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This is a review of evidential ideas that appear in the Muqadimmah *and* India, *Medieval Arabic works. The ideas concern numerical evidence, its collection, distortion, analysis, and interpretation, and its use in making statements about change and cause. Potential mistakes in educing the ideas from such translated texts are discussed briefly. Erudite attention to the topic is encouraged in the interest of understanding early parallels to contemporary evaluation problems.*

IDEAS ABOUT SOCIAL RESEARCH, EVALUATION, AND STATISTICS IN MEDIEVAL ARABIC LITERATURE

Ibn Khaldun and al-Biruni

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One of the motives for developing this article stems from recent UNESCO conferences on evaluation techniques in Asia and the Near East (Mukherjee, in press). Several participants expressed the concern that the techniques of applied social research in general and statistical evaluation in particular are more compatible with western culture than eastern. This article's intent is to illuminate this concern in a limited way, notably by identifying early Arabic precedents for some of the "modern" ideas implicit in methods of applied social research.

The second motive is more general. The history of social research, including statistics, deserves serious intellectual attention on its own

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account. Kruskal and Mosteller (1980) and others have increased our understanding of the topic based on relevant occidental literature. Eastern and Middle Eastern material has received far less attention than it deserves to judge from historians and philosophers such as Hacking (1978) and others. This is an effort to rectify the matter in a small way, using two remarkable works, Ibn Khaldun's *Muqaddimah* and al-Biruni's *India.*[1]

BACKGROUND

Ibn Khaldun (1332-1406) was, to judge by his writing, a marvelously talented man. Born to an aristocratic family, he served as a statesman and as advisor to sultans, practiced diplomacy on Spain's Pedro the Cruel, and raised at least one army for dynastic warfare. More importantly, he managed to invent, for the Arab world of the 14th century, a philosophy of history and crude frameworks for new disciplines: applied social and political science and civilization studies.

The *Muqaddimah,* completed in 1377, is an introduction to his history of the world. It reflects a great deal of his invention and scholarship. It has been lauded by Arnold Toynbee, among other historians, as the most remarkable work of its kind. The work has been recognized as a progenitor of modern disciplines of sociology and human ecology by scholars such as O. D. Duncan (1964).

Al-Biruni's (973-1051) work, *India,* is less well-known and is based on his tour of Asia with the conqueror Mahmud of Ghazna. It is important here for two reasons. First, his works contain ideas pertinent to social statistics, applied social research, and numerical evidence. Second, parts of Ibn Khaldun's work reiterate issues discussed by al-Biruni. The similarity in some of their views seems not to have been recognized or investigated by occidental historians. For instance, Duncan's (1964) fascinating treatment of human ecology introduces the topic with quotations from Ibn Khaldun, but there is no reference to similar passages in *India* and other works by al-Biruni (e.g., Wilczynski, 1959). On the other hand, India has been recognized as providing "the kind of materials on which Ibn Khaldun could base his general observations of human history" by Nasr (1968: 231) among others. Works by al-Biruni besides *India* have been analyzed by Eisenhart and Kennedy (1971) in the interest of discovering early predecessors to the contemporary measures of central tendency in statistical data.

The parts of each work that are of special interest here concern activities that the applied social scientist and the statistician must take seriously: determining the quality of information, educing the implications of fragmentary data, developing inferences, and so forth. The *Muqaddimah* treats ideas that underlie such activity partly because Ibn Khaldun's field of inquiry is so great:

> Information about human social organization . . . conditions affecting civilizations, as for instance, savagery and sociability, group feelings. . . . It deals with . . . authority . . . the different kinds of gainful occupations . . . the sciences and crafts and with all the other institutions that originate in civilization [Ibn Khaldun, 1978: 35].

Some of the specific issues he considered fall often into territory now claimed by the pollster, the demographer, social scientist, statistician, and evaluation researcher.

Subject and treatment are distinctive in that this is "an independent science with its own peculiar object . . . human civilization and social organization. . . . [T]his topic is . . . highly useful . . . an entirely original science." Ibn Khaldun admitted that his science includes fragments of other serious intellectual endeavor; e.g., the study of language, jurisprudence, prophecy, and politics. And he acknowledged that other people may have invented such a science but he is unaware of the products.

He distinguished his new science from history partly by recognizing that although history did raise important problems, as it was practiced best at the time, it consisted of only one result: "mere verification of historical information" (Ibn Khaldun, 1978: 39). The stress on usefulness makes the work similar in spirit and often in practice to applied social science.

SOURCES

The material that follows on the *Muqaddimah* is drawn primarily from Rosenthal's (1958) translation from Arabic, from an abridgment of this by Dawood (1978), and from work by Issawi (1950). Most of the direct quotes are taken from Dawood's edition because it is likely to be more accessible to readers. For brevity, translators are indicated by letter—R, D, S, and I respectively—and quotes are followed by letter and page number in parentheses. Remarks on *India* are based on an

abridged edition of the Sachau translation (1971) and on Nasr's (1968) disquisition.

ERRORS IN INFORMATION, ESPECIALLY NUMERICAL INFORMATION

Ibh Khaldun was extraordinarily sensitive to errors of many kinds in reporting. Recognizing that one must rely on a variety of sources whose reliability is unknown, he discourages simple acceptance of reports and identifies numerical information as being particularly susceptible to distortion:

> If one trusts . . . information in its plain transmitted form . . . he often cannot avoid stumbling and slipping and deviating from the path of truth.
>
> This is especially the case with figures, either sums of money or soldiers, whenever they occur. . . . They offer a good opportunity for false information and constitute a vehicle for nonsensical statements [D., 1978: 11].

The reasons for false information, he avers, include the "desire for sensationalism" and an unhealthy "disregard of reviewers and critics" (D., 1978: 13).

To buttress the case that it is wrong to "make a feast of untrue statements" as his antecedents and contemporaries did, he appealed to the Koran (cited in D., 1978: 14): "They procure for themselves entertaining stories in order to lead others away from the path of God" and ends with the announcement that "this is a bad enough business" (p. 14). That is, ploughing through accidentally poor reports is difficult enough without having to cope with stories that are deliberately untrue.

Al-Biruni also made an appeal for truth embellished by less fiction (Sachau, 1971: 4). In considering Hindu reports about the dimensions of a particular mountain, for instance, he remarked that "if there is no limit fixed to guesswork, guesswork may without any hindrance develop into lying" (S., 1971: 248). He looked to both the Koran and the New Testament to sustain his views; e.g., "speak the truth, even if it were against yourselves" (Surah, 4: 134) and "do not mind the fury of winds in speaking the truth before them" (Matthew 10: 18, 19, 28) (S., 1971: 4-5).

Because al-Biruni had to rely heavily on records copied in Sanskrit, he focused on linguistic and reproduction problems. He had strong opinions about quality control:

> Add to this [problem of translation] that the Indian scribes are careless, and do not take pains to produce correct and well collated copies. In consequence, the highest

> results of the authors mental development are lost by their negligence, and his book becomes already in the first or second copy so full of faults, that the text appears as something entirely new [S., 1971: 18].

Partly on account of this problem, al-Biruni admired the Hindu practice of metrical composition of books because it facilitated accuracy (S., 1971: 127). He likens it to Galen's preference for metric composition in medical writing because the "weights of medicines" are less likely to be corrupted in copying when this approach, rather than prose, is used. Still, the matter becomes complicated because a variety of words and phrases had to be used by the Hindus to describe a number yet conform to poetic meter in astronomical and other handbooks. A "two" might be represented for instance by "everything which is double; e.g., black and white" (S., 1971: 177).

SOURCES OF ERROR

Error was for Ibn Khaldun a "natural" and "unavoidable" influence on the information with which he dealt. Accepting this, he explored reasons for flaws in reports and individual reporting. This catalog of causes of distorting anticipates Donald Campbell's ideas on corruption of social indicators and includes the following:

> If the soul is infected with partisanship for a particular opinion or sect, it accepts without a moment's hesitation the information that is agreeable to it . . . [uncritical] reliance upon transmitters [of information] . . , attributing to it [information] the significance [one] assumes or imagines it to have, . . . unfounded assumption as to the truth of a thing, . . . ignorance of the nature of various conditions arising in civilization (such that one has no guide to) help . . . distinguish truth from untruth [D., 1978: 35-36].

His illustrations concern reports of events and of numerical data.

RESPONSE BIAS: EXAGGERATION AND NUMBERS

Ibn Khaldun's conception of what is now labeled as response bias in methodological texts and his attempt to provide an order of magnitude estimate for the bias were remarkable:

> When the officials in charge are questioned about their armies, when the goods and assets of wealthy people are assessed, and when the outlays of extravagant spenders are looked at in ordinary light, the figures will be found to be a tenth of what those people have said [D., 1978: 13].

Ethnocentrism and class centrism are said to play a role in producing such biases:

> Whenever contemporaries speak about the dynastic armies of their own or recent times, and whenever they engage in discussions about Muslim or Christian soldiers, or when they get to figuring the tax revenues and the money spent by the government . . . they are quite generally found to exaggerate, to go beyond the bounds of the ordinary, and to succumb to the temptation of sensationalism [D., 1978: 13].

Al-Biruni also recognized ethnocentrism as a cause of response bias, contending that the truth of claims about events depends on "the character of reporters who are influenced by the divergency of interests and all kinds of animosities and antipathies between . . . nations" (S., 1971: 3). He went a step further, however, to recognize another major cause of exaggeration—a cultural style such that even the

> scientific theorems . . . are in a state of utter confusion . . . always mixed up with the silly notions of the crowd, e.g. immense numbers, enormous spaces of time.

He then enumerated a list of reasons for error, focusing on why reporters lie (S., 1971: 3-5). The motives include lying in order to attack or praise a family, in which case the individual "acts from motives of objectionable cupidity and animosity." A lie may be told regarding a class of people that the reporter hates or likes, in which case the motives are the same. A lie may be told because the individual is afraid of telling the truth or he aims at making some profit. Still other reporters dissemble because it is in their nature to lie and they can do little else. And finally, some reporters mislead out of ignorance. Al-Biruni's view is that one ought to get to the source of information so as to avoid such problems; that is, find out who provided the information in order to assay its quality.

RELIABILITY AND VALIDITY OF REPORTS

Ibn Khaldun and at least some of his contemporaries attended vigorously to "personality criticism," according to Dawood. This activity was dedicated to investigating the validity of reports of the transmitters of information. It was methodological discipline of the time, devolved from the need to be suspicious of records and oral testimony.

Still, he maintained that there are better ways to determine the validity of information. Indeed, personality criticism "should not be resorted to until it has been ascertained whether a specific piece of information is itself possible . . . if it is absurd, there is no use engaging in personality criticism" (D., 1978: 38). External standards of evidence are given priority.

Al-Biruni anticipated Ibn Khaldun on this, suggesting that "the tradition regarding an event which in itself does not contradict either logical or physical laws will invariably depend for its character as true or false on the character of the reporters, or moved by the diversity of interests and all kinds of animosities and antipathies between the various nations. We must distinguish different classes of reporters" (S., 1971: 3).

DO THE DATA MAKE SENSE? ERRORS AND CORROBORATION

Ibn Khaldun's standards for judging information quality included "knowledge of the principles resulting from custom, the fundamental facts of politics, the nature of civilization, or the conditions governing human organization," and he encourages assessment of "remote or ancient material through comparison with near or contemporary material" in the interest of avoiding error (D., 1978: 11).

The poor quality in reporting facts is attributable, he suggests, to those who do not "compare them with similar material." Numerical information in particular must be "controlled and checked with the help of known fundamental facts" (D., 1978: 11).

To illustrate the point, Ibn Khaldun considered reports by historian Al-Mas'udi and others that Moses' Israelite army numbered more than 600,000 men. He suggested the number is unrealistic on several grounds. Egypt and Syria could not possibly have supported such a militia. The territory is too small, he maintained, for such an army to fight as a unit, and more pragmatically, an army of this size could not be controlled because its lines would extend well beyond the field of vision. An army known to be much smaller, Nebuchadnezzar's, "swallowed up their country and gained complete control over it" (D., 1978: 13), a task that would have been impossible if claims about army size were true. Finally, he argued that militia size is generally related to the size of the dynasty's jurisdiction, and because the Israelite territory was small, the report of a large army must be rejected.

Almost incidentally, Ibn Khaldun reminded the reader that historians placed Solomon's army at the same size. In this instance, he relied partly on Israelite history, which he regards as more reliable in this case, to reiterate this estimate of 12,000 (D., 1978: 13).

Al-Biruni also took pains to understand whether numbers are plausible and to deduce their source and implications. So, for instance, in explaining a Hindu legend about the origins of islands and seas, he attempted to recalculate the sizes of each given in the legend. He was frustrated at one point because the author of the manuscript in which the legend appears failed to provide clear arithmetic: "[T]herefore we cannot compare his numbers with ours" (S., 1971: 234). He pursued some assumptions about the basis for calculation but eventually gave up and seemed to apologize for belaboring the reader with the additional information.

CAUSALITY, CORRELATION, AND THE EXPERIMENTAL INTELLECT

For Ibn Khaldun, a fundamental virtue of the *Muqaddimah* is that he "gives causes and reasons for happenings in the various dynasties" (D., 1978: 9). At the time, examining reasons constituted a remarkable deviation from the practice of merely documenting events and codifying gossip. For philosopher Mario Bunge (1979), this new scientific approach was nothing short of astonishing in view of Machiavelli's much later inauguration "of the explanation of historical facts . . . in the West" (p. 137). The professional historian suggests this interest in causes stemmed partly in terms of the influence of Avicenna (D., 1978: x), Arab physician and philosopher, the courts of scholarship to which Ibn Khaldun had access, and his own remarkable inventiveness.

His views about the import of understanding causes are registered in formidable announcements, for example,

> The more a man's reflective power is capable of comprehending a regular chain of causes and effects, the more fully is the human quality developed in him. Some men are capable of following up two or three links in a chain of causes and effects but no more; yet others can push on to the fifth or sixth [Issawi, 1950: 166].

No formal technology of working through such chains of events is given. Still, the idea does register the intent and spirit of contemporary path analysis. As a matter of fact, the formidability of Ibn Khaldun's

announcement probably presages the difficulty of some modern varieties of path analysis as well.

He also encourages emulation and lists the qualifications of a good historiographer, suggesting that among other requirements, "he must know the causes of the similiarities . . . between current and past conditions . . . in certain cases and of the differences in other" (D., 1978: 24). Further,

> His goal must be to have complete knowledge of reasons for every happening and to be acquainted with the origins of every event [D., 1978: 24].

Because many scholars forgot this and other high standards for their work, he avers that "[i]n consequence, historiography became nonsensical and confused, and its students fumbled around."

GENETICS AND ENVIRONMENT

Ibn Khaldun discussed the way geographic zones, especially the extreme and temperate ones, influenced human development. Quarreling with genealogists who maintained that Negroes are black because they are descended from Ham, he maintains that the genealogists are wrong in regarding this genetic explanation as the only one and admits the possibility of competing explanations.

> Distinctions between races and nations are in some cases due to a different descent, as in the case of the Arabs, and the Israelites, and the Persians. In other cases, they are caused by geographic locations and physical marks, as in the case of . . . the Slavs and the Sudanese Negroes. . . . Or they may be caused by anything else among the conditions, qualities, and features peculiar to the different nations [D., 1978: 61].

The arguments he uses to buttress his case include recognizing that the Torah's description of Noah's curse on Ham makes no mention of color and recognizing the likely influences (definite, in his opinion) of climate on physical characteristics of people.

His discourse contains some material that is alarmingly close to modern, naive arguments about race and intelligence:

> Al-Mas'udi undertook to investigate the reason for the levity . . . of Negroes . . . he did no better than to report, on the authority of Galen . . . and al-Kindi that the reason is a weakness of their brains which results in a weakness of their intellect. This is an inconclusive and unproven statement [D., 1978: 64].

RELATIONSHIPS

Ibn Khaldun actively sought relations among variables of different kinds. For instance, in arguing that the Israelite army of Moses could not have exceeded a certain number, 600,000, he suggests that

> the extent of their rule would have been larger [if this estimate was true], for the size of administrative units and provinces under a particular dynasty is in direct proportion to the size of its militia and the groups that support the dynasty . . . it is well known that the territory of the Israelites did not (comprise a large areas) [D., 1978: 12].

In discussing how the abundance and nature of foods affect the physical appearance, attitudes, and even character of people, he remarks that

> the condition of the inhabitants within a single city can be observed to differ according to the different distribution of luxury and abundance [D., 1978: 67].

To strengthen his position, he cross-classifies the health of peoples against extremes of access to foods—desert versus urban living, for example.

THE EXPERIMENTAL INTELLECT

The empirical and theoretical perspectives are combined in Ibn Khaldun's brief discourse on the experimental intellect. The first of two ideas introduced under this rubric is that an individual's taking action is, at its best, a consequence of a chain of conditional reasoning.

> A principle must have another principle to which its own existence is posterior. This may go on in an ascending order [from principle to principle], or it may come to an end. Now, when man in his thinking, has reached the last principle on two, three or more levels, and starts the action that will bring the [planned] thing into existence, will start with the last principle. . . . This is what is meant by the saying: "The beginning of action is the end of thinking, and the beginning of thinking is the end of action" [D., 1978: 335].

In the second idea, he treats experience as a personal exercise of this experimental faculty and experience as the origin of the faculty:

> From events, the student of . . . concepts can learn them . . . with the help of experience among the events that occur in his dealings with his fellow man.

> Those who follow this during their whole life become acquainted with every single problem; things that depend on experience require time. Such is the experimental intellect. It is obtained after the discerning intellect that leads to action . . . after these two intellects, there is the higher degree of the speculative intellect [D., 1978: 337].

He applies this perspective in rejecting alchemy as a legitimate science, observing that some of the products are forgeries that can be produced easily by mixing metals with gold or treating a metal such as copper with mercury to achieve the appearance of silver. He speaks to alchemists who he believes are honest:

> Yet, we know of no one in the world who has attained the goal or got any desirable results out of it. They tell stories about other alchemists who attained the goal . . . [but] when they are asked whether the story has been verified by actual observation, they do not know [D., 1978: 410].

Four hundred years before, al-Biruni considered alchemy in his chapter "On Hindu Sciences which Prey on the Ignorance of the People." He did not trouble with explanations, being content to label the activity as gross deception at best. He was also skeptical of charms for snakebites (S., 1971: 194) despite claims. But because he actually witnessed the effective use of music in hunting and regards it as custom rather than charm, he regards related stories as credible.

CHANGE, DIFFERENCES, AND THE VALIDITY OF COMPARISONS

Just as Ibn Khaldun sought to be conscientious in establishing causes and relationships, he was thorough in his attention to trends, changes that occur over time. He criticized his colleagues for their

> disregard for the fact that conditions within nations and races change with the change of periods and the passage of time. This is a sore affliction and is deeply hidden, becoming notable only after a long time, so that rarely do more than a few individuals become aware of it.
>
> The condition of the world and of nations, their customs and sects, does not persist in the same form or in a constant manner. There are differences according to days and periods and changes from one condition to another. Such is the case with individuals, times, and cities, and it likewise happens in connection with regions and districts, periods and dynasties [D., 1978: 25].

In criticizing the dull researchers' failure to recognize temporal variation better and to accommodate it, he suggest that they

> went to the extreme of being satisfied with the names of kings . . . and with only a numerical indication of the length of their reigns. This was done by Ibn Rahiq . . . and by the lost sheep who followed him [D., 1978: 7].

These scholars also failed to recognize cohort and generational changes and their importance, and

> they neglected the importance of change over the generations in their treatment of [historical material] . . . their works therefore give no explanation for it [D., 1978: 7].

POPULATION GROWTH

In attempting to estimate the size of the Israelite army during Moses' time, Ibn Khaldun used data that he believed to be accurate from Solomon's regime, eleven generations earlier. He showed no explicit calculation, but he maintains that

> the descendants of one man in eleven generations would not branch out into such a number, as has been assumed. They might indeed reach hundreds or thousands. This often happens. But an increase beyond that to higher figures is improbable [D., 1978: 13].

DIFFERENCES AND THE VALIDITY OF COMPARISONS

Though the *Muqaddimah* stresses the need to evaluate information relative to explicit standards, such as prior information or custom, its author is careful to warn that comparison can also be misleading:

> Analogical reasoning and comparison are well known to human nature. They are not safe from error. . . . Often someone who has learned a good deal of past history remains unaware of the changes that conditions have undergone. Without a moment's hesitation, he applies his knowledge of the present to historical information, and measures such information by the things he has observed . . . although the difference between the two is great. Consequently, he falls into an abyss of error [D., 1978: 26].

The examples he uses include the historical reports that the father of a certain governor of Iraq was a school teacher. In Ibn Khaldun's day, teaching was "an occupation restricted to weak individuals" (D., 1978:

27). Contemporary judgments about the governor's origins would then be misleading because in earlier days teachers were respected for their scholarship and indeed were scholars rather than tradesmen. The position of judge apparently engendered similar change—the position's import being entirely different from one period to the next.

Ibn Khaldun's lexical sensitivity toward titles such as judge and school teacher reflects a remarkable general sensitivity to social change of many kinds. He was fascinated not only with the disappearance of nations, institutions, and customs, but also with why they changed and the consequences of change. Change in the meaning of titles, words, and ideas is one such consequence.

Some of Ibn Khaldun's attention focused on gradually increasing differences that have dramatic consequences. In trying to understand the nature of changes in institutions, customs, and cultures, for example, he broaches the idea that things measurable in principle on a continuous scale become, after a time, qualitatively different. His example is dynastic change:

> New [political] power, in turn, is taken over by another dynasty, and customs are further mixed with those of the new dynasty. More discrepancies come in, so that the contrast between the new dynasty and the first one is much greater than that between the second and first one. Gradual increase in the degree of discrepancy continues. The eventual result is an altogether different [set of customs and institutions] [D., 1978: 25].

Finally, a simple form of discriminant analysis that presages contemporary statistical analyses of literature (e.g., Kenny, 1982) appears in his discussion of the painfulness of religious revelation.

> Gradual habituation to the process of revelation brings some relief. It is for this reason that the earliest passages, *surahs*, and verses of the Koran, revealed to Muhammad in Mecca, are briefer than those revealed to him in Medina. This may serve as a criterion for distinguishing the Meccan *surahs* and verses from the Medinese [D., 1978: 78].

DATA SHARING AND CRITICISM

INFORMATION AND DATA SHARING

Both Arabic works anticipate contemporary concerns that researchers are at times professionally bound to share the data they have collected with other scientists.

The fact of some information sharing in North Africa and elsewhere is clear from Ibn Khaldun's conscientious acknowledgement of Greek writings and their translation and abridgment by Arabs. These include Avicenna's and Averroes' translation of Ptolemy's (D., 1978: 381) work on astronomy, the translations of others' monographs on dream interpretation (D., 1978: 367), Aristotle's *Book on Politics,* Galen's work on medicine, and so on.

To judge from the *Muqaddimah,* numerical data were also shared in the spirit of scientific enterprise:

> Recent contemporary Maghribi scholars are using as their reference work the *Zij* that is ascribed to Ibn Ishaq based on his work on astronomical observations. A Jew in Sicily who was skilled in astronomy and the mathematical sciences, and who occupied himself with astronomical observation, sent him information on the conditions and motions of the stars he had ascertained [D., 1978: 382].

To judge from *India*, the idea of information sharing in the interest of scholarship was also extant in the tenth to eleventh centuries. Indeed, al-Biruni was annoyed at resistance to the practice. He maintained (S., 1971: 22) that the Hindus

> are by nature niggardly in communicating that which they know, and they take the greatest possible care to withhold it from men of another caste among their own people, still much more, of course from any foreigner.

He was specific in complaining about alchemists' refusal to talk to him (S., 1971: 188), although he is incredulous about alchemy.

Still, he says, "their ancestors were not as narrow minded as the present generation is" (p. 23). He cites the scholar Varahamihira to make his point that at least the ancestors acknowledged the Greek contribution to Hindu science. The difficulties are not sufficient to deter al-Biruni from investigating more accessible work on astronomy. *India's* contents include, for example, "a critical investigation . . . distinguishing between correct and corrupt passages in the texts of . . . treatises and handbooks . . . arithmetic . . . and scientifical calculation of the mean places of planets" (S., 1971: 154-155).

CRITICISM, IGNORANCE, AND THE LIMITS OF KNOWLEDGE

Ibn Khaldun was conscientious in balanced criticism of work he admired. After recognizing that antecedent history by Al-Masudi is to

be much admired in some specific respects, Ibn Khaldun recognized shortcomings in others, notably al-Masudi's reliance on unverifiable testimony and perhaps hearsay. To temper this, and put it into perspective, he remarks that "God is the repository of all knowledge. Man is weak and deficient. Admission [of one's ignorance] is a specific [religious] duty" (D., 1978: 30).

Al-Biruni also viewed ignorance as an obstacle to understanding that has to be acknowledged. Chapter I of *India,* for example, enumerates the impediments to study of Hindu science and culture: "The knowledge of these difficulties will either facilitate the progress of our work, or serves as an apology for any shortcomings of ours" (S., 1971: 3).

The difficulties include the language, Sanskrit, which lexically and phonetically differs a great deal from Arabic. They include the carelessness of scribes, a metrical system of writing, and religious and social insularity.

He, like Ibn Khaldun, distinguishes between first and secondhand reports, but recognizes both flaws and merits in each (S., 1971: 3):

> No one will deny that in questions of historic authenticity, hearsay does not equal eyewitness; for in the latter the eye of the observer apprehends the substance of that which is observed . . . whilst hearsay has its peculiar drawbacks. But for these, it would even be preferable to eyewitness; the object of eyewitness can only be actual momentary existence, whilst hearsay comprehends alike the present, the past, and the future.

NUMBERS, COUNTING, AND CALCULATION

For al-Biruni,

> Counting is innate to man. . . . [T]he measure of a thing becomes known by its being compared with another thing which belongs to the same species and is assumed as a unit by general consent [Embree, 1971: p. xiv].

He spent a great deal of time investigating systems of Hindu chronology and astronomy, and the counting systems that underlie each, and transforming the Hindu measurement systems to more familiar Arabic ones.

Al-Biruni observed that most nations of the time used 10 as a base for counting, notably in powers of 10, up to a thousand. The Hindus, he suggests, were remarkable in providing names of the ten to the fourth

through ten to the eighteenth power for religious reasons. There was no nomenclature beyond 19, and even the latter he suggests is of "an artificial and hyperaccurate nature" (S., 1971: 175).

To complicate matters, small numbers were often given several names to facilitate the process of constructing poetic descriptions. Al-Biruni listed 11 synonyms for the number 2, for instance. However, he says the Hindus "do not usually go beyond twenty-five with this kind of numerical notation" (S., 1971: 178-179). And to complicate matters still further, it was customary to discard fractions in counting years (S., 1971: 3), and eras have widely varying years attached to them. This seems to have irritated the author.

The concept of frequency distribution or relative frequency distribution is not explicit in either the *Muqaddimah* or *India.* But fragments of the latter suggest that intuition about the concept was developing in a piecemeal way. In discussing unusual customs of the Hindus, for example, al-Biruni digresses to articulate a definition of rare events (S., 1971: 179):

> The strangeness of a thing evidently rests on the fact that it occurs but rarely, and that we seldom have the opportunity of witnessing it. If such strangeness reaches a high degree, the thing becomes a curiosity, or even something like a miracle, which is no longer in accordance with the ordinary laws of nature, and which seems chimerical as long as it has not been witnessed.

Relative frequency appears in his brief description of the treatment of smallpox and the odds on the treatment's success. Amputation of an infected limb and medicine are described, and he suggests that "if these precautions are taken, perhaps nine out of ten will be proof against this malady" (S., 1971: 309).

The *Muqaddimah* contains a brief description of the "sciences concerned with numbers." The description does not differ much from others of the period. Calculation—arithmetic operations on whole numbers and on fractions—is regarded as a craft, eminently useful in business transactions and in training children.

Algebra is defined as a craft that makes it possible to discover "the unknown from the known da'a if there exists a relationship between them" (D., 1978: 376). Ibn Khaldun's remarks on the solutions of what apparently were sets of independent, simultaneous equations suggest that six equations could be solved easily.

> We have heard that great eastern mathematicians have extended the algebraic operations beyond the six types and brought them up to more than twenty [D., 1978: 377].

The book contains a one-page primer on geometry as well. Euclid's and other Greek contributions are acknowledged conscientiously as is the existence of various translations. Geometry's links to mechanics, surveying, and options are described briefly.

In *India,* al-Biruni does not discuss arithmetic itself, but does discuss its use in Hindu economic life. The fractions of income that are typically spent for protection and taxes, saved to "guarantee the heart against anxiety" (S., 1971: 149) and other allocations, are cataloged. "Usery or taking percentages is forbidden" (p. 150).

Antecedents of modern statistical calculations used by al-Biruni have been explored periodically in the scholarly literature. For example, Eisenhart's (1979) special interest lies in measures of the mean, particularly the early use of a midrange of a set of values, a statistic, that was taken as representative of the set while still preserving recognition of others in the set. Eisenhart's studies, with Edward Kennedy, involve a review of al-Biruni's treatises, apart from *India*, on astronomy, metals, and other topics. He argues for the existence of a midrange rule during the ninth to eleventh centuries as an antecedent to modern statistical summaries such as the arithmetic mean.

DISCUSSION AND CONCLUSIONS

Any attempt to identify statistical and probabilistic ideas in prose is risky. If the literature is over four centuries old and, furthermore, is translated from an ancient language into contemporary English, the project is very risky indeed. At worst, what is presented here represents no more than this author's wishful and ignorant thinking. At best, it will provide some basis for more expert, penetrating treatment of the topic.

The first broad area of concern, one that may limit substantially the worth of this review, is lexical. The first obvious problem in this area, i.e., identifying statistical ideas in the translated work, is that there may be no good literal translation of particular Arabic words or phrases that appear. Ibn Khaldun himself recognizes this problem in the *Muqaddimah* (D., 1978: 31). Al-Biruni also recognizes the problem in discussing his efforts to translate Sanskrit into Arabic.

A related problem is that the translator's particular choice of words or phrases may be inappropriate in view of our purposes. For example, in Dawood's translation, the word "improbable" is used twice by Ibn

Khaldun to describe historical reports of the number of Solomon's troops (p. 13). The word implausible is close in meaning, yet there may be no way of determining the reasons for Dawood's choice between the words improbable and implausible, and the justifiability of the choice. In fact, implausible may be more appropriate given the absence of formal probabilistic thinking during the period.

A third, related problem concerns complete statements that are unclear either because the translation is unclear or because Ibn Khaldun does not provide sufficient detail. For instance, "the largest number of equations recognized by algebraists is six" (D., 1978: 377). I have interpreted the word "recognized" in this context as "solved."

The words and phrases that cause the most concern on this account include improbable (p. 13), personality criticism (p. 35), evidence (p. 38), prophecy (versus prediction) (p. 37), determinable (versus measurable), and experimental (p. 336).

This kind of problem suggests that more collaboration among Arabic scholar, translator, and statistician is warranted. It is doubtful that such collaboration occurs frequently; the Eisenhart-Kennedy work mentioned earliar is a fascinating exception.

A second broad class of problems in this arena concerns the writers' access to Western and Eastern tracts. Both Ibn Khaldun and al-Biruni were well read. Doubtless some of their ideas were shaped by Greek and Roman views of the world; e.g., Ptolemy and Aristotle for Ibn Khaldun, and Aristotle and Heraclitus for al-Biruni. Doubtless, they were influenced by other Arab scholars; e.g.; al-Masudi in the case of Ibn Khaldun. The influence of these others on the methodological standards and views on the two authors has not been traced here. That must be done by scholars with far more expertise in ancient cultures than this author has.

A third area of concern lies with the various levels of imputation. Generally speaking, one cannot use a contemporary definition of, say, a random sample in discovering the idea of random sampling in ancient literature. The formal definition is too confining to permit any discovery at all. How much do we then allow ourselves to relax the constraint? Do we go so far as to admit "very haphazard" as part of the idea? Or, should we demand more of this ancient literature? Such questions are ubiquitous. They are present for example in Wilczynski's (1959) criticism of Rainow's attempt to identify al-Biruni's ideas about natural selection as predecessors to Darwinian theory. They also appear in Zabell's (1976) comments on Rabinovitch's (1973) investigation of ideas about statistical inference in medieval Jewish literature.

Despite these qualifications, there is sufficient evidence here to judge that some ideas underlying contemporary research methods, especially quantitative methods, were recognized by Ibn Khaldun and al-Biruni and were discussed. To judge by other commentators, there is evidence for the contention that Ibn Khaldun did go well beyond his own contemporaries in this respect. The detail and false imputation here is important, and we ought to be cautious. Still, it seems fair to regard both men as legitimate predecessors to the applied social researcher—conscientious models of what can be done to understand what happens, why it happens, and with what consequences.

A final reason for concern lies in the lack of external corroborating evidence for some of the points made here. Other papers by Ibn Khaldun ought to be examined to strengthen the case. Other papers by al-Biruni warrant attention because they may add to or subtract from the argument. The resources available now are simply not sufficient to engage in so thorough a search. Others may be able to strengthen the case or perhaps show us clearly why the ideas were not really implicit in their writings.

NOTE

1. For background, see Bernard Lewis's (1982) fascinating history of Islamic interest and disinterest in Western culture from the seventh to the eighteenth centuries. Lewis gives Ibn Khaldun little attention. But then, as Lewis points out, Ibn Khaldun paid little attention to Europe. See Rabinovitch (1973) for an analysis of some middleeastern antecedents of modern ideas in statistics.

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