enrich the existing instruments with new aspects.

In the beginning of this research it looked as if one had to throw away conventional selection and training instruments. Now the picture looks much more realistic. Booth (1991) points out that the problem is not whether or not one uses PC technology but rather, when, and to what degree. This is also true for the use of PC-based simulations in selection and training.

What *has* become clear in the meantime is the fact that not all simulation programs on the market are useful for selection. Simply to program a nice scenario which poses a high demand on the players' abilities for information integration and decision making is not enough. Psychometric data on reliability and validity of derived quality measures must be available before scenarios are presented to subjects – and, most important, selection should not rely on scenario data alone. For a full impression of a candidate's qualities, data from PC-based simulations will not be enough because such data touch only some aspects.

(2) Purely behavioral data which can be easily recorded from the PC (e.g., number of questions, frequency of decision making) are, per se, meaningless. If one neglects the context of their occurance, validity of such information decreases and an 'information loss' occurs.

Especially in PC-based simulations purely behavioral data seem to solve the problem of assessing the quality of gaming performance because at the end of the assessment these data can be collected automatically. But think, for example, of a variable such as 'number of posed questions'. This number should be optimally high in the beginning of the simulation and low at the end – if your program computes something like 'total number of questions posed' then you cannot evaluate that figure because you lost the important time context. But even if your program computes this figure differentially for the beginning and the end section, the *quality* of questions is not reflected in these figures. Similar arguments are given by Strohschneider and Schaub (1995, p. 201f.).

(3) PC-based simulations have to realize a high degree of 'fidelity' if generalization and transfer to real life situations are expected.

In training contexts, most subjects like PC-based simulations because they are often fun. But what ensures that – besides the subject's enjoyment – a transfer from the game situation to real life occurs? It can be stated as a general rule: the more realistic the simulation (i.e., the more the simulation becomes a simulator) the better the expected transfer! Using a flight simulation program on a PC leads to different experiences than being in one of the big flight simulators used for professional pilots.

Simulations in the North American tradition show high fidelity with respect to the simulated domain and, thus, allow for the training of context-specific skills. In contrast, simulations in the European tradition show high fidelity with respect to the required use of domain independent rules and heuristics by the manager to be trained.

(4) The use of video-clips could enhance the fidelity of the presented scenario by giving more context information.

Even more realistic, virtual reality (VR) could become an important tool for simulating domains of reality within assessment and training by means of interactive role play. VR is one of the most powerful interfaces between computers and humans. It is an interactive, three-dimensional, multisensory experience that immerses the individual in a computer-simulated world. VR promises to minimize the barriers currently inherent in prosocial skill training programs via its real life, immersion simulation. Limitations in the technology currently exist and applications that attempt to generate accurate simulations that model human behavior may prove to be the most difficult challenge of all.

(5) The simulation approach could be used to estimate training requirements.

Before one starts extensive training one needs to know the training requirements of specific persons – otherwise training time will be wasted. Simulations can present 'critical incidents' in order to assess how the trainee reacts to such situations. With properly designed simulations and reliable indicators, one can provide the trainer with a list of weaknesses and strength of the person's decision making and problem solving qualities.

5 Concluding remarks

The influence of PC-based simulations on selection, placement, and training will increase due to the ever-increasing and ubiquitous use of PCs. In light of the fact that such simulations not only bring advantages but disadvantages into the R&D field a careful decision about when, why, and how to use them seems most important. This is where basic research can help with carefully designed evaluation studies which show the advantages as well as the disadvantages of the new scenarios in more detail. It is the task and responsibility of the practitioners of PC-based simulation not to hastily rely on such fascinating assessment instrumentation without first carefully analyzing their many caveats.

Author note

Thanks to John Booth and two anonymous reviewers who all gave valuable comments to earlier versions of this paper.

References

Anderson, J.R., Boyle, C.B. and Reiser, B.J. (1985) Intelligent tutoring systems. *Science*, **228**, 456–462.

Anzai, K. and Simon, H.A. (1979) The theory of learning by doing. *Psychological Review*, **86**, 124–140.

Arbeitskreis Assessment Center (1996) Standards der Assessment Center-Technik [Standards of the Assessment Center technique]. In Arbeitskreis Assessment Center, (ed.), *Assessment Center als Instrument der Personalentwicklung* 485–493. Hamburg, Windmühle.

Bakken, B., Gould, J. and Kim, D. (1992) Experimentation in learning organizations: A management flight simulator approach. *European Journal of Operational Research*, **59**, 167–182.

Berry, D.C. and Broadbent, D.E. (1995) Implicit learning in the control of complex systems. In Frensch, P.A. and Funke, J. (eds.), *Complex problem solving: The European Perspective*, 131–150. Hillsdale, NJ, Lawrence Erlbaum Associates.

Bhaskar, R. and Simon, H.A. (1977) Problem solving in semantically rich domains: An example from engineering thermodynamics. *Cognitive Science*, **1**, 193–215.

Billard, E.A. and Pasquale, J.C. (1995) Adaptive coordination in distributed systems with delayed communication. *IEEE Transactions on Systems, Man, and Cybernetics*, **25**, 546–554.

Booth, J. (1991) The key to valid computer-based testing: The user interface. *European Review of Applied Psychology*, **41**, 281–293.

Bourne, L.E. and Dominowski, R.L. (1972) Thinking. *Annual Review of Psychology*, **23**, 105–130.

Broadbent, D.E. (1977) Levels, hierarchies, and the locus of control. *Quarterly Journal of Experimental Psychology*, **29**, 181–201.

Buchner, A. (1995) Basic topics and approaches to the study of complex problem solving. In Frensch, P.A. and Funke, J. (eds.), *Complex problem solving: The European Perspective*, 27–63. Hillsdale, NJ, Lawrence Erlbaum Associates.

Chase, W.G. and Simon, H.A. (1973) Perception in chess. *Cognitive Psychology*, **4**, 55–81.

Chi, M.T.H., Feltovich, P.J. and Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. *Cognitive Science*, **5**, 121–152.

Dörner, D. (1975) Wie Menschen eine Welt verbessern wollten [How people wanted to improve a world]. *Bild der Wissenschaft*, **12**, 48–53.

Dörner, D. and Wearing, A. (1995) Complex problem solving: Toward a (computersimulated) theory. In Frensch, P.A. and Funke, J. (eds.), *Complex problem solving: The European Perspective*, 65–99. Hillsdale, NJ, Lawrence Erlbaum Associates.

Frensch, P.A. and Funke, J. (eds.), (1995) *Complex problem solving: The European perspective*. Hillsdale, NJ, Lawrence Erlbaum Associates.

Funke, J. (1983) Einige Bemerkungen zu Problemen der Problemlöseforschung oder: Ist Testintelligenz doch ein Prädiktor? [Some remarks on the problems of problem solving research or: Does test intelligence predict control performance?] *Diagnostica*, **29**, 283–302.

Funke, J. and Geilhardt, T. (1996) Diagnostik mit Hilfe von PC-Simulationen [Diagnosis based on PC-simulations]. In Arbeitskreis Assessment Center (ed.), *Assessment Center als Instrument der Personalentwicklung*, 201–209. Hamburg, Windmühle.

Funke, U. (1995) Using complex problem solving tasks in personnel selection and training. In Frensch, P.A. and Funke, J. (eds.), *Complex problem solving: The European Perspective*, 219–240. Hillsdale, NJ, Lawrence Erlbaum Associates.

Geilhardt, T. and Mühlbradt, T. (eds.), (1995) *Planspiele im Personal- und Organisationsmanagement* [Scenarios for personnel and organization management]. Göttingen, Verlag für Angewandte Psychologie.

Graf, J. (ed.), (1992) *Planspiele – simulierte Realitäten für den Chef von morgen. Mit Planspiel-Marktübersicht* [Scenarios – simulated realities for tomorrows' manager]. Speyer, GABAL-Verlag.

Graham, A.K., Morecroft, J.D.W., Senge, P.M. and Sterman, J.D. (1992) Model-supported case studies for management education. *European Journal of Operational Research*, **59**, 151–166.

Guion, R.M. (1991) Personnel assessment, selection, and placement. In Dunnette, M.D. and Hough, L.M. (eds.), *Handbook of industrial and organizational psychology*, **2** (2nd edition) 327–397. Palo Alto, CA, Consulting Psychologists Press.

Hasselmann, D. (1993) *Computersimulierte komplexe Problemstellungen in der Management-Diagnostik* [Computersimulated complex problems for diagnosis of management skills]. Hamburg, Windmühle.

Leutner, D. (1995) Computerunterstützte Planspiele als Instrumente der Personalentwicklung [Computer-based scenarios as instruments in personnel development]. In Geilhardt, T. and Mühlbradt, T. (eds.), *Planspiele im Personal- und Organisationsmanagement*, 105–116. Göttingen, Verlag für Angewandte Psychologie.

Morecroft, J. (1988) System dynamics and microworlds for policymakers. *European Journal of Operational Research*, **35**, 301–320.

Obermann, C. (1991) *AIRPORT. Problemlösesimulation* **2.2** [AIRPORT problem solving simulation]. Göttingen, Hogrefe.

Obermann, C. (1995) Computergestützte Planspiele in der Mitarbeiterauswahl – Anwendungsbeispiel Airport [Computer-based scenarios in personnel selection – Airport scenario as an application example]. In Geilhardt, T. and Mühlbradt, T. (eds.), *Planspiele im Personal- und Organisationsmanagement*, 401–409. Göttingen, Verlag für Angewandte Psychologie.

Rasmussen, J., Brehmer, B. and Leplat, J. (eds.), (1991) *Distributed decision making: Cognitive models for cooperative work*. New York, Wiley.

Rogalski, J. and Samurcay, R. (1993) Analysing communication in complex distributed decisonmaking. Special Issue: Cognitive processes in complex tasks. *Ergonomics*, **36**, 1329–1343.

Sternberg, R.J. and Frensch, P.A. (eds.), (1991) *Complex problem solving: Principles and mechanisms*. Hillsdale, NJ, Lawrence Erlbaum.

Strauß, B. and Kleinmann, M. (eds.), (1995) *Computersimulierte Szenarien in der Personalarbeit* [Computer-simulated scenarios in personnel selection and training]. Göttingen, Verlag für Angewandte Psychologie.

Streufert, S., Pogash, R. and Piasecki, M. (1988) Simulation-based assessment of managerial competence: Reliability and validity. *Personnel Psychology*, **41**, 537–557.

Strohschneider, S. and Schaub, H. (1995) Erforschung komplexen Problemlösens durch computerunterstützte Planspiele: Kritische Anmerkungen zur Forschungsmethodologie [Research on complex problem solving by means of simulation games: Critical comments on the research methodology]. In Geilhardt, T. and Mühlbradt, T. (eds.), *Planspiele im Personal- und Organisationsmanagement*, 187–203. Göttingen, Verlag für Angewandte Psychologie.