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ABSTRACT

This paper examines the pattern of diffusion in the academic literatures of the sciences, social sciences, and arts and humanities based on citations. An examination of the citations of articles in the Science Citation Index, Social Science Citation Index, and Arts and Humanities Citation Index from a given year to the year in which the cited article was published reveals a pattern. The percentage is initially small when there is no lag between the years; it then increases, reaching a peak in less than two years. Then, it gradually decreases over time. A mathematical model was developed to describe this pattern, which, when tested, explains between 96.9% and 98.3% of the variance, depending on the data set. The results, which are presented in tabular form, are interpreted as an example of social learning and forgetting. Findings are illustrated in five graphs, and references are provided. (Author/KM)

The Diffusion of Academic Information: A Mathematical Model of Citations in the Sciences, Social Sciences and Arts and Humanities

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This paper examines the pattern of diffusion in the academic literatures of the Sciences, Social Sciences and Arts and Humanities based on citations. An examination of the citations of articles from a given year to the year in which the cited article was published reveals a pattern. The percentage is initially small when there is no lag between the years. It then increases, reaching a peak in less than two years. Then, it gradually decreases over time. A mathematical model was developed to describe this pattern, which when tested explained between 96.9 and 98.3% of the variance depending on the data set. The results are interpreted as an example of social learning and forgetting.

The Diffusion of Academic Information: A Mathematical Model of Citations in the Sciences, Social Sciences and Arts and Humanities

Theory

One of the central areas of study within Communication is the diffusion of innovation and the dissemination of information. Rogers (1983:11) defines an innovation as, "an idea, practice, or object that is perceived as new by an individual or other unit of adoption. ...The 'newness' of an innovation may be expressed in terms of knowledge, persuasion or a decision to adopt." In the academic environment, published manuscripts in the form of books or journal articles present new ideas. While they are generally considered channels for disseminating information about innovations, they are, in fact, innovations themselves; new objects capable of initiating cognitive change in adopters (Barnett, 1978).

Academia is often characterized as an invisible college or a "highly interconnected network of scholars who share a theoretical-methodological framework" (Crane, 1972). Essential to the maintenance of this network is the sharing of ideas and knowledge. This takes place through academic literature (Price, 1963). The process of communication among academics may be described by the practice of scholars referencing the published research of one another. Citations represent communication links among academic researchers. In fact, networks of scientists have been studied using citations as their relationship (Price, 1965; Goffman, 1966; Small & Griffith, 1974; Garfield, 1979; Brittain, 1985). They also represent manifestations of the adoption process serving as indicators that an innovation, a new idea, was adopted by an individual scholar. Thus, the practice of referencing another's published research may be used to describe the process of the diffusion of innovations in the academic community.

Clique integration and individual connectedness are related to the adoption of an innovation (Rogers & Kincaid, 1981). When researchers are connected to one another, it follows that the new ideas would be adopted more readily by those within his/her network than by those outside the network's boundaries. The adoption of the innovation would be expressed in terms of a scientist's knowledge as manifested in citations of academic articles. In a sense, these networks are based on shared adoption of innovations.

The growth of knowledge may also be described by the citation process. Price (1965) reports exponential growth of the body of world literature for the last few centuries. This growth rate is expected to continue at its present rate at about 5% per year. There will be about seven new papers each year for every 100 previously published papers in a given field.

Price (1965) describes the networks that emerge from citation of scientific papers. He found that in an average year, 35% of all existing papers are not cited and that 49% are cited only once. The percentages then decrease until only 1% of papers are cited six or more times. Patterns exist within networks, such that multiple relationships emerge out of half of the references from new papers. These new papers cite about half of the papers that were published previously. "Thus, each group of new papers is 'knitted' to a small, select part of the existing scientific literature but connected rather weakly and randomly to a much greater part" (Price, 1965:512).

This suggests that the change of paradigms, theoretical-methodological frameworks, may be described by which articles are referenced (Kuhn, 1970). That is, certain seminal articles are published and cited. Their frequency of citation as an indicator of the importance of the manuscript and the degree of acceptance of the paradigm (Garfield, 1979). The citation practice takes on specific characteristics over time. For any given article or area of study, the frequency of citation grows to a peak before it drops off. Burton and Kebler (1960) and McRae (1969) report that the number of citations a manuscript receives decays exponentially with time. The drop off in citation takes place as the paradigm shifts. Goffman (1966) described this pattern for investigation of the mast cell. Dieks and Chang (1976) report a similar pattern in the literature of magnetic resonance. Thus, the pattern which describes the practice of citation may be used to develop models of the diffusion of innovations and the dissemination of knowledge.

The study of communication networks among academics and how they change over time is made possible by citation indexing (Institute for Scientific Information, 1982, 1984a,b). Citation indexing is the practice of systematically recording and organizing the references that authors make to previously published manuscripts. Almost all authors of academic articles and books make reference to the work of other authors. The references indicate that the cited authors support, elaborate, or illustrate some idea(s) presented by the author. Garfield (1979: 1) describes citations as "formal, explicit linkages between papers that have particular points in common." Referencing another's work is considered a scholarly practice within the academic environment. For this reason, bibliographies, and therefore, an index of ideas as presented in the Science Citation Index (SCI), the Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI) are powerful means of search effectiveness. Economically, it is impossible to use the references from all journals. However, the Citation Indicies identify several thousand journals from all the academic disciplines which are considered to publish the highest quality material. From these journals, all of the references are indexed, regardless of who wrote it, when it was written or where it appeared. By this method, SCI, for example, is able to annually index 7 million references from 3,000 to 4,000 journals and books from all scientific disciplines. Because of the extensive overlap of the areas within the disciplines, this method of indexing "accounts for an overwhelming majority of the material important enough to be referenced or abstracted" (Garfield, 1979:21).

Garfield stresses the advantages of citation indexing in terms of cost and simplicity over subject and title word indexing. The indices are compiled such that key papers, all presenting ideas in the same area of study, would be located together. In a subject index, if the name of this same idea had changed over time, the search for key papers could be quite difficult. An article in the SCI is not limited to just one subject area, however, "each reference citation is associated with as many subject meanings as other scientists attribute to it" (Garfield, 1979: 10).

Garfield (1979) describes the use of the Science Citation Index (SCI) for defining historical accounts of the development of innovative ideas in the scientific field. By networking citation behaviors of researchers in a specific area of knowledge, relationships and events can be identified, and the route of the innovation mapped. Garfield (1979) demonstrated the use of the SCI in identifying the links between academic researchers by the networking of citations. Scientists involved in co-citation at a perscribed frequency and strength were considered to have a mutual relationship. Clusters of authors were identified for specific areas of research, each scientist having mutual influence with at least one member within the cluster.

This paper develops a mathematical model which describes how ideas manifested in academi. articles are diffused within academic disciplines, specifically, the Sciences, Social Sciences, and Arts and Humanities. It focuses on citations as the innovations.

Introduction to Model

The diffusion process is typically described by an S-shaped curve in which the cumulative numbers of adopters is plotted with respect to the time of an innovation's adoption (Rogers, 1983). The distribution of adopters initially rises slowly. The curve has a small positive slope. It then accelerates to exponential growth to a maximum until half of the population adopts the innovation. It then increases at a decreasing rate. Although still positive, the slope approaches zero. The curve becomes a decaying exponential, becoming asymptotic with the number of members of the adopting population. The frequency of adoption at any single point may be described over time by a bell-shaped normal curve. Mathematical descriptions of these curves are presented by Barnett (1978).

There are a number of problems with diffusion research and thus, the mathematical description of the process. Rogers (1983) suggests a number of criticisms including the pro-innovation bias of diffusion research, the focus on the individual rather than the system in which the process takes place and the lack of longitudinal investigation. These problems are addressed in this paper.

The pro-innovation bias is the implication of most diffusion research that any innovation should be diffused and adopted by all members of a society. Further, the innovation should be diffused more rapidly and that the innovation should be neither re-invented nor rejected (Rogers, 1983:92). One manifestation of this bias is the focus of diffusion research on adoption rather than disadoption. Rogers (1983: 21) labels this discontinuence, "a decision to reject an innovation after it had previously been adopted". There has been relatively little research designed to investigate the nature of discontinuance, and as a result relatively little is known about this aspect of diffusion behavior. Rogers (1983) identifies two types of discontinuance, replacement and disenchantment. A replacement discontinuance is a decision to cease using an idea in order to adopt a better idea which supersedes it. Certain academic fields change rapidly. Particularly in the sciences there are constant waves of innovations. Each new idea replaces an existing practice which in its day was also an innovation.

A disenchantment discontinuance is a decision to cease using an idea as a result of dissatisfaction with its performance. The dissatisfaction may come about because the innovation is inappropriate for the individual and does not result in a perceived advantage over an alternative practice.

Both types of discontinuance may occur in the pursuit of academic knowledge. A change in research paradigm may bring about the discontinuance of the use of a literature because the ideas have been rejected in favor of better research justification or because the ideas in those articles were simply inappropriate (Kuhn, 1970).

Diffusion research has traditionally focused on the individual adopter rather than the system in which the process takes place. Individuals are generally treated as passive receivers of information about an innovation. This has led to an overreliance of the examination of role of psychological variables in the adoption process. Seldom are the investigations about the sources or channels by which the information about the innovations is dissmeminated. Journal articles are one of the sources academics use to gather information about new ideas. Thus, an examination of the pattern of citations of academic journals may provide new insights into the diffusion process.

Further, the use of individuals as the unit of analysis has led to imprecise descriptions of the diffusion process. An alternative would be to examine the communication networks of the system in which the process takes place (Rogers & Kincaid, 1981). Also, one may use aggregates, such as groups, as the unit of analysis (Barnett, 1982). Averaging the responses over a large number of individual cases eliminates random variation from the data. It allows one to unambiguously determine the functional relations that underlie the process. This is stated as "The Random Error Corollary" by Hamblin, et al. (1973:210).

> Investigations in which random measurement is averaged out are more desirable for determining an underlying or expected relationship than are investigations in which random measurement error is not averaged out.

In this research networks of academics are examined through the citation process for the collectives of the natural sciences and engineering, the Social Sciences and the Arts and Humanities, rather than for individuals. In this way a precise model of the diffusion of academic ideas may be developed.

Typically, the measurement of the diffusion process is made at a single point in time through surveys which ask respondents to recall their attitudes toward the innovation and the date and reasons for adoption (Rogers & Kincaid, 1981; Rogers, 1983). Research of this type makes it impossible to assert causality and leads to a pro-innovation bias. This problem may be overcome through longitudinal research. One method which may be used to build in time to the study of diffusion is to gather data about respondents' time of adoption from alternative sources, such as archival records. The Citation Indices provide a source for longitudinal archival data (Institute for Scientific Information, 1984).

In summary, this paper presents a model of the diffusion of innovations which is neither inherantly pro-innovation nor does it focus on the psychological states of individual adopters. Rather, it focuses on disadoption as well as adoption, on an information source or channel used by social networks in the aggregate. Further, it is longitudinal, examining the diffusion process over time based on data from archival records.

Mathematical Model of Disadoption

Rogers (1983) suggests that researchers can investigate how a practice is discontinued. Almost as an after-though he presents a graphic representation of the "discontinuance curve". It describes a decaying exponential. Coleman (1969) and Hamlin, et al. (1973) provide precise mathematical descriptions of the curve. A decaying exponential has been empirically observed for the use of information over time by Goffman, (1966), Dieks and Chang (1976) and Levy and Fink (1984).

The Model

The distribution of citations may be modelled as,

$$y(t) = a\,(\exp[-b(t+d)] - \exp[-c(t+d)])$$

where $y(t)$ is the proportion of citations made in a given year to papers published t years previous, and a, b, c, and d are non-negative constants, with $c>b$. When $t+d$ equals zero, $y(t)= 0$, and as $t \rightarrow$ infinity, $y(t) \rightarrow 0$. Thus, citations are presumed to start at time equal to -d. This is so since articles are often cited prior to their actual publication date; the d parameter corrects for this situation as much as possible, given the data set. The parameter d is the time, in years, prior to publication at which citation is initiated. Given the data set (described below), it is unlikely that d can be greater than +1.

The model assumes that the citation process involves an initial increase in the aggregate probability of citation, followed by a decline which eventually reaches zero. Even seminal articles decline in citation frequency after a peak, since new ideas ultimately become common knowledge of a field or discipline, and after a period no longer has the need for the active researcher to cite its originator. Of course, fields differ in this characteristic, and work which is fundamentally of an historical nature will necessarily have citations to primary sources which may be quite old. Furthermore, fields that can present new knowledge as "discoveries," which makes old knowledge out of date, are less likely to have citations that go back very far in time. Thus, the discipline type may differ in the extent that they cite works at different lags. It is hypothesized that the Sciences are least likely to cite work in the distant past, the Social Science next, an the Arts and Humanities more likely (Garfield, 1979; Koshy, 1976).

One way to evaluate the trajectory of citations over time is to find that point in time on the curve derived from the model at which the proportion of citations is at a maximum. This point, which we call t^*, is

$$t^* = ((\log c - \log b)/(c-b)) - d,$$

with the maximum proportion of citations (y_{MAX}) being

$$y_{MAX} = a((c-b)/b)(b/c)^{(c/(c-b))}$$

This model has been used to model drug concentration in the blood, which is also a process that starts at zero, rises, and then returns to zero as time increases (Burghes & Wood, 1980). Diffusion curves, as already pointed out, do not allow for disadoption over time, which is a fundamental aspect of the problem here. Epidemic models, which have also been used to model the process here (Goffman, 1966) assume that once one is in the pool of "infected" (i.e. once one has cited a paper at a particular lag), one is no longer eligible to be "reinfected" (to cite a paper at a given lag again). Finally, a model derived from a Poisson distibution (Dieks & Chang, 1976) assumes that citations are independent, which is almost certainly unrealistic; to compensate for this, the authors did not count citations, but the number of different citing authors to the same paper by a given set of authors. Even doing this fails to eliminate the dependency problem.

In sum, the model proposed allows the citation proportion to go from zero to a positive value and back to zero. It provides for the prediction of the point in time at which citation is set at a maximum (t^*), and also for that citation proportion (y_{MAX}). Utilizing this model, comparisons between fields is possible and useful, since the extent that the model's parameters differ across fields may be examined. The reader should take note that the model presented here uses articles written in a given year and examines the pattern of citation made by these articles to articles previously published. An alternative approach to the proposed model would be to take articles published in a given year and look at citations to them in subsequent years.

Methods

Data Source

The data used to test the model comes from the Guide and List of Source Publications (Institute for Scientific Information, 1982, 1984a,b) of the Science, Social Science and Arts and Humanities Citation Indices. These are extensive data bases which provide accurate and stable measures of the over time citation process. In 1984, 3,281 scientific journals and monographs were examined. These contained 361,989 articles and book reviews which cited 8,911,676 articles and mongraphs. In the same year, 4,653 Social Science journals were examined. They contained 57,301 artices and 36,416 book reviews which cited 1,460,363 manuscripts. In 1982, the Arts and Humanities Citation Index, examined 5,418 monographs and journals which contained 30,893 articles. There were 756,460 unique citations.

The specific data used to test the model were the percentage of unique citations for a given publication date. For example, what percentage of the citations from 1984 articles were originally published in 1983, 1982, and so on? For the Sciences, the annual percentage of citations were presented between 1950 and the year the citations were indexed for the years 1961 to 1984. Thus, there were 564 data points. Between 72.82% (1961) and 95.99% (1984) of the scientific citations were printed during this time span. For the Social Sciences the data also went back to 1950, but only for 1969 to 1984. There were 440 data points. Between 80.49% (1969) and 90.47% (1984) of Social Science citations were published during this period. For the Arts and Humanities the annual data went back to 1800 for the years 1976 to 1982, resulting in 1260 data points. Between 96.16% (1977) and 98.16% (1982) of dated citations in the Humanities were published after 1800. Thus, these data provide the length of time for the diffusion and discontinuance of academic information. The actual data is presented in an appendix.

Analysis Procedures

SPSS NONLINEAR was used to evaluate the model. It requires the user to estimate the model parameters before it can provide the best fit and estimates for the parameters. The initial estimations were as follows:

a = 1.0

b = -1.0, with an upper limit of 0.0, to comform with the theoretical assumptions of the model.

c = -.1.0, with an upper limit of 0.0, to comform with the theoretical assumptions of the model.

d = +0.5 The unit of time in this data set was the year. A percentage of the citations occurred with a time lag of zero. This suggests that the value required to set t equal to zero (to account for the lag) was $0.0 < d < 1.0$. Thus, the middle value, +.5, was chosen for the initial estimate.

There are differences among the curves from the three disciplines (Garfield, 1979). Due to the nature of the fields, the diffusion process in the Sciences occurs faster than the Social Sciences, which, in turn, occurs faster than the Arts and Humanities. Scientists cite a greater percentage of more recent articles. Thus, their curve reaches a higher peak in a shorter period of time as they adopt new ideas. Disadoption starts earlier as the articles in use are replaced by new up-to-date ones. In the Arts and Humanities, it takes a long period of time for ideas to be adopted and longer for the disadoption of an idea. Their curve rises more slowly. A smaller percentage of citations comes from any given year. Thus, it has a lower peak. Also, it falls more slowly over a longer period of time. The diffusion process for the Social Sciences is moderate between the other disciplines. It rises more slowly than Science, but faster than for the Arts and Humanities, resulting in a peak between the two. It then falls at a rate between them, faster than the Arts and Humanties but more slowly than the Sciences. The differences in the curves should be reflected in the model's parameter values. A graphic representation of the relation among the curves is presented in figure 1.

To evaluate the goodness of fit of the proposed model, several tests will be employed. The R-squared from the nonlinear regression and the plausibility of the derived parmeters, particularly d, t^*, and y_{MAX}, will be examined. Further, the residuals from the nonlinear regression for the model should be homoscedastic, normal, and will not exhibit any systematic patterns. For a full discussion of these issues see Bauer and Fink (1983). To the extent that the residuals fail to meet these assumptions, transformation of the dependent variable will be attempted. To the extent that the data fail to confirm to these assumptions, regardless of transformation, the model wil be considered incomplete: i.e., some important factor that "explains" the systematic character of the residuals has been left out.

Since the data consist of proportions, candidate transformations include the arc sine, log-odds and the square root transformation, as well as other transformations which cause the data to behave similarly. Again, failure to meet the assumptions indicate above point out the incompleteness of the model.

FIGURE 1 ABOUT HERE

Results

The results of the test of the model for the three data sets are presented in table 1. Scatterplots for the three data sets (per cent citation on time) are presented in figures 2a, b and c. The model fit the data very well, explaining 96.9% of the variance for Science citations, 98. for Social Science and 97.1% for Arts and Humanities. All coefficients are within the specified theoretical limits. Coefficients b and c are less than 0.0 and the values of c (-1.95, -1.35, -2.76) are greater than b (-.138, -.139, -.074). The values of coefficient d are all between 0.0 and 1.0 (.195, .139, .160). It was predicted that the coefficients would be monotonically ordered Science, Social Science and Arts and Humanities. This is not the case. However, they do have this relation if each coefficient may take on any value within its confidence limits.

TABLE 1 AND FIGURES 2A, B AND C ABOUT HERE

The values for t^*, the point on the curve at which the proportion of citations are at a maximum, were 1.53 (Science), 1.74 (Social Science) and 1.16 Arts and Humanities). Again, the hypothesized order was not observed. Diffusion for the citations of the Arts and Humanities occurred at a faster rate than for the other two disciplines.

The values for y_{MAX}, the maximum proportion of citations, were 10.0

(Science), 9.40 (Social Science) and 4.20 (Arts and Humanities). These are as hypothesized.

An analysis of the residuals raises some concern over the model. In all three cases, the residuals are not normally distributed. While they are only slightly skewed, 1.602 for Science, -.279 for Social Science and .160 for the Arts and Humanities, they are very peaked. The kurtosis was 17.69 for Science, 10.00 for Social Science and 15.53 for Arts and Humanities. Further, the residuals correlated significantly with the dependent variable for Science ($r = -.103$, $p < .006$) and the Arts and Humanities ($r = -.091$, $p < .000$). The correlation was -.023 ($p < .318$) for Sciences. A graphic representation of the residuals for Sciences is presented as figure 3. It reveals a pattern. The residuals are large when t is small. They become smaller when t becomes large. A similar pattern was for the Sciences and Arts and Humanities. This suggests that there may be some other parameter effecting the relations described by the model.

FIGURE 3 ABOUT HERE

An examination of the scatterplots of the per cent citation by time (presented in figures 2a,b & c) reveals that the pattern of the residuals is due to heteroscedasticity. The variance in the percentage of citation is greater for those cases with a short lag than those with a long lag. This results in a skewed and peaked distribution of residuals and a significant correlation with the per cent citation. The points with a shorter lag had greater residuals. One solution to this problem would be to transform the dependent variable to remove the heteroscedasticity from the data.

Discussion

This paper developed a mathematical model to describe the diffusion process. The proposed model has an advantages over ones currently in use because it describes the process of disadoption in which the use of an innovation is discontinued. As a result, the model does not suffer from a pro-innovation bias. The model was tested using citation data from the Sciences, Social Sciences and Arts and Humanities. These data are based on aggregates rather than focusing on individuals and are longitudinal rather than measuring diffusion at a single point in time. It fit the three sets of citation data excellently. It accounted for 96.9% of the variation for Science, 98.3% for Social Science and 97.1% for Arts and Humanities. All coefficients were within theoretically specified limits. The values of t^* suggest a more rapid diffusion for the Arts and Humanities than for the Social Sciences or the Sciences. y_{MAX} indicates that the diffusion process is more peaked for the Sciences than Social Sciences than the Arts and Humanities.

The model is not without its problems. Foremost is the issue of heteroscedasticity. The residuals were not distributed normally. For all three data sets, they are skewed and peaked. Further, for two data sets they are significantly correlated with the dependent variable, the proportion of citations for a given year. Several attempts were made to transform the raw data to remove the heteroscedasticity. Log, square root, arc sine and log-odds transformations were applied without any improvement in the goodness of fit. Adjustments to the basic model were made to account for the pattern of the residuals without success.

The pattern of the residuals and the problems of heteroscedasticity suggests that future research must be conducted to more accurately describe the pattern of academic citation. This may take the path of transforming the raw data or changing the basic model. This research is ongoing.

This model has implications for social learning theory (Bandura, 1977). Academic research may be considered an example of social learning. Students are taught research procedures through exemplars, classic experiments which serve as models for them to observe (Kuhn, 1970). Scholars learn from another by reading each other's research publications. Research manuscripts in print serve as models for future work. The individual scholar extracts the essential elements of the research paradigm from published manuscripts and perform similar research. The learner adopts the ideas in the articles to meet their individual research needs.

Social learning theory makes an important contribution to diffusion theory because it suggests that individiuals may modify innovations and use them as they feel appropriate rather than as prescribed by their designer. Hamblin, et al. (1973) even provide a mathematical model for social learning. However, what has not been addressed is social forgetting. In the proposed model, social learning is represented as (exp[bt+d]) and the social forgetting process by the expression (-exp[ct+d]). Overtime, as ideas are no longer invoked they are forgotten by the members of society. They are not communicated and newly socialized members cannot observe elders working with those ideas. Likewise, academic research may be viewed as being forgotten. Paradigms may be disadopted. Cited articles may be no longer referenced. Exemplar experiments, taught in laboratories, may be dropped in favor of newer models which take advantage of technological advances and paradigmatic shifts. This paper presented a model of social learning and forgetting. For academia, these results suggest that new ideas are learned faster than others are forgotten. This implies the fortunate consequence that some ideas are retained allowing academia to acculumlate knowledge.

Summary

This paper examined the pattern of diffusion in the academic literatures of the Sciences, Social Sciences and Arts and Humanities based on citations. An examination of the citations of articles from a given year to the year in which the cited article was published revealed a pattern. The percentage was initially small when there was no lag between the years. It then increases, reaching a peak in less than two years. Then, it gradually decreased over time. A mathematical model was developed to describe this pattern, which when tested explained between 96.9 and 98.3% of the variance depending on the data set. The proposed model had problems due to the heteroscedasticity in the citation variable. The results were interpreted as an example of social learning and forgetting.

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TABLE 1

DESCRIPTIVE PARAMETERS FOR CITATION DATA
BY DISCIPLINE TYPE

	Science		Social Science		Arts & Humanities	
	coefficient	range	coefficient	range	coefficient	range
a	13.895	.41	13.645	.35	4.773	.11
b	-0.138	.004	-0.139	.003	-0.074	.001
c	-1.547	.14	-1.353	.10	-2.759	.74
d	0.195	.024	0.139	.018	0.160	.052
t*	1.53		1.74		1.16	
YMAX	10.00		9.40		4.20	
R(squared)	.969		.983		.971	
Residual Analysis:						
skew	1.602		-0.279		0.160	
kurtosis	17.69		10.00		15.53	
correlation of residuals	-.103 p<.006		-.023 p<.318		-.09 p<.000	
N	564		440		1260	
Starting year	1950		1950		c.1800	

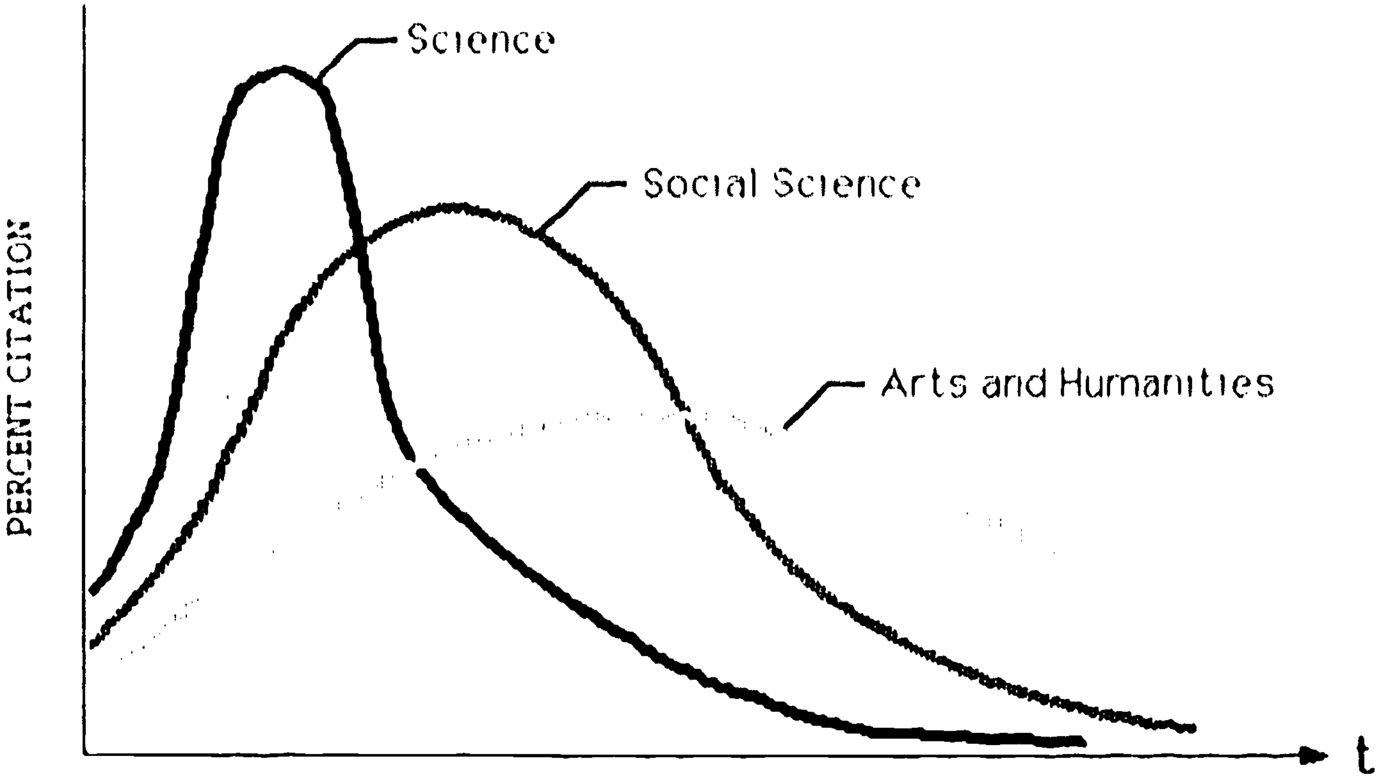

Figure 1.
Relative percent citation over time for Science, Social Science, and Arts and Humanities.

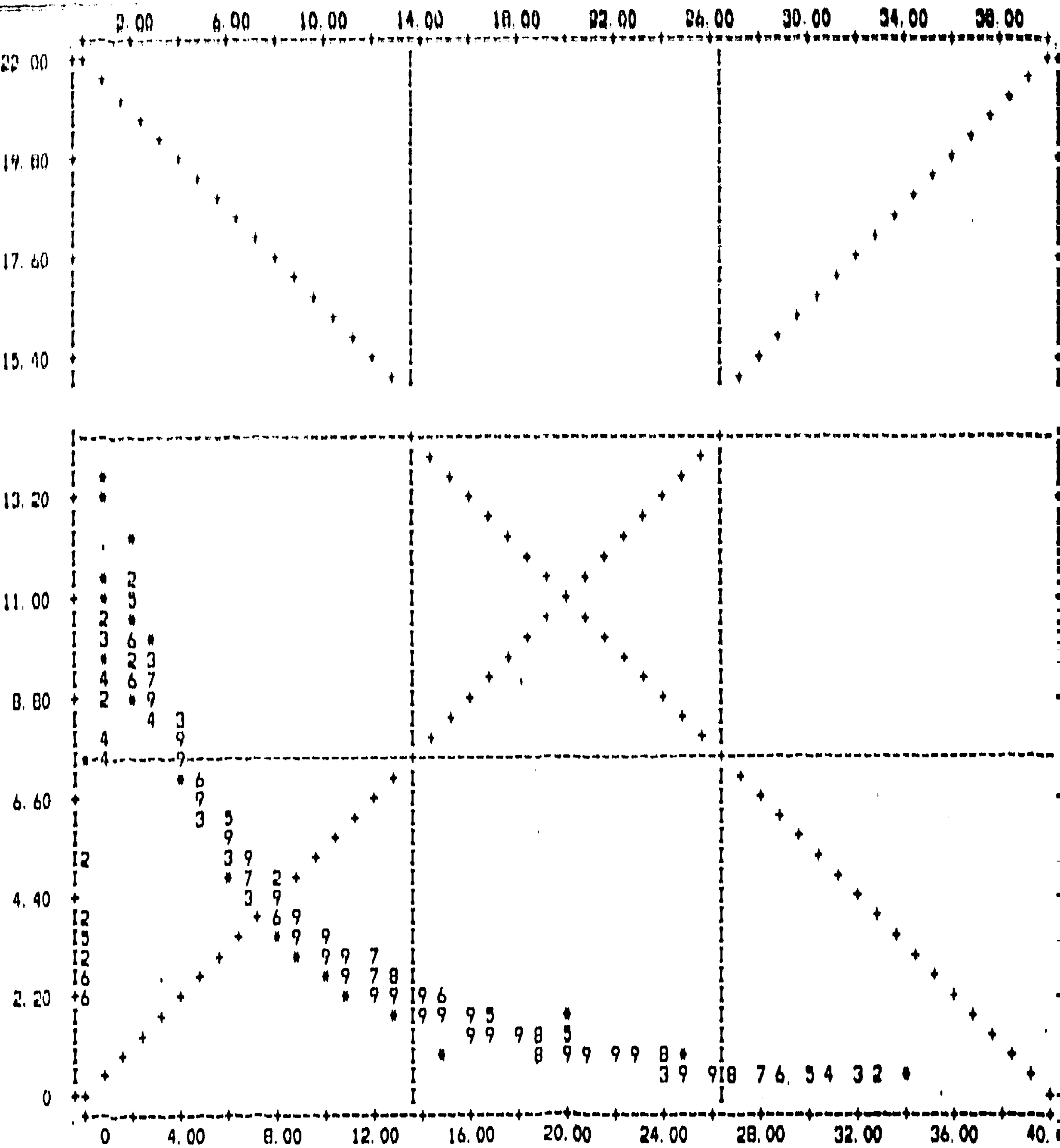

FIGURE 2A

PER CENT CITATION BY TIME--SCIENCE

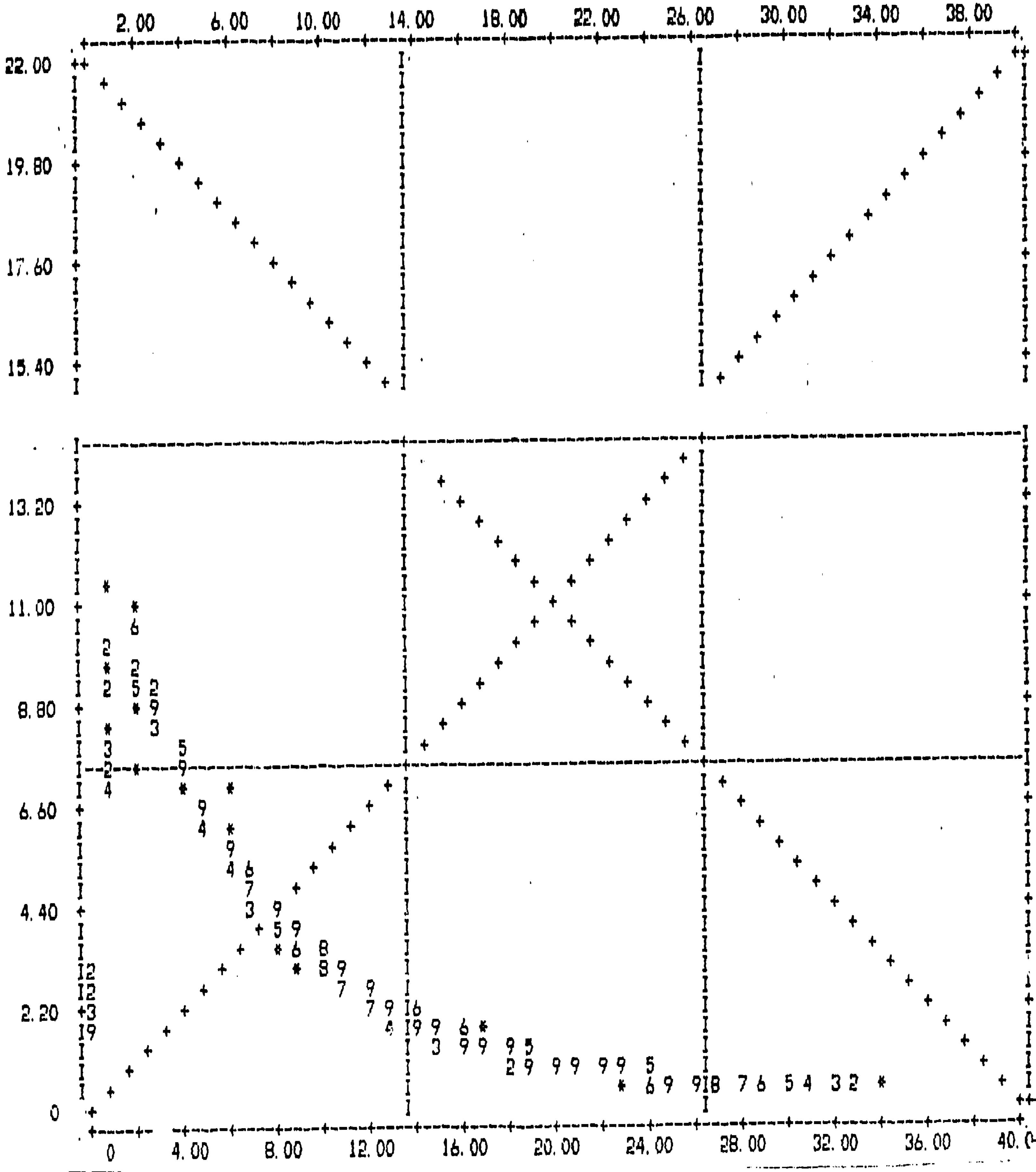

FIGURE 3B

PER CENT CITATION BY TIME--SOCIAL SCIENCE

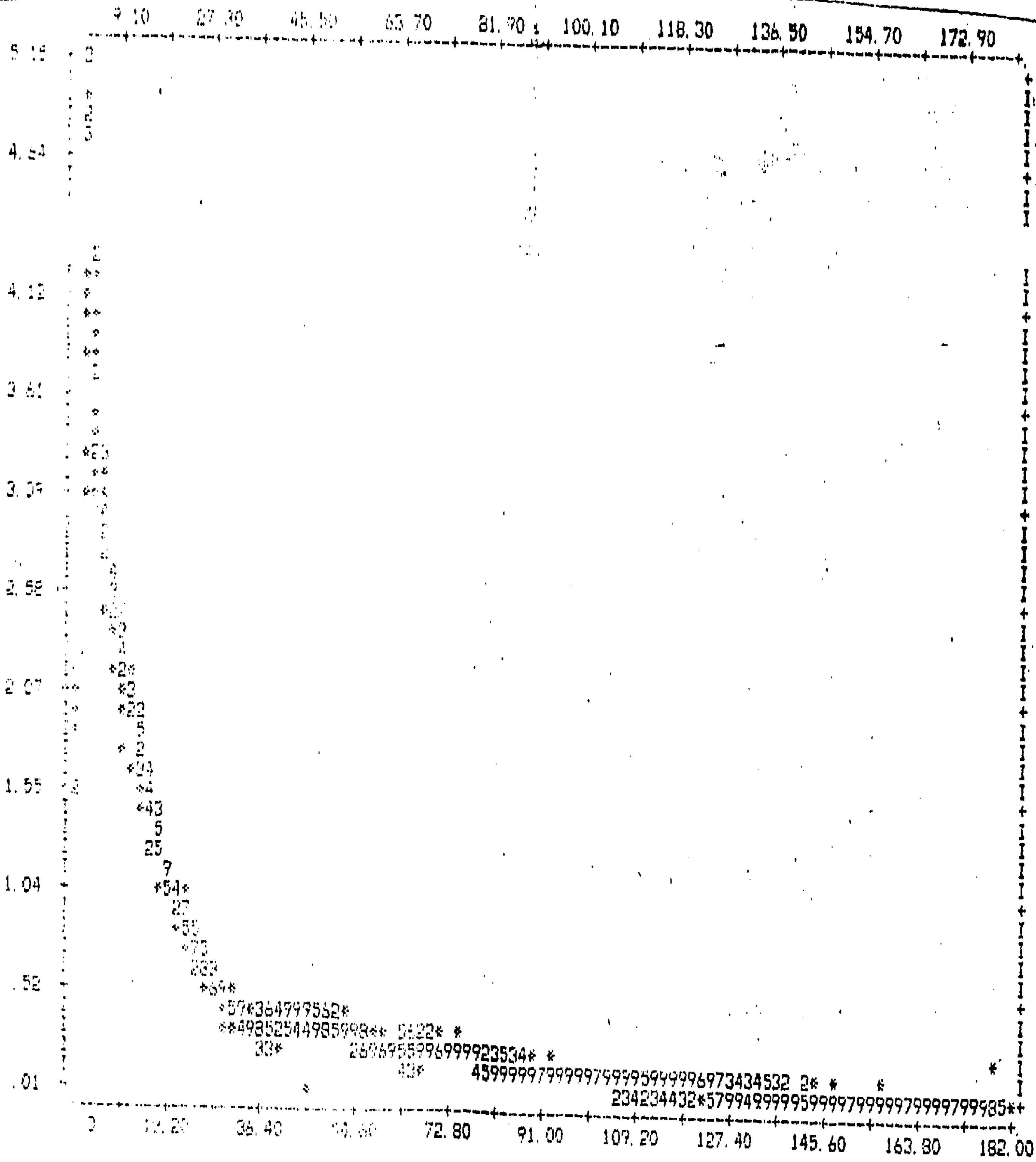

FIGURE 2C

PER CENT CITATION BY TIME--ARTS AND HUMANITIES

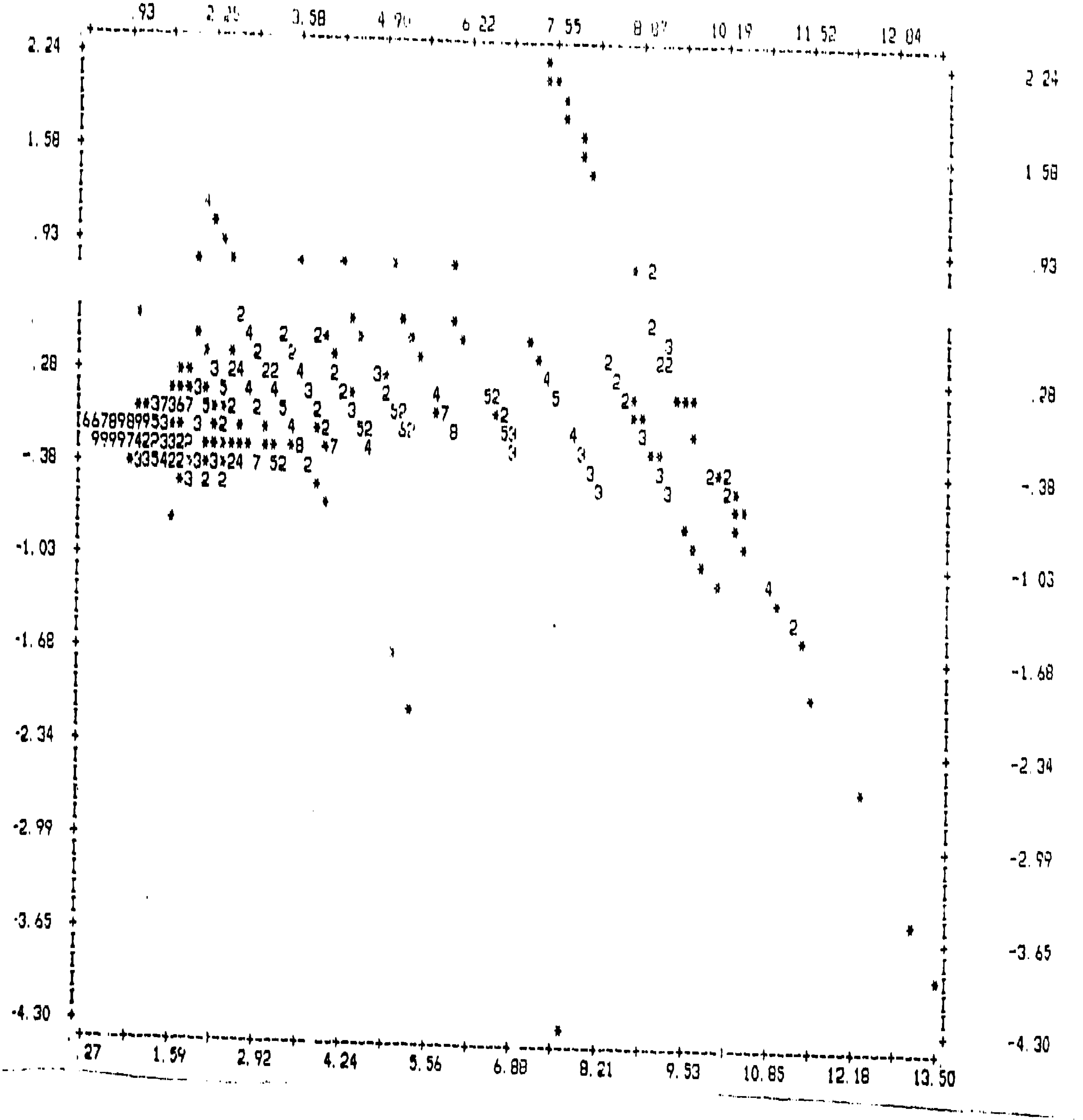

FIGURE 3
RESIDUALS FROM SCIENCE

SCIENCE CITATION INDEX® 1961-1984
CHRONOLOGICAL DISTRIBUTION OF CITATIONS TO AUTHORED ITEMS (NON-PATENTS)

Percentage of Unique Citations

Reference Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1984																								2.66
1983																							2.77	7.74
1982																						2.79	7.96	8.97
1981																					2.20	7.91	9.06	8.34
1980																				2.09	7.35	9.25	8.51	7.55
1979																			2.08	7.42	9.02	8.39	7.40	6.53
1978																		2.17	7.52	9.31	8.48	7.42	6.53	5.77
1977																	2.16	7.65	9.22	8.65	7.46	6.54	5.75	5.11
1976																7.62	9.39	9.22	8.60	7.57	6.50	5.75	5.05	4.52
1975															2.41	8.13	9.56	8.70	7.61	6.65	5.79	5.12	4.54	4.05
1974														2.54	8.73	9.61	8.82	7.56	6.60	5.81	5.07	4.49	3.99	3.58
1973													2.63	9.14	10.15	8.98	7.83	6.75	5.92	5.18	4.59	4.06	3.60	3.24
1972												2.77	8.95	10.23	9.09	7.90	6.85	5.95	5.24	4.62	4.11	3.65	3.24	2.92
1971											3.13	9.13	10.13	8.93	7.78	6.80	5.96	5.16	4.58	4.03	3.62	3.21	2.88	2.59
1970										3.20	9.22	10.26	9.13	7.77	6.79	5.96	5.25	4.62	4.08	3.63	3.29	2.92	2.62	2.36
1969									3.63	9.69	10.20	9.25	7.94	6.77	5.93	5.21	4.61	4.06	3.60	3.22	2.91	2.59	2.32	2.09
1968								3.38	9.95	10.40	9.27	8.04	6.89	5.93	5.21	4.60	4.09	3.62	3.25	2.87	2.62	2.34	2.10	1.90
1967							3.39	10.34	10.76	9.18	8.04	6.94	6.00	5.18	4.55	4.08	3.63	3.24	2.89	2.58	2.36	2.11	1.89	1.72
1966						3.31	10.50	10.90	9.30	7.78	6.69	5.86	5.06	4.39	3.89	3.48	3.11	2.78	2.50	2.24	2.05	1.83	1.65	1.50
1965					5.07	10.79	11.21	9.76	8.10	6.84	5.96	5.21	4.50	3.94	3.51	3.14	2.84	2.53	2.29	2.04	1.89	1.69	1.52	1.38
1964				5.36	13.05	11.24	9.68	8.18	6.77	5.76	5.06	4.43	3.83	3.37	3.01	2.71	2.44	2.19	1.98	1.78	1.64	1.46	1.33	1.21
1963			3.92	13.50	11.34	9.55	8.16	6.90	5.68	4.94	4.32	3.81	3.33	2.61	2.92	2.36	2.13	1.92	1.75	1.56	1.45	1.29	1.17	1.07
1962		3.86	9.98	11.04	9.10	8.00	6.79	5.82	4.78	4.23	3.71	3.28	2.87	2.52	2.24	2.04	1.85	1.69	1.53	1.37	1.28	1.14	1.03	0.95
1961	3.51	10.27	10.07	8.78	7.50	6.62	5.74	4.92	4.06	3.62	3.17	2.84	2.48	2.19	1.97	1.79	1.62	1.48	1.34	1.20	1.12	1.01	0.91	0.83
1960	11.58	10.88	8.90	7.40	6.54	5.85	5.09	4.41	3.68	3.28	2.90	2.60	2.26	2.01	1.80	1.64	1.49	1.36	1.25	1.11	1.04	0.93	0.85	0.78
1959	12.20	8.90	7.16	5.95	5.41	4.82	4.16	3.65	3.07	2.78	2.39	2.15	1.88	1.66	1.51	1.38	1.26	1.14	1.04	0.95	0.87	0.79	0.71	0.66
1958	10.01	7.31	6.02	5.00	4.53	4.11	3.58	3.14	2.66	2.39	2.12	1.90	1.67	1.48	1.34	1.22	1.11	1.02	0.93	0.84	0.79	0.71	0.64	0.59
1957	8.16	6.13	5.12	4.21	3.89	3.52	3.10	2.74	2.33	2.09	1.84	1.66	1.47	1.31	1.19	1.08	1.00	0.91	0.84	0.76	0.71	0.62	0.58	0.53
1956	6.88	5.26	4.39	3.64	3.39	3.12	2.75	2.43	2.04	1.86	1.66	1.20	1.32	1.18	1.07	0.98	0.90	0.83	0.76	0.69	0.65	0.58	0.53	0.49
1955	5.82	4.60	3.90	3.26	3.02	2.79	2.44	2.16	1.82	1.66	1.49	1.34	1.19	1.06	0.95	0.89	0.82	0.75	0.68	0.63	0.58	0.52	0.48	0.44
1954	4.85	3.91	3.35	2.78	2.57	2.41	2.12	1.87	1.61	1.46	1.30	1.18	1.03	0.93	0.84	0.79	0.72	0.66	0.61	0.55	0.52	0.46	0.43	0.40
1953	4.25	3.46	2.97	2.47	2.27	2.12	1.87	1.67	1.43	1.33	1.19	1.06	0.95	0.84	0.77	0.72	0.66	0.61	0.56	0.51	0.48	0.43	0.40	0.37
1952	3.56	2.98	2.58	2.11	2.00	1.88	1.64	1.45	1.25	1.15	1.04	0.92	0.84	0.75	0.68	0.63	0.59	0.54	0.49	0.46	0.43	0.39	0.36	0.33
1951	3.12	2.59	2.23	1.85	1.74	1.64	1.45	1.30	1.12	1.01	0.93	0.83	0.74	0.67	0.61	0.57	0.53	0.48	0.45	0.40	0.39	0.34	0.32	0.29
1950	2.66	2.29	1.98	1.67	1.54	1.47	1.29	1.17	1.00	0.91	0.84	0.75	0.66	0.60	0.56	0.51	0.48	0.44	0.40	0.37	0.35	0.31	0.29	0.27

SOCIAL SCIENCES CITATION INDEX® 1969-1984
CHRONOLOGICAL DISTRIBUTION OF CITATIONS TO AUTHORED ITEMS

Percentage of Unique Citations
Citing Years

CITED YEARS	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1984																1.99
1983															2.06	7.66
1982														1.90	7.70	9.25
1981													1.66	7.16	9.41	8.36
1980												1.77	6.92	9.02	8.68	7.57
1979											1.65	7.19	9.01	8.55	7.57	6.62
1978										1.82	7.17	9.33	8.62	7.71	6.75	5.96
1977									1.77	7.73	9.29	8.62	7.72	6.81	5.92	5.25
1976								1.76	7.55	7.69	8.55	7.63	6.70	5.92	5.15	4.55
1975							1.90	7.99	9.55	8.69	7.64	6.65	5.92	5.20	4.47	4.01
1974						1.91	8.38	9.67	8.65	7.43	6.54	5.71	5.07	4.42	3.85	3.45
1973					2.31	9.28	10.47	8.89	7.69	6.59	6.82	5.04	4.54	3.99	3.44	3.07
1972				2.73	9.34	10.63	9.20	7.74	6.67	5.80	5.15	4.50	4.00	3.55	3.06	2.75
1971			2.71	9.79	10.68	8.99	7.69	6.64	5.75	4.94	4.42	3.92	3.46	3.05	2.72	2.41
1970		2.92	10.29	10.59	9.29	7.71	6.66	5.83	5.10	4.40	3.94	3.43	3.10	2.75	2.40	2.15
1969	2.93	11.26	10.57	8.94	7.75	6.54	5.66	4.90	4.40	3.76	3.36	2.96	2.68	2.38	2.10	1.90
1968	10.33	11.06	8.99	7.61	6.71	5.64	4.87	4.34	3.86	3.31	3.00	2.65	2.41	2.15	1.90	1.72
1967	10.48	8.67	7.46	6.31	5.68	4.80	4.24	3.81	3.38	2.93	2.62	2.34	2.12	1.90	1.65	1.54
1966	8.64	7.15	6.15	5.24	4.76	4.12	3.60	3.22	2.90	2.49	2.28	2.00	1.81	1.65	1.46	1.35
1965	7.44	6.11	5.39	4.69	4.16	3.65	3.23	2.87	2.61	2.24	2.09	1.81	1.67	1.51	1.34	1.25
1964	6.22	5.09	4.50	3.86	3.51	3.07	2.76	2.46	2.23	1.93	1.73	1.56	1.44	1.29	1.17	1.07
1963	5.23	4.36	3.92	3.33	3.02	2.69	2.35	2.14	1.95	1.70	1.56	1.39	1.28	1.16	1.05	0.95
1962	4.45	3.72	3.32	2.94	2.59	2.33	2.06	1.88	1.71	1.52	1.38	1.21	1.12	1.04	0.94	0.85
1961	3.85	3.18	2.93	2.57	2.25	2.09	1.82	1.69	1.51	1.34	1.21	1.09	1.01	0.94	0.85	0.78
1960	3.45	2.88	2.62	2.29	2.06	1.87	1.65	1.52	1.38	1.23	1.16	1.01	0.93	0.86	0.78	0.71
1959	2.92	2.44	2.17	1.94	1.74	1.59	1.41	1.29	1.20	1.06	0.96	0.89	0.81	0.73	0.69	0.60
1958	2.54	2.17	1.94	1.76	1.55	1.41	1.27	1.18	1.07	0.95	0.86	0.79	0.73	0.66	0.61	0.57
1957	2.19	1.90	1.74	1.50	1.36	1.27	1.13	1.05	0.96	0.87	0.80	0.71	0.68	0.60	0.54	0.52
1956	1.96	1.63	1.56	1.36	1.26	1.14	1.01	0.93	0.87	0.79	0.73	0.65	0.60	0.55	0.51	0.46
1955	1.69	1.49	1.34	1.22	1.07	0.97	0.88	0.84	0.78	0.71	0.65	0.57	0.54	0.49	0.46	0.42
1954	1.53	1.33	1.24	1.14	0.95	0.93	0.81	0.77	0.71	0.66	0.57	0.53	0.49	0.44	0.41	0.39
1953	1.38	1.20	1.09	1.00	0.89	0.84	0.74	0.71	0.64	0.60	0.54	0.49	0.45	0.43	0.39	0.36
1952	1.16	1.05	0.96	0.87	0.78	0.74	0.65	0.61	0.58	0.53	0.47	0.45	0.41	0.38	0.33	0.31
1951	1.10	0.97	0.89	0.84	0.73	0.70	0.62	0.58	0.54	0.60	0.46	0.41	0.39	0.35	0.34	0.30
1950	1.00	0.91	0.83	[illegible]	0.68	0.63	[illegible]	0.54	0.51	0.45	0.43	0.40	0.37	0.33	0.31	0.29

ARTS & HUMANITIES CITATION INDEX™—1976-1982
CHRONOLOGICAL DISTRIBUTION OF CITATIONS TO AUTHORED ITEMS

PERCENTAGE OF UNIQUE CITATIONS

Reference Year	1976	1977	1978	1979	1980	1981	1982
1982							1.81
1981						1.94	4.23
1980					1.60	4.10	4.70
1979				1.53	3.98	4.02	4.26
1978			1.73	3.79	5.10	4.79	3.72
1977		2.05	4.74	4.91	4.37	3.66	3.31
1976	2.19	3.05	5.15	3.89	1.77	3.26	3.00
1975	4.55	3.32	4.01	3.30	1.29	2.88	2.75
1974	4.75	3.25	3.42	2.97	3.03	2.70	2.46
1973	3.99	3.14	3.13	2.80	2.82	2.54	2.35
1972	3.47	3.15	3.00	2.66	2.70	2.40	2.25
1971	3.07	2.92	2.72	2.45	2.44	2.22	2.05
1970	2.83	2.78	2.59	2.34	2.32	2.12	1.98
1969	2.50	2.53	2.26	2.07	2.03	1.87	1.77
1968	2.17	2.50	2.20	1.98	1.95	1.82	1.70
1967	2.17	2.29	2.01	1.86	1.81	1.70	1.56
1966	1.99	2.05	1.80	1.69	1.61	1.50	1.44
1965	1.80	1.91	1.68	1.59	1.51	1.45	1.37
1964	1.64	1.67	1.47	1.41	1.36	1.27	1.17
1963	1.53	1.65	1.45	1.33	1.27	1.19	1.11
1962	1.46	1.52	1.34	1.29	1.17	1.12	1.06
1961	1.28	1.41	1.23	1.12	1.07	1.01	.95
1960	1.25	1.32	1.15	1.08	1.00	.99	.92
1959	1.07	1.16	1.02	.96	.90	.86	.79
1958	1.01	1.11	.98	.88	.87	.81	.76
1957	.99	1.05	.94	.89	.83	.78	.73
1956	.82	.93	.81	.77	.74	.70	.65
1955	.82	.91	.80	.71	.70	.67	.61
1954	.74	.78	.68	.64	.63	.62	.57
1953	.71	.79	.68	.64	.60	.58	.54
1952	.65	.71	.62	.58	.56	.53	.49
1951	.56	.65	.57	.57	.52	.50	.47
1950	.58	.66	.58	.54	.52	.48	.45
1949	.54	.60	.52	.51	.47	.45	.42
1948	.48	.56	.50	.47	.44	.42	.38
1947	.45	.51	.46	.45	.38	.37	.33
1946	.36	.42	.38	.38	.34	.32	.29
1945	.31	.37	.33	.31	.27	.27	.22
1944	.28	.33	.30	.29	.25	.23	.23
1943	.28	.31	.28	.29	.28	.24	.25
1942	.30	.36	.32	.31	.27	.28	.26
1941	.32	.39	.34	.35	.30	.27	.27
1940	.36	.42	.37	.34	.31	.30	.29
1939	.39	.47	.42	.40	.36	.36	.33
1938	.42	.47	.42	.41	.37	.36	.35
1937	.40	.45	.40	.39	.37	.35	.34
1936	.43	.46	.42	.39	.38	.38	.35
1935	.44	.46	.41	.41	.36	.35	.32
1934	.42	.47	.42	.38	.34	.35	.34
1933	.37	.40	.38	.39	.33	.34	.29
1932	.39	.45	.41	.35	.36	.33	.32
1931	.39	.45	.41	.35	.33	.33	.31
1930	.40	.46	.43	.37	.37	.35	.32
1929	.37	.40	.37	.37	.34	.32	.31
1928	.36	.40	.35	.33	.32	.31	.30
1927	.34	.42	.37	.34	.32	.32	.31
1926	.32	.39	.34	.30	.30	.27	.26
1925	.31	.38	.33	.11	.30	.29	.28
1924	.30	.35	.30	.28	.29	.27	.25
1923	.27	.34	.29	.25	.29	.26	.25
1922	.26	.33	.28	.26	.25	.24	.23
1921	.23	.29	.25	.22	.22	.21	.20
1920	.24	.29	.24	.22	.25	.20	.19
1919	.19	.27	.22	.20	.21	.17	.16
1918	.21	.25	.20	.17	.18	.16	.14
1917	.20	.30	.24	.20	.19	.15	.14
1916	.18	.25	.21	.20	.18	.16	.15
1915	.19	.25	.21	.20	.18	.17	.15
1914	.25	.34	.28	.27	.21	.22	.21
1913	.28	.36	.30	.29	.26	.21	.24
1912	.28	.33	.29	.25	.26	.24	.22
1911	.25	.29	.24	.24	.23	.23	.22
1910	.26	.31	.26	.23	.24	.22	.22
1909	.24	.28	.23	.23	.22	.21	.20
1908	.24	.28	.23	.22	.22	.20	.19
1907	.22	.28	.23	.21	.22	.19	.18
1906	.20	.27	.22	.20	.21	.19	.17
1905	.20	.28	.24	.21	.20	.18	.17
1904	.20	.24	.20	.19	.18	.18	.17
1903	.23	.27	.22	.21	.18	.18	.16
1902	.19	.24	.20	.18	.17	.16	.14
1901	.18	.21	.17	.17	.17	.15	.13
1900	.17	.21	.18	.17	.16	.14	.15
1899	.17	.18	.16	.16	.16	.14	.13
1898	.17	.20	.17	.15	.15	.14	.12
1897	.17	.19	.17	.16	.16	.13	.12
1896	.16	.19	.16	.17	.15	.14	.13
1895	.16	.20	.17	.14	.15	.12	.12
1894	.13	.18	.17	.14	.14	.13	.11
1893	.14	.17	.15	.15	.15	.13	.12
1892	.15	.18	.17	.15	.14	.12	.12
1891	.12	.21	.18	.14	.13	.12	.10
1890	.13	.19	.17	.14	.12	.11	.11
1889	.13	.17	.14	.12	.12	.11	.11
1888	.13	.17	.14	.13	.11	.11	.11
1887	.13	.16	.11	.12	.12	.11	.12
1886	.13	.16	.14	.12	.12	.11	.10
1885	.14	.15	.13	.11	.10	.12	.08
1884	.13	.18	.15	.12	.10	.10	.10
1883	.12	.16	.13	.13	.10	.11	.08
1882	.11	.14	.12	.11	.10	.10	.08
1881	.10	.13	.10	.09	.09	.10	.09
1880	.11	.12	.10	.11	.10	.10	.08
1879	.10	.11	.09	.09	.09	.08	.07
1878	.11	.11	.09	.10	.10	.08	.07
1877	.10	.13	.11	.09	.10	.10	.06
1876	.10	.12	.10	.07	.10	.08	.07
1875	.08	.11	.10	.08	.09	.07	.06
1874	.08	.10	.08	.07	.08	.07	.06
1873	.08	.09	.08	.06	.07	.07	.06
1872	.08	.09	.08	.09	.08	.07	.06
1871	.07	.09	.07	.06	.06	.06	.06
1870	.08	.10	.08	.08	.08	.06	.06
1869	.07	.11	.08	.07	.07	.07	.06
1868	.08	.11	.09	.08	.09	.06	.06
1867	.09	.12	.10	.09	.08	.06	.05
1866	.10	.10	.08	.07	.07	.06	.06
1865	.10	.13	.10	.08	.08	.07	.06
1864	.10	.10	.09	.07	.07	.07	.05
1863	.08	.12	.10	.09	.06	.07	.05
1862	.10	.11	.09	.06	.07	.07	.05
1861	.10	.12	.11	.07	.08	.08	.05
1860	.08	.10	.09	.08	.07	.07	.05
1859	.08	.09	.07	.08	.07	.07	.05
1858	.07	.08	.07	.08	.07	.05	.04
1857	.08	.09	.08	.09	.07	.06	.05
1856	.08	.09	.08	.09	.07	.06	.05
1855	.08	.10	.08	.06	.06	.06	.04
1854	.08	.12	.10	.06	.07	.08	.05
1853	.09	.11	.10	.06	.06	.05	.05
1852	.08	.10	.08	.06	.06	.05	.04
1851	.07	.08	.06	.06	.06	.05	.04
1850	.07	.10	.08	.06	.06	.05	.04
1849	.06	.08	.07	.06	.05	.04	.04
1848	.06	.09	.07	.08	.06	.05	.04
1847	.06	.08	.06	.06	.06	.05	.04
1846	.06	.08	.06	.06	.06	.05	.05
1845	.07	.08	.06	.06	.06	.05	.05
1844	.07	.09	.07	.06	.06	.06	.04
1843	.07	.10	.06	.05	.05	.05	.04
1842	.07	.08	.07	.05	.05	.04	.04
1841	.07	.06	.05	.05	.05	.04	.04
1840	.07	.06	.05	.05	.05	.05	.04
1839	.07	.06	.05	.05	.06	.04	.04
1838	.07	.07	.06	.04	.06	.04	.04
1837	.06	.06	.05	.05	.04	.04	.04
1836	.05	.06	.05	.04	.05	.05	.04
1835	.06	.08	.06	.04	.04	.05	.04
1834	.07	.07	.06	.04	.04	.05	.04
1833	.06	.05	.04	.04	.05	.04	.03
1832	.06	.04	.04	.04	.05	.05	.03
1831	.05	.06	.05	.03	.04	.04	.03
1830	.05	.07	.06	.04	.04	.04	.04
1829	.04	.06	.05	.04	.03	.03	.03
1828	.04	.05	.04	.04	.01	.04	.02
1827	.04	.04	.03	.03	.03	.03	.02
1826	.04	.03	.04	.03	.03	.02	.02
1825	.04	.05	.04	.03	.03	.03	.03
1824	.03	.04	.03	.03	.03	.03	.02
1823	.04	.04	.03	.02	.03	.03	.02
1822	.04	.04	.03	.03	.03	.03	.03
1821	.06	.04	.03	.03	.03	.03	.02
1820	.07	.03	.03	.03	.03	.03	.03
1819	.04	.04	.04	.03	.03	.03	.02
1818	.04	.04	.03	.03	.02	.03	.02
1817	.04	.05	.04	.03	.02	.02	.02
1816	.03	.04	.03	.02	.02	.02	.02
1815	.03	.03	.03	.02	.02	.02	.02
1814	.04	.03	.02	.02	.02	.02	.02
1813	.03	.03	.02	.02	.02	.02	.02
1812	.03	.03	.03	.02	.02	.02	.02
1811	.04	.03	.02	.01	.02	.02	.02
1810	.03	.03	.03	.02	.03	.03	.02
1809	.04	.03	.03	.02	.02	.02	.02
1808	.03	.04	.03	.04	.03	.02	.02
1807	.03	.02	.02	.02	.02	.02	.01
1806	.03	.03	.03	.02	.02	.02	.01
1805	.03	.03	.03	.02	.02	.02	.01
1804	.02	.04	.03	.01	.01	.02	.01
1803	.03	.04	.03	.02	.02	.02	.01
1802	.01	.04	.03	.02	.02	.02	.02
1801	.03	.04	.03	.02	.02	.02	.02
1800	.03	.05	.04	.03	.02	.02	.02
1700-99	1.69	1.91	1.60	1.49	1.28	1.28	.96
1600-99	.82	1.18	.96	.83	.71	.67	.54
1500-99	.52	.61	.51	.51	.43	.40	.29
pre-1500	.12	.14	.11	.12	.09	.08	.05
unavailable	23.00	17.81	18.84	22.46	19.95	21.15	22.72