USING THINK-ALOUD INTERVIEWS AND COGNITIVE LABS IN EDUCATIONAL RESEARCH

UNDERSTANDING QUALITATIVE RESEARCH

JACQUELINE P. LEIGHTON

OXFORD

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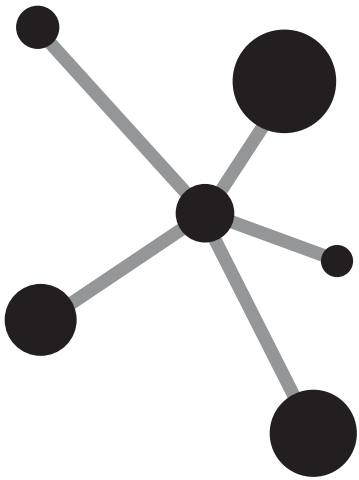

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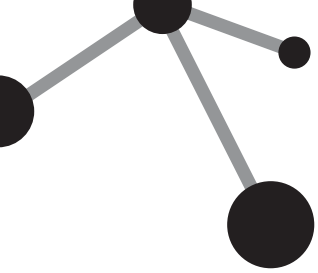

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WHAT IS THE PROBLEM TO BE SOLVED?

The Purpose for Using Think-Aloud and Cognitive Laboratory Interviews

Introduction

Human Verbal Responses as a Source of Qualitative Data

The objective of this book is to identify the most recent procedures and best practices for collecting, analyzing, and interpreting human *verbal response reports* (or verbal reports)—a type of qualitative data—arising from *think-aloud* and *cognitive laboratory interviews* (cognitive laboratory interviews and "cognitive labs" are used interchangeably in this text but do not include think-aloud interviews) methods. Verbal reports are being collected more and more frequently in educational and other social science research. This book focuses on how to collect verbal reports, a qualitative data source; how to *codify* or *quantify* the reports, in some cases for the purpose of their analysis with inferential statistics; and how to consider the generalization of results to a wider population.

Many articles and books have been written on both these methods. However, there are differences between the two methods with regard to the research questions they are designed to answer. These differences have been considered carefully in several publications. Two seminal articles are Ericsson and Simon's (1980) *Verbal Reports as Data* and Chi's (1997) *Quantifying Qualitative Analyses of Verbal*

Data: A Practical Guide. The seminal textbook on think-aloud interviewing is Ericsson and Simon's (1993) *Protocol Analysis: Verbal Reports as Data*, but other notable books include van Someren, Barnard, and Sandberg's (1994) *The Think Aloud Method: A Practical Guide to Modelling Cognitive Processes*, Pressley and Afflerbach's (1995) *Verbal Protocols of Reading: The Nature of Constructively Responsive Reading*, Willis's (2005) *Cognitive Interviewing: A Tool for Improving Questionnaire Design*, Bowles' (2010) *The Think-Aloud Controversy in Second Language Research*, Willis's (2015) *Analysis of the Cognitive Interview in Questionnaire Design: Understanding Qualitative Research,* and Miller, Willson, Chepp, and Padilla's (2014) *Cognitive Interviewing Methodology.*

It is noteworthy that the think-aloud interview method was originally developed for studying psychological phenomena. This is significant because the method has been refined and developed to be so rigorous as to warrant making claims about unobservable psychological phenomena. However, many of the books that have followed Ericsson and Simon's (1993) *Protocol Analysis* have been instrumental in helping users adapt think-aloud interviewing methods for implementation in other disciplines to collect verbal report data. For example, cognitive laboratory interviews or "cognitive labs" as they are frequently called are a more recent adaptation of think-aloud interviews that merit special focus because they are similar to think-aloud interviews but differ in their methodology in non-trivial ways.

Since the last published book on interviews to collect verbal report data—Willis's (2015) *Analysis of the Cognitive Interview in Questionnaire Design: Understanding Qualitative Research*—the use of this method has continued to increase. Figure 1.1 is an *Ngram Viewer* plot of the terms *think-aloud method* and *cognitive lab* from 1975 to 2005—the most recent year for which information on the frequency of their use is available from the English corpus. What is of interest is the way use of the terms parallels the publication of key resources. For example, instances of the term *think-aloud method* in published works is negligible prior to the 1980s, picks up thereafter, shows a local peak between 1990 and1995, drops again, and then shows another resurgence in 2000. Ericsson and Simon's first major scholarly article on the topic (*Verbal Reports as Data*) appeared in 1980 in the American Psychological Association's (APA) *Psychological Review*; their book *Protocol Analysis* was published in

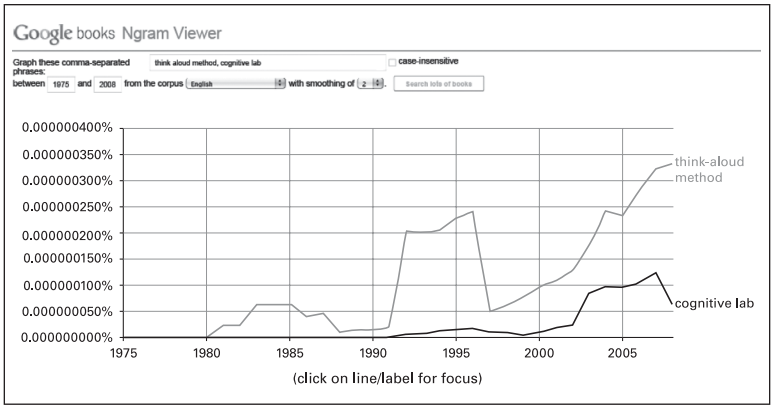

Figure 1.1 *Ngram Viewer* plot of the terms *think-aloud method* and *cognitive lab* from 1975 to 2008. Note: The term *cognitive lab* was used instead of *cognitive laboratory* in Google books Ngram Viewer because the former term is often used to denote these types of interviews when applied in different domains, whereas the latter (cognitive laboratory) is broad and can be confused to mean an environment in which research on cognition takes place, such as at a university.

1993, and the resurgence in 2000 likely mirrors the use of the 1993 book to guide application of the method not only in the discipline of psychology but in other disciplines as well, including education, medicine, computer science, and media and communication.

In particular, educational testing specialists (psychometricians) have become interested consumers of think-aloud interview methods, primarily the variant the cognitive laboratory, using it both to supplement empirical evidence gathered about students' test item responses and to generate claims that educational and psychological tests measure specific constructs (see validity and responses processes in *The Standards for Educational and Psychological Testing* [2014], issued by the American Educational Research Association [AERA], American Psychological Association [APA], and National Council on Measurement in Education [NCME]). Although Shear and Zumbo (2014) indicate that validity evidence of response processes, often collected using think-aloud and cognitive laboratory interviews, has traditionally lagged behind other types of validity evidence, the influence of such data is changing with a transformation of educational tests focused on measuring high-level thinking skills (Figure 1.2). To illustrate, consider the Programme for International Student Assessment

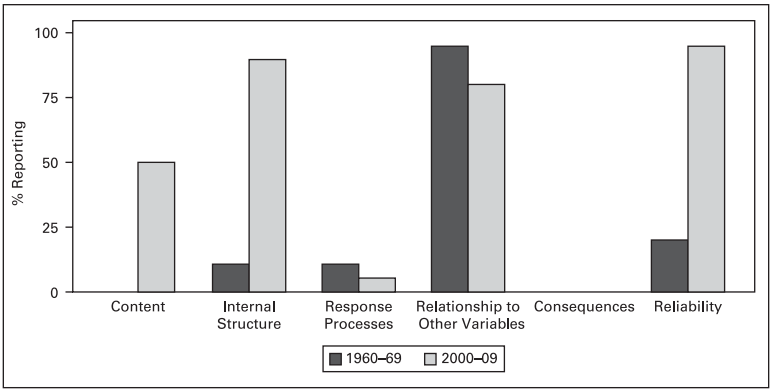

Figure 1.2 Bar graph showing "Percent of studies reporting each source of validity evidence by decade," 1960–69 and 2000–09. Reproduced with permission of Springer Science + Business Media from Shear, B. R. & Zumbo, B. D. (2014). What counts as evidence: A review of validity studies in educational and psychological measurement (Figure 6.2, p. 103). In B. D. Zumbo and E. K. H. Chan (Eds.), *Validity and validation in social, behavioral and health science* (pp. 91–111). New York: Springer.

(PISA). The PISA is a multi-format survey designed to measure how well 15-year-old students in OECD (i.e., Organization for Economic Cooperation and Development) countries can respond to questions on literacy, science, and numeracy to meet real-life challenges. The survey is administered every 3 years.

In 2009, the PISA administration focused on literacy, and students' item responses were used as evidence of their competencies to meet real-life literacy challenges. Thus, in the design of the 2009 PISA, survey developers needed to ensure that test items measured literacy knowledge as they defined it: "capacity to: understand, use, reflect on and engage with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society" (OECD, 2009, p. 14). Survey developers of the 2003 and 2009 PISA employed cognitive laboratory interview methods in the first phase of item development to check on whether items were measuring the expected knowledge and skills of students. For example, items, including stimulus materials, and options were presented to student participants to "ascertain the thought processes typically employed as students attempted [to respond to] the items" (OECD, 2012, p. 33). The use of cognitive laboratory interviews in the development of test items for PISA is a classic illustration of how

human verbal responses (data) are used to help design and develop educational tools. In the following section, the qualitative nature of verbal responses as data is considered, especially as it pertains to collecting such data within distinct research designs.

Distinguishing Qualitative Data Sources from Research Designs

Social and educational scientists often ask research questions that require open-ended data sources and multifaceted analytical techniques. Consider the following examples: (1) How do newly licensed psychologists with young families balance a clinical practice and home life responsibilities? (2) What are the challenging features of using digital technology in classrooms today from both students' and teachers' perspectives? (3) What are the cognitive strategies by which adolescents solve trigonometry questions? These three questions are designed to gain data about practices, perspectives, and processes. In the first question, the focus is information about practices; the second seeks information about perspectives; and the third requests information about mental processes. In all three examples, numerical data could be collected using surveys or closed-response questionnaires, observational schedules, and even, for the third question, eye tracking profiles or reaction times. However, collecting only numerical data would probably not be the only or even the best source of information for answering these questions. In part, because the questions posed are largely about phenomena that are not well enough understood to inform the design of instruments to collect specific numerical data. In other words, the questions are exploring phenomena: (1) procedures or practices used by psychologists that affect work–life balance, (2) perspectives from students and teachers, and (3) cognitive processes. All three therefore necessitate a form of data that allows a wide range of responses leading to an understanding of the boundaries, parameters, nature and character of the phenomena. Qualitative data contribute to that understanding; they are collected from individual research participants, normally by means of their natural language, from handcrafted images, or via other open-ended constructed responses.

Qualitative data—such as verbal reports—can be collected for analysis using qualitative or quantitative research designs.

This should not be surprising as it is important to distinguish the *data source* from the *research designs* in which the data are embedded. For example, *grounded theory, ethnographic*, and *narrative* research designs are but three among many qualitative research designs (Creswell, 2005; see also Creswell, 2013 for additional designs such as phenomenology and the case study approach). These designs are described as "qualitative" because their primary purpose is exploratory, and they are used, respectively, to survey the common thematic experiences of individuals (i.e., grounded theory), the shared culture of groups of individuals (i.e., ethnography), and the personal stories told by individuals to describe and understand their lives (i.e., narrative). Unsurprisingly, data derived from textual stories and images are common in qualitative research designs; they are often extracted using text analysis with the end goals of (1) identifying themes, (2) developing a coherent understanding of those themes, and (3) indicating how the themes enhance the researchers' understanding of the phenomena.

However, verbal reports can also be collected within *quantitative* research designs. For example, *experimental, correlational*, and *survey* research designs are usually considered to be quantitative in nature because their primary use is to evaluate whether one variable is statistically associated with another, while controlling or holding other variables constant. Another use of quantitative research designs is to describe numerical response trends for groups of participants. For example, in an intervention study for vaccine awareness, one experimental group is exposed to instructional video A whereas another group in exposed to instructional video B. Members of the two groups are then asked to complete a closed-response questionnaire about child vaccination preferences. As in this example, quantitative data (e.g., responses to closed-response questionnaires) are normally collected within quantitative research designs; that is, data about quantities are collected from individual research participants, normally by means of specific responses, such as multiple-choice questions and closed survey items, or by behavioral measurements such as reaction time. In either case, once collected and if not already in a form that reflects a quantity, the data are transformed into numbers (e.g., multiple choice items are scored and aggregated to yield a total test score) and linked to individual participants.

When data are collected from verbal reports, one of the critical decisions to be made concerns the form—qualitative or quantitative—to be used in analyzing the reports. For example, the investigator can choose to retain the verbal reports in narrative (qualitative) form and proceed with an analysis of the text. In this case, the investigator might choose to conduct a text analysis of the themes in the verbal reports. This qualitative analysis can then be used to complement any numerical, quantitative data also collected in the study. Retaining the qualitative form to complement the quantitative data leads to what can be considered a mixed-methods approach because the qualitative and quantitative data sources are combined to answer a research question (see Creswell, 2005). Alternatively, the investigator can decide to first analyze the verbal reports for specific themes, and then *quantify* the themes by assigning *numbers* to different coded features of those verbal reports; for example, using a nominal scale, an investigator could assign numbers to reflect different codes, which can then be interpreted into themes (see Chapter 5) in the reports. Alternatively, an investigator could use an ordinal or even an interval or ratio scale to assign numbers to reflect different levels of sophistication, response quality, or correctness of verbal report utterances. By deciding to codify and quantify the verbal reports, investigators buy themselves the opportunity to apply analytical, inferential statistical techniques. Furthermore, depending on the sample of participants, investigators also give themselves an opportunity to generalize the results to a larger population.

Qualitative Versus Quantitative Data: Verbal Responses

More often than not the verbal response data gathered from think-aloud interviews and cognitive laboratory interviews are maintained in a qualitative format—that is, in word- or text-based form for analysis. Analysis of qualitative data can be accomplished using Computer Assisted Qualitative Data Analysis software (CAQDAS) such as ATLAS.ti, Dedoose, Digital Replay System (DRS), or NVivo. The University of Illinois at Urbana-Champaign provides an online resource (http://uiuc.libguides.com/caqdas) of viable CAQDAS software that includes reviews of the various applications.

Before briefly describing the nature of think-aloud interviews and cognitive laboratory interviews in the next section, it is worthwhile to clarify the different forms verbal response data can take—for present purposes, qualitative versus quantitative forms. Generally speaking, *qualitative data* are collected from individual research participants, normally by means of their natural language, handcrafted images, or via other open-ended constructed responses. The qualitative data collected, often in raw form, consist of personal views, stories or self-reports in oral or textual form, and responses to interview questions or other stimuli. For example, investigators may design an interview schedule to guide the questioning of participants for the purpose of collecting verbal responses about a specific subject. Figure 1.3 is a standardized interview schedule or guide developed by Leighton and Bisanz (2003) with which to collect information (verbal responses) from students in kindergarten, grades 3 and 5, and university students about their knowledge of the ozone layer and ozone hole. When developing such interview schedules, investigators must anticipate several decisions; for example, whether all questions can and need to be asked of all participants (i.e., how to ensure standardization) and, if so, whether the full sample of participants will be able to provide responses to the questions such that their responses permit movement to answering subsequent interview questions. The responses, if kept in their qualitative, narrative form, are analyzed for themes in order to provide the investigator with a basis for a coherent understanding of how the interviewed participants think about the topic and can contribute to knowledge of the topic.

For purposes of analysis, qualitative data need to be distinguished from *quantitative data*, which consists of quantities or numerical responses from or associated with participants. These data are normally provided or recorded in response to selected-response (multiple-choice) questions, demographic queries, or even in light of behavioral observation such as a student-respondent's weight, height, or frequency of raising a hand in classroom discussions. For example, survey tools that require participants to answer a series of statements using a Likert-type response scale, such as 5 "Strongly Agree," 4 "Agree," 3 "Neutral," 2 "Disagree," and 1 "Strongly Disagree," are used to collect numerical information about individual preferences. Verbal response data are rarely provided initially in quantitative form, as the nature of

1.	*Some people say that you should wear sunscreen or suntan lotion when you are out in the sun. Why do you think some people say that you should do this?*
2.	*Why would it be bad for us to be burned by the sun's rays?*
3.	*Do all of the sun's rays cause problems or just some of them?*
4.	*Do you know what the harmful rays are called?* *4a. Have you ever heard of ultraviolet (UV) light?* *4b. Can you tell me what you know about ultraviolet (UV) light?* *4c. Is there anything else you can tell me about ultraviolet (UV) light?*
5.	*Is there anything between us and the sun that surrounds our planet? If yes, what is it called?* *5a. Have you ever heard of the atmosphere?* *5b. Can you tell me what you know about the atmosphere?* *5c. Is there anything else you can tell me about the atmosphere?*
6.	*Is there anything between us and the sun that helps protect us from the harmful rays of the sun?* *6a. Have you ever heard of the ozone layer?* *6b. Can you tell me what you know about the ozone layer?* *6c. Is there anything else you can tell me about the ozone layer?*
7.	*Is there something about the ozone layer that makes us worry today?* *7a. Have you ever heard of the ozone hole?* *7b. Can you tell me what you know about the ozone hole?* *7c. Is there anything else you can tell me about the ozone hole?*
8.	*Why did this ozone hole start?*
9.	*Can you tell me what are some of the things that people use that harm the ozone layer?*
10.	*Can you tell me what it is about these things that harms the ozone layer?* *10a. Have you ever heard of CFCs (chlorofluorocarbons)?* *10b. Can you tell me what you know about CFCs (chlorofluorocarbons)?* *10c. Is there anything else you can tell me about CFCs (chlorofluorocarbons)?*
11.	*Are we the only ones that should protect ourselves from this hole in the ozone layer or are there other things on our planet that should also be protected?*
	Note: *Category 1: The Sun and Adverse Consequences (Questions 1, 2, 3, 4)* *Category 2: UV Light (Questions 1, 3, 4)* *Category 3: UV Light and Human Behavior (Questions 1, 2, 8, 9, 11)* *Category 4: Ozone Composition (Questions 5, 6, 9)* *Category 5: Ozone Destruction (Questions 1, 2, 7, 9, 10)*

Figure 1.3 Structured Interview of Questions Used to Elicit Verbal Reports and Conduct Verbal Analysis. Reproduced with permission of the publisher (Taylor & Francis Ltd, http://www.tandfonline.com) from Leighton, J. P., & Bisanz, G. L. (2003). Children's and adults' knowledge and models of reasoning about the ozone layer and its depletion. *International Journal of Science Education, 25*, 117–139.

these data are often not numerical but, rather, text-based narratives. Nonetheless, verbal response data can be transformed into quantitative form, for example, by assigning numerical codes to selected portions (segments) of the response to identify and, in some cases, evaluate complexity of thinking processes reflected in the text. How this is done is described in later chapters. The section that follows provides an introductory description of think-aloud and cognitive laboratory interviews.

Think-Aloud Interviews and Cognitive Laboratory Interviews: One-to-One Methods

As mentioned at the outset, the objective of this book is to identify the procedures for collecting, analyzing, and interpreting qualitative data arising from the *think-aloud* and *cognitive laboratory interview* methods. Think-aloud interviews have grown in popularity in the last 30 years as tools for collecting research data in the areas of education, psychology, medicine, computer science, and media and communications (e.g., Ericsson & Simon, 1993; Eveland & Dunwoody, 2000; Leighton, 2004, 2009; Leighton & Gierl, 2007; Mazor, Canavan, Farrell, Margolis, & Clauser, 2008). Cognitive laboratory interviews have developed on the heels of think-aloud interviews, borrowing significantly from the methods used in the think-aloud interview. However, cognitive laboratories are primarily tailored for use in educational measurement and testing research, including questionnaire design, such as in the PISA example described earlier (e.g., Johnstone, Bottsford-Miller, & Thompson, 2006; Zucker, Sassman, & Case, 2004). Much of the published research on cognitive laboratory interviews is not found in journal articles but in technical reports. The general procedural framework for collecting think-aloud (protocol analysis; see Chapters 2 and 4) and cognitive laboratory interviews (verbal analysis; see Chapters 3 and 5) is shown in Figure 1.4. Each method is briefly described here and elaborated in those later chapters.

Think-aloud interviews involve a one-to-one meeting between a research participant and an investigator (or assistant). The purpose of the interview is to ask the participant to *think aloud*—that is, to articulate thoughts—as he or she considers specific scenarios and concepts, or solves problems through a series of tasks. The purpose of having participants think aloud is to provide the investigator

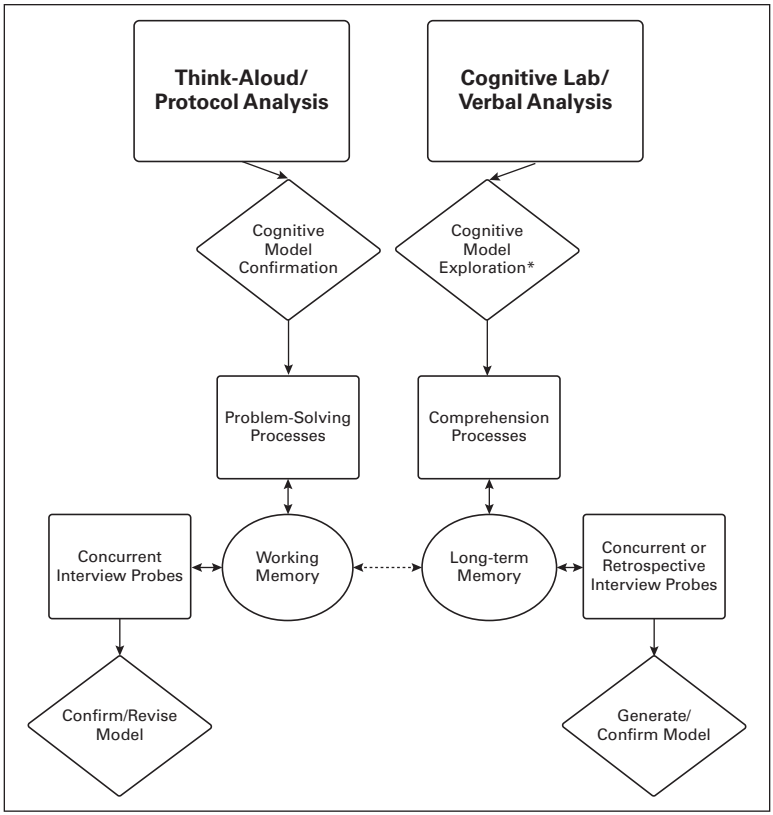

Figure 1.4 Differential measurement objectives for think-aloud interview (protocol analysis) and cognitive laboratory interview (verbal analysis). *Can be in confirmatory mode as well.

with the means to identify the thoughts and/or cognitive processes and strategies the participants experience in response to questions or in the course of problem solving specific tasks. For example, the investigator might begin an interview designed to identify the cognitive strategies a student will use to solve algebra word problems with the following statement:

> Hello [participant's name].
>
> My name is [investigator's name].
>
> Thank you for participating in the interview today. As described in the information letter, the study we are conducting is focused on understanding how students think through

> and solve algebra word problems. I am going to show you five problems; each on a separate page, and what I'd like you to do is tell me everything that passes through your mind as you try to solve each of the problems. If you are silent for more than 5–10 seconds, I will ask you to "keep talking" because it is important that I hear everything you are thinking as you solve the problem. Have you ever done this? We can do a practice problem. . . . .

A key aspect of the think-aloud interview is to have participants articulate their thoughts as they are solving the task so that the process of problem solving can be recorded or "captured." Thus, the participant must think-aloud in a sufficiently audible way to permit recording, normally via audio but in some cases with audio and video. The participant's orally articulated thoughts are captured and then transcribed, usually verbatim, to produce a verbal (response) report. The verbal report is a narrative of the thoughts the participants expressed during the interview; as already indicated, it is a piece of qualitative datum. Normally, verbal reports are collected from many participants who are asked to respond to the same stimuli (i.e., scenarios, concepts, or problem-solving tasks) during the one-to-one interviews. These verbal reports constitute the qualitative data to be analyzed and coded for content themes and/or transformed into numerical quantities.

There is a reason for conducting think-aloud interviews (Ericsson & Simon, 1993) and cognitive laboratory interviews individually with participants; that is, conducting one-to-one interviews instead of using focus groups with many participants as they engage in thinking about or problem solving through a task. The reason is as follows: The main objective in using think-aloud interviews or cognitive laboratory interviews in much educational or psychological research is to collect data that will *provide empirical evidence of human response processes* in some content domain. This empirical evidence is then used to support claims or inferences related to the evaluation or testing of psychological theories of *individual* cognition, problem solving, or building validity arguments for educational test scores (Chi, 1997; Ericsson & Simon, 1993; see also AERA, APA, & NCME, 2014). If an interviewer engages with many participants at the same time, the collaborative or communal aspect of the interview may bias and influence the

verbal responses provided by any one participant, in which case claims about individual response processes cannot be supported.

One way to understand think-aloud interviews and cognitive laboratory interviews is as tools to tap into the content of human minds. Consider the following example: A researcher is interested in identifying the cognitive or response processes by which individuals solve two-digit multiplication problems to inform theories of mathematical cognition. A participant is interviewed, one-to-one, and asked to think aloud while solving the multiplication task of 36 × 24. Borrowing this example from Ericsson (2003, p. 11), the participant produces the following verbal response:

> 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.
>
> 36 times 24, 4, carry the — no wait, 4, carry the 2, 14, 144, 0, 36 times 2 is, 12, 6, 72, 720 plus 144, 4, uh, uh, 6, 8, uh, 864.

At least three points can be made about the preceding verbal report. First, the verbal report, in its initial raw form, presents an oral narrative or story-like account of the thoughts the individual participant is experiencing as he or she attempts to solve the multiplication problem of 36 × 24. Second, as mentioned previously, although the verbal report produced by a participant in a think-aloud or cognitive laboratory interview is not normally quantitative, it could contain numerical aspects—especially if the participant includes numerical information as part of the narrative. In addition to the expressed thoughts, participants may also provide a corresponding written account of their problem solving. In this multiplication example, the participant could have been shown the stimulus 36 × 24 on a computer screen and, in addition to articulating his or her thoughts, would have been provided with scratch paper to facilitate problem solving while thinking aloud. Once the verbal report is collected from the individual, all corresponding notes made on scratch paper or a similar device are also collected to facilitate transcription of the verbal report into a textual or word-based form for the purpose of analysis. Third, the verbal report is designed to present *observable* indicators (evidence) of phenomena that are technically *unobservable*—that is, the contents of the human mind; a participant's response