

A Case for the Usefulness and Plausibility of Thinking-Aloud Verbal Data

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Cognitive problem-solving paradigms have generated a demand for evidence of the cognitive strategies by which people solve tasks, and of the means by which people access information from their knowledge structures for application to particular problems and puzzles. Since the focus of such paradigms is on the processes of human thought rather than on its products, behaviouristic data-bases cannot satisfy the demand for evidence of covert mental procedures. Since process analyses are used to describe thought-in-action, clinical retrospective techniques cannot elicit information of procedures as they are actually generated and applied to tasks. What is needed is the kind of data-base which will provide information that is concurrent to covert cognitive processes. In searching for reliable evidence of mental states, a number of experimenters have revived the thinking-aloud technique which Duncker used in his 1945 problem-solving studies and which he distinguished from introspective techniques.

Under the thinking aloud condition an individual is asked to verbalize his or her thoughts as they occur during the time in which s/he is working on a task. The verbalized running commentary usually is audio-taped and transcribed into verbal protocols for analysis in terms of a prototypic model of the solution of the task. The assumption is made that the verbalized reports will provide useful information of covert, sequential mental operations. It is not assumed that the verbalized reports will be isomorphic with internal operations, but that they will yield direct and at least partial reflections of problem-solving strategies which would not otherwise be available for analysis (Hayes, 1968; Newell & Simon, 1972).

While use of the thinking aloud technique has grown in popularity, there had been little justification of the assumptions under which it is employed as a primary source of data prior to Ericsson & Simon's (1980) argument based on the intimate relationship of process models and verbalization conditions. It is important that cognitivists do not use this kind of technique only for the sake of expediency or by default, but that we examine the bases and implications of eliciting people's reports of their own mental operations.

In this paper a case is laid out for the utility of thinking aloud evidence, (and) for the plausibility of admitting such evidence as serious psychological data. The case focusses on usefulness rather than verification because it is argued that the evidence is the most direct available. There is no objective source of verification. In any case cognitivists in general do not subscribe to the positivistic principle of verification and assert the probabilistic nature of scientific endeavour. It is necessary to establish decision rules and the terms under which information is accepted as empirical evidence of any phenomena (Chalmers, 1979).

Reasons for admission of thinking aloud reports can be obtained by conceptual and empirical investigations. In this paper I will outline a rationale for the usefulness of thinking aloud reports as psychological data of a particular kind. Then I will demonstrate how this case is supported empirically. The case is conceptually dependent on Harré & Secord's (1973) argument for the acceptability of all forms of self-report. The empirical evidence is drawn from experimental and convergent evidence and from the descriptive power of the data as it is framed in problem-solving models.

A General Case for the Acceptance of Self-Reports as Psychological Data:

Harré & Secord (1973)

Harré & Secord argue cogently for a reappraisal of tacit acceptance of positivists' rejection of personal reports on the criterion of empirical verification. Their argument not only rests on the probabilistic nature of empirical investigation, but also on acceptance of the implications of the ontological status of human persons as agents rather than as objects. Agents have the power of monitoring their own behaviour and the power of linguistic communication (Strawson, 1959). If it is accepted that agent status is a distinctive characteristic which is attributable to all human persons, then it follows that as agents persons can make observation statements about behaviour in the form of "I" statements as well as in the form of "He, She" statements. Self-reports can be accepted as linguistic commentaries on personal actions and states. Thus statements that I make about myself, like statements that I make about Joe Bloggs can provide "authentic but revisable reports of phenomena, subject to empirical criticism" (p.101).

The authors draw support for their position from two observations about human behaviours. For some occurrences a person's statement about internal states may be revealed in his or her communication, as for example in the force of an expletive of annoyance, or in the complaining tone of a report of discontent. Under other circumstances states of readiness cannot be fully explained if changes in psychic states are ignored. Changes in emotions and beliefs are as foundational as physical factors for an understanding of a person's readiness to behave in certain ways. For example, if Bill punches Henry, his action may be explained by his outrage at Henry's derogatory allusions to his parentage on one occasion just as much as by his blood alcohol level on another.

Human sciences have been held down by their tacit ignorance of the ramifications of human agency, and by their unnecessary dichotomization of references to persons into body predicates which can be verified and therefore are scientific, and mental predicates which cannot be verified and therefore are unscientific. Harré & Secord argue that all statements about persons are of similar status as statements about agents. Person-statements should be judged in terms of their applicability to particular referents, and in terms of the criteria of logical adequacy which can be applied to statements under review. Thus there is no plausible rationale for accepting the observation statement "he is tired" while rejecting another observation statement "I am tired", if the same external conditions can be applied in order to test the adequacy of each statement. There are some criteria under which we can accept verbal reports, just as there are criteria for assessing tiredness, and in these cases at least the same criteria can be applied to first person and third person reports. For other kinds of reports which are based on covert features of an individual's behaviour, that individual is the usual authority for the statement since his or her covert states are not usually accessible to other persons. To accept people as human agents implies accepting that they can provide communications about their own actions, and that they can contribute to understanding of those actions. On the basis of these several premises Harré & Secord propose their "Open Souls Doctrine" as an alternative conceptualization of the status of self-report data. A schematic model of their position as an alternative to traditional views of self-reports is presented in Figure 1. Inspection of their basic position reveals that they are not attempting to invest self-reports with unassailable veridicalness, but rather that they are asserting that the reports of persons should be treated as serious data of their behaviours. Self-referenced reports are open to the same scrutiny and evaluation as any other observational data.

<i>Traditional View of Self-Reports (Behaviouristic)</i>	<i>Open Souls Doctrine of Self-Reports (Harré &amp; Secord)</i>
1. Self-report = report (only) of the report.	1. Self-report is a report on the phenomenon to be observed and on the self-report.
2. So the phenomenon of the report is the report PHR.	2. So the phenomenon of the report is the report and the report = PHR, behaviour observed = PH.
3. PHR cannot be taken as serious evidence of the phenomenon of the behaviour to be observed (ie. of PH).	3. PHR is serious evidence of the phenomenon of the behaviour (PH).
4. Evidence of PH must be found elsewhere, PHR is not evidence of PH.	4. Evidence of PH is obtained from PHR and from elsewhere, evidence is PHR and other than PHR.

Key: PHR = the phenomenon of the report, PH = the phenomenon.

Figure 1: Schematization of the traditional and open souls views of self-reports as argued by Harré & Secord

All psychological observations ultimately are processed by a human head, or by a machine whose output is interpreted by a human. Dulany (1968) argues that all observations are private and are reported in a particular report-language which requires human processing. Why not obtain such reports from the observer with the most privileged access to the phenomena: The person whose behaviour is the object of observation. The kinds of limitations which would pertain in that instance, also can be shown to constrain reports of external observers. No two observers' reports of the same phenomenon can be assured of being unaffected by attention and categorization processes (Klinger, 1977). Both Dulany and Klinger argue that the trustworthiness of human reports lies not in externality and objectivity, but in the lawfulness of the experimental conditions in which they were obtained, and in the theory and language in which they are framed. Mitroff (1969) and Churchman (1971) make similar claims about the effects of an experimenter's frames and Weltanschauung on any research data. Empirical criteria for admission of data are bound to the validation processes of manipulation and replicability, and the usefulness and predictive powers of the theory-cum-data combination.

#### The Special Case for Thinking-Aloud Reports

Thinking aloud reports are different from other self-reports in their form and content. Not only do they provide access to individual agent's thoughts but it is access to thought as it is being directed to a specific task. Verbal reports obtained under the thinking aloud condition are not observations about mental states or emotional responses. They are running commentaries of cognitive operations which are in the process of execution. A subject addresses a problem or task, and verbalizes what s/he is thinking. The object of the report is the task. Its content is evidence of problem-solving strategies or knowledge-states, and its form is that of a personal running commentary on specific cognitive behaviour. The data are neither introspection of one's own mental states, nor retrospective remembering of behaviours.

The uniqueness of information which is verbalized in thinking aloud reports has been demonstrated in Ericsson & Simon's (1980) recent modelling of the effect of instructions to report on cognitive processes. Under instructions to think out loud, reports are comprised of vocalization of information readily available in short-term memory, or its equivalent in other surface memory models. Articulation is made of data which is verbally encoded or of non-verbal but accessible information.

In the case of verbally coded information thinking aloud does not change the course or structure of cognitive processing and does not slow down the process. In the case of verbal recoding, while the procedure may slow down cognitive processing of a problem, it does not alter the course and structure of processing. They distinguished this type of report from that in which a subject must retrieve specific information from long-term memory.

Thus the case for thinking aloud reports incorporates the concepts of privileged access and directness and adds the concept of concurrent verbalization. The case is set out in Figure 2 in a similar way to the Harré & Secord argument. The claim for its usefulness rests on uniqueness and directness of access and its quality as a running commentary on other behaviours.

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| <ol style="list-style-type: none"><li>1. Thinking aloud reports are concurrent reports of problem-solving operations = TAR.</li><li>2. Problem solving operations are the phenomena under observation = PSO.</li><li>3. TAR provide a direct and unique evidence of PSO not otherwise available.</li><li>4. TAR are concurrent evidence of PSO.</li></ol> <hr style="border-top: 1px dashed black;"/> <ol style="list-style-type: none"><li>5. Evidence of problem-solving operations (PSO) can be obtained in Thinking-Aloud Reports (TAR), and from other sources.</li></ol> |
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Figure 2: Schematization of the case for thinking aloud reports as evidence of problem-solving operations

The claim for the directness and usefulness of thinking aloud reports was made in 1969 by the philosopher Gunderson and has met with little rejoinder by cognitivists (cf. Lawrence, 1979a). Ericsson & Simon's model provides a way of laying that particular ghost about the status that is being claimed for concurrent verbal reports. Gunderson (1971) argued that cognitivists should specify whether verbal reports are identical with the cognitive processes they report and therefore are the same behaviours, or if they are claimed to be evidence of processes and therefore separate behaviours. If a protocol is regarded as isomorphic with problem-solving processes then they could be generally understood "in the sense of being able to use it we see what the person is up to" (p.130). However if isomorphism is not claimed then the data are open to all the criticisms of classical introspection. Isomorphism requires a series of unsupportable conflation, and has not been seriously entertained by cognitivists (Hayes, 1968). Interestingly Gunderson argued that the separate behaviours' claim would present no problem for a behaviourist interpretation.

The verbal utterances of the subject were as much behaviour as his arm movements or galvanic skin responses. The subject was not introspecting; he was simply emitting a continuous stream of verbal behaviour while solving the problem that explains the salient features of this stream of behaviour (pp.281-283).

Yet taken further, this is precisely the rationale behind Ericsson & Simon's modelling. Given that one behaviour can be taken as evidence of another (Lawrence, 1979a), then a continuous stream of concurrent verbalization can be shown to provide the most direct source of evidence of cognitive processes. The model is based on the function of memory and the interaction between processing of external material and information retrieved from memory storage. When information has been taken out of long-term storage and focussed on a particular task, extra processing is not necessary for the kind of verbal stream Gunderson approves. The stream can be articulated without retrieval of additional material from memory.

Ericsson & Simon provide conceptual and empirical bases for distinguishing this flow of verbalization from another level of verbal report in which the individual must engage in specific cognitive processing of additional material in order to articulate the type of report required. Such material may be comprised of identification and report of particular features in the stimulus array, or it may constitute that individual's interpretations or justifications of problem-solving moves. Thus in addition to meeting Gunderson's claims that only isomorphism guarantees unique information, Ericsson & Simon's model provides the basis for refuting two other criticisms of the value of thinking aloud reports. Their demonstration of the differential effects of instructions answers Gagné & Smith's (1962) long-standing incompleteness criticism. Their finding of the relative incompleteness of verbalized processing of mathematics problems can be shown to be dependent on their specific instructions that their subjects provide justifications for their moves rather than running commentaries.

In another influential paper Nisbett & Wilson (1977) criticised the veracity of verbal reports about personal behaviour on the basis of information of reconstruction and misrepresentation of information by subjects in several studies. People report more than they know. While Smith & Miller (1978) provide a useful re-working of their data, the level of verbalization model shows that Nisbett & Wilson's comments are not pertinent to thinking aloud reports. Concurrent verbalizations do not involve retrieval of material or later reporting of material which may have undergone modification. They are immediate and concurrent, and that proposition can be supported empirically.

#### Empirical Evidence

Since more direct sources of information are not available for comparing the veracity of thinking aloud data of cognitive processes, empirical support for the plausibility of relying on them as evidence must be drawn from experimental demonstration of their comparative directness and representativeness. Two other forms of empirical support can be drawn from studies which provide evidence from data-sources which converge with evidence gleaned from concurrent verbalizations, and from a range of studies in which thinking aloud data and their companion models have yielded useful descriptions and interpretations of human processing.

#### Experimental Comparisons

Experimental examinations of directness and representativeness compare thinking aloud with other report conditions or with silent working. Benjafield (1969) obtained reports from two groups of undergraduates on their processes for solving the same tetrahedron problem. One group worked on the problem in a thinking aloud condition, while the other made introspective reports immediately after problem-solving. The two types of report were different in both content and form. Thinking-aloud reports were given in the present tense while introspection reports were in the past tense. Thinking-aloud reports were more complete, used more indefinite referents and were more elliptical in form. Benjafield interpreted these surface differences as evidence that thinking aloud was tapping into students' "inner speech" by which they planned and organized actual moves as they worked on the problem.

The growing influence of cognitivist perspectives has lessened the need to distinguish thinking aloud and introspective reports, and other manipulations have tended to address the question of whether the directness claim is viable in light of claims of distortion and the effect of the condition on the representativeness of the data. However the distinction of types of verbalization is required especially since Nisbett & Wilson's criticism of the general veracity of reports which depends on their idea of people's reconstruction of their observations.

In relation to the effects of verbalization on processing, Dansereau & Gregg (1966) had shown that only speed differentiated the processing of mental arithmetic problems obtained from one thinking-aloud and one silent subject. Ericsson & Simon report Karpf's (1973) dissertation study in which subjects' discriminations of simple features of visual slides were compared for thinking aloud and silent conditions. Again only speed differentiated the groups. Ericsson & Simon drew support for their levels of processing model from this result, since the model would predict that recoding of visual processing would require greater time, but would not effectively alter processing of the task. Ericsson (1975) provided some promisory evidence of the absence of influence on processing of an 8-puzzle tile manipulation game. Unfortunately the data of non-verbalized and concurrently verbalized processing were not obtained in directly replicative studies. However he reports that comparisons of the problem-solving processes exhibited in the two studies were not very different. The greater number of problem-solving moves made in the thinking aloud study involved greater planning (Ericsson & Simon). Newell & Simon reported similar findings that students' thinking aloud processing of logic problems produced no substantial differences

from processes used by other students who worked silently. They interpreted their findings as evidence of the absence of modifying effects of verbalization on the direction of problem-solving moves. Further experimental manipulations now can be made on the basis of Ericsson & Simon's predictions.

### Converging Evidence

Several experimenters have collected additional evidence which converged with thinking aloud data (Garner, Hake & Erikson, 1956). In some studies other manifestations of problem-solving moves were obtained while subjects worked and talked. These data were used to supplement or interpret the verbal records. For example Newell & Simon's analysis of Winikoff's (1967) evidence of eye-movements led them to conclude that the physical movements provided corroboration of, or supplemented the verbal data. Ericsson's subjects' manipulation of the physical stimulus materials, like de Groot's (1956) chess players' moves also provided extra concurrent data. Payne (1976) had his subjects select and remove information cards as they deliberated on features relevant to their choice of accommodation. Pitt (1976), and Svenson (in preparation) used subjects' written workings and experimenter's observation notes as aids in coding verbalizations. Information was collected after the basic processing by Svenson & Montgomery (1974) and Lawrence (1979b). Svenson & Montgomery's subjects reported that verbalizations did not interfere with their decision-making in a simulation of choice of a home. In the Lawrence moral judgment study, two card-sorts corroborated verbal evidence of subject's level of understanding and decision-making use of standard stimulus materials. All of these studies indicate the usefulness of obtaining additional data, with the override that physical responses will be processed and interpreted by agents with less direct access than the talking problem-solver.

### Breadth of Use

While a list of studies using a method is no substitute for experimental evidence, the claim of usefulness is supported by the diversity of the growing body of studies in which the technique has yielded interpretable data on different types of problems and across different task domains. A sampling of studies is presented in Figure 3 in order to illustrate the range of problems and content areas in which thinking aloud protocols have yielded descriptions of individual's operations, or the base for comparing individual or group differences.

Study Type	Exemplar Study	Problem Domain	Focus of Analysis
<u>1. Well-structured problems:</u>			
games	de Groot, 1965	chess plays	grandmasters' use of patterns & strategies.
deduction	Dansereau & Gregg, 1966	mathematics solution	comparison of solutions under thinking aloud and silent conditions.
<u>2. Cognitive-development tasks:</u>			
Piagetian task	Pitt, 1976	formal operations combinatorial	comparison of processes used by expert chemists, undergraduates, adolescents.
<u>3. Diagnosis and teaching of academic skills:</u>			
expert Vs novice problem-solving	Larkin, 1978	physics	description of expertise of professors, development of model for teaching students.
instructional device	Bash & Camp, 1981	teacher training	thinking aloud technique as basis of curriculum development.
<u>4. Professional behaviour and practice:</u>			
clinical expertise	Elstein, Shulman & Sprafka, 1978	medical diagnosis	comparisons of strategies for diagnosing diseases.
professional practice	Braunstein & Coleman, 1967	aircraft accident assessment	identification of heuristics for forming, testing hypotheses.
training models	Bacon & Lawrence, 1981	clinical practice	training model for family planning procedures, planning clinical practice.
<u>5. Personal choice and decision-making:</u>			
choice behaviour	Payne, 1976	apartment choice	analysis of feature extraction, weightings.
moral reasoning	Lawrence, 1979b	hypothetical dilemmas	process and analysis of standard test of moral judgment development.

Figure 3: Sampling of Studies Using Thinking Aloud Technique

In Type 1 studies performance on well-structured problems is broken down into strategies and knowledge and means-end analyses, for example, games, puzzles. Type 2 studies involve the investigation of processes behind performance on tasks demonstrating cognitive development, and Type 3 the diagnosis and description of academic skills and pedagogical behaviours. Type 4 professionally-oriented studies are comprised of (a) examinations of clinical and diagnostic work-ups and the use of knowledge and expertise, and descriptions of experts' prototypic behaviours in professional domains, and (b) the development of training and instructional models. Studies in the Type 5 category include (a) examination of personal choices and the reasoning behind deciding activities, and (b) the reasoning behind the production of social and moral judgments. In each study cited subjects were asked to verbalize their thoughts of concurrent task-oriented behaviour. The data were suitable for interpretation of the covert cognitive knowledge and information-processing strategies which lay behind a variety of overt behaviours.

#### The Usefulness and Predictive Power of Theory-cum Data Combinations

Any data are only as informative as the conceptual models in which they are collected, interpreted and communicated. Theory-data combinations are evaluated in terms of empirical regularity of predictions, and empirical productivity and theoretical progressiveness in terms of the novel information they generate (Lakatos, 1970). The analysis of thinking aloud protocols has been undertaken on the explicit or implicit assumption that this type of data will yield new or more illuminating information of cognitive processes. The assumption has been upheld by the use of model-data combinations to generate new empirical "facts", to re-examine old assumptions, and to provide instructional prototypes.

New understanding of cognitions has been revealed by studies in which the rich verbal data have led to the description of expert behaviour in areas where it had not been scrutinized previously, as for example, in de Groot's seminal description of chess grandmasters' remembrance and use of patterns.

Working from a different perspective than that behind most of the studies cited in Figure 3, Cronbach and Meehl argued in 1955 that information pertinent to construct validation could be obtained by asking subjects to talk while they completed standardized tasks. They showed how different strategies were used in a study assumed to test a unitary construct. Similarly Revlis (1975) showed that college students' failure to solve logic tasks resided not in their deductive abilities, but in their original miscoding of the problem. Asking adults and adolescents to think out loud while completing a standard test of moral judgment-making, it was possible to show differences in their understanding of principled concepts, and to reveal how some subjects invested distractor nonsense items with high-level meanings. The alternative data-base and process model also showed that the usual technique of coding only prescriptive responses neglected two-thirds of people's processing of moral dilemmas (Lawrence, 1979b).

Descriptive and predictive power is extended when model-cum-data analyses can be used as foundations for instructional design. The intricacy and precision obtained by breaking-down rich data into component procedures and sequences yields powerful diagnostic tools and instructional direction, for example, Larkin's (1978) development of a model for teaching physics which was based on detailed analysis of physics experts' problem-solving. Bash & Camp (1981) recently proposed a class-room curriculum model based on thinking aloud instruction of trainee teachers and primary school pupils. Yet there is one difficulty associated with demonstrating the versatility of a data-base across task-domains, interests and models.

The structuring of tasks and the collection and interpretation of data are open to experimenter bias and manipulation. Mitroff has argued very strongly that data and theory must be examined as a single unit, "data

are not material which exist in their own right... the theory directs" (p.8-637). If he is correct and the theory-data combination is a given, there must be a way of examining the usefulness of that enclave.

There are a few examples of re-examination of data-model combinations. Hunt (1974) showed how a pattern recognition model could provide an alternative explanation of how subjects' completed the Raven's Matrices Test. Pattern recognition could produce the same terminal results as the assumed analytical reasoning. Bynum, Thomas & Weitz (1972) re-analyzed one of Piaget's foundational protocols and contradicted his assertion that the data yielded evidence of 16 binary propositions. Pitt's study demonstrated that the explanatory power of the General Problem Solver could be extended by developing a more comprehensive model. She combined the means-end analysis of the General Problem Solver with Polya's concept of definition of the problem. Pitt's comprehensive model strategy may be more attractive to theorists working with expensive techniques than re-examination of opposing assumptions. Nevertheless these studies suggest that model-cum-data combinations can be evaluated.

In summary I am suggesting that the case for the usefulness of thinking aloud reports is conceptually plausible and empirically supportable. The data are full and interpretable, and their inter-dependent models have promoted paradigmatic growth. Cognitivists have no need to be tentative in endorsing the technique. Further empirical work now can be directed towards extending and refining the means of analysis.

#### References

- Bacon, J., & Lawrence, J.A. Medical problem-solving: Comparison of experts and novices in a skill relating to the provision of contraceptives. *External Studies*, Murdoch University, 1981.
- Bash, M.A., & Camp, B. Teacher training in the think aloud classroom program, Ch.5 in G.Cartledge & J.Fellow Millburn (Eds.), *Teaching Social Skills to Children: Innovative Approaches*. New York: Pergamon, 1981, 143-179.
- Benjafield, J. Evidence that "thinking aloud" constitutes an externalization of inner speech. *Psychonomic Science*, 1969, 14(6), 83-84.
- Braunstein, M.L., & Coleman, O.F. An information-processing model of the aircraft accident investigator. *Human Factors*, 1967, 9, 61-70.
- Bynum, T.W., Thomas, J.A., & Weitz, L.J. Truth-functional logic in formal operational thinking. *Developmental Psychology*, 1972, 7, 129-132.
- Chalmers, A. *What is This Thing Called Science?* Brisbane: University of Queensland Press, 1979.
- Churchman, C.W. The role of Weltanschauung in problem solving and inquiry. In R.B. Banerji & M.D. Mesarovic (Eds.), *Theoretical Approaches to Non-Numerical Problem Solving: Proceedings of Fourth Systems Symposium, Case Western Reserve University*. New York: Springer-Verlag, 1970, 141-151.
- Cronbach, L.J., & Meehl, P.E. Construct validity in psychological testing. *Psychological Bulletin*, 1955, 52(4), 281-302.
- Dansereau, D., & Gregg, L.W. An information-processing analysis of multiplication. *Psychonomic Science*, 1966, 6, 71-72.
- de Groot, A.D. *Thought and Choice in Chess*. The Hague: Mouton, 1965.
- Dulany, D.E. Awareness, rules, and propositional control: A confrontation with S-R behavior theory. In Dixon, T.R., & D.L. Horton (Eds.), *Verbal Behavior and General Behavior Theory*. Englewood Cliffs, NJ: Prentice-Hall, 1968, 340-387.
- Duncker, K. On problem solving. *Psychological Monographs*, 1945, 58(2). (Whole No. 270).
- Elstein, A.S., Shulman, L.S., & Sprafka, S.A. *Medical Problem Solving: An Analysis of Clinical Reasoning*. Cambridge, Mass: Harvard University Press, 1978.
- Ericsson, K.A. Instruction to verbalize as a means to study problem solving processes with the 8-puzzle: Preliminary Study. Reports from the Department of Psychology, University of Stockholm, Nov.1975, No.458.
- Ericsson, K.A., & Simon, H.A. Verbal reports as data. *Psychological Review*, 1980, 87(3), 215-251.
- Gagné, R.H., & Smith, E.C. The study of the effects of verbalization on problem solving. *Journal of Experimental Psychology*, 1962, 63, 12-18.
- Garner, W.R., Hake, H.W., & Eriksen, C.W. Operationism and the concept of perception. *Psychological Review*, 1956, 63(3), 149-159.
- Gunderson, Keith. *Mentality and Machines*. Garden City, New York: Anchor Books, 1971.
- Hayes, J. Strategies in judgmental research. In B. Kleinmuntz (Ed.), *Formal Representation in Human Judgment*. New York: Wiley, 1968, 251-259.
- Harré & Secord. *The Explanation of Social Behaviour*. Totowa, NJ: Littlefield & Adams, 1973.
- Hunt, E. Quote the Raven? Nevermore. In L.E. Gregg (Ed.), *Knowledge and Cognition*. Potomac, Maryland: Lawrence Erlbaum Associates, 1974, 129-158.
- Klinger, E. Modes of normal conscious flow. In J.L. Singer & K.S. Pope (Eds.), *The Stream of Consciousness: Psychological Investigations*. New York: Plenum, 1977.
- Lakatos, I. Falsification and the methodology of research programs. In I. Lakatos & A. Musgrave (Eds.), *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press, 1970, 91-196.
- Larkin, J.H. Information processing models and science instruction. Paper presented at AAAS Symposium on Models of Learning and Their Implications for Science Instruction, February, 1978.
- Lawrence, J.A. Thinking Aloud Data: A Justification of Its Plausibility and Usefulness. *External Studies*, Murdoch University, 1979(a).
- Lawrence, J.A. The components of moral judgment-making. Doctoral dissertation, University of Minnesota. *Dissertations Abstracts International*, 1979(b), 40(2), 896-B.
- Mitroff, I.I. Fundamental issues in the simulation of human behaviour: A case in the strategy of behavioural science. *Management Science*, 1969, 15(12), 635-649.
- Newell, A.H., & Simon, H.A. *Human Problem-Solving*. Englecliff Hills, NJ: Prentice-Hall, 1972.



- Nisbett, R.E., & Wilson, T.D. Telling more than we can know: Verbal reports on mental processes. Psychological Review, 1977, 84, 231-259.
- Payne, J.W. Complexity and contingent processing in decision-making: An information search and protocol analysis. Organizational Behavior and Human Performance, 1976, 16, 366-387.
- Pitt, R.B. Toward a comprehensive model of problem-solving: Application to solutions of chemistry problems by high school and college students. Doctoral dissertation, University of California. Dissertations Abstracts International, 1977, 37, 4730-B.
- Revlis, R. Syllogistic reasoning: Logical decisions from a complex data-base. In R.J. Falmagne (Ed.), Reasoning: Representation and Process. Hillsdale, NJ: Lawrence Erlbaum & Associates, 1975, 93-133.
- Smith, E.R., & Miller, F.S. Limits on perception of cognitive processes: A reply to Nisbett & Wilson. Psychological Review, 1978, 85, 355-362.
- Svenson, I.F. Distance students' use of course materials while solving a mathematics exercise. Masters dissertation in preparation, Murdoch University, 1981.
- Svenson, O., & Montgomery, H. A frame of reference for the study of decision processes: Report of psychology laboratories. University of Stockholm, 1974, No.409.