Adults' Statistical Literacy: Meanings, Components, Responsibilities

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Summary

Statistical literacy is a key ability expected of citizens in information-laden societies, and is often touted as an expected outcome of schooling and as a necessary component of adults' numeracy and literacy. Yet, its meaning and building blocks have received little explicit attention. This paper proposes a conceptualization of statistical literacy and describes its key components. Statistical literacy is portrayed as the ability to interpret, critically evaluate, and communicate about statistical information and messages. It is argued that statistically literate behavior is predicated on the joint activation of five interrelated knowledge bases (literacy, statistical, mathematical, context, and critical), together with a cluster of supporting dispositions and enabling beliefs. Educational and research implications are discussed, and responsibilities facing educators, statisticians, and other stakeholders are outlined.

Key words: Statistics education; Numeracy; Adult education; Educational policy; Statistical reasoning.

1 Introduction and Need

Many curriculum frameworks and national and international educational initiatives, including but not limited to those focusing on the mathematical sciences, underscore the importance of enabling all people to function effectively in an information-laden society (e.g., UNESCO, 1990; Australian Education Council, 1991; American Association for the Advancement of Science (AAAS), 1995; European Commission, 1996; National Council of Teachers of Mathematics, 2000). The present paper focuses on *statistical literacy*, one critical but often neglected skill area that needs to be addressed if adults (or future adults) are to become more informed citizens and employees.

Statements regarding the importance of statistical reasoning or statistical knowledge in society have been eloquently made in the past. For example, Moore (1998), in his Presidential address to the American Statistical Association (ASA), claimed that it is difficult to think of policy questions that have no statistical component, and argued that statistics is a general and fundamental method because data, variation and chance are omnipresent in modern life. Wallman (1993), in a 1992 ASA Presidential address, emphasized the importance of strengthening understanding of statistics and statistical thinking among all sectors of the population, in part due to the various misunderstandings, misperceptions, mistrust, and misgivings that people have towards the value of statistics in public and private choices. Researchers interested in cognitive processes have emphasized the contribution of proper judgmental processes and probabilistic reasoning to people's ability to make effective decisions (Kahneman, Slovic & Tversky, 1982) and showed that training in statistics can aid in solving certain types of everyday problems (Kosonen & Whinne, 1995). Industry trainers and education planners have pointed to the important role of statistical understanding and mathematical competencies as a component of the skills needed by workers in diverse industries (e.g., Carnevale, Gainer & Meltzer, 1990; Packer, 1997).

While these and other sources have helped to highlight the centrality of statistical literacy in various life contexts, few attempts to describe the nature of adults' overall statistical literacy have been published to date. It is necessary to first grapple with definitional issues. In public discourse "literacy" is sometimes combined with terms denoting specific knowledge domains (e.g., "computer literacy"). In such cases the usage of "literacy" may conjure up an image of the *minimal* subset of "basic skills" expected of *all* citizens, as opposed to a more advanced set of skills and knowledge that only some people may achieve. Along these lines, statistical literacy may be understood by some to denote a minimal (perhaps formal) knowledge of basic statistical concepts and procedures. Yet increasingly the term literacy, when used as part of the description of people's capacity for goal-oriented behavior in a specific domain, suggests a broad cluster not only of factual knowledge and certain formal and informal skills, but also of desired beliefs, habits of mind, or attitudes, as well as general awareness and a critical perspective.

In line with the expanding conception of the term literacy, Wallman (1993) argued that statistical literacy is the ability to understand and critically evaluate statistical results that permeate daily life, coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions. Watson (1997) presented a framework of statistical literacy comprised of three tiers with increasing sophistication: a basic understanding of probabilistic and statistical terminology; an understanding of statistical language and concepts when they are embedded in the context of wider social discussion; and a questioning attitude one can assume when applying concepts to contradict claims made without proper statistical foundation.

The complex and expanding meaning of domain-specific literacy can also be illustrated by examining extant conceptions of "scientific literacy". Shamos (1995) reviews prior works on scientific literacy that suggest common building blocks: basic vocabulary, understanding of science process, and understanding of the impact of science and technology on society. Jenkins (1996) suggests that scientific literacy can be characterized as scientific knowledge and attitudes, coupled with some understanding of scientific methodology.

Shamos (1995) argues that it would be a simplification to assume that somebody is either literate or illiterate in science, and suggests a continuum along which scientific literacy can be described, comprised of three overlapping levels that build upon each other in sophistication. The most basic one, "cultural" scientific literacy, refers to a grasp of basic terms commonly used in the media to communicate about science matters. Next, "functional" scientific literacy adds some substance by requiring that "the individual not only have command of a science lexicon but also be able to converse, read and write coherently, using such science terms in perhaps a non-technical but nevertheless meaningful context" (p. 88). This level also requires that the person has access to simple everyday facts of nature, such as some knowledge of the solar system (e.g., that the earth revolves around the sun, how eclipses occur). Finally, "true" scientific literacy requires some understanding of the overall scientific enterprise (e.g., basic knowledge of key conceptual schemes or theories that form the foundation of science and how they were arrived at), coupled with understanding of scientific and investigative processes. Examples are (see also Rutherford, 1997): Appreciation of the relativity of "fact" and "theory", awareness of how knowledge accumulates and is verified, the role of experiments and mathematics in science, the ability to make sense of public communications about scientific matters, and the ability to understand and discuss how science and technology impinge on public life.

With the above broad usage of "literacy" and "statistical literacy" in mind, this paper develops a conception of statistical literacy that pertains to what is expected of adults (as opposed to students actively learning statistics), particularly those living in industrialized societies. It is proposed here that in this context, the term "statistical literacy" refers broadly to two interrelated components, primarily (a) people's ability to *interpret and critically evaluate* statistical information, data-related arguments, or stochastic phenomena, which they may encounter in diverse contexts, and when

relevant (b) their ability to *discuss or communicate* their reactions to such statistical information, such as their understanding of the meaning of the information, their opinions about the implications of this information, or their concerns regarding the acceptability of given conclusions. These capabilities and behaviors do not stand on their own but are founded on several interrelated knowledge bases and dispositions which are discussed in this paper.

Statistical literacy can serve individuals and their communities in many ways. It is needed if adults are to be fully aware of trends and phenomena of social and personal importance: crime rates, population growth, spread of diseases, industrial production, educational achievement, or employment trends. It can contribute to people's ability to make choices when confronted with chance-based situations (e.g., buying lottery tickets or insurance policies, and comprehending medical advice). It can support informed participation in public debate or community action. The need for statistical literacy also arises in many workplaces, given growing demands that workers understand statistical information about quality of processes (Packer, 1997), and the contention that workers' understanding of data about the status of their organization can support employee empowerment (Bowen & Lawler, 1992).

The many examples of contexts where statistical literacy may be activated indicate that most adults are consumers (rather than producers) of statistical information. Yet, despite the centrality of statistical literacy in various life contexts, the nature of the skills and dispositions that comprise adults' statistical literacy have not received detailed discussion in the literature (Gal, 1994; Watson, 1997), and are thus the focus of this paper. Clarity on the characteristics of the building blocks of statistical literacy is needed before other questions can be addressed in earnest regarding assessment and instruction focused on statistical literacy.

2 A model

This paper concerns itself with people's ability to act as effective "data consumers" in diverse life contexts that for brevity are termed here *Reading contexts*. These contexts emerge, for example, when people are at home and watch TV or read a newspaper, when they look at advertisements while shopping, when they visit Internet sites, when they participate in community activities or attend a civic or political event, or when they read workplace materials or listen to reports at work. They include but are not limited to exposure to print and visual media, and represent the junctures where people encounter the much-heralded "information-laden" environments (European Commission, 1996). In such contexts, statistical information may be represented in three ways—through text (written or oral), numbers and symbols, and graphical or tabular displays, often in some combination. To simplify the presentation in this paper, the term *readers* will be used throughout to refer to people when they participate in reading contexts as actors, speakers, writers, readers, listeners, or viewers, in either passive or active roles.

Reading contexts should be distinguished from *enquiry contexts*, where people (e.g., students, statisticians) engage in empirical investigation of actual data (Wild & Pfannkuch, 1999). As part of this process such individuals serve as "data producers" or "data analyzers" and usually have to interpret their own data and results and report their findings and conclusions. Reading contexts may differ from enquiry contexts in important ways that have not been sufficiently acknowledged in the literature on statistical reasoning and are examined later.

This paper proposes a model, summarized in Table 1, of the knowledge bases and other enabling processes that should be available to adults, and by implication to learners graduating from schools or colleges, so that they can comprehend, interpret, critically evaluate, and react to statistical messages encountered in reading contexts. Based on earlier work such as cited above on statistical literacy and scientific literacy, the model assumes that people's statistical literacy involves both a *knowledge* component (comprised of five cognitive elements: literacy skills, statistical knowledge, mathematical

Table 1

A model of statistical literacy.

Knowledge elements	Dispositional elements
Literacy skills Statistical knowledge Mathematical knowledge Context knowledge Critical Questions	Beliefs and Attitudes Critical stance

Statistical Literacy
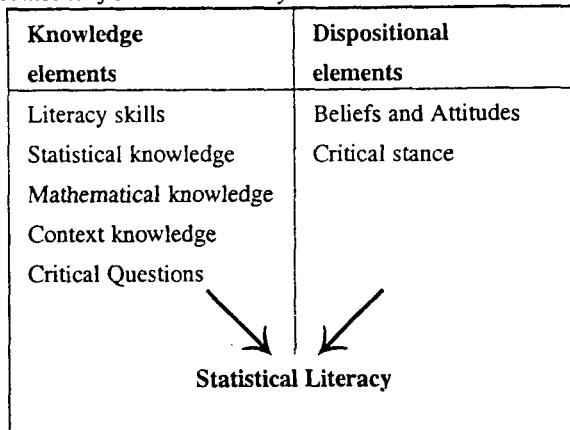
knowledge, context knowledge, and critical questions) and a *dispositional* component (comprised of two elements: critical stance, and beliefs and attitudes).

As with people's overall numeracy (Gal, 2000), the components and elements in the proposed model should not be viewed as fixed and separate entities but as a context-dependent, dynamic set of knowledge and dispositions that together enable statistically literate behavior. *Understanding and interpretation* of statistical information requires not only statistical knowledge per se but also the availability of other knowledge bases: literacy skills, mathematical knowledge, and context knowledge. However, *critical evaluation* of statistical information (after it has been understood and interpreted) depends on additional elements as well: the ability to access critical questions and to activate a critical stance, which in turn is supported by certain beliefs and attitudes.

The model's elements are described in subsequent sections, although some overlap with each other and do not stand in isolation. The final section of the paper discusses resulting educational and policy challenges and implications for needed research. The expected contribution of this paper is to facilitate further dialogue and action by educators, practicing statisticians, policy makers, and other professionals who are interested in how citizens can be empowered to make sense of real-world messages containing statistical elements or arguments.

3 Knowledge Elements of Statistical Literacy

This section reviews the five elements listed in Table 1 as comprising the knowledge component of statistical literacy. It is proposed that these elements jointly contribute to people's ability to comprehend, interpret, critically evaluate, and if needed react to statistical messages.

To provide a context for some of the ideas presented below, Figures 1, 2, 3, and 4 illustrate key modes through which statistical concepts and statistics-related information or arguments are communicated to adults in the printed media, a prime reading context. Figure 1 contains six excerpts illustrating statistical messages in daily newspapers and magazines from different countries. Figure 2 presents a statistics-related table from an American newspaper. Figure 3 presents a bar graph that appeared in a widely-circulated Israeli newspaper. Figure 4 includes a pie-chart used in the International Adult Literacy Survey (IALS; Statistics Canada and OECD, 1996) to simulate a newspaper graph.

#1: "The study found that women of average weight in the U.S. had a 50 per cent higher chance of heart attack than did women weighing 15 per cent below average." (Watson, 1997, p. 109; from *Hobart Mercury*, Tasmania, February 10, 1995).

#2: "JUDGES COUNT OUT CENSUS SAMPLING: ... at issue is far more than the accuracy of sampling in the Census held every 10 years: Billions of dollars in federal funds are allocated on the basis of how many people live in each state and city, and shifts in population can lead to the redrawing of House districts. A boost in the count of minorities would normally help Democrats." (*Philadelphia Inquirer*, August 25, 1998).

#3: "POLL BACKS LIMITS ON DRINKING BY TEENS: The survey of more than 7000 adults ... which has a margin of error of 2 percentage points, found that ... more than half favored restrictions on alcohol advertising ... more than 60% would ban TV ads for beer and wine." (*USA Today*, October 5, 1998).

#4: "The human race held this year many more sexual intercourses than last year; the world average was 112 per person this year, compared to 109 last year. This, according to a comprehensive survey initiated and funded, for the second year, by Durex, a manufacturer of prophylactics. The survey was held in 14 countries that according to experts represent all the world citizens ..." (*Yediot Aharonot*, Israel, October 28, 1997).

#5: "The Department of Education is investigating whether state scores on a national reading test were inflated by decisions states made on which students to exclude from the test ... in both 1994 and 1998 ... the overall exclusion rate was the same, about 6% ... Kentucky, Connecticut and Louisiana were among states with increases in students left out of their 1998 testing sample—primarily those with learning disabilities or limited knowledge of English." (*USA Today*, April 13, 1999).

#6: If you care about breast cancer, [a] new risk assessment test ... will give you a number that estimates your chances of developing breast cancer over the next 5 years. A score of 1.7 or above is considered high risk. Most likely you won't be at high risk, but you owe it to yourself to find out. The proof? In a landmark study of women 35 years or older and at high risk of breast cancer, women who took Nolvadex had fewer breast cancers than women taking sugar pills. Nolvadex decreases but does not eliminate the risk of breast cancer, and did not show an increase in survival .... In the study, women taking Nolvadex were 2 to 3 times more likely to develop uterine cancer or blood clots in the lung and legs, although each of these occurred in less than 1% of women .... You and your doctor must ... discuss whether the potential benefit of Nolvadex will outweigh these potential side affects. (Excerpt from a full-page commercial advertisement in *People* magazine, August 30, 1999).

Figure 1. *Illustrations of statistical texts in daily newspapers and magazines.*

'Matrix' a virtual lock at No. 1

The Keanu Reeves sci-fi thriller *The Matrix* remained the box office champ for the second consecutive week. Newcomers had mixed results: The romantic comedy *Never Been Kissed* opened fairly strong at No. 2, ... The top 10:

| Film	Box office (millions) Wkd.	Total	Avg. Per site	Pct. Chg.	Weeks Out
1 *The Matrix*	$22.6	$73.3	$7,772	-19%	2
2 *Never Been Kissed*	$11.8	New	$4,821		1
3 *10 Things I Hate About You*	$5.05	$20.4	$2,218	-39%	2
4 *The out-of-Towners*	$5.01	$16.2	$2,380	-39%	2
5 *Analyze This*	$5.0	$85.8	$2,125	-21%	6

*Re-creation of a selected portion of a table from *USA Today* (April 13, 1999). Some details omitted to conserve space.

Figure 2. *Illustration of a tabular display in a newspaper.*

Graph in *Yediot Aharonot*, the daily newspaper with the largest circulation in Israel, July 11, 2000. The title says: "Women in Israel are more educated". The subtitle says: "Israel holds the world record in the percentage of women among students for Master and Doctoral degrees". The bars represent percentages for (from top to bottom): Israel (55.4%), United States, Australia, Denmark, Great Britain, Finland, Sweden, Switzerland, and Japan (21.5%). (Reprinted with permission).

Figure 3. *Women's education in different countries.*
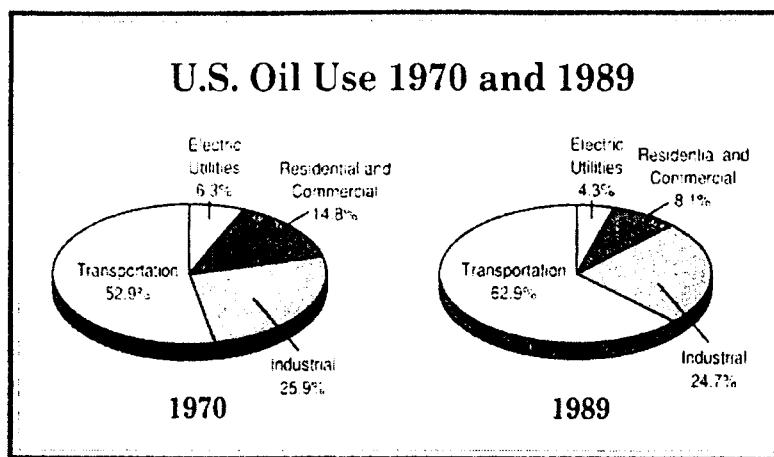
Stimulus from an IALS item. (Reprinted with permission).

Figure 4. *Oil use in two years.*

3.1 Literacy Skills

A discussion of literacy skills opens the review of the knowledge bases needed for statistical literacy, given that virtually all statistical messages are conveyed through written or oral text, or require that readers navigate through tabular or graphical information displays that require the activation of specific literacy skills (Mosenthal & Kirsch, 1998).

The understanding of statistical messages requires the activation of various text-processing skills in order to derive meaning from the stimulus presented to readers. The written portion of a message may be quite long (as in some of the excerpts in Figure 1) and demand complex text comprehension skills, or may sometimes involve a graph with only a few words (Figures 3 or 4). Readers also have to comprehend surrounding text, i.e., within which the statistical portion is embedded or which explains a graph or chart presented, to place the statistical part in the proper context. Depending on the circumstances, readers may have to communicate clear opinions, orally or in writing, in which case their response should contain enough information about the logic or evidence on which it is based to enable another listener or reader to judge its reasonableness. Thus, statistical literacy and general literacy are intertwined.

In the real world, readers have to be able to make sense of a wide range of messages, formulated at different levels of complexity and in different writing or speaking styles (Wanta, 1997). Messages may be created by journalists, officials, politicians, advertisers, or others with diverse linguistic and numeracy skills. Message originators may have diverse aims in terms of the presumed facts, images, or conclusions they aim to create or instill in the mind of the reader. Some messages may be created to convince the reader or listener to adopt a specific point of view or reject another, and hence may use one-sided arguments or present selective information (Clemen & Gregory, 2000), or may use modifiers (e.g., "a startling 5% gain ...") to shape a desired impression.

As several authors have pointed out (Laborde, 1990; Gal, 1999), coping with mathematical or statistical messages presents various demands on readers' literacy skills. For instance, readers have to be aware that the meanings of certain statistical terms used in the media (e.g., random, representative, percentage, average, reliable) may be different than their colloquial or everyday meaning. Messages

may use technical terms in a professionally appropriate way but may also contain statistical jargon that is ambiguous or erroneous. Some newspapers and other media channels tend to employ conventions in reporting statistical findings, such as referring to "sampling error" (or "margin of error") when discussing results from polls, but without explaining the meaning of terms used.

Space and time limitations or editorial decisions may force writers (or professionals who speak on TV) to present messages that are terse, choppy, or lack essential details. Readers may need to make various assumptions and inferences, given the absence of details or the inability in many cases to interrogate the creators of messages encountered. Overall, these factors can make comprehension more challenging, complicate the interpretation task, and could place heavy demands on readers' literacy skills. This is true for adults from all walks of life, but especially of adults who are bilingual or otherwise have a weak mastery of the national/dominant language (Cocking & Mestre, 1988). However, results from the International Adult Literacy Survey (IALS; Statistics Canada and OECD, 1996) suggest that in most of the countries surveyed, a large proportion of adults have only basic comprehension skills and are unable to cope effectively with a range of everyday literacy and computation tasks. Hence, people's literacy skills may be a bottleneck affecting their statistical literacy skills.

Document Literacy. The literacy skills needed for statistical literacy are not limited to those involving processing of prose text. This subsection extends the preceding discussion by examining Document Literacy skills, which pertain to reading various non-prose texts, including graphs, charts, and tables. The growing literature on graph comprehension examines various processes involved in making sense of graphs, from simple graph-reading to making inferences based on graphs (Bright & Friel, 1998), but has seldom viewed graphs as a subtype of documents in general.

The notion of Document Literacy comes out of the influential work of Kirsch and Mosenthal (Kirsch, Jungeblut & Mosenthal, 1998), who view literacy as comprised of three interrelated components: Prose Literacy, Document Literacy, and Quantitative Literacy. This conceptualization of literacy served as a basis for several large-scale studies, most recently the International Adult Literacy Survey (IALS; Statistics Canada and OECD, 1996; OECD & Human Resources Development Canada, 1997), and prior national studies of the literacy of adults and young adults, mainly in the United States and Canada (e.g., Kirsch, Jungeblut, Jenkins & Kolstad, 1993), but also in Australia.

Kirsch & Mosenthal (1990) claim that documents tend to be the predominant form of literacy in non-school settings, and serve as an important source of information and a basis for enabling actions and decisions. Document Literacy tasks require people to identify, interpret, and use information given in lists, tables, indexes, schedules, charts and graphical displays. The information in such displays often includes explicit quantitative information, such as numbers or percents, in addition to the quantitative or statistical information conveyed by graphs and charts. Mosenthal & Kirsch (1998) argue that documents, which include graphs and charts, are usually arranged in arrays of varying degrees of complexity: they may include "simple lists" or "combined lists", as in a simple table or a simple bar graph or pie chart (Figures 3 and 4); or "intersecting lists" or "nested lists", as in a two-way table (Figure 2) or in a complex multi-element graph.

An important aspect of the Kirsch and Mosenthal work (Kirsch, Jungeblut & Mosenthal, 1998) is the description ("grammar") provided of the cognitive operations required to locate information in documents, and the reading strategies required to match information in a question or directive to corresponding information in arrays of varying degrees of complexity. Key processes include *locating* specific information in given texts or displays, *cycling* through various parts of diverse texts or displays, *integrating* information from several locations (e.g., across two graphs, as in Figure 4), and *generating* new information (e.g., finding the difference between percentages in different parts of a table or between bars in a graph). Further, readers have to make *inferences*, quite often in the presence of irrelevant or distracting information, and perhaps apply mathematical operations as well to information contained in graphs or tables.

As Mosenthal & Kirsch (1998) argue, many types of common statistical information can be displayed in both graphs and tables, and one form is often a mere transformation of the other (e.g., when a table with a simple list is transformed into a simple bar chart). Hence, putting aside specialized aspects of graph comprehension (Tufte, 1997), their work provides a generalized way to understand literacy aspects of interpreting multiple types of documents and displays, and enables us to embed a discussion of statistical literacy within a broader framework of general literacy.

3.2   Statistical Knowledge Base

An obvious prerequisite for comprehending and interpreting statistical messages is knowledge of basic statistical and probabilistic concepts and procedures, and related mathematical concepts and issues. However, almost all authors who are concerned about the ability of adults or of school graduates to function in a statistics-rich society do *not* discuss what knowledge is needed to be statistically literate per se, but usually focus on what needs to be taught in schools and argue that all school (or college) graduates should master a range of statistical topics, assuming this will ensure learners' statistical literacy as adults. A recent example can be found in Scheaffer, Watkins & Landwehr (1998). Based on their extensive prior work in the area of teaching statistics and on reviewing various curriculum frameworks, these authors describe numerous areas as essential to include in a study of statistical topics in high-school:

- Number sense.
- Understanding variables.
- Interpreting tables and graphs.
- Aspects of planning a survey or experiment, such as what constitutes a good sample, or methods of data collection and questionnaire design.
- Data analysis processes, such as detecting patterns in univariate or two-way frequency data, or summarizing key features with summary statistics.
- Relationships between probability and statistics, such as in determining characteristics of random samples, background for significance testing.
- Inferential reasoning, such as confidence intervals or testing hypotheses.

It is tempting to regard this list as a possible candidate for an "ideal" set of mathematical and statistical knowledge bases that can guarantee statistical literacy. (Indeed, this author would be happy if most adults possessed such knowledge.) However, what is "basic" knowledge cannot be discussed in absolute terms, but depends on the desired level of statistical literacy expected of citizens, on the functional demands of contexts of action (e.g., work, reading a newspaper), and on the characteristics of the larger societal context of living. Hence, the above list may not be appropriate for all cultural contexts, may be an overspecification in some cases, and other elements could be added to it.

Unfortunately, no comparative analysis has so far systematically mapped the types and relative prevalence of statistical and probabilistic concepts and topics across the full range of statistically-related messages or situations that adults may encounter and have to manage in any particular society. Hence, no consensus exists on a basis for determining the statistical demands of common media-based messages. To date, only a single comparative study (Joram, Resnick & Gabriele, 1995) addressed this complex issue, by analyzing the characteristics of rational numbers (especially fractions, percents, and averages) that appear in weekly or monthly magazines written for children, teenagers, and adults in the United States. This study was based on the assumption that it is useful to view literacy not only as a skill or ability but also as a set of cultural practices that people engage in, and hence that it is important to examine the characteristics of the texts that people may have to make sense of, and ask how these characteristics shape people's literacy practices.

Regarding adults, Joram *et al.* (1995) sampled seven widely-circulated magazines that aim at different types of readers: *Reader's Digest, National Geographic, Better Homes and Gardens, National Enquirer, Time, Consumer Reports,* and *Sports Illustrated.* They applied a complex coding scheme to capture the number of occurrences of rational numbers, especially fractions, percents, and averages, in the middle 20 pages of one issue. Some findings that are relevant for the present paper were:

- The mean frequencies (per 20 pages) of fractions, percents, and averages were 4.86, 10.00, and 2.00, respectively.
- Regarding percents found in these magazines, about half expressed part/whole relations ("The nation's 113 nuclear reactors already generate 20 percent of our electricity"), and one third referred to increase/decrease ("If ... electricity consumption increases by 2.5 percent a year, we could be headed for real problems").
- Only 14% of statements regarding rational numbers in adult magazines were modified by a part of speech such as an adjective ("An astonishing 35 percent of all ..."). This finding suggested to Joram *et al.* that authors in adult magazines do not provide a great deal of interpretation of numbers in their immediate context and hence numbers are usually allowed to speak for themselves.
- Four of the seven adult magazines contained within the pages sampled at least one table or graph. Overall, the seven magazines included four tables, four bar graphs, and one pyramid graph (used to show quantities).

These and other findings reported by Joram *et al.* suggest that percents are the most common rational number in magazines used to convey statistical information (see also Parker & Leinhardt, 1995), and that numerical or statistical information may appear in tables and not only in graphs. In order to make full sense of statistical information appearing in magazines, adults should be able to understand plain passages that provide the context for the rational numbers or graphs shown, and relate different elements in given passages or displays to each other. These conclusions agree with and complement the earlier discussion of literacy skills needed for interpreting statistical messages.

Table 2

Five parts of the statistical knowledge base.

1. Knowing why data are needed and how data can be produced
2. Familiarity with basic terms and ideas related to descriptive statistics
3. Familiarity with basic terms and ideas related to graphical and tabular displays
4. Understanding basic notions of probability
5. Knowing how statistical conclusions or inferences are reached

Beyond the data by Joram *et al.* (1995), there is no comprehensive research base from which to establish the statistical literacy requirements in the full range of domains and environments where adults function. Five key parts of the statistical knowledge base required for statistical literacy are proposed here and summarized in Table 2. These building blocks were identified on the basis of reviewing writing by mathematics and statistics educators (such as Shaughnessy, 1992; Moore, 1990, 1997b; chapters in Steen, 1997; chapters in Gal & Garfield, 1997; chapters in Lajoie, 1998; NCTM, 2000), sources on scientific literacy (e.g., Shamos, 1995; AAAS, 1995), and sources discussing mathematics and statistics in the news (e.g., Huff, 1954; Hooke, 1983; Crossen, 1994; Paulos, 1995; Kolata, 1997).

1. *Knowing why data are needed and how data can be produced.* Overall, adults should posses some understanding of the origins of the data on which reported findings or displays are based, understand the need to know how data were produced, and be aware of the contribution of a good design for data production to the possibility of answering specific questions (Cobb & Moore, 1997). Adults should also be aware that public officials, organizations, employers, advertisers, and other players in the public arena need to base claims or conclusions on credible empirical evidence, and that properly produced data can inform public debate and serve as a basis for decisions and allocation of resources, much better than anecdotal evidence (Moore, 1998).

To enable critical understanding of reported findings or data-based claims, adults should possess some knowledge, at least informal, of key "big ideas" that underlie statistical investigations (Garfield & Gal, 1999). The first on the list of most statisticians is the existence of variation (Moore, 1998). The need to reduce data in order to identify key features and trends despite noise and variation should be understood by adults as it provides the basis for accepting the use of statistical summaries (e.g., means, graphs) as tools for conveying information from data producers to data consumers (Wild & Pfannkuch, 1999).

Further, adults should possess some understanding of the logic behind key research designs commonly mentioned in the media, primarily experiments and the reason for using experimental and control groups to determine causal influences (see Excerpt #6 in Figure 1); census (Excerpt #2); polls/surveys (Excerpts #3 and #4); and perhaps the role and limitations of a pilot study. Given the prevalence of polls and surveys, adults should also understand, at least intuitively, the logic of sampling, the need to infer from samples to populations, and the notions of representativeness and especially bias in this regard (Cobb & Moore, 1997; Wild & Pfannkuch, 1999). Some specific ideas to be known in this regard are the advantages of probability sampling, the dangers of convenience sampling, or the influence of the sampling process, sample size, and sample composition on researchers' ability to generalize safely and infer about a population from sample data.

2. *Familiarity with basic terms and ideas related to descriptive statistics.* Assuming adults understand why and how data are produced, they need to be familiar with basic concepts and data displays that are commonly used to convey findings to target audiences. Two key types of concepts whose centrality is noted by many sources are percents (Parker & Leinhardt, 1995) and measures of central tendency, mainly the arithmetic mean (often termed "average" in newspapers) but also the median. Gal (1995) argues that it is desirable for consumers of statistical reports to know that means and medians are simple ways to summarize a set of data and show its "center"; that means are affected by extreme values, more so than medians; and that measures of center can mislead when the distribution or shape of the data on which they are based is very uneven or bi-modal, or when the data or sample from which they are calculated are not representative of the whole population under study (see excerpt #5 in Figure 1). More broadly, it is useful for adults to be aware that different types of seemingly simple summary indices (i.e., percent, mean, median) may yield different, and at times conflicting, views of the same phenomena.

3. *Familiarity with graphical and tabular displays and their interpretation.* Adults should know that data can be displayed or reported in both graphical and tabular displays, which serve to organize multiple pieces of information and enable the detection or comparison of trends in data (Tufte, 1997). In this regard, one hopes that adults can first of all perform literal reading of data in tables or graphs, be familiar with standard conventions in creating graphs and charts, and be attentive to simple violations of such conventions (Bright & Friel, 1998) such as those in the graph in Figure 3: the relative length of the bars is not proportional to the actual percentages, and neither is the positioning of the boxes with percents inside each bar; the decision of the graphical artist to add a female figure on the left (probably for decoration or to gain attention) masks the length of some bars and renders the visual appearance misleading. In this case, one hopes that readers realize the need to examine the actual percentages.

It is also expected that adults can do, on some level, what Curcio (1987) and Wainer (1992) call "reading between the data" and "reading beyond the data", such as understand that projections can be made from given data, and that one should look at overall patterns and not only at specific points in a graph or a table (Gal, 1998). Adults should also realize that different graphs and tables may yield different (and possibly conflicting) views of the phenomena under investigation. Finally, adults should be aware that graphs can be intentionally created to mislead or highlight/hide a specific trend or difference. Various examples in this regard have been presented by Huff (1954). (See also Orcutt & Turner's (1993) analysis, discussed later, of how *Newsweek* magazine manipulated survey data on drug use to advance a specific point of view).

4. *Understanding basic notions of probability.* Ideas regarding chance and random events are explicit or implicit in many types of messages adults encounter. Many statistical reports make probabilistic statements in the context of presenting findings from surveys or experiments, such as the likelihood of obtaining certain results (see Excerpts #1 and #6). Messages can also include probabilistic estimates made by various professionals (weather forecasters, genetic counselors, physicians, admissions administrators in colleges) regarding the likelihood of various events or the degree of confidence in their occurrence (rain, risks, side-effects, or acceptance, respectively). Some of these claims may not be based on statistical studies, and could be couched in subjective estimates of individuals.

It is safe to expect that at a minimum, adults should be sensitive to the problem of interpreting correctly the "language of chance" (Wallsten, Fillenbaum & Cox, 1986). Adults should have a sense for the many ways in which estimates of probability or risk are communicated by various sources, such as by percents, odds, ratios, or verbal estimates. (Excerpt #6 illustrates how these combine in complex ways within a single article.)

Next, there is a need for adults to be familiar with the notion of randomness, understand that events vary in their degree of predictability or independence, yet also that some events are unpredictable (and hence that co-occurrence of certain events does not mean that they are necessarily related or cause each other). Unfortunately, while possible, it is difficult to present more advanced or explicit expectations for adults in terms of understanding random processes without appearing simplistic or naive. People from all walks of life have been shown to hold many misconceptions and discontinuities in understanding and reasoning about stochastic phenomena (Konold, 1989; Gal & Baron, 1996; Shaughnessy, Garfield & Greer, 1997). Further, understanding of random phenomena also takes part in cognitive processes of judgment, decision-making, and rationality, in which various deficiencies have been documented as well (Baron, 1988; Mellers, Schwartz & Cooke, 1998).

Nonetheless, if adults are to understand and critically evaluate probabilistic claims, they should at least recognize the importance of ascertaining the *source* for probability estimates. Adults should realize that estimates of chance and risk may originate from diverse sources, both formal (e.g., frequency data, modeling, experimentation) and subjective or anecdotal, and that estimates may have different degrees of credibility or accuracy. Thus, they should expect that the evidence or information basis for statements of chance can be specified by those who make claims, and that judgments of chance may fluctuate and forecasts may change when additional data become available (Clemen & Gregory, 2000).

A final and more advanced expectation is that adults understand, at least intuitively, the idea of a chance variability in (random) phenomena. As Cobb & Moore (1997) explain, "When a chance mechanism is explicitly used to produce data, probability . . . describes the variation we expect to see in repeated samples from the same population" (p. 813). Some understanding of probability is thus also a gateway to making sense of statements about the significance of differences between groups or likelihood of obtaining certain results, since standard statistical inference is based on probability (Cobb & Moore, 1997).

5. *Knowing how statistical conclusions or inferences are reached*. Whereas most adults are data-consumers and not producers, they do need to have a grasp on some typical ways to summarize data, such as by using means or medians, percents, or graphs. However, given that there are different designs for collecting data, and that sampling processes or random processes may be involved, adults also need to possess some sense of how data are analyzed and conclusions reached, and be aware of relevant problems in this regard.

First, adults need to be sensitive to the possibility of different *errors* or *biases* (in sampling, in measurement, in inference) and possess a healthy concern regarding the stability and generality of findings. Second, it is useful to realize that errors may be controlled through proper design of studies, and can be estimated and described, e.g., by means of probability statements. One concept mentioned in the media in this regard is "margin of error" (see Excerpt #3, and the implicit mentioning of inflated scores in Excerpt #5). Third, it is useful to know that there are ways to determine the significance or "trueness" of a difference between groups, but that this requires attention to the size of the groups studied, to the quality of the sampling process and the possibility that a sample is biased (understanding of these notions is needed if one is to think critically of the claims in Excerpts #1 and #6). Finally, it is important to be aware that observed differences or trends may exist but may not necessarily be large or stable enough to be important, or can be caused by chance processes (as is the case with the reported increase in sexual intercourses in Excerpt #4).

3.3 Mathematical Knowledge Base

A determination of the types of mathematical knowledge expected of adults to support statistical literacy should be made with caution. On the one hand, adults clearly need to be aware of some of the mathematical procedures underlying the production of common statistical indicators, such as percent or mean. At the same time, expectations regarding the amount and level of formal mathematics needed to comprehend basic statistical ideas taught at the introductory college level (or in high schools) have been changing in recent years (Moore, 1998). A brief detour to describe leading ideas in this regard is offered below to help frame later statements about the mathematical knowledge base needed for statistical literacy.

Statisticians have gradually clarified over the last few years the nature of some fundamental differences between mathematics and statistics (Moore & Cobb, 2000), and have formulated some working assumptions about the general level of mathematics one needs to learn statistics, at least at the introductory college level. Cobb & Moore (1997) summarize recommendations of the ASA/MAA committee on statistics instruction (Cobb, 1992), and suggest that while statistics makes heavy use of mathematics, statistics instruction at the introductory college level should focus on *statistical* ideas (need for data and importance of data production, omnipresence of variability, need to explain and describe variability).

Understanding the mathematical derivations that underlie key ideas presented in introductory statistics is of some importance but should be kept limited, since computers now automate many computations. While there is no intention of leading students to accept statistical derivations as magic (i.e., without knowing any of the underlying mathematics), too much emphasis on mathematical theory is not expected early on; it may disrupt the development of the necessary intuitive understanding of key statistical ideas and concepts that often do not have mathematical representations and are unique to the discipline of statistics (Moore, 1997a; Wild & Pfannkuch, 1999). Cobb & Moore (1997) further claim that probability is conceptually the hardest subject in elementary mathematics, and remind that psychological studies have documented confusion about probability even among those who master the computational side of probability theorems and can solve textbook exercises. Hence, even for understanding of the formal aspects of inference or of probability, only a limited amount of mathematical knowledge is expected.

The above logic can help in determining the mathematical knowledge that adults need to support statistical literacy. Given that most adults in any country do not study statistics at the college level (Moore & Cobb, 2000; UNESCO, 2000), the amount and level of formal knowledge of mathematics needed to support adult statistical literacy can be restricted.

Perhaps the simplest knowledge expected of adults is the realization that any attempt to summarize a large number of observations by a concise quantitative statement (percent, mean, probability, etc.) requires some application of mathematical tools and procedures. Adults need to have numeracy skills at a sufficient level to enable correct interpretation of numbers used in statistical reports. "Number sense" is increasingly being touted as an essential skill for proper understanding of diverse types of numbers (Paulos, 1995; Curry, Schmitt & Waldron, 1996; Scheaffer et al., 1998; NCTM, 2000), such as large numbers (e.g., trends in GNP) and small numbers, including fractions, decimals, and percents (e.g., estimates of risk or side effects).

Understanding of basic statistical findings pertaining to percents or "averages" requires familiarity, intuitive and to some extent formal, with underlying mathematical procedures or computations used to generate these statistics (Garfield & Gal, 1999). Citizens should know *how* an arithmetic mean is computed in order to fully appreciate the meaning of the claim that an arithmetic mean can be influenced by extreme values in a data set and hence may not represent the "middle" of a set of values if the data are skewed. Excerpt #5 shows a variant on this demand, i.e., understanding of the impact of *excluding* a certain proportion of extreme observations (6% in the example given) on the central tendency.

Many types of statistical information reported in the media are described in terms of percents (Joram et al., 1995) and are sometimes included in graphs. Numerous examples can be found in Figures 1 and 2. Percent is a seemingly simple mathematical concept, commonly perceived as expressing a proportion or ratio; it is presumably mastered in the middle grades, and hence it could be expected that the vast majority of schooled adults will understand it. Yet, its understanding is far from being simple. Parker & Leinhardt (1995) address the prevalence and complexity of percents, and also point to specific types of percents that normally are not encountered in routine classroom teaching but may appear in newspaper statements, such as percents larger than 100% or percent of percent. These authors argue that generations of students, including at the college level, have failed to fully master percent, in part because it is a multi-faceted concept that has multiple mathematical meanings and also statistical uses (e.g., a number, an expression of a relationship, a statistic, a function, an expression of likelihood). Understanding the mathematical and statistical meaning of a reported percent can be difficult. Readers may have to make inferences and assumptions, e.g., when a message does not specify the base for calculating a percent. Percents may represent complex relationships (e.g., conditional probabilities) and, as illustrated in Figure 1, may be linked to concepts that themselves have multiple meanings (such as "15 percent below average", "2% margin of error").

The examples pertaining to percents and computations of means and medians imply that interpretation of even seemingly simple statistics reported in the media requires some familiarity with their derivation (though not always formal training in this regard). It follows that adults should understand, at least informally, some of the mathematics involved in generating certain statistical indicators, as well as the mathematical connection between summary statistics, graphs, or charts, and the raw data on which they are based.

Questions about the amount of mathematics one needs to know to understand more sophisticated concepts are more difficult to answer and have been the source of some debate among statistics and mathematics educators (Moore, 1997a). Terms or phrases that appear in the media, such as "margin of error" or "statistically significant difference", *can* be understood intuitively in a way that can help adults without formal statistical training make a superficial sense of news items. After all, such ideas are being successfully taught at an introductory level to children in elementary or middle schools (Friel, Russell & Mokros, 1990). However, deeper understanding of the above or related concepts,

and proper interpretation of their *exact* meaning, require more solid understanding of underlying statistical ideas (quantification of variance, repeated sampling, sampling distributions, curves, logic of statistical inference, etc). These ideas are hard to grasp for college-bound students (Cobb & Moore, 1997; Watson & Moritz, 2000) even without the added complication of the need to understand their mathematical underpinnings.

3.4 Context/World Knowledge Base

Proper interpretation of statistical messages by adults depends on their ability to place messages in a context, and to access their world knowledge. World knowledge also supports general literacy processes and is critical to enable "sense-making" of any message. Moore (1990) has argued that in statistics, the context motivates procedures; data should be viewed as numbers with a context, and hence the context is the source of meaning and basis for interpretation of obtained results. In Reading contexts, however, people do *not* engage in generating any data or in carrying any computations or analysis. Their familiarity with the data-generation process (e.g., study design, sampling plan, questionnaires used), or with the procedures employed by the researchers or statisticians to analyze the data, depends on the details and clarity of the information given in the messages presented to them. As passive receivers of messages they are at the mercy of message creators.

It follows that adults' ability to make sense of statistical claims or displays will depend on whatever information they can glean from the message about the background of the study or data being discussed. Context knowledge is the main determinant of the reader's familiarity with *sources for variation and error*. If a listener or reader is not familiar with a context in which data were gathered, it becomes more difficult to imagine why a difference between groups can occur, what alternative interpretations may exist for reported findings about an association detected between certain variables, or how a study could go wrong.

The ways in which a study is reported in the media can easily mask or distort the information available to the reader about the source of the evidence presented. An example is when a reporter uses the term "experiment" in a way that enhances the face validity of a study that is non-experimental in nature. Thus, world knowledge, combined with some literacy skills, are prerequisites for enabling critical reflection about statistical messages and for understanding the implications of the findings or numbers reported. Adults can be helped by having a sense for, and expectations about, elements of good journalistic writing, such as for objective writing, presentation of two-sided arguments, accuracy in reporting, or provision of background information to orient readers to the context of a story.

3.5 Critical Skills

Messages aimed at citizens in general may be shaped by political, commercial, or other agendas which may be absent in statistics classrooms or in empirical enquiry contexts. Fred Mosteller said, "Policy implies politics, and politics implies controversy, and the same data that some people use to support a policy are used by others to oppose it" (cited in Moore, 1998, p. 1255). Not surprisingly, the need for critical evaluation of messages to the public has been a recurring theme in writings of educators interested in adults' literacy and numeracy (Freire, 1972; Frankenstein, 1989).

As noted in discussing literacy skills, messages in the general media are produced by very diverse sources, such as journalists, politicians, manufacturers, or advertisers. Depending on their needs and goals, such sources may not necessarily be interested in presenting a balanced and objective report of findings or implications. A potent example is Orcutt & Turner's (1993) analysis of how the print media, especially *Newsweek* magazine, selectively analyzed and intentionally manipulated trend data collected by the Institute for Social Research (ISR) regarding drug use among American high-school

students between 1975–1985. According to Orcutt & Turner, the media attempted to create for the public an image of a "drug plague", by selecting at its convenience only some of the data collected as part of a multi-year survey project, using graphical methods to augment small percentage differences (after truncating and censorizing), to appear visually large.

Orcutt & Turner (1993) add that later in 1992 *Newsweek* attempted again to create a sense of national danger by reporting that the use of LSD is "rising alarmingly" and that for the first time since 1976, more high-school seniors used LSD than cocaine. However, analysis of the ISR data on which *Newsweek* based this argument showed that this argument had no empirical basis. Cocaine use decreased from 6.5% in 1989 to 5.3% in 1990, a statistically significant change (given sample size used), whereas LSD use increased from 4.9% to only 5.4%, which was within the range of sampling error. The contrast between these figures, which were available to *Newsweek*, and the narrative and graphs used in the articles published, suggest an intentional misuse of data and highlights the media's tendency for sensational reporting practices.

Excerpts #4 and #6 (Figure 1) further illustrate how data can be tailored to serve the needs of specific organizations (e.g., states and manufacturers), and how reports about data are shaped to influence the opinions of the listener or reader in a specific direction. Paulos (1995, p. 79) notes that originators of messages regarding diseases, accidents, or other misfortunes that afflict humans, depending on their interest, can make them appear more salient and frightening by choosing to report absolute numbers (e.g., 2500 people nationwide suffer from X), or in contrast can downplay them by using incidence rate (e.g., 1 in every 100,000 people suffer from X). Many examples are also presented by Huff (1954) and Crossen (1994).

Table 3

Sample "worry questions" about statistical messages.

1. Where did the data (on which this statement is based) come from? What kind of study was it? Is this kind of study reasonable in this context?

2. Was a sample used? How was it sampled? How many people did actually participate? Is the sample large enough? Did the sample include people/units which are representative of the population? Is the sample biased in some way? Overall, could this sample reasonably lead to valid inferences about the target population?

3. How reliable or accurate were the instruments or measures (tests, questionnaires, interviews) used to generate the reported data?

4. What is the shape of the underlying distribution of raw data (on which this summary statistic is based)? Does it matter how it is shaped?

5. Are the reported statistics appropriate for this kind of data, e.g., was an average used to summarize ordinal data; is a mode a reasonable summary? Could outliers cause a summary statistic to misrepresent the true picture?

6. Is a given graph drawn appropriately, or does it distort trends in the data?

7. How was this probabilistic statement derived? Are there enough credible data to justify the estimate of likelihood given?

8. Overall, are the claims made here sensible and supported by the data? e.g., is correlation confused with causation, or a small difference made to loom large?

9. Should additional information or procedures be made available to enable me to evaluate the sensibility of these arguments? Is something missing? e.g., did the writer "conveniently forget" to specify the base of a reported percent-of-change, or the actual sample size?

10. Are there alternative interpretations for the meaning of the findings or different explanations for what caused them, e.g., an intervening or a moderator variable affected the results? Are there additional or different implications that are not mentioned?

In light of such examples, and the possibility for biased reporting (Wanta, 1997), adults have to worry about and examine the reasonableness of claims presented in the media. They have to be concerned about the validity of messages, the nature and credibility of the evidence underlying the information or conclusions presented, and reflect upon possible alternative interpretations of conclusions conveyed to them. It follows that adults should maintain in their minds a list of "worry questions" regarding statistical information being communicated or displayed (Gal, 1994; Moore, 1997b; Garfield & Gal, 1999). Ten such questions are listed in Table 3. When faced with an interpretive statistical task, people can be imagined running through this list and asking for each question, "Is this question relevant for the situation/message/task I face right now?"

The answers people generate to these and related questions can support the process of critical evaluation of statistical messages and lead to the creation of more informed interpretations and judgments. This list can of course be modified, and some of its elements regrouped, depending on the life contexts and functional needs of different adults. It can expand beyond basic statistical issues to cover broader issues of probability and risk, or job-specific statistical topics such as those related to statistical process control or quality assurance.

3.6 Interaction of Knowledge Bases

Five knowledge bases were described above separately for ease of presentation, but they overlap and do not operate independently from each other. For example, familiarity with possible language ambiguities and reporting conventions comprise part of the literacy skills required of adults, yet are also part of general world knowledge, and related to the need for knowledge about intentional (and possibly biased) reporting practices listed as part of critical skills. Some aspects of the statistical knowledge base overlap with mathematical knowledge, for example regarding the difference in the computational procedures used to find medians and means and their implication for interpretation of such statistics under different conditions.

The characteristics of certain real-world messages require that adults jointly activate all the knowledge based described in order to manage tasks at hand (Gal, 1997). Figure 2 exemplifies the complex task that may face readers of print media with regard to interpreting information of a statistical nature, and illustrates the interconnected nature of the knowledge bases that underlie people's statistical literacy.

Figure 2 recreates a portion of a table that appeared in *USA Today* (a nationally circulated daily newspaper) in 1999. This table combines an off-beat opening passage with a tabular display of several simple lists, each containing information of a different nature: absolute numbers, averages, percents. Interpretation of the table requires not only basic familiarity with averages and percents, but also literacy skills and access to different kinds of background knowledge. Some details needed to make complete sense of the mathematical information are not fully stated, forcing the reader to perform inferences, based on his or her general world knowledge: averages are denoted as "avg." and percent as "pct. chg", both non-standard abbreviations; the averages are "per site", but it is not explained what is a "site" and if the average is calculated for a whole week or a weekend only; percents describe *change* in negative numbers, yet the base is not given, only implied.

4 Dispositional Aspects of Statistical Literacy

The notion of "critical evaluation", highlighted in several of the conceptions of statistical literacy cited earlier (e.g., Wallman, 1993), implies a form of action, not just passive interpretation or understanding of the statistical or probabilistic information available in a situation. It is hard to describe a person as fully statistically literate if this person does not show the *inclination to activate* the five knowledge bases described earlier or share with others his or her opinions, judgments, or alternative interpretations.

Statistically literate action can take many forms, both overt and hidden. It can be an internal mental process, such as thinking about the meaning of a passage one read, or raising in one's mind some critical questions and reflecting about them. It can be extended to more external forms, such as re-reading a passage, scanning a graph one encountered in the newspaper, stopping a game of chance after one remembers reading an article about the Gambler's Fallacy, or discussing findings of a survey one heard about on TV with family members at the dinner table or with co-workers. However, for any form of action to occur and be sustained, certain dispositions need to exist and be activated.

The term 'dispositions' is used here as a convenient aggregate label for three related but distinct concepts, critical stance, beliefs, and attitudes, which are all essential for statistical literacy. These concepts are interconnected (McLeod, 1992), and hence are harder to describe in a compartmentalized way, unlike the description of the five knowledge bases above. This section first describes critical stance, and then examines beliefs and attitudes that underlie a critical stance.

Critical stance. A first expectation is that adults hold a propensity to adopt, without external cues, a questioning attitude towards quantitative messages that may be misleading, one-sided, biased, or incomplete in some way, whether intentionally or unintentionally (Frankenstein, 1989). They should be able and willing to spontaneously invoke their personal list of worry questions (see Table 3) when faced with arguments that purport to be based on data or with reports of results or conclusions from surveys or other empirical research (Gal, 1994).

It is important to keep in mind that willingness to invoke action by adults when they encounter statistical information or messages may sometimes be required under conditions of uncertainty. Examples are lack of familiarity with the background of the issues discussed or estimates conveyed, partial knowledge of concepts and their meanings, or the need to cope with technical terms that "fly above the head" of the Reader. This may be the case for many adults without much formal education or effective literacy skills, who constitute a sizable percentage of the population in many countries (Statistics Canada and OECD, 1996; UNESCO, 2000). Action or reaction in such situations may involve taking some personal risks, i.e., exposing to others that one is naive about, or unfamiliar with, certain statistical issues, and possibly suffering some embarrassment or the need to argue with others.

Beliefs and attitudes. Certain beliefs and attitudes underlie people's critical stance and willingness to invest mental effort or occasionally take risks as part of acts of statistical literacy. There is a definitional challenge in discussing "beliefs" and "attitudes" as the distinction between them is somewhat murky. (Researchers, for example, often implicitly defined statistics attitudes or beliefs as whatever their favorite assessment instrument measures in the context of a specific target population, such as school students, college students, or adults at large).

Based on McLeod's (1992) work on affective aspects of mathematics education, a distinction should be made between emotions, attitudes, and beliefs (see also Edwards, 1990; Green, 1993). Emotions are transient positive and negative responses triggered by one's immediate experiences (e.g., while studying mathematics or statistics, or while facing a certain probabilistic situation, such as receiving medical information about the chances of side-effects of a proposed treatment). Attitudes are relatively stable, intense *feelings* that develop through gradual internalization of repeated positive or negative emotional responses over time. Attitudes are expressed along a positive-negative continuum (like-dislike, pleasant-unpleasant), and may represent, for example, feelings towards objects, actions, or topics ("I don't like polls and pollsters, they always confuse me with numbers"). Beliefs are individually held *ideas* or opinions, such as about a domain ("government statistics are always accurate"), about oneself ("I am really naive about statistical information", "I am not a numbers person"), or about a social context ("The government should not waste money on big surveys"; see Wallman, 1993). Beliefs take time to develop and cultural factors play an important part in their development. They have a larger cognitive component and less emotional intensity than

attitudes, and are stable and quite resistant to change compared to attitudes.

Adults should develop a positive view of themselves as individuals capable of statistical and probabilistic reasoning as well as a willingness and interest to "think statistically" in relevant situations. This assumes that adults hold some *appreciation for the power of statistical processes*, and accept that properly planned studies have the potential to lead to better or more valid conclusions than those obtained by relying on anecdotal data or personal experiences (Moore, 1998). Broader metacognitive capacities that are considered part of people's general intellectual functioning can further support statistically literate behavior, such as having a propensity for logical reasoning, curiosity, and open-minded thinking (Baron, 1988).

Gal, Ginsburg & Schau (1997) examined the role of attitudes and beliefs in statistics education, and argued that to enable productive problem-solving, learners need to feel safe to explore, conjecture, and feel comfortable with temporary confusion or a state of uncertainty. It was argued earlier that reading contexts, where people are data consumers, differ in several ways from those encountered in enquiry contexts such as those addressed by Gal *et al.* (1997). Yet, some commonality between these two contexts does exist regarding the required beliefs that support action. Even in reading contexts adults have to feel safe to explore and hypothesize, feel comfortable being in the role of a critical reader or listener, and believe in their ability to make sense of messages (Gal, 1994), as a condition for developing and sustaining their motivation for critical action.

Finally, we come to a point where "critical stance" and "beliefs and attitudes" mesh together. For a critical stance to be maintained, adults should develop a *belief in the legitimacy of critical action*. Readers should uphold the idea that it is legitimate to be critical about statistical messages or arguments, whether they come from official or other sources, respectable as they may be. Adults should agree that it is legitimate to have concerns about any aspect of a reported study or a proposed interpretation of its results, and to raise pertinent "worry questions", even if they have not learned much formal statistics or mathematics, or do not have access to all the background details needed.

5 Discussion and Implications

The main goal of this paper was to propose a conceptualization of statistical literacy and describe its key components. Given the patchy nature of literature on statistical literacy, the availability of such a model was seen as a necessary prefatory step before further scholarly discussion can ensue regarding the issues involved in developing or studying adult statistical literacy. Statistical literacy was portrayed in this paper as the ability to interpret, critically evaluate, and if needed communicate about statistical information, arguments, and messages. It was proposed that statistically literate behavior requires the joint activation of five interrelated knowledge bases (literacy, statistical, mathematical, context/world, and critical), yet that such behavior is predicated on the presence of a critical stance and supporting beliefs and attitudes.

The proposed conceptualization highlights the key role that *non*-statistical factors and components play in statistical literacy, and reflects the broad and often multi-faceted nature of the situations in which statistical literacy may be activated. That said, several observations should be made. First, the five knowledge bases discussed in this paper were sketched in broad strokes to clarify the key *categories* of knowledge to be considered when thinking of what adults needs to know to be statistically literate. Each could be modified or elaborated, depending on the cultural context of interest, and on the sophistication of statistical literacy expected of citizens or workers in a given country or community. As with conceptions of other functional skills, the particulars viewed as essential for statistical literacy in a specific country will be dynamic and may have to change along with technological and societal progress.

Secondly, although five knowledge bases and a cluster of beliefs, attitudes and a critical stance were proposed as jointly essential for statistical literacy, it does not necessarily follow that a person

should fully possess all of them to be able to effectively cope with interpretive tasks in all reading and listening contexts. Following current conceptions of adult literacy (Wagner *et al.*, 1999) and numeracy (Gal, 2000), statistical literacy should be regarded as a set of capacities that can exist to different degrees within the same individual, depending on the contexts where it is invoked or applied. Descriptions of what constitutes statistical literacy may differ in work contexts, in personal/home contexts, in public discourse contexts, and in formal learning contexts.

In the light of the centrality of statistical literacy in various life contexts, yet also its complex nature, educators, statisticians, and professionals interested in how well citizens can interpret and communicate about statistical messages face numerous challenges and responsibilities. Below is a preliminary discussion regarding two key areas, education for statistical literacy, and suggested research in this area.

5.1   Educational Challenges

Several countries and organizations have introduced programs to improve school-level education on data-analysis and probability, sometimes called data handling, stochastics, or chance (Australian Education Council, 1991; National Council of Teachers of Mathematics, 2000). Yet, at the school level, where most individuals will receive their only formal exposure to statistics (Moore, 1998), these topics overall receive relatively little curricular attention compared to other topics in the mathematical sciences. The most credible information in this regard comes from the curriculum analysis component of TIMSS, the Third International Mathematics and Science Study (Schmidt, McKnight, Valverde, Houang & Wiley, 1997), which examined curriculum documents and textbooks and consulted with expert panels from over 40 countries. TIMSS data also pointed to an enormous diversity in curricular frameworks. Various gaps have been documented by TIMSS between the intended and implemented curriculum, i.e., between curriculum plans and what actually appears in mainstream textbooks, which tend to be conservative.

TIMSS tests included few statistics items, hence it was not possible to create a separate scale describing student performance in statistics. However, achievement on individual statistical tasks was problematic. For example, Mullis, Martin, Beaton, Gonzalez, Kelly & Smith (1998) reported performance levels of students in their *final* year of schooling (usually grade 12) on a task directly related to statistical literacy: explain whether a reporter's statement about a "huge increase" was a reasonable interpretation of a bar graph showing the number of robberies in two years that was manipulated to create a specific impression. The graph included a bar for each year but a truncated scale, causing a small difference between years to appear large. Performance levels varied across countries; on average, *less than half* of all *graduating* students appeared to be able to cope (at least partially) with this task that exemplifies one of the most basic skills educators usually use as an example for a statistical literacy skill expected of all citizens: i.e., ability to detect a discrepancy between displayed data and a given interpretation of these data. Keeping in mind that in many countries a sizable proportion of students drop out or leave *before* the final year of high school, the overall percentage of all school leavers who can cope with such tasks is bound to be even lower.

Efforts to improve statistics education at the secondary or post-secondary levels examine needed changes in a range of areas, including in content and methods, teacher preparation and training, assessments, the use of technology (e.g., Cobb, 1992; Pereira-Mendoza, 1993; Gal & Garfield, 1997; Lajoie, 1998). Yet, a crucial question is, To what extent can such efforts develop students' interpretive and statistical literacy skills? To appreciate the complexity of the issues implicated by this question, consider the situation in the related area of scientific literacy. Eisenhart, Finkel & Marion (1996) have argued that the broad, progressive, and inclusive vision of scientific literacy in reform proposals is being implemented in narrow and conventional ways, hence reform efforts may not lead to significant changes in national scientific literacy. To help define educational goals, it may be possible to identify levels of statistical literacy (Watson, 1997; Watson & Moritz, 2000) in a similar

fashion to the continuum proposed to describe levels of scientific literacy (Shamos, 1995).

This paper argues that statistical literacy depends on possession of elements from *all* five different knowledge bases, and that literacy skills, contextual knowledge, critical skills, and needed dispositions, play a significant role in this regard. It is not at all clear that learning statistical facts, rules, and procedures, or gaining personal statistical experience through a data-analysis project in a formal classroom enquiry context can in itself lead to an adequate level of statistical literacy.

Calls to change traditional approaches to teaching statistics have been repeatedly made in recent years, and met with some success (Moore & Cobb, 2000). Yet, educators have to distinguish between teaching more statistics (or teaching it better) and teaching statistics *for a different (or additional) purpose*. Literacy demands facing students who are learning statistics are more constrained than those described in Section 3.1 as characterizing Reading contexts. When students who learn statistics read or listen to project reports created by their fellow students (Starkings, 1997), or when they read academic research papers, findings and conclusions are likely to be shared through language that is less varied than what appears in real-world sources. This may happen because academic conventions inhibit or channel the type of expressions and styles that authors, students and teachers are expected to use, or due to logistical limitations in large introductory statistics courses that restrict the richness and scope of classroom discourse that teachers can afford to conduct (Wild, Triggs & Pfannkuch, 1997). When students encounter an unfamiliar or ambiguous term, they can clarify its interpretation by talking with the teacher, unlike consumers of the media. The upshot is that the literacy demands in statistics classes do not necessarily represent the heterogeneous communicative environment within which adults in general have to cope with statistical messages.

To develop statistical literacy, it may be needed to work with learners, both younger students and adults, in ways that are different from, or go beyond, instructional methods currently in use. To better cover all knowledge bases supporting statistical literacy, topics and skills that are normally not stressed in regular statistics modules or introductory courses, for lack of time or teacher preparation, may have to be addressed. Some examples are:

- understanding results from polls, samples, and experiments (Landwehr, Swift & Watkins, 1987; MacCoun, 1998) *as reported in newspapers or other media channels*,
- understanding probabilistic aspects of statements about risk and side effects (Clemen & Gregory, 2000) *as reported in newspapers or other media channels*,
- learning about styles, conventions, and biases in journalistic reporting or advertisements,
- familiarity with "worry questions" (Table 3), *coupled* with experience in applying them to real examples (such as one-sided messages, misleading graphs), or seeing someone else, e.g., a teacher, model their application.
- development of a critical stance and supporting beliefs, including positive beliefs and attitudes about the domain (usefulness of statistical investigations) and oneself.

TIMSS reports on curriculum planning and other school-related variables imply that young people who will be leaving schools in coming years may continue to have insufficient preparation in data analysis and probability. An important and presently much larger population is that of adults in general. The majority of the current adult population in any country has not had much if any formal exposure to the statistical or mathematical knowledge bases described earlier, given known education levels across the world (Statistics Canada & OECD, 1996; UNESCO, 2000). As IALS (Organisation for Economic Co-operation and Development (OECD) & Human Resources Development Canada, 1997) and other studies have shown, even in industrialized countries, literacy levels of many adults are low. This paper argues that literacy skills, including document literacy skills, are an important component of the knowledge base needed for statistical literacy. It follows that achieving the vision of "statistical literacy for all" will require a concerted effort by various educational and other systems, both formal and nonformal.

Large numbers of adult learners receive important educational services from adult basic education centers, adult literacy programs, workplace learning and union-based programs, and continuing education or tertiary institutions. These services have an important role in promoting statistical literacy of adults, and some have began to formally recognize the need to attend to statistical issues and to critical evaluation of messages as part of designing curricula for adult learners (European Commission, 1996; Curry *et al.*, 1996; Stein, 2000). Yet, media organizations and media professionals (Orcutt & Turner, 1993) public and private agencies and institutes that communicate with the public on statistical matters, such as national statistical offices (Moore, 1997b), and even marketers and advertisers (Crossen, 1994), all have some responsibility in this regard. All the above stakeholders will have to devise innovative and perhaps unorthodox ways in order to jointly reach and increase statistical literacy in the general population.

5.2   Research and Assessment Challenges

As pointed earlier, the current knowledge base about statistical literacy of school or university students and of adults in general is patchy. In the absence of solid empirical information, the speculative ideas raised in this paper may not translate into action by decision-makers who are in a position to allocate resources to educational initiatives. Three related areas where further research is needed are as follows.

1. **Research on students' and adults' statistical literacy skills.** Studies such as TIMSS (aimed at school students) and IALS (aimed at adults) provided useful but only preliminary data on restricted aspects of people's statistical literacy, mainly because their main thrust was planned to address other mathematical topics. Many knowledge elements basic to statistical literacy were left out of these assessments, e.g., understanding of averages and medians, knowledge about sampling or experimental designs, or understanding of chance-related statements. New international large-scale assessments, such as OECD's Program for International Student Achievement (http://www.pisa.oecd.org), or the Adult Literacy and Lifeskills survey (http://nces.ed.gov) will include broader coverage of statistical matters, in line with expanded notions of mathematical literacy and numeracy developed for these projects. However, given the restrictions on testing time in large-scale studies and the number of domains competing for item coverage, focused studies are needed that can provide more comprehensive information on statistical literacy skills and related attitudes, and on gaps in this regard. Qualitative studies should further enable in-depth examination of thinking processes, comprehension, and effects of instruction in this regard.

2. **Research on statistical literacy demands of various functional environments.** The Joram *et al.* (1995) findings reported earlier shed some light on the range of ways in which selected statistical and numerical information can be conveyed to readers of magazines, and point to the strong linkage between literacy and statistical elements in print media. Yet, little is known about the demands facing consumers of other media channels, such as daily newspapers, workplace materials, or TV broadcasts, and with regard to a range of statistical and probabilistic topics beyond rational numbers. The absence of credible data from which to establish the statistical literacy requirements in the full range of domains where adults have to function is alarming. Research in this area, taking into account variation both within and between countries, is a prerequisite for designing effective and efficient instruction that aims at different levels of statistical literacy.

3. **Research on dispositional variables.** This paper argued that a view of statistical literacy as an action-oriented set of interrelated knowledge-bases and skills, one which people will actually use in everyday contexts, must consider people's inclination to apply a critical stance and the motivations, beliefs, and attitudes that affect or support statistically literate behavior. However, the conceptualization and assessment of these variables present many challenges (Gal *et al.*, 1997). Development of research methods in this regard is essential for understanding the forces that shape statistically literate

behavior in different contexts. Changes in dispositions should be measured as part of evaluating the impact of educational interventions aimed at improving statistical literacy of people in all walks of life.

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Résumé

Dans les sociétés qui voient circuler beaucoup d'information, les citoyens doivent absolument savoir lire des données statistique. Cette compétence clé passe souvent pour un résultat attendu de l'enseignement scolaire et pour une dimension nécessaire de la capacité des adultes à savoir lire, écrire et compter. Pourtant, on a accordé peu d'attention à la signification et à la construction de cette compétence. Cet article propose une conceptualisation de l'aptitude à lire des données statistiques et décrit ses aspects essentiels. Savoir lire des données statistique est présenté comme l'aptitude à interpréter, évaluer de façon critique et communiquer sur l'information et les messages statistique. On soutient que cette aptitude se déduit de l'association simultanée de cinq types de connaissances (alphabétisation, statistique, mathématique, contexte et critique), ainsi que de dispositions personnelles et de convictions favorables. Les implications en termes d'éducation et de recherche sont discutées, et on brosse à grands traits les responsabilités des éducateurs, des statisticiens et des autres personnes concernées.