Protocol analysis and Verbal Reports on Thinking

An updated and extracted version from Ericsson (2002)

Protocol analysis is a rigorous methodology for eliciting verbal reports of thought sequences as a valid source of data on thinking.

When Psychology emerged as a scientific discipline at the end of the 19th century, the majority of psychologists were interested in consciousness. They sought to examine the structure and elements of their thoughts and subjective experiences through introspective analysis. Within a few decades, the introspective method was discredited, and introspective descriptions were rejected as a scientific evidence. Psychology turned away from studies of individuals’ descriptions of their thoughts and first-hand experiences and focused on observations of how other adults performed tasks in the laboratory. The rejection of introspection made the study of thinking come to a virtual halt until the 1950’s, when the technical innovations such as the computer lead to the emergence of cognitive and information-processing theories of psychological phenomena. In the new research approach to the study of thought processes, subjects were asked to “think aloud,” leading to a new type verbal reports of thinking that differed from the earlier introspective methods and became the core method of protocol analysis.

The cognitive revolution in the 1960’s renewed interest in higher-level cognitive processes and how thinking allows individuals to generate solutions to novel tasks. Cognitive theories describe how individuals are able to apply acquired knowledge and procedures to novel problems, such as mental multiplication of any combination of two 2-digit numbers. Information processing theories (Newell and Simon 1972) proposed computational models that could reproduce the observable aspects of human performance on well-defined tasks through the application of explicit procedures.

One of the principle methods of the information processing approach is task analysis. Task analysis specifies the range of alternative procedures that people could use, in light of their prior knowledge of facts and procedures, to generate correct answers to a task. Let me illustrate how task analysis can be applied to mental multiplication. Most adults have only limited mathematical knowledge: they know their multiplication table and only the standard “pencil and paper” procedure taught in school for solving multiplication problems. Accordingly, one can predict that they will solve a specific problem such as 36*24 by first calculating 4*36=144 then adding 20*36=720. More sophisticated subjects may recognize that 24*36 is equivalent to (30+6)*(30-6) and use the formula (a+b)*(a-b)=a^2-b^2, thus calculating 36*24 as 30^2-6^2=900-36=864. The choice of alternative procedures participants use to generate the answer can be inferred by the time needed and verbal reports of their thoughts during problem solving.

In conclusion, the theoretical and methodological controversies about verbal reports have never cast doubt people’s ability to recall part of their thought sequences. The controversies have centered around efforts to go beyond the sequence of thoughts (see Figure 1), to analyze their detailed structure through introspection, and infer
the processes controlling the generation of new thoughts. In fact, all major theoretical frameworks concerned with thinking have advocated the use of verbally reported sequences of thoughts (Ericsson and Crutcher 1991). For example, the behaviorist John B. Watson pioneered the use of “think aloud,” and the gestalt psychologist Karl Duncker established it as a major method.

**Protocol-Analysis Methodology—Eliciting Verbal Reports**

The central assumption of protocol analysis is that it possible to instruct subjects to verbalize their thoughts in a manner that doesn’t alter the sequence of thoughts mediating the completion of a task, and can therefore be accepted as valid data on thinking.

Based on their theoretical analysis, Ericsson and Simon (1993) argued that the closest connection between thinking and verbal reports is found when subjects verbalize thoughts generated during task completion. When subjects are asked to think aloud, some of their verbalizations seem to correspond to merely vocalizing “inner speech,” which would otherwise have remained inaudible. Non-verbal thoughts can also be often given verbal expression by brief labels and referents. For example, when one subject was asked to think aloud while mentally multiplying 36*24 on two test-occasions one week apart the following protocols were obtained:

OK, 36 times 24, um, 4 times 6 is 24, 4, carry the 2, 4 times 3 is 12, 14, 144, 0, 2 times 6 is 12, 2, carry the 1, 2 times 3 is 6, 7, 720, 720, 144 plus 720, so it would be 4, 6, 864.

The reported thoughts are not introspectively analyzed into their perceptual or imagery components, but merely verbally expressed and referenced, such as “carry the 1,” “36,” and “144 plus 720.” Similarly, subjects are not asked to describe or explain how they solve these problems. Instead, they are asked to remain focused on solving the problem and merely to give verbal expression to those thoughts that emerge in attention while generating the solution under normal (silent) conditions.

If the act of verbalizing subjects’ thought processes doesn’t change the sequence of thoughts, then subjects’ task performance should not change as a result of thinking aloud. In a comprehensive review of dozens of studies, Ericsson and Simon (1993) found no evidence that the sequences of thoughts (accuracy of performance) were changed when subjects thought aloud as they completed the tasks, compared to subjects who completed the same tasks silently. However, some studies showed that think-aloud subjects would take somewhat longer to complete the tasks—presumably due to the additional time required to produce the overt verbalization of the thoughts.

The same theoretical framework can also explain why other types of verbal report procedures consistently change cognitive processes. For example, when subjects are instructed to explain or carefully describe their thoughts, they are not able to merely verbalize each thought as it emerges, they must engage in additional cognitive processes
to generate the thoughts corresponding to the required explanations and descriptions. This additional cognitive activity changes the sequence of mediating thoughts. Instructions to explain and describe the content of thought are reliably associated with changes in ability to solve problems correctly (Ericsson and Simon 1993).

In sum, after brief training in giving verbal reports, subjects can think-aloud without any systematic changes to their thought process (See Ericsson and Simon 1993, for detailed instructions and associated warm-up tasks recommended for laboratory research). This means that subjects must already possess the necessary skills for verbalization of thoughts.

Protocol-Analysis Methodology—Validity of Verbal Reports

When adults are able to perform tasks while thinking aloud without sacrificing accuracy and speed, the verbalized information would almost have to reflect some aspect of the regular cognitive processes. By analyzing the information expressed as verbalized thoughts, it is possible to assess the validity of the verbalized information. In Protocol Analysis the verbalized thoughts are compared to intermediate results generated by different strategies that are specified in a task analysis (Ericsson and Simon 1993). The sequence of thoughts verbalized while multiplying 24*36 mentally (reproduced above) agrees with the sequence of intermediate thoughts specified by one, and only one, of the possible strategies for calculating the answer.

Even when subjects think aloud with its close connection between thoughts and reports, correspondence between verbalized thoughts and intermediate products predicted from the task analysis isn't perfect (see Figure 2). The lack of one-to-one correspondence is due primarily to the fact that not all thoughts which pass through attention are verbalized and some processing steps (thoughts) may be short-circuited with acquired skill. However, there is persuasive evidence of validity for the thoughts that are verbalized (Ericsson and Simon 1993). Even if a highly skilled participant's think-aloud report in the multiplication task only consisted of “144” and “720,” the reported information would still be sufficient to reject many alternative strategies, because these strategies did not involve generating both of the reported intermediate products. The general finding that a task analysis can identify, a priori, the specific intermediate products that are later verbalized by subjects during their problem solutions, provides the strongest evidence that concurrent verbalization reflects the processes that mediate the actual generation of the correct answer.

More generally, verbal reports are only one indicator of the thought processes that occur during problem solving. Other indicators include reaction times (RTs), error rates, patterns of brain activation, and sequences of eye fixations. Given that each kind of empirical indicator can be separately recorded and analyzed, it is possible to compare the results of such independent data analyses. In their review, Ericsson and Simon (1993) found that longer RTs were associated with verbal reports of a larger number of intermediate thoughts than those corresponding to shorter RTs. Furthermore, there seemed to be close correspondence between subjects’ thoughts and what information that
they looked at—when subjects verbalized thoughts about objects in the environment they very frequently looked at them.

Finally, the validity of verbally reported thought sequences depends on the time interval between the occurrence of a thought and its verbal report, where the highest validity is observed for concurrent, think aloud verbalizations. For tasks with relatively short response latencies (less than 5-10 seconds), subjects are able to recall their sequences of thoughts accurately immediately after the completion of the task and the validity of this type of retrospective reports remains very high. However, for cognitive processes of longer duration, the problems of accurate recall of prior thoughts increases, with a corresponding decrease in validity of the verbal reports.

**Concluding remarks**

Protocol analysis has emerged as one of the principal methods for studying thinking in Cognitive Psychology (Crutcher 1994), Cognitive Science (Simon and Kaplan 1989), and Behavior Analysis (Austin and Delaney 1998). As further evidence of its validity, protocol analysis now plays a central role in applied settings, such as in the design of surveys and interviews (Sudman Bradburn and Schwarz, 1996) and user testing of computer software (Henderson Smith Podd and Varela-Alvarez, 1995). Finally, several interesting adaptations of verbal-report methodology are emerging in the study of text comprehension (Pressley and Afflerbach 1995) and education (Renkl 1997).

**Bibliography**


