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THE IMPACT OF AUDIENCE
ON
ISAAC ASIMOV'S POPULAR SCIENCE WRITING

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Daisy J. Whiting

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ABSTRACT

Isaac Asimov has enjoyed phenomenal success as a popularizer of science for over 30 years. The volume and diversity of his works, his many honors, and his large following make him a model technical writer worthy of study.

Even though Asimov denies any knowledge of audience analysis, this study shows that he gives careful consideration to rhetorical and stylistic techniques that are especially suited for the lay audience. He achieves an informal, personal style through the use of autobiographical comment, first and second person personal pronouns, direct address, rhetorical questions, plays on words, parenthetical expressions, self-effacement, and self-praise. Asimov's stylistic approach (sentence length, paragraph length, and sentence structure) is also adapted to the audience.

Many critics consider Asimov to be America's greatest explainer, yet two readability measures (the Flesch test and the cloze procedure) applied to samples of Asimov's popular science writing do not corroborate the claims that Asimov's material is highly readable.

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My special thanks go to Thomas Tallant, who now recognizes me as a member of his exclusive "Gentle Readers" fan club. His wise counsel, patient encouragement, and many acts of thoughtfulness in helping me meet problems when they arose are appreciated beyond measure.

Whatever errors remain in my work are solely my responsibility.

CONTENTS

CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The communication process involves four basic elements: the sender, the message, the subject, and the audience. Although each element is a necessary part of any act of communication, the audience, in the final analysis, determines the success or failure of a communication act.

Scientific and technical information today has the potential for reaching vast audiences. Experts have calculated that over four million technical articles are published annually in over 70,000 scientific periodicals (Witkiewicz & Pilak 105). This explosion of scientific information is principally a product of modern funding that establishes grants for specific scientific projects, and the results of those projects are expected to be published even though they may be incomplete and often trivial. Keith Thompson judges that the increase of the quantity of scientific information has led to a reduction of quality: "scarcely one-hundredth of it has any literary value deriving from qualities of expression, form, and meaning." He adds that science seems to be preoccupied with "dissemination of information rather than real communication" (Thompson 186).

Much scientific and technical information never reaches audiences that it is designed to benefit because it is often written in a style that most general audiences cannot comprehend. Communication barriers consist of specialized terminology, technical jargon, multiple strings of modifiers, acronyms, and mathematical equations. Technical communication that is designed to be "mathematically plain" tries to capture in unambiguous language the realities discovered in the

laboratories. In their attempts to write clearly, many scientists are so abstruse that a high portion of their work is rarely referred to. Keith Thompson cites Derek de Solla Price's calculation in Little Science, Big Science that "the average readership of a scientific paper, apart from the author and editorial types, is one" (Thompson 185).

Recent studies related to developing better ways to communicate scientific and technical information to general audiences suggest that the usefulness of the mathematically plain style of writing is a myth. This plain style of scientific writing was initiated by Francis Bacon and members of the Royal Society in the seventeenth century to counter the stylistic excesses of the previous century. However, the emphasis on rhetorical plainness gradually resulted in new excesses which created new communication barriers. Marder and Guinn have observed that "the machinelike encodings in the usual technical documents are far more ornamental than any produced by a writer sensible of a graceful aesthetic." Their studies show that the writing produced by many scientists contains more complexity of expression than complexity of thought, where the audience must "struggle to decode what the writer has muddily encoded, often sifting through layers of circumlocution, abstract verbiage, and phrases and clauses strung together every which way" (Marder and Guinn 36).

Whitburn also believes that plainness is no longer an ideal for today's scientific and technical writers. He points out that the rapid developments in modern science have increased the need for scientists to address nonexperts such as government and foundation representatives

who provide funding for scientific projects, supervisors, colleagues from other fields, laborers, and the general public. Whitburn recalls that his own experience in industry has convinced him that "audience adaptation is the most serious problem in our discipline." He believes scientists and technologists need to develop alternative ways of presenting scientific information to their audience (Whitburn et al. 353). It is this need that forms the context for this study.

CONTEXT FOR THIS STUDY

Audiences consisting of nonscientists need scientific and technical information to keep abreast of changes so that they can make wise decisions about important issues that affect their lives. Knowledge about science can dispel fear of the unknown and offer alternatives and solutions to pressing problems such as overpopulation, environmental pollution, dwindling supplies of energy, and finding cures of dreaded diseases. Since public funds are often allocated toward scientific research, scientists should feel obligated to present their findings in a format that makes science intelligible to the public.

Scientists have been reluctant or unable to communicate their findings to the general public in a language that can be readily understood. The interpretation and dissemination of scientific news have been left to popular science writers; they have developed audience analysis skills that enable them to make scientific information intelligible to nonscientists. Because the terms "audience analysis" and "popular science" are used throughout this thesis, a brief

explanation is presented below for the reader who may be unfamiliar with them.

AUDIENCE ANALYSIS

The term "audience analysis," in the context of technical writing, refers to gaining as much knowledge as possible about potential readers before beginning to write a technical document and then tailoring the format of the document to suit their needs. Samples of the types of questions technical writers might ask about their audience before they begin to write scientific information include the following:

- What does the reader already know about this subject?
- Will the reader understand this technical information without definition or explanation?
- Will the reader understand specialized vocabulary?
- Will the reader be able to understand mathematical formulas and detailed charts and graphs?
- Will the reader benefit from simple analogies, background information, or graphics?
- Will the reader respond to humorous anecdotes or personal references?

Although audiences are never uniform, technical writers generally write for four different types: the lay audience, the executive audience, the technician audience, and the expert audience. Audience analysis begins with an understanding of these classifications of readers.

Lay Audience. Members of the lay audience usually have a high school education and read popular magazines to keep informed about the changes going on around them. Generally, lay audiences have a practical purpose for reading technical documents; they want to know how scientific developments will affect them personally. They are motivated to read information that provides human interest, background material necessary to understand technical concepts, analogies, definitions, simple graphics, a conversational tone, and simple sentence structure.

Executive Audience. Members of the executive audience generally have college degrees and read business and professional magazines to gain information to help them make business and economic decisions about scientific and technical developments. Writing for executives involves using techniques to help them make efficient use of their time: formatting text with clear headings, subheadings, lists prefaced by bullets for ease of recognition of important steps or procedures, simple tables, figures, charts, maps, photographs and drawings, standard abbreviations and symbols, and only limited mathematical concepts.

Technician Audience. Technicians are generally high school or college graduates who have technical aptitude and training. They read technical documents, magazines, and proposals that give them information about how technological developments work, how products are made, or how machines operate.

Technicians make practical use of information presented in technical documents; therefore, they depend on technical writing that presents clear definitions, descriptions, precise measurements, diagrams, and charts that explain relevant processes.

Expert Audience. Expert audiences generally are college graduates with advanced degrees who read information found in specialized, scholarly journals that keep them experts in their narrow areas of specialization. Because experts have an intimate knowledge of their fields, technical writers for this audience can present their information in a factual manner using abbreviations, complex mathematical, chemical, and scientific details, line graphs, drawings, maps, and photographs with little background information or definition.

Often audiences cannot be narrowly defined, and, frequently, they consist of combinations of the four types. However, the successful technical writer analyzes his audience closely before he begins to write so that he can meet the special needs of his readers.

A technical writer's success can be measured by his ability to communicate effectively with his audience. Some technical writers have better audience analysis skills than others, but one area in which audience analysis skills are essential is that of popular science writing. A brief overview of popular science writing is presented below.

POPULAR SCIENCE WRITING

Popular science writers should be adept at communicating effectively with the lay audience (general public). Hillier Krieghbaum defines popular science writing as

> the dissemination of such [scientific] news and information to the general public through the mass media. It does not include how scientists, technicians, engineers, or physicians communicate with their colleagues and peers--unless, of course, this is done through daily newspapers, news magazines, radio, or television programs aimed at the average individual, not the specialist (Krieghbaum 2).

Popular science writers of the future must have a close rapport with their lay audience, for, according to John Kowal, they "will have the responsibility to provide the information necessary for the great public policy debates that await us in the Technological Age." He adds that the popular science writer "will be faced with the problem of making sense out of the technical and specialized arguments in a broad range of scientific and technical activity." Kowal suggests that the popular science writer must be proficient in audience adaptation:

> The science writer must be able to perform several functions, all at the same time. He or she must report news from the frontiers of scientific research and development, present all sides fairly when issues of the merit and application of the scientific enterprise are questioned, and put the information in the context of public policy and implications for the everyday world.
>
> The science writer must be more than conversant in what is happening in exotic areas. He or she must be able to ascertain and evaluate the work through independent sources. From that basic understanding will come the implications of the scientific activity for our social, economic, and political lives.
>
> In short, the science writer must make the science news and its implications understandable (Kowal 308).

Some popular science writers enjoy more success than others. The anthropologist Loren Eiseley, the mathematician Jacob Bronowski, the biologist Lewis Thomas, and the scientist Carl Sagan, for example, have

their large bodies of loyal fans. But no popular science writer has enjoyed such phenomenal success as Isaac Asimov, the subject of this study.

PURPOSE OF THIS STUDY

Although the subject of this study is Isaac Asimov, a successful writer of popular science for over thirty years, the purpose of the study is to analyze Asimov's use of audience analysis. The results of the study should prove beneficial to technical writers in general and popular science writers in particular.

ORGANIZATION

Chapter I presents the rationale for selecting Asimov as a popular science writer worthy of study. Chapter II presents Asimov's image as a popular science writer as seen both by the critics and by Isaac Asimov. Chapter III identifies Asimov's close connection with the lay audience; Chapter IV outlines Asimov's rhetorical methods that are effective in reaching the lay audience; and Chapter V presents a stylistic examination of those methods. Chapter VI addresses the issue of Asimov's readability from the perspective of two popular readability measures: the Flesh test and the cloze procedure. It also presents the results from an application of these two readability measures to samples of Asimov's popular science writing.

CHAPTER I

ASIMOV'S STANDING AMONG POPULAR SCIENCE WRITERS

Popular science writing began in the seventeenth century with the Cartesian revolution in 1637, the founding of the Royal Society in 1660, and the founding of the French Academy of Sciences in 1666 (Richardson 111). With the launching of the Space Age in 1957, popular science writers were in great demand. Many of our best popular science writers today entered the profession at that time. Selecting only one popular science writer among so many on which to base a study of audience analysis presents a real challenge. However, I believe Isaac Asimov is a worthy choice for such a study. He has three important qualifications that are evidence of his importance as a popular science writer: (1) the volume of his publications, (2) the diversity of his publications, and (3) the honors he has received. (A discussion of the quality of Asimov's work appears in Chapter II.)

1.1 VOLUME OF PUBLICATION

Isaac Asimov's incredible amount of published material has earned him the label of "the writing machine" (Calendar, New York Times Book Review 1976). Asimov publishes articles and books so rapidly that bibliographers find it difficult to keep an accurate record of his work. Before a specific count of his books and articles can appear in print, the figure is already outdated. Nevertheless, his standing among popular science writers can by judged by his volume of (1)books,

(2) articles, and (3) his unique ability to get extra mileage from his writing.

1.1.1 Volume of books. Asimov writes that his most frequently asked question is "How many books have you published?" (The Left Hand of the Electron 145). He admits that giving an exact count is difficult. He explains that although a writer does not generally count second editions as new books, there have been some occasions when he has done so. For instance, the updating of the third edition of his The Intelligent Man's Guide to Science (1972) required substantial changes. He spent as much time and energy on the update as he would have on a new book, so he counts the revision as a new book.

According to Bette Chambers, Asimov's estimate of the number of books he has published as of December 1986 is "more than 330 books." In this estimate, Asimov includes the books he has co-authored, his anthologies of the articles he has written for magazines, his anthologies of others' works, and his story collections. Chambers notes that the majority of these books are "nonfiction on science subjects" (Chambers 13).

Asimov admitted to some number-fudging when he included 54 anthologies in his third set of 100 books timed to be released just before his 65th birthday in January 1985. One reviewer of Asimov's 300th book noted that Asimov made no apology for including the anthologies as his own works, for he explained that it took "time and talent to edit anthologies." Moreover, Asimov pointed out that his readers expect "prolificity" of him (Kirkus Reviews 985). Another

reviewer, Peter Gareffa, calculates that Asimov has averaged six books per year during the last 30 years (Gareffa 29).

Asimov's enormous volume of written material results from a writing schedule most of us find incredible. He reports that he is an easy-going person who likes to sit at his electric typewriter and hit at the keys at a rate of 90 words per minute. He explains: "I work between 8 a.m. and 10 p.m., seven days a week, with frequent interruptions that I try to tolerate" (Gareffa 30).

Asimov reports that when he combines the output of a twelve hour work day (he apparently has only two hours of interruptions in his daily schedule) with his ability "to write rapidly and clearly," the result is "an average of 2,500 words per day (written and published) over a considerable number of years" (Quasar, Quasar, Burning Bright 17). With this kind of output it is easy to understand why Gareffa believes that "no single author has ever written more books about more subjects than Isaac Asimov" (Gareffa 30).

1.1.2 Volume of articles. So far, I have only mentioned Asimov's books, the volume of which is impressive to say the least. But "the writing machine" also produces an even larger volume of articles that, according to Chambers, are "too numerous to count" (Chambers 13). Asimov's articles include science fiction stories for science fiction anthologies and periodicals and nonfiction popular science articles for science journals and popular periodicals.

Asimov produces material for the nonprint media as well. He has participated in panel discussions, made presentations, and been

interviewed on national television and radio. He is a lecturer and an after-dinner speaker. He often makes oral presentations to science fiction conventions and writing workshops. Most of these nonprint contributions find their way into print in the form of articles, or they appear in Asimov's books.

1.1.3 Extra mileage. Asimov says that he is often accused of "getting every last bit of mileage" out of everything he writes (Buy Jupiter 81). For example, Asimov gave a particularly well-received talk on the Biblical heroine Ruth at the Bread Loaf Writers' Conference in Bread Loaf, Vermont, in 1971. His presentation received a standing ovation, and he judged it to be the most effective talk of his career. Asimov's remarks were off-the-cuff, but he said he could not let something like that go. He writes: "A cardinal rule for me (and surely for anyone who writes as much as I do) is that nothing must be wasted." He wrote a version of the talk as an article "Lost in Non-Translation," and later, he wrote a full-length treatment which appeared as The Story of Ruth, a book for young people (The Tragedy of the Moon xii).

Another way Asimov gets extra mileage is by publishing his articles in book collections as a way of preserving them. He explains that his nonfiction articles often appear in such a large variety of magazines that his readers have problems locating them. Indeed, many libraries do not have some of the magazines that publish his material. Some of the periodicals for which he writes do not appear in the standard

indexes, so some of his earlier works can only be found by browsing in used book stores.

When Marjorie Miller compiled her bibliographical Checklist, which covers Asimov's publications for the years 1939 to 1972, she discussed the difficulty of locating Asimov's published articles. She says "Finding these can be almost as much a matter of luck as of diligent search" (Miller ix).

1.2 DIVERSITY OF PUBLICATION

Another way of determining Asimov's standing among popular science writers is to consider the diversity of his publication history, which illustrates his broad experience of addressing many audiences. This section presents the beginnings of Asimov's diversification from his initial writing of science fiction, and it gives examples of this diversity from his fiction and nonfiction.

1.2.1 Beginnings of diversification. Asimov explains that the start of his diversification into a variety of outlets began with the publication of "Darwinian Pool Room," written for Horace Gold's Galaxy Science Fiction magazine (1950) and his first science fiction novel, Pebble in the Sky (published by Doubleday in 1950). From 1939 to 1950, Asimov had written only science fiction (for John Campbell's Astounding Science Fiction magazine). He believed that if Campbell's magazine ever folded, his writing career would be over. These publications (Pool Room and Pebble), however, ended his sole dependence on Campbell (Buy Jupiter, 4).

Asimov branched into nonfiction in 1952 when he became one of the authors of a textbook for medical students, Biochemistry and Human Metabolism. This textbook was his first voyage into nonfiction, but Asimov credits Bob Mill, editor of the short-lived magazine, Venture, as being responsible for his switching predominately to the writing of nonfiction.

Asimov explains that he disliked writing research articles, so in 1953 he began writing imaginative pieces for the Journal of Chemical Education. This journal was considered a professional journal, which meant he was not getting paid. He later began writing nonfiction for the science fiction magazines because these publishers paid him for his contributions. His first essay, "Hemoglobin and the Universe," was written in 1955 for Astounding followed by "Fecundity Limited," written for Venture in 1958. When Venture folded soon thereafter, Asimov continued his popular science column (originally written for Bob Mill) for Fantasy and Science Fiction (F&SF). Asimov soon discovered to his delight that his nonfiction articles written for F&SF gave him "far more scope and far more variety than any scholarly journal could" (Buy Jupiter 125).

The nonfiction writing career of Asimov became firmly entrenched with the coming of the Space Age in 1957 after the launching of Sputnik. Asimov notes that the masses "were interested in the oddest matters." They especially wanted articles "on the frontiers of science, and they even grew increasingly interested in science

fiction." Public demand for science news, then, increased Asimov's diversity.

Asimov believes his science fiction background helped rather than hindered his career and opened doors that led him to write on a wide variety of topics. Since he was well-known as a science fiction writer, he explains: "I was asked to write articles by publications I would scarcely have dared approach a few years earlier" (Is Anyone There? xii).

1.2.2 Diversity of fiction. Asimov is also quite productive in writing fiction, but because this study treats his nonfiction writing, I will only mention the categories of fiction that are listed in his official "Catalog of Books" from Volume Two of his autobiography, In Joy Still Felt: science fiction novels, mystery novels, science-fiction short stories, short-story collections, and mystery short-story collections. Asimov has also edited science-fiction anthologies, which he lists in his catalog of fiction.

Typical of Asimov's acclaim as a science fiction writer is the statement by Bette Chambers that "Isaac Asimov is the world's foremost science fiction writer" (Chambers 13). Asimov's Foundation Trilogy is considered by many to be a science-fiction classic. He is also considered an authority on robots because of his science fiction series of novels on that subject.

1.2.3 Diversity of nonfiction. Asimov's "Catalog of Books" lists the following nonfiction categories: general science, mathematics,

astronomy, earth sciences, chemistry and biochemistry, physics, biology, science essay collections, history, the Bible, humor and satire, autobiography, miscellaneous fact books, and literature. Subjects in the category of literature include books on myths, guides to Shakespeare, annotations of "Don Juan," "Paradise Lost," and other familiar poems, and original Sherlockian limericks about Doyle's mysteries.

The primary focus of this thesis is on Asimov's nonfiction popular science articles, but since he has contributed to so many different publications, a separate listing appears in Appendix A. It should be noted that no complete bibliography exists for his nonfiction articles, so the listing is incomplete. A total of 57 titles of periodicals (not titles of articles) is given to show the wide range of experience Asimov has in writing for different lay audience readers. Asimov has also contributed nonfiction articles to Encyclopedia International, World Book Year Book, Collier's Encyclopedia, and Merit Student's Encyclopedia.

And does Asimov have a favorite nonfiction writing assignment? He surely does. It is the monthly popular science column he writes for the magazine of Fantasy and Science Fiction. His first column appeared in the November 1958 issue, and he has not missed an issue since that time. These articles are collected periodically by Doubleday into books of essays. With the publication of Quasar, Quasar, Burning Bright (1978), Asimov logs in an introduction to his thirteenth collection of F&SF science essays. Asimov considers writing these science essays fun, and he always meets his deadline from one to two

months ahead of schedule. He notes "To this day I get more pleasure out of them than out of any other writing assignment" (Buy Jupiter 125).

If we judge Isaac Asimov's standing among other popular science writers by his diversity and volume of publication, his productivity has not been equaled.

1.3 HONORS

A third method of determining Isaac Asimov's standing among popular science writers is to consider the honors he has received. Two types of honors give him much credibility as a science writer: (1) his educational achievements as a scientist and (2) the recognition he has received as a result of his achievements as a writer.

1.3.1 Educational achievements as a scientist. Although Isaac Asimov is a household name to most of the American public, his educational achievements are probably less well known. These achievements show that he is well grounded in science and give him impressive credentials as a popular science writer. He was awarded three degrees from Columbia University where he majored in chemistry. He received the B.S in 1939, the M.A. in 1941, and the Ph.D. in 1948.

Asimov became a teacher at the Boston University School of Medicine in 1949 where he was awarded an instructorship for two years. He served as an assistant professor from 1951 to 1955, an associate professor from 1955 to 1979, and he became a full professor of biochemistry in 1979. Asimov resigned his duties as a teacher of

biochemistry in 1958 to become a full-time writer. He presently retains his title of "professor" with the Boston University School of Medicine because the title is valuable to him as a popular science writer. In the bargaining process, he admits that his name has given wide publicity to Boston University as well; he considers the arrangement beneficial to both parties. Many people still refer to him as Dr. Asimov or "The Good Doctor."

1.3.2 Recognition as a writer. In addition to his educational achievements, Asimov has also received much recognition for his skills as a writer. His miscellaneous honors include the following: The Edison Foundation National Mass Media Award, 1958; Blakeslee Award for Nonfiction, 1960; James T. Grady Award (American Chemical Society), 1965; American Association for the Advancement of Science (Westinghouse award for science writing), 1967; Hugo Award (World Science Fiction Convention), 1973; Science Fiction Writers Award, 1973; Nebula Award, 1973; and Glenn Seaborg Award (International Platform Association), 1979.

Of course, this is only a small sampling of the total recognition Asimov has received. Some awards cannot be framed; nevertheless, they are high honors. Asimov has been the guest of honor at many banquets such as the annual presentations of the Hugo Awards in Science Fiction. He has held leadership offices in national organizations (president of the American Humanist Association, for example), been interviewed on national television by Dick Cavett and Walter Cronkite, and conducted many writing workshops (at the Bread Loaf Writer's Conference, for

example). He has also received recognition from many of his colleagues; Theodore Sturgeon writes that Asimov is "respected by professionals in some 20-odd scientific disciplines" (Sturgeon, The New York Times Jan 28, 1973).

Another valuable honor that is an important consideration when judging Asimov's standing among popular science writers is that of approval given to Asimov by his reading audience. Asimov's readers recognize his achievements and skill in making science intelligible by continuing to purchase and enjoy his popular science books and articles.

CHAPTER II

ASIMOV'S REPUTATION AS A POPULAR SCIENCE WRITER

Asimov's volume and diversity of publications and the honors he has received are evidence of his importance as a popular science writer, but they are not evidence that his work is good. For this judgment, we must defer to others. For an objective view of Asimov's reputation as a popular science writer, we can weigh the views of the critics; for a subjective view of his success, we can weigh the views of Isaac Asimov.

2.1 CRITICS' VIEWS OF ASIMOV'S SUCCESS

Critics who judge Asimov's success as a popular science writer are faced with a unique Asimovian problem, which is discussed in this section. The section also presents samples of several critics' observations of Asimov's ability as a popular science writer.

2.1.1 The Asimovian problem. The major problem regarding any study of Asimov is that there is no well defined body of literary criticism of his works. The most recent critical book available on Isaac Asimov is James Gunn's Isaac Asimov: The Foundations of Science Fiction (1982). In the appendix to this book, Gunn lists eight works about Isaac Asimov. Of the eight works listed, two are bibliographies, two devote only a small space to Asimov, four devote the entire space to Asimov, but only one of these treats his nonfiction. For an artist whose writing career spans nearly half a century and whose volume of

publication is unsurpassed, it would seem that more critical works should exist on his nonfiction.

As for criticism of Asimov's nonfiction, Neil Goble's Asimov Analyzed (1972), is the only critical study that treats Asimov's work in detail. Other criticism does exist, but it is usually brief. The best sources for these brief critical analyses of Asimov's nonfiction, according to Goble, are book reviews. Goble cautions that researchers should shun dust jacket reviews of Asimov's books because "they may be a little lopsided" (Goble 5). Another problem for the critics who write about Asimov is that they seem to be able to find little new to say about him. Virtually all of Asimov's nonfiction is prefaced with autobiographical commentary. He has left critics with few secrets to discover about his writing habits, his methods of composing, his purposes, his writing strengths and weaknesses, and all conceivable topics that critics usually address. Gunn notes the critics' dilemma: writing about Asimov "is like pouring water into the ocean. . . . Asimov has written more about himself than any living author, and generally with frankness and insight" (Gunn 3).

Goldman points out that Asimov has stated elsewhere that "his works do not easily lend themselves to traditional literary criticism." Asimov has the habit of "clearly stating to his reader, in rather direct terms, what is happening in his stories and why it is happening." Goldman explains that "stories that clearly state what they mean in unambiguous language are the most difficult for a scholar to deal with because there is little to be interpreted" (Goldman 21).

2.1.2 Asimov as a popular science writer. Although critical reviews of Asimov's popular science books are usually brief, there is an abundance of them because he is such a prolific writer. Marjorie Miller states that most reviews on Asimov "have been predominantly favorable." This observation is not true, however, of the reception of his historical and literary works, which Miller notes, "has ranged from good through lukewarm to unfavorable" (Miller xi). The following is a sample of how most critics rank Asimov as a popular science writer.

Gerald Jonas, in a 1979 New York Times Book Review, sees Asimov as "the pre-eminent science popularizer of our day." He suggests that when critics review Asimov, "it is beside the point to apply the usual critical standards to his output." Jonas praises Asimov's clarity of style. He applauds Asimov's "compulsion to describe the most arcane discoveries in simple declarative sentences," and he suggests that Asimov "has probably done more than anyone else to give scientifically illiterate readers a feeling for the excitement and accomplishments of modern science" (Jonas, New York Times Book Review Feb. 25, 1979).

Neil Goble suggests that anyone who aspires to write popular science or science fiction "should be able to gain something useful from a study of Asimov's methods." He offers unqualified praise of Asimov as a science writer:

> To have achieved this degree of success as a writer of popular science and science fiction Asimov must be doing something right--perhaps everything--the right way. Whether his way of writing is well-suited to scientific reports or technical manuals is another matter, but when it comes to popularizing science for the layman, it is difficult to argue with Asimov's success (Goble 4).

Finally, Alfred Bester of Publisher's Weekly gives Asimov the ultimate compliment: "There is no doubt that Isaac Asimov is the finest popular science writer working today. . . . He comes close to the ideal of the Renaissance Man" (Bester Publisher's Weekly, April 17, 1972).

2.2 ASIMOV'S VIEWS OF ASIMOV'S SUCCESS

Asimov admits that a writer is not always the best judge of his own works; nevertheless, he offers an abundance of personal judgment on his own writing. His autobiographical comments are communicated through a persona, which gives readers insights about Asimov's judgments concerning his skill as a writer. The person's comments take the forms of self-praise and self-effacement. Readers also learn of Asimov's views about his writing ability through his comments about his interaction with the typewriter.

2.2.1 The persona. Asimov discusses his own strengths and weaknesses as a writer through his persona, which is often viewed by readers as being arrogant and conceited. He explains how sometimes this persona is often mistaken for the real Asimov:

> Considering that I work so hard at establishing my chosen persona as a man who is cheerfully self-appreciative, I am sometimes absurdly sensitive to the fact that every once in a while people who don't know me take the persona for myself (Of Matters Great and Small 105).

What some people see as arrogance and conceit, Asimov explains is only "cheerful self-appreciation." He adds that "anyone who knows me has no trouble seeing the difference." Asimov says that he could save

himself a lot of trouble by choosing a different persona "by practicing aw-shucks modesty and learning how to dig my toe into the ground and bring the pretty pink to my cheeks at the slightest word of praise." But Asimov believes that if he were to begin to practice a "charming diffidence," he would begin to doubt his ability "to write on just about every subject and for every age level." And for Asimov, "that would be ruinous" (Of Matters Great and Small 105).

2.2.1 Self-praise. Asimov insists there is no secret to his writing success. He explains: "The industry comes to me without trouble, and I don't have to indulge in backbreaking self-discipline. I like to write. And as for the ability, why, as far as I know, that I was born with" (Quasar, Quasar, Burning Bright 17).

When reviewers talk about Asimov's enthusiasm, his liveliness, and his warmth, he merely concurs. He writes: "My excitement in my subject seems to stick out all over my writings and one would suppose that this is the result of my own particular ebullient and extroverted personality." And he adds: "I can't deny that I am ebullient and extroverted" (Quasar, Quasar, Burning Bright 73).

Asimov is not shy about liking to read his own work. If his readers tire of him, Asimov promises to continue writing: "I will just have to continue writing the essays for myself alone, and pile them up one on top of the other, and every once in a while leaf through them and read them and reread them and enjoy them all by myself" (Left Hand of the Electron xii).

Once in a while, Asimov has to remind himself to project the image of conceit. For example, when he was called (because of his popularizations) "the Leonard Bernstein of science," he was quite flattered. He suddenly remembered his "pose of brash self-esteem" and gathered his wits together and responded: "Quite wrong! Bernstein is the Isaac Asimov of music" (The Tragedy of the Moon 54).

Asimov unashamedly admits that he has a "writing talent" he can't define. When he is in the grips of this talent, he can tell a story without spending all day thinking about it, deciding "what to put in, what to leave out, what to emphasize, what to hint at." He admits that he is often" fascinated by what emerges," and he adds that "all of it is more or less unexpected." He suggests there is a "daemon" within him that does the writing and "inserts subtleties and intricacies." He states: "If I ever started trying to do all these wonderful things on purpose, I might, in the excitement of it all, forget how to tell a story" (Olander and Greenberg 206).

In another autobiographical comment, Asimov writes: "My calling is that of a writer, and that's what I am. In particular, my calling is that of an explainer, and that's what I am, too" (The Magazine of Fantasy and Science Fiction, Feb 1984, 109).

When Asimov was being considered for tenure at the University of Boston, he was not sure about his abilities as a researcher and scientist, but he was not reticent about his abilities as a science writer. One of the arguments he gave to his superiors when he insisted upon being granted tenure was that as a researcher he was only "credible," but as a science writer, he insisted "I am one of the best

in the world, and I intend to [be] come the best. I am perhaps B- as a researcher, but I am A+ as a science writer" (In Joy Still Felt 111).

Good comments make Asimov feel good. After receiving a compliment about his work, he unashamedly remarked: "After all, I know that my stories are great and terribly thought-provoking." The conceited persona jokingly adds that it is nice to have readers agree with him, but the only thing to be learned from good comments is that his critics have "keen literary judgement" (The Hugo Winners 679).

In a similar autobiographical comment, Asimov explains (with his usual modesty): "I attribute my success entirely to an incredible fluency of ideas and a delightful facility in writing" (Nightfall and Other Stories 286).

When asked about his filing system, Asimov says he has none. "I've been a classifier ever since I can remember. Everything falls into categories with me. Everything is divided and counted up and put into neat stacks in my mind. I don't worry about it; it happens by itself" (The Left Hand of the Electron 145).

These observations by Asimov (and his persona) about his writing process are obviously subjective evaluations; nevertheless, they offer some basis for forming a judgement about Asimov's reputation as a popular science writer.

2.2.3 Self-effacement. For every ounce of praise in which Asimov indulges, there is probably an equal measure of self-effacement. Although he admits he has adopted a persona to praise his own works, he denies deliberately setting up a pose when he disclaims any knowledge

about the craft of writing. Sometimes it is very difficult to know when Asimov is being serious and when he is joking, for he often makes statements that are contradictory. But James Gunn writes: "He really thinks he does not know much about writing" (Gunn 24).

One example of a disclaimer appears in Asimov's introduction to Nightfall and Other Stories. He explains: "As far as writing is concerned, I am a complete and utter primitive. I have no formal training at all and to this day I don't know How to Write." He adds: "I just write any old way it comes into my mind to write and just as fast as it comes into my mind" (Nightfall and Other Stories 9).

Even as Asimov was lecturing on how to write nonfiction to students at the Bread Loaf Writer's Conference in Bread Loaf, Vermont, he disclaimed any knowledge of the craft of writing. He writes of that experience: "My protestations to the effect that I didn't know how to write nonfiction, but just did it instinctively, were brushed aside with contempt" (The Tragedy of the Moon xi).

Early in Asimov's writing career he disclaimed any knowledge of writing style: "I thought I would try a story that stressed style but since I didn't (either then or now) know what style was, or how one went about getting it, I hadn't the faintest idea whether I had succeeded or not" (Nightfall and Other Stories 229).

Yet Asimov is quick to show offense when others concur with his own slurs at his writing skills. For example, a Columbia professor once told him: "The trouble with you, Asimov, is that you can't write." Asimov, slightly insulted, answered: "I'll thank you, Professor Mayer,

not to repeat that slander to my publishers" (Quasar, Quasar, Burning Bright 31, 32).

Asimov again showed his offense when a publisher asked him to do a book of limericks for children. He suggested that Asimov might not know how to write clean limericks. Asimov answered: "'Of course I know how,' I said, in the aggrieved tone I use when someone suggests there is some kind of writing I can't do if I put my mind to it." And a week later Asimov brought his publisher fifty limericks (F&SF, Sept. 1983, 134).

And even though Asimov disclaims any knowledge of writing, he (not unlike other writers) is touchy about editorial changes in his compositions: "If anyone thinks I am so arrogant that I can never accept editorial correction, he is quite wrong. I don't enjoy editorial correction (no writer does) but I accept it quite often" (Nightfall and Other Stories 230).

2.2.4 Asimov's interaction with his typewriter. Most of Asimov's readers find it incredible that he believes he does not know how to write. It is equally incredible that he attributes his writing skill to his interaction with the typewriter.

As Asimov became more popular and his audience reacted well to his personal commentary in his popular science articles, his editors began to press him for a full length autobiography to satisfy his readers' curiosity about him. Asimov modestly pointed out that "I keep telling them there is no aspect except my typewriter" (Buy Jupiter 2). Asimov's wife agrees that the typewriter plays an important role in Mr.

Asimov's composing process. Mrs. Asimov once gave her husband a surprise birthday party. Later, when his friends suggested that he knew about it all along, Mrs. Asimov was positive that her husband was truly surprised. She remarked: "he would have to put two and two together, and unless he's at his typewriter, he never can" (In Joy Still Felt 23).

Asimov makes constant reference to the importance of his typewriter. He says "I'm a compulsive writer. That means my idea of a pleasant time is to go up to the attic, sit at my typewriter, and bang away, watching the words take shape like magic before my eyes" (Nightfall and Other Stories 249).

Asimov, who writes a great deal about technology, says he requires technology (in the form of a typewriter) to help him capture ebullience in his subjects. He explains:

> The reason the ebullience has a chance to show up in my writing is that it doesn't evaporate in the process of converting thoughts into words. I think quickly in unspoken words and sentences[,] and I need a device that will put them on paper as fast as they are created.
>
> A quill pen wouldn't do it; nor would a steel pen, a fountain pen, or a ball-point pen. I can, and have, written articles and stories...with pen and ink, but it's a painful job and I can't keep it up very long at a time. If that were the only way I could write, the quality, I assure you, would be different--more somber. Even an ordinary typewriter won't do since I wear myself out, pounding those keys, after an hour or so.
>
> No, what is needed is an electric typewriter, which requires only a delicate touch and on which I can stroke out my ninety words a minute through a whole, reasonably long working day, if I feel like it. Such a typewriter allows me to see what I write (dictating is like walking through a crowded thoroughfare with one's eyes closed) and it keeps up with me, so that I lose none of my excitement in the irrelevant process of shaping a letter or pushing down a key by force (Quasar 73, 74).

Asimov once tried dictating his stories into a dictaphone for his wife to type. He recalls: "I was a little dubious. It sounded great in theory, but I had never dictated a story. I was used to typing my stories and watching sentences appear steadily, word by word." Although he dictated three stories in one month, the experience taught him how important the typewriter was to his composing process. He says: "I discovered that I participated in a story to a greater extent than I realized." His wife explained that she could not type his dictation of a quarrel between two characters. As the characters became more emotional, so did Asimov. His wife reported that as he dictated, he was making "nothing more than incoherent sounds of rage." He finally had to dictate that part over again, but he explains: "Heavens, it never happens when I type" (Nightfall 60).

Asimov was slow to accept the new technology of word processors. As late as 1983, he still preferred to type his first drafts on a typewriter. In his July 1983 science column for Fantasy and Science Fiction magazine, he writes of purchasing a new green electric typewriter "on which the first draft of this essay is now being written (final copy will be on my word-processor)" (F&SF July 1983, 126).

In the introduction to The Roving Mind (also in 1983), Asimov seems reluctant to give up his typewriter, for he writes: "I have the roving mind of the title, as well as an easy touch at the typewriter (or word-processor)." Two paragraphs later, he adds: "The only thing I really want to do is to sit at a typewriter (or word-processor) and unreel my thoughts." In a 1983 essay, "Technophobia," Asimov explains that he is a prime sufferer from this disease. Although he writes about the

changes that technology brings, he is not in the forefront of change. He explains: "I have used a typewriter of one sort or another for well over forty years. All around me now, however, my fellow-writers are shifting to word-processors...I clung to my typewriter." When he admitted to his editor that he did not have a word-processor, Radio Shack presented him with a TRS-80 Model II Micro-Computer with a daisywheel printer and a Scripsit program ("Technophobia" 77).

Asimov notes that word processors have not increased his speed, for speed is not an issue with him. He has always typed 90 words per minute on his typewriter. But he is quick to explain that there are plenty of errors that he has learned not to be bothered by: "After all, I started my writing for the pulp-fiction market where payment had to be placed under a strong magnifying glass to be seen. One either typed quickly, without regard to errors, and collected many of these microscopic payments--or one stopped to correct errors, and starved." The only change the word-processor brings is that his copy is much neater now. Asimov suggests he is the worst proofreader in North America, so he allows just enough time to stare at the screen to correct about half of the typos because "there's always another article or story or book waiting to be written" ("A Question of Speed" 339).

Asimov's views on his reputation as a popular science writer are not unlike the critics' views. He believes he is a very good science writer, but he disclaims any knowledge of the craft of writing. And the role that his typewriter plays in his composing process is worthy of a more detailed study than presented here. Because he is able to type so quickly (90 words per minute), his manner of written expression

is as natural as if he were speaking to his audience in a personal conversation. But before we examine how Asimov suits his manner of presentation to his audience, we must first identify his audience.

CHAPTER III

ASIMOV AND HIS AUDIENCE

A successful communicator of scientific and technical information must present his material in a clear, straightforward, precise, and simple manner. For technical information to flow rapidly and efficiently, it must be written at the appropriate audience level. If the reader believes technical information is directed toward him and his understanding, he will read earnestly. If the information is what the reader desires, he will read with enthusiasm. If the information is written with quality of expression, he will read with delight. Adapting technical information to a particular reader and retaining his interest are fundamentals of good popular science writing. I believe Asimov has mastered these fundamentals. This section (1) identifies Asimov's principal readers as the lay audience and (2) presents evidence from Asimov's own statements that shows he uses audience analysis for these readers.

3.1 ASIMOV'S LAY AUDIENCE

Most critics of Isaac Asimov's popular science writing agree that he has a special talent for addressing the lay audience. Maxine Moore observes: "having written texts on numerous aspects of scientific study, Asimov is especially adept at making scientific writing clear to the layman" (Moore 49).

(including math) and the layman" (Sturgeon, New York Times Book Review, Jan. 28, 1973). And in describing Asimov's popular science writing career, Jean Stine concurs: "Asimov also writes nonfiction science books to introduce the general public to complex scientific procedures and discoveries to alert readers to the effects of these scientific advancements" (Stine 35).

Asimov also identifies his audience for popular science articles as the general public. He explains that from the start of his writing career, he felt compelled to write for the lay audience. After the Soviet Union sent up Sputnik, he remarks that he went into a kind of tizzy. He writes: "I was overcome by the ardent desire to write popular science for an America that might be in great danger through its neglect of science." Fortunately for Asimov, a number of publishers "got an equally ardent desire to publish popular science for the same reason" (Nightfall 327).

The successful writer for the general populace must have special skills as an explainer. Clearly, Asimov possesses these special skills. And, clearly, Asimov considers the needs of the lay audience when he writes popular science, even though he denies ever having heard of audience analysis.

3.2 ASIMOV'S AUDIENCE ANALYSIS

Although Asimov denies ever having heard of audience analysis, his lack of knowledge of the term does not mean that he never uses the process. Evidence suggests that he knows the technique but not the name. About the best proof I have that Isaac Asimov disavows the use

of audience analysis is that he has told me so himself. In a personal letter to me, he writes: "In my whole life, I have never used audience analysis. I have never even heard of audience analysis. What is it?" (Asimov, Personal letter July 3, 1986).

Asimov's denial of any knowledge of audience analysis may be seen as a part of his larger denial that there is any underlying significance to anything he writes. Asimov explains: "I can prove quite easily that no purposeful pattern or smooth subtleties can possibly lie below the clear surface of what I write." In the next breath, however, he contradicts this statement with "there's more to my writing than my conscious intentions" (Olander and Greenberg 201).

Asimov's own statements offer the best evidence that he uses audience analysis. Audience analysis is apparent when Asimov explains his instinct is to write in a manner that his readers can understand what he has to say. He observes:

> When I read a book that is intended (presumably) for the general public and find that I can neither make head nor tail of it, it never occurs to me that this is because I am lacking in intelligence. Rather, I reach the calmly assured opinion that the author is either a poor writer, a confused thinker, or most likely both.
>
> Holding these views, it is not surprising that I "opt for a clearer but more pedestrian" style in my own writing.
>
> For one thing, my business and my passion (even in my fiction writing) is to explain. Partly it is the missionary instinct that makes me yearn to make my readers see and understand the universe as I see and understand it, so that they may enjoy it as I do. Partly, also, I do it because the effort to put things on paper clearly enough to make the reader understand, makes it possible for me to understand, too (The Left Hand of the Electron 14, 15).

Asimov's statement that he yearns to make his readers see and understand the universe and understand it as he does, is evidence that he uses audience analysis. Asimov made another statement that shows he

uses audience analysis when he answered a critic's charge that he was too much of an explainer. A critic objected to Asimov's thorough annotation of Shakespeare's plays (in which he explained all the historical, legendary, and mythological references). The critic pointed out that the chief glory of Shakespeare's works was the language and the poetry; he was not concerned with understanding Shakespeare's allusions to history, legends, and myths. Asimov answered that if the language that a writer uses cannot be understood by the reader, there can be no real enjoyment regardless of the beauty of the words.

Asimov asked the critic to suppose he (as a science writer) had written the following: "The logarithm of two is a transcendental number; and, indeed, the logarithm of any integer to any integral base is transcendental except where the integer is equal to the base or to a power of that base." To say that this statement about logarithms and transcendental numbers "bore within it all the poetry and symmetry and beauty of mathematics and that to try to explain it would simply hack it up," would be giving the same type of answer that the critic did in objecting to Asimov's Shakespeare annotations. Asimov shows he uses audience analysis with the comment: "But I don't answer that way. I explain such matters [as logarithms and transcendental numbers] and many more, and go to a lot of trouble to do so" (The Left Hand of the Electron 188, 189).

Asimov demonstrates that he considers the needs of his audience when he makes the statement that he feels compelled to rewrite scientific articles that are unclear. For example, he once came across a short

science news article that tried to explain a complicated scientific concept involving a connection between "the non-conservation of parity and the optical activity of naturally occurring compounds." The writer tried to explain the concept in 500 words. Asimov felt driven to rewrite the article, using different techniques to reach his audience. He states: "At once I am on fire to explain this to my readers in my way." He even proceeds to explain his method:

> First I have to explain about parity; how it is conserved and how it is not conserved; which takes up two articles of four thousand words each. Then I have to explain all that jazz about optical activity, which takes up two more articles. Then I combine the two in a fifth article and here is the whole bunch (pant, pant) as the first five chapters of this book (The Left Hand of the Electron xi).

Asimov again shows he uses audience analysis with his statement that the articles collected in his book, Today and Tomorrow, were "written at different times for different audiences" (Today and Tomorrow xii).

Asimov often expands and popularizes material he has published in scholarly journals. He acknowledges that he writes in different ways for different audiences with this statement:

> In fiction, every story has to be different, no matter what. Not so in nonfiction. I could write an article for The Journal of Chemical Education, expand and popularize it for Analog, shorten and simplify it for Science World. Though it remained essentially the same article, the changes were useful and did not represent "cheating," since each article was aimed at a different audience and had to be tailored to suit (In Joy Still Felt 81).

The words "had to be tailored to suit" are the key words that show Asimov does analyze his audience. That he does it instinctively, is immaterial.

Asimov shows that he uses audience analysis when he speaks of the different requirements of periodicals that have different audiences.

He recalls that the editor of Science Digest once asked him to write a full-length article for that publication. Length requirements for this publication are generally shorter than for other magazines. However, Asimov got his signals crossed and wrote a long article. He unwittingly confesses to using audience analysis when he makes this observation:

> Having written it, I found, rather to my amazement, that I had hooked up my fingers to the wrong brain outlet (or whatever it is I do when I sit down to write in a specific manner for a specific audience) and had turned out an F&SF [Fantasy and Science Fiction] essay" (Of Matters Great and Small xi).

This statement implies that Asimov is not conscious of any particular method he uses when he writes for a specific audience. But he is conscious that a specific method is necessary for different audience when he says he hooked his fingers to the wrong outlet of his brain and wrote the wrong type of article. With Asimov's words "when I sit down to write in a specific manner for a specific audience" he shows he is using audience analysis.

Asimov demonstrates that he uses audience analysis when he explains to one of his readers why he never wrote about Hubble's Law; he could not figure out how to do it. He writes that

> Now I will, because I've thought of a way of doing it that, [sic] I've never seen anyone else try. But I won't get to that right away. I will sneak up on it in my usual oblique fashion by making the article deal, first, with successive enlargements of man's picture of the universe" (Of Matters Great and Small 16).

When Asimov says "I've thought of a way of doing it," he acknowledges that he is thinking of his rhetorical purpose before he writes for a specific audience. This is audience analysis.

Audience analysis, then, for Isaac Asimov is an instinctive practice. He thinks ahead about how he will present his information and how he will tailor the information for his audience. He is obviously aware of the technique but not the terminology. Asimov's rhetorical techniques that are especially suited to the lay audience will be the subject of the next chapter.

CHAPTER IV

ASIMOV'S RHETORICAL METHODS FOR THE LAY AUDIENCE

Audience analysis is an important first step in preparing scientific information for the lay audience. The readers that comprise this audience are separated by subtle distinctions. Writing popular science for these reader presents rhetorical challenges which Asimov does not ignore. This section examines two of Asimov's most successful rhetorical techniques that are especially effective for the lay audience: (1) a personal style and (2) an informal tone.

4.1 ASIMOV'S PERSONAL STYLE

Asimov's personal writing style is a deliberate and contemplated rhetorical device that he considers especially appropriate for the lay audience. He achieves this personal style (1) by inserting autobiographical comments, (2) by following his own set of guidelines for writing personal essays, and (3) by including many first and second person personal pronouns in his writing.

4.1.1 Autobiographical comment. Asimov recognized early in his writing career that he did not enjoy writing scientific information in a cold, straightforward, and factual manner. One of his earliest publications was a reaction against this style of writing. Asimov explains that as the time drew near for the writing of his dissertation when he was a student at Columbia University, he dreaded the task

because he knew his chemical research "would have to be written in a convoluted and stylized fashion or it would never pass" (Joy 498).

To practice the style of writing a scientific dissertation demanded, he wrote a mock dissertation, "The Endochronic Properties of Resublimated Thiotimoline," which appeared in Astounding in March of 1948. This mock dissertation was deliberately written "turgidly and sloppily." It contained fabricated information placed in tables, graphs, and charts, and many references were made to nonexistent scholarly journals. Asimov feared the spoof might be used against him "to prove that I lacked the proper gravity of character to make a good chemist." Consequently, he persuaded his editor, Campbell, to publish the piece under a pseudonym (Joy, 517).

The mock dissertation was just the beginning of Asimov's objection to the style of writing associated with many scientific writers. He believes that most scientific and technical papers are written in a "dry, stilted phraseology," where writers record their findings by "inlarding every statement with a semiwithdrawal in the shape of a qualifying phrase, and translating the whole into a grammatical construction peculiar to the scientific paper--the Impersonal Passive." Asimov suggests that very few scientists are brave enough to dare write in an informal, personal style (From Earth to Heaven vi).

Asimov adopted a personal style early in his nonfiction popular science writing career:

> By the time 1960 had come and I had written a dozen or so [of] the essays, I was talking about myself in the first few paragraphs every time and this has continued ever since.
>
> As you might expect, what started as a kind of personal touch, a kind of stylistic signature, has gotten out of control. It's not just that I've grown used to it; my readers have grown

used to it. If I can judge from the letters that reach me, they are pleased with it; it removes some of the impersonality of the printed page and they feel my existence more clearly.

So when people ask me why I talk about myself so much in the course of my writing and hint that it is the result of a swinishly besotted love affair I have with myself, I always answer austerely that I do so because my readers insist on it (Of Matters Great and Small x, xi).

The book that set the pattern for Asimov's personal style and caused Asimov fans to anticipate further personal commentary was The Hugo Winners, his first anthology, published in 1962. His introduction begins with the following:

> Let me introduce this book my own way, please; by which I mean I will begin by introducing myself.
>
> I am Isaac Asimov and I am an old-timer.
>
> Not, you understand, that I am (ha, ha) really old. Quite the contrary. I am rather young actually, being only mumblety-mumble years old and looking even younger! (The Hugo Winners x).

Since the publication of this personal introduction, Asimov's lay audience has insisted on personal commentary in his science writing.

4.1.2. Asimov's guidelines for writing personal essays. Asimov believes that "Most of all, an essay is distinguished from more formal expository works by the personal touch. The author does not hesitate to put himself into an essay." Asimov points out that writing an essay "sounds easy":

> You just sit down and maunder about a bit. It doesn't have to be formal because it's supposed to be informal. It doesn't have to be very abstruse because it's supposed to be just an easy going attempt at the subject. And it doesn't have to induce mental cramps through overlong concentration since you are supposed to break the spell with asides or little jokes or anything else that occurs to you.

But, Asimov continues, "it takes considerable skill to sound as though you're maundering and yet lead the reader to the point." He outlines three steps for making essays personal:

1. Have something to say.
2. Cultivate the knack of saying it informally, but saying it.
3. Learn to be unself-conscious so that you can get yourself into the essay without blushing or shuffling about uneasily (Quasar, Quasar, Burning Bright 13).

Asimov's technique can be seen in almost any of his popular science essays. On an essay he wrote concerning radioactivity, he begins by talking about his daughter, Robyn: "My beautiful, blonde-haired, blue eyed daughter, who has been figuring in the various essays I write since she was a preschooler, is now a freshman in college." Asimov admits: "I do have a personal writing style and I do suffer from a lack of reticence, and sometimes I feel defensive about it." But he explains that his personal essay beginnings have a specific purpose:

> Yet ask yourself, if I had started this essay with: 'The two chief methods by which a radioactive nucleus can break down involve, one, the emission of an alpha particle. . . ,' would you have plunged in quite as readily as you would with a beginning like 'My beautiful, blonde-haired, blue-eyed daughter. . . ?'" (Of Matters Great and Small 157).

Asimov's personal style pulls the reader into his essays; almost before the reader knows it, he has completed reading the essay with little effort. Most lay audience receive enjoyment in reading nonfiction essays with the personal touch.

4.1.3 Asimov's use of personal pronouns. Asimov relies heavily on personal pronouns to put himself into his science writing. He includes the personal pronoun "I" somewhere in the first paragraph of most of his essays. It is very often the first word. Of the 17 essays that

appear in The Left Hand of the Electron, all of them have the personal pronoun "I" in the first sentence except three. And those three essays use the pronoun "I" within the first three sentences. Listed below are the initial sentences of the first ten essays from that publication, which will illustrate how Asimov achieves his personal style:

1. I have just gone through a rather unsettling experience ("Odds and Evens" 3).

2. I received a letter yesterday which criticized my writing style ("The Left Hand of the Electron" 14).

3. I currently do my writing in a two-room suite in a hotel, and about a month ago I became aware of someone banging loudly against the wall in the corridor outside ("Seeing Double" 26).

4. In the days when I was actively teaching, full time, at a medical school, there was always the psychological difficulty of facing a sullen audience ("The 3-D Molecule" 42).

5. Only yesterday (as I write this) I was on a Dayton, Ohio, talk show, by telephone, one of those talk shows where the listeners are encouraged to call in questions ("The Asymmetry of Life" 51).

6. Cocktail parties bring out the worst in me in the way of self-righteousness, for I don't drink ("The Thalassogens" 65).

7. One of the occupational hazards of popularizing the scientific view of the universe for the general public is the occasional collision with readers who prefer some variety of religious view of the universe instead. To reduce some wonderful phenomenon from the provenance of God to the blind consequence of some physical or chemical "law" offends them, and their response, very often, is to accuse the science writer of atheism.
Thus, only yesterday, I received a letter from a lady which began by addressing me austerely as "Dear Sir," and then continued, somewhat less austerely, "According to the Scriptures, and using the language of the Scriptures, you are a 'fool'" ("Hot Water" 78).

8. About half a year ago (as I write this) I was hurrying through the wintriness of New York City ("Cold Water" 91).

9. Not long ago I got a letter from a young amateur mathematician which offered me a proof that the number of primes was infinite and asked, first, if the proof were valid, and,

second, if it had ever been worked out before ("Prime Quality" 105).

10. Some of my articles stir up more reader comment than others, and one of the most effective in this respect was one I once wrote in which I listed those who, in my opinion, were scientists of the first magnitude and concluded by working up a personal list of the ten greatest scientists of all time ("Euclid's Fifth" 116).

Each sentence is structured to capture the reader's curiosity and interest before Asimov ever starts to present any scientific information. The personal pronoun "I" appears a total of 14 times in these introductory sentences. In addition, the possessive case "my" appears five times, and the objective case "me" appears three times. This sampling is enough to illustrate on a small scale the magnitude of the personal touch Asimov brings to his popular science essays on a larger scale.

4.2 ASIMOV'S INFORMAL TONE

According to Asimov's formula for writing successful popular science essays, a writer (after deciding on something to say) must "cultivate the knack of saying it informally" (Quasar 13). Asimov confesses: "I tend to be informal, chatty, colloquial" (Today and Tomorrow xii). To achieve informality he relies heavily on the following techniques: (1) conversation, (2) a subtle approach to humor, and (3) parenthetical expressions.

4.2.1 Conversation. Asimov often addresses readers directly and carries on a one-sided conversation with them. This direct address makes his readers feel Asimov is talking to them directly;

consequently, they have a feeling of acceptance as they approach his science lessons.

Asimov credits Bob Mills of Venture with helping him establish his present article-writing style, which he identifies as "one of intense informality." While Asimov was writing a science column for Venture, Mills referred to Asimov as "the Good Doctor." And Asimov called Mills "the Kindly Editor" (Buy Jupiter 125). Asimov frequently uses these titles to create a conversational tone in his essays.

But the title his fans identify with best is that of "Gentle Reader." The following examples of this title of endearment appear in Asimov's The Tragedy of the Moon:

> (1) But that reminded me of our seven-day week and of some of its peculiarities, so if the Gentle Reader will hold still for a moment. . . ("Moon over Babylon" 27).
>
> (2) I obliged and talked quite forcefully on the subject of rationalism versus mysticism--with myself, as all my Gentle Readers know, on the side of rationalism ("The One and Only" 79).
>
> (3) Especially since I am notoriously a non-traveler and my faithful Gentle Readers may wish to know how I came to make the trip and how I survived it (The Cruise and I" 198).

Asimov also converses with the reader through the second person "you." The following examples appear in Asimov's The Left Hand of the Electron:

> (1) Well, I'll tell you. If you all fail me (as let's hope you never do) I will keep on writing the essays anyway. . . ("Introduction" x).
>
> (2) You can see a crude analogy of this if you pass a rope through a picket fence and tie it to a pole somewhere on the other side. If you make up-and-down waves in the rope, they will pass through the opening between the pickets, so that the rope on the other side of the fence also waves. . .("Seeing Double 32).

(3) The light you see becomes dimmer and dimmer as you rotate the second prism, until, when you have turned through ninety degrees, you see no light at all (Seeing Double 33).

(4) You might very well ask, though, where a chemist gets the asymmetric p in the first place ("The Asymmetry of Life 55).

Another technique, rhetorical questions, contributes to Asimov's conversational style. The questions are, in effect, questions that Asimov anticipates the lay reader would ask if he were conversing with them. He generally answers the questions. The following examples appear from Asimov's View from a Height:

(1) To begin: How large is a cell? [Answer] There is no one answer to that, for there are cells and cells, and some are larger than others ("The Egg and Wee" 18).

(2) But what if an element has eight electrons in its outermost shell to begin with? [Answer] Why, then, it is "happy" and need not react at all--and doesn't ("The Elements of Perfection" 67).

(3) Why? [Answer] Well, outside the ring system, Saturn possesses a family of nine satellites, each of which has a gravitational field that produces perturbation in the motion of the particles of the rings ("The Trojan Hearse" 215).

The effect of direct address, the second person "you", and the question-and-answer pattern add a conversational tone to Asimov's popular science writing.

4.2.2 Subtle humor. Another rhetorical technique that contributes to Asimov's informality is a subtle sense of humor. Although Asimov admits that he failed at his first attempts to write funny material, his later attempts were more successful. He writes: "And, Gentle Reader, if you don't think they're funny, do your best not to tell me so. Leave me to my illusions." He happily quotes Groff Conklin's

praise of his ability to write humorously: "When the Good Doctor. . . decides to take a day off and be funny, he can be very funny indeed" (Buy Jupiter 47).

Asimov's image of being a witty guy probably originated from his unique introduction to his first anthology, The Hugo Winners (1962). Since he had not won a Hugo himself at that time, he explained why he was especially qualified to be the editor of a collection of Hugo winners:

> The person qualifying as editor for such an anthology would naturally have to be someone who had not himself received a Hugo, so that he could approach the job with the proper detachment. At the same time, he would have to be a person of note, sane and rational, fearless and intrepid, witty and forceful, and, above all, devilishly handsome (The Hugo Winners xiv).

Asimov often achieves humor through a play on words. His puns generally derive from well known literature, from famous historical characters, and from a familiarity with the commonplace. All of these sources supply him with wordplay that is not "over the heads" of his lay readers. He particularly likes to use puns in his essay titles. He even has a favorite. He explains:

> If I come across an interesting and far-out coincidence in writing one of my other books--say, one on Roman history--I don't have to let it lie there. I can get to work and pound the thing firmly into the ground in "Pompey and Circumstance," managing to get off, at the same time, a title containing one of the noblest puns I have ever invented in a lifetime of inventing noble puns (The Left Hand of the Electron x).

Another title that rates highly among Asimov's favorites is Buy Jupiter. He remarks: "To a punster like myself, it is the perfect title for the story--so perfect that I have given it to this entire collection" (Buy Jupiter 117).

One of Asimov's titles, "Shah Guido G.," involves a pun that is not immediately apparent. Asimov later explained the pun:

> Now that you've read the story, you'll notice that the whole thing is for the purpose of that final lousy pun, right? In fact, one person came up to me and, in tones of deep disgust, said, "Why, "Shah Guido G." is nothing but a shaggy-dog story."
> "Right," I said, "and if you divide the title into two parts instead of three, you get "Shahgui Dog," so don't you think I know it?" (Buy Jupiter 32).

The popular science essay, "The World Ceres," ranks high on Asimov's list of puns, for he explains in a footnote: "While I was wondering whether I ought to do an article on Ceres, I thought of the title for this piece, and after that there was no holding me" (The Tragedy of the Moon 54).

A small sampling of other puns Asimov uses in his essay titles include the following: "Moon over Babylon," "The Week Excuse," "Through the Microglass," "The Asymmetry of Life," "Prime Quality," "Euclid's Fifth," "The Plane Truth," "Signs of the Times," "The Weighting Game," and "The Trojan Hearse."

Asimov's manner of gently poking fun at himself and others also adds subtle humor to his popular science essays. He often takes himself to task for his inability to write anything but mild expletives: "I rebelled and said to myself, 'Goodness gracious' (for I use strong language when moved and that is my favorite)" (The Left Hand of the Electron xi). Again the same expletive surfaces in another book: "Goodness, I thought (for in the privacy of my mind I use strong expletives)." And on the same page he writes an expletive that is considerably stronger: "So I thought, Well, heck (what did I tell you about expletives?" (Of Matters Great and Small xi).

Asimov also pokes fun at his age. In his unique introduction to The Hugo Winners, he writes: "I am an old-timer. Not, you understand, that I am (ha, ha) really old" (The Hugo Winners x).

Again, Asimov seems to be ageless when he recalls that he started writing science essays "ever so many years ago when I was a little over thirty." He adds a footnote at the bottom of the page: "Oddly enough, I am still a little over thirty today" (Quasar 12).

Asimov also pokes fun at his personal appearance, usually joking about his handsomeness: "If Arthur C. Clarke had more hair and were considerably more handsome, he could easily be mistaken for me" (The Hugo Winners 122).

4.2.3 Parenthetical expressions. Parenthetical expressions are important in creating an informal tone in Asimov's popular science essays. Sometimes his parentheses clarify or define scientific terminology; sometimes they direct the reader to another source; sometimes they personalize his writing; and sometimes they add humor. The following examples from his popular science essay "Neutrality!" (written about radium) will give the reader a sample of Asimov's use of parenthetical expressions. (Page numbers appear at the end of each set of parentheses.)

> (1) This is especially true of the "alpha particles" which are as massive as helium atoms (indeed, it eventually turned out that they were naked helium nuclei) (147).
>
> (2) For nuclei more massive than that of potassium (with a nucleus carrying a charge of +19) no alpha particle found in nature possessed enough energy even to strike the nucleus, let alone rearrange it (148).

(3) It was clear that nuclear reactions produced far more energy per mass of reacting materials than chemical reactions did. (Chemical reactions involve only the outer electron cloud of the atoms) (148).

(4) The chemical nature of an atom depends on the number of protons in the nucleus (the "atomic number") so neutron bombardment frequently changed an atom of a particular element with a particular atomic number to an atom of another element which was one-higher up in the atomic-number scale (151).

(5) For instance, if cadmium (atomic number 48) were bombarded with neutrons, indium (atomic number 49) would be formed (151).

(6) They saw that the first and easiest (almost inevitable) use of nuclear energy would be the kind of atomic bomb H. G. Wells had talked about, and they knew that the Nazis must not get it first (153).

(7) Well then, if Szilard and Weizmann had started working on it in the middle 1930s and word had gotten out (as it surely would have), the western powers, anxious for peace and eager not to annoy the Nazis, would never have supported it (153).

(8) It occurred to Hahn and Meitner that a double dose of alpha particle emission might be brought about by neutron bombardment, [sic] and that this would convert uranium atoms into radium atoms. (I don't know the details of the reasoning [,]and I sometimes wonder if Hahn and Meitner thought of the double-alpha-particle emission--which, in hindsight, seems so unlikely--because of the general glamor of radium (154).

(9) Hahn continued his work with Fritz Strassman (1902-), however, and when the added barium was separated, it <u>did</u> emerge radioactive, which was cause for jubilation (154).

In this essay selected at random, Asimov includes 28 sets of parenthesis. They do not so much create humor as they do an informal tone. Most of the examples clarify or define technical information for the lay reader. Asimov is particularly considerate of his reader in that he includes the dates of birth and death of the early scientists who played prominent roles in our present understanding of radioactivity.

In this same essay Asimov includes parenthetical information in the form of two footnotes.

> (1) The explanation arose out of the work of the Japanese physicist, Hildek Yukawa (1907-) in 1935 (150).
>
> (2) Did you think I wouldn't get back to uranium (151)?

Both types of parenthetical expressions (in the form of regular parentheses and in the form of footnotes) add informality to Asimov's essays. The lay reader generally appreciates having technical information clarified and defined. Parentheses help Asimov achieve this clarity.

The lay reader is also more receptive to scientific information if he believes the scientist is talking directly to him in an informal tone. Asimov achieves informality with personal commentary, first and second person pronouns, and rhetorical questions. The lay reader often enjoys subtle humor, which Asimov achieves through plays on words and poking fun at himself and others.

CHAPTER V

ASIMOV'S STYLISTICS

Neil Goble's critical book, Asimov Analyzed, gives a detailed treatment of Asimov's popular science writing style. He was chiefly interested in Asimov's reputation for clarity and eloquence; "What I want to know is how he does it," Goble explains (Goble 43).

Goble's findings reinforce the idea that audience analysis is an important consideration for Asimov. Goble never uses the words "audience analysis," but he observes that "Asimov's style varies depending on what he is writing about and to whom he is writing" (Goble 43). This section examines stylistic techniques identified by Goble that are particularly suited for the (1) the general lay audience, (2) the science fiction lay audience (i.e., readers of Asimov's nonfiction popular science essays appearing in science fiction magazines), and (3) the juvenile lay audience.

5.1 STYLISTICS FOR THE GENERAL LAY AUDIENCE

Asimov's general lay audience consists of readers of popular science articles and essays that appear in the popular magazines like The Reader's Digest, Mademoiselle, Popular Science, and The Science Digest. This audience also includes readers of his popular science books for the general adult public like The Human Body, The Human Brain, The Noble Gases, The Intelligent Man's Guide to Science, and Understanding Physics.

Stylistic techniques that increase a writer's clarity are especially important to popular science writing. Goble's findings show that Asimov's popular science achieves clarity through (1) sentence length, (2) paragraph length, and (3) sentence structure.

5.1.1 Sentence length. Asimov's clarity of style has been noted by many reviewers of his popular science work. David Allen's observations are typical:

> Asimov is a scientist and a writer of factual scientific material for the layman, as well as of fiction, and this background has affected his view of writing. He has repeatedly stated that he is concerned with writing clearly, rather than writing in a "literary" style that is, he thinks, unduly concerned with devices and "precious" phrasing. In other words, as long as any element in one of his stories is clearly presented and understandable, he is satisfied (Allen 270).

Clearly presenting scientific ideas to the general public, for Asimov, involves employing a variety of sentence lengths. In Asimov's popular science books, Goble found that Asimov did not limit his sentences to a specific word count. Instead, his sentences ranged from 1 word to 85 words (Goble 73).

For his popular science essays and articles addressed to the general lay audience, specific word counts per sentence were somewhat lower, ranging between 3 and 48 words (Goble 73).

5.1.2 Paragraph length. Average paragraph length for the general lay audience varied with each book analyzed. Goble observes that "As a general statement, about all I can say is that 10-word paragraphs are not uncommon, and within each book, paragraphs occasionally run more than double the 'average' length" (Goble 59).

Goble notes that paragraphs tended to be shorter in Asimov's science articles for the general public:

> Occasionally there will be a one-word paragraph; about one paragraph in 15 will be 10 words or less. On the other hand, hardly ever are there extra-long paragraphs as we saw now and then in his books; the upper limit, seldom reached, seems to be 100 words (Goble 59).

The narrow columns of magazines make long paragraphs appear longer, and long paragraphs are especially discouraging to lay readers.

5.1.3 Sentence structure. Goble's term "sentence structure" is a broad term that often includes comments on simple, compound, and complex sentences; declarative, imperative, and interrogative sentences; first, second, and third person; and intransitive, active, and passive verbs.

Asimov's popular science books addressed to the general lay audience have "a greater percentage of third-person usage" than Asimov's popular science articles for the same audience. His popular science books have "about 10 percent first-person, 7 percent second-person, and 83 percent third-person" (Goble 73). Even Asimov's technical books written for a more expert audience employ stylistic devices that are similar to those used for the general lay audience. Goble notes that Asimov's "medical textbook style falls between the dissertations and the science books for the general public, and is much nearer the latter." Although the medical textbook has complicated technical terms in it, Goble notes that "the language is straightforward," and it contains "more personal sentences than the average popular science book for the general public" (Goble 79).

Asimov's humor essays written for the lay audience are "jumping with active verbs," and his dissertations (mock or real) are "smothered with passive verbs. . .; about two-thirds of Asimov's verbs are intransitive" (Goble 83).

Goble believes that a high percentage of intransitive verbs is not peculiar to Asimov's style because most informative writing relies on intransitive verbs. Goble explains that intransitive verbs can be just as clear as transitive verbs: "Nothing could be clearer or more direct than the simple intransitive statement 'He's dead'" (Goble 83). (It is important to note that the issue of intransitive verbs is not the same as the issue of passive vs active voice. Goble does not comment on this issue.)

5.2 STYLISTICS FOR THE SCIENCE FICTION LAY AUDIENCE

Asimov has a long history of writing popular science articles that appear in science fiction magazines, and he has indicated that these essays are his favorite writing assignments. Naturally, Asimov feels comfortable with his science fiction readers, and his stylistic patterns, according to Goble, do differ from patterns used for other audiences regarding (1) sentence length, (2) paragraph length, and (3) sentence structure.

5.2.1 Sentence length. Not unexpectedly, Goble observes that the close rapport that exists between Asimov and his Gentle Readers affects the way he addresses popular science articles to them: "more than one-fifth of the sentences are personal sentences directly to the reader."

Goble notes that Asimov also "gets a greater variety of sentence lengths into his Fantasy and Science Fiction essays than into any of his other writing." Asimov writes "several one- and two-word sentences, and many 40- to 50-word sentences." His longest sentence to the science fiction audience in Goble's sample was 79 words (Goble 72).

5.2.2 Paragraph length. Asimov appears to be especially conscious of paragraph length when he writes popular science articles for science fiction magazines. He tends to keep them short. Although Asimov had a few very short paragraphs (10-15 words, for example), his paragraphs were never very long and seemed to average about 100 words (Goble 73).

5.2.3 Sentence structure. Asimov's popular science articles aimed at the science fiction audience were approximately 87% declarative. His sampling showed 9% are questions and 2% are fragments. Sentences written in the first person were 10%; sentences written in the second person were 7%; sentences in the third person were 83%.

5.3 STYLISTICS FOR THE JUVENILE LAY AUDIENCES

Asimov has awakened the love of science in many young people as a result of his gift for explaining. For the young lay readers, Asimov makes appropriate adjustments in (1) sentence length and (2) sentence structure.

5.3.1 Sentence length. Asimov's style of writing popular science for the juvenile audience employs techniques that achieve clarity above

all else. According to Goble, there are three main differences between Asimov's books for teens and his books for adults: "sentences are much shorter, syllabication is much lower, and personal sentences are twice as prevalent, (almost predominant, in fact, in the two 'easy math' books)." Asimov's short sentences make technical material easier to read for young readers. Goble observes, however: "I felt a slight monotony developing because of a great many 13- and 14-word sentences. Hardly a sentence in a hundred exceeds 30 words. . . .It appears Asimov has simply bisected any sentence which began to run long. One would gather Asimov believes teenagers do not trust any sentence over 30" (Goble 61).

Goble suggests that Asimov's monotony of style for young readers probably originates from requirements by editors that he keep sentence length for juveniles under a maximum of 25 words (Goble 62).

In analyzing a juvenile book, Kingdom of the Sun, Goble sampled 148 sentences. He found only "10 were 30 words or more; three of these were longer than 45. Average sentence length remained under 17 words."

5.3.2 Sentence structure. Scientific information is often challenging for young readers. Asimov adjusts his sentence structure accordingly when writing popular science for this audience. Goble reports that Asimov's books for teenagers have "conspicuously fewer complex sentences, and conspicuously more simple sentences, declarative sentences, and first- and second-person sentences" (Goble 62).

Goble's examination of Asimov's stylistics for science books and articles addressed to the general lay audience, the science fiction lay

audience, and the juvenile audience shows that Asimov makes stylistic changes to suit his material to his audience. Asimov's stylistics, therefore, show that he uses audience analysis.

CHAPTER VI

AN EVALUATION OF THE READABILITY OF ASIMOV'S POPULAR SCIENCE FOR THE LAY AUDIENCE

Asimov's remarkable ability to explain scientific concepts and technological advances in terms that the general lay audience can comprehend is recognized by many critics. Moreover, Asimov's lay audience usually enjoys reading his literature of fact. With so much emphasis on Asimov's readability, it only seems fitting that his work should be scientifically tested for readability.

This chapter measures the readability of Asimov's popular science for the lay audience using the Flesch readability formula and the cloze procedure. Section 1 presents a general assessment of readability measures, outlining some of their weakness and strengths. Section 2 presents the application and results of the Flesch Reading Ease Formula to writing samples from Asimov's Guide to Halley's Comet (1985). Section 3 presents the application and results of the cloze procedure to the same popular science book.

6.1 ASSESSMENT OF READABILITY MEASURES

Numerous approaches exist for evaluating the readability of written material. This discussion makes no attempt to present a thorough analysis of the endorsements and challenges of the various readability formulas. However, any attempt to check the readability of written texts should be grounded in a rudimentary knowledge of the subject of

readability. To that end, this section presents the following discussion: (1) a review of the literature on readability, (2) an overview of the growth and development of readability, (3) weaknesses of readability measures, and (4) strengths of readability measures.

6.1.1 Review of the literature on readability. Glenn J. Broadhead gives a comprehensive review of sources on measuring readability in his article, "Style in Technical and Scientific Writing," appearing in Research in Technical Communication: A Bibliographic Sourcebook (1985) edited by Michael G. Moran and Debra Journet.

Another thorough assessment of readability is the March 1981 issue of IEEE Transactions on Professional Communication. This issue devotes an entire section to readability. Seven authors contribute articles on the subject. George R. Klare also provides a discussion and review of the most widely used readability measures, which can be found in a comprehensive article appearing in Reading Research Quarterly Vol. X No. 1 (1974-75).

6.1.2 Overview of the growth and development of readability measures. Janice Redish defines readability formulas as "mathematical equations for predicting the reading ability needed to understand a particular piece of prose" (Redish 47).

Kenneth Powell explains that readability formulas are "equations which state that readability is a function of some other variables, such as word complexity and sentence complexity." He notes that "during the past five decades, readability formulas by the hundreds

have been developed" (Powell 43). Alinda Drury, on the other hand, calculates that only about 50 readability formulas have been developed and that only 4 or 5 are commonly used (Drury 11).

Broadhead identifies five of the most familiar readability formulas and the sources from which they derive: Rudolf Flesch's How to Test Readability (1951); Robert Gunning's How to Take the Fog Out of Writing (1964); Edward Fry's "A Readability Formula That Saves Time" (1968); Harry McLaughlin's "SMOG Grading: A New Readability Formula (1969); and Wilson Taylor's "Cloze Procedure: A New Tool for Measuring Readability" (1953) (Broadhead 234).

Readability formulas that originated in the 1920s were first confined to academics. Later the publishers of school textbooks used them to judge reading levels for specific grades. Readability is generally expressed in terms of the educational level of a reader who can understand the material. For example, if an article has a readability index of 9, then any audience with a 9th grade education should be able to understand the material.

Many new readability formulas, however, are merely variations of these early formulas that are modified to suit specific purposes. One of these purposes is the testing of the readability of written material addressed to different audiences: Catholic children, deaf audiences, persons with a language deficiency, and readers of military manuals, insurance policies, and income tax instructions, for example.

Another purpose for variations in readability measures is to allow for computer analysis of textbooks. Standard readability measures are also modified for application in the field of advertising to measure

how well the audience responds to color, sound, graphics, or other advertising techniques.

Interest in applying readability formulas has spread to the whole spectrum of audiences. Readability measures are particularly useful to technical writers who are concerned with audience analysis. Jeanne Barry recognizes a great need for standards of readability concerning technical information that is addressed to different audiences. She observes: "During the past decade, there has been more technological information generated than in all the previous years of recorded history." She suggests: "communication between specialists and lay persons, between government bureaucrats and citizens, between textbook writers and students, has become a problem of national concern" (Barry 45).

Although readability measures are helpful in audience analysis, they have a number of weaknesses, as well. Knowledge of these weaknesses will assist evaluators in drawing conclusions about readability scores.

6.1.3 Weaknesses of readability measures. Kenneth Powell echoes the caution of many who write about readability measures. He warns: "Readability formulas have some weaknesses and should not be the final arbiter in how we write, but used with understanding, they can be a useful tool in the writer's bag" Powell 43).

Broadhead sounds a similar warning, and he cautions that there are limitations to any readability test that is used for audience analysis:

> It fails to take into account the varying characteristics of audience needs and wishes; it ignores important aspects of linguistic structure and cohesion ...; and it does not consider the ultimate goal of style in writing--which is not merely to

> achieve speed, ease, or personal involvement, but rather to create understanding or comprehension of the information in the text (Broadhead 236).

Klare and Buck outline specific limitations to readability measures. They point out that readability tests do not consider word order, slang, analogies, satire, organization, logical progression of important points, poetry, special background experience, reader interest, reader purpose, the intelligence of the reader, or introduction and conjunction of sentences, paragraphs, chapters or sections (Klare and Buck 146).

Alinda Drury believes that "the use of formulas to calculate readability levels provides a misleading and inappropriate measure of text difficulty." She explains that readability formulas rely on counts of difficult or long vocabulary words and on a measure of sentence length. The measure of sentence length for readability is based on the assumption that longer sentences are more difficult for audiences to comprehend. Drury observes: "This assumption simply does not hold up; a long sentence can consist of simple structures and be easily comprehended, while shorter sentences can be quite complex and difficult for non-fluent English users to understand." Therefore, she believes "the length/complexity relationship is not a reliable one." She outlines four characteristics of written materials that have been shown to affect readability: (1) vocabulary difficulty, (2) sentence structure, (3) text cohesion (i.e., clarity of writing), and (4) visual presentation of the text [i.e., layout] (Drury 11).

Kenneth Powell suggests several misuses of readability formulas. One misuse occurs when the results are interpreted as being an exact

revelation of readability. In fact, Powell notes, "the standard error varies from a grade to grade and a half, plus or minus."

Powell notes that another misuse of readability measures occurs when technical writers use the formulas "without modification for desired comprehension level." Readability formulas are based on a comprehension level of 50-75 percent, but Powell suggests that "technical writers should aim for 90-100 percent comprehension, the level at which a student can learn without help."

Powell suggests that readability testing can be made more reliable for technical writers if several samples are pulled at random from articles to be tested. He points out that technical articles have low readability where an author describes what he did or what he found. On the other hand, the readability is significantly higher in sections of an article where an author explains <u>why</u> something happened.

Powell explains the second major problem with readability formulas: "They don't tell a writer how to improve his writing." The formulas suggest an author should simplify complex words and complex sentences, but they do not suggest which words and sentences should be simplified. Powell believes if a three-syllable word has been used because it has important nuances to the context of the sentence, it should remain.

And regarding sentence length, Powell shows that readability indexes are not much help for the writer. For example, one article could have every sentence range from 10 to 12 words. A second article might have a variety of sentence lengths ranging from 4 to 54 words. But if the average sentence length is 11 words, both articles would have the same readability level. In actuality, the second article would have more

interest for the reader because of the sentence variety (Powell 43 ff.).

Finally, Janice Redish discusses eight limitations to readability formulas. These limitations are paraphrased below:

1. The formulas can only be used on prose passages.

2. The formulas assume that the text is composed of well-formed, grammatical sentences.

3. Gibberish, made-up words, and acronyms will cause a passage to score poorly only on a readability formula that uses a vocabulary list.

4. In many technical applications, writers allow themselves to improve their scores by making adjustments in the formulas: by adding a specific set of technical terms to a vocabulary list as being acceptable, or by deleting long, technical terms, for example.

5. Writers often reduce the number of words in a sentence to improve their readability scores, but shorter sentences are not always clearer sentences.

6. The formulas do not measure how relevant the content is for the audience.

7. The formulas do not give the writer an indication of how well a document is organized.

8. The formulas do not measure typographical features such as type size, typeface, use of white space, attractiveness of presentation--all items which affect reader motivation (Redish 46 ff.).

6.1.4 Strengths of readability measures. Some readability measures have been designed to measure comprehension, and others are designed to test reading ease. As long as technical writers are aware of the limitations of readability measures, there are certain benefits to be derived from their application.

One important advantage of readability formulas, according to Christian Todenhagen, is that they are "a quick and convenient way to check the level of relative ease or difficulty of technical texts."

Todenhagen cautions that this quickness and convenience can be considered an advantage only if the user of the formula realizes that such tests "come with a margin of error that can be quite considerable" and that "readability cannot be influenced by simply manipulating word and sentence length." Todenhagen explains that word length is just one determinant among six vocabulary factors which influence readability. The others are "word frequency, association value, concreteness, the use of active verbs, pronouns, and other referring expressions" (Todenhagen 55 ff.). Although reading ease tests are quick and convenient, the tester must realize that keeping his sentence length at 18 or 20 words, for example, may give him a good readability score, but short sentence lengths are not the only determinant of readability.

Glenn Broadhead believes that the most useful application of readability formulas to the writing process is that they are "a helpful tool for adapting specific information to a specific audience for a specific purpose." He observes that readability "is well entrenched in the literature about technical writing--as a technique for audience analysis, as a set of norms based on that technique, and as a general equivalent for 'good' or 'clear' or 'simple' writing" (Broadhead 234 ff.).

Klare and Buck acknowledge that "readability formulas, as scientific tools, can and should be useful to writers." However, they help to evaluate only one aspect of style--difficulty. "A formula can distinguish difficult and easy pieces quite well, and can serve as a valuable aid in telling whether revisions of an original draft are more readable or less" (Klare and Buck 142-146).

Kenneth Powell observes that although it is difficult to determine the reliability and validity of readability formulas, "over the years a body of evidence has been developed that confirms that they are good and useful, if used wisely." He notes that "generally, the formulas have been tested against comprehension tests with resulting correlations of 60-90 percent depending on material, test group, and formulas." He voices the opinion that "no one formula is consistently better than the others" (Powell 43 ff.).

6.2 APPLICATION OF THE FLESCH READING EASE FORMULA TO ASIMOV'S GUIDE TO HALLEY'S COMET

Acknowledging that readability formulas are only as good as scientific research can make them, and that they are in no way perfect measures of a writer's style, this section presents a discussion of the application of the Flesch Reading Ease Formula to writing samples from Asimov's popular science book, Asimov's Guide to Halley's Comet (1985), which is addressed to the lay audience. The discussion includes the following topics: (1) the Flesch Reading Ease Formula (2) the selection and presentation of Asimov's writing samples, and (3) an interpretation of the results of the Flesch readability test.

6.2.1 Flesch Reading Ease Formula. Rudolf Flesch introduced his first readability formula in 1943, revised it in 1948, and published his book How to Test Readability in 1951. This small book outlines the Flesch method of testing readability. It is recognized as a standard among hundreds of variations. Kenneth Powell believes the Flesch

Flesch Reading Ease Formula "is one of the most popular indexes" (Powell 43). Glenn Broadhead also recognizes the importance of the Flesch Formula. He writes: "Undoubtedly the greatest influence on the development in technical writing of an absolute norm of style called 'readability' is Rudolf Flesch" (Broadhead 234). And George Klare assesses the Flesch Reading Ease formula as being "one of the most widely used in the history of readability measurement" (Klare RRQ 69).

Rudolf Flesch's book, How to Test Readability, gives precise guidelines for determining readability. Refer to the flow chart in Fig. 1 for a quick view of the procedure to follow in determining readability. A detailed explanation of these steps is paraphrased below (Flesch 1-6).

1. How to Pick Samples

Take enough samples for a fair test. Choose samples at random rather than selecting "good" or "typical" examples. Going by a numerical scheme is best, such as every third paragraph of a short article or every other page of a longer piece. For books, take samples from the beginning, middle, and end. Avoid introductory paragraphs (they are not generally typical of the whole piece).

Take samples of 100 words each, being sure to start each sample at the beginning of a paragraph.

2. How to Count Words

Count each word in the sample up to 100. Place a mark of identification after the 100th word.

Count as words anything that is surrounded by white space: all letters, numbers, symbols, contractions, and hyphenated words, for example.

3. How to Figure the Average Sentence Length

Count all the sentences in each sample. Add the number of sentences in all samples. Divide the number of words (counted in step 1) by the total number of sentences, rounding off the result.

If the 100th word mark falls in the middle of a sentence, follow this procedure: count as one sentence if the 100th mark falls after more than half of the words in it, otherwise disregard it.

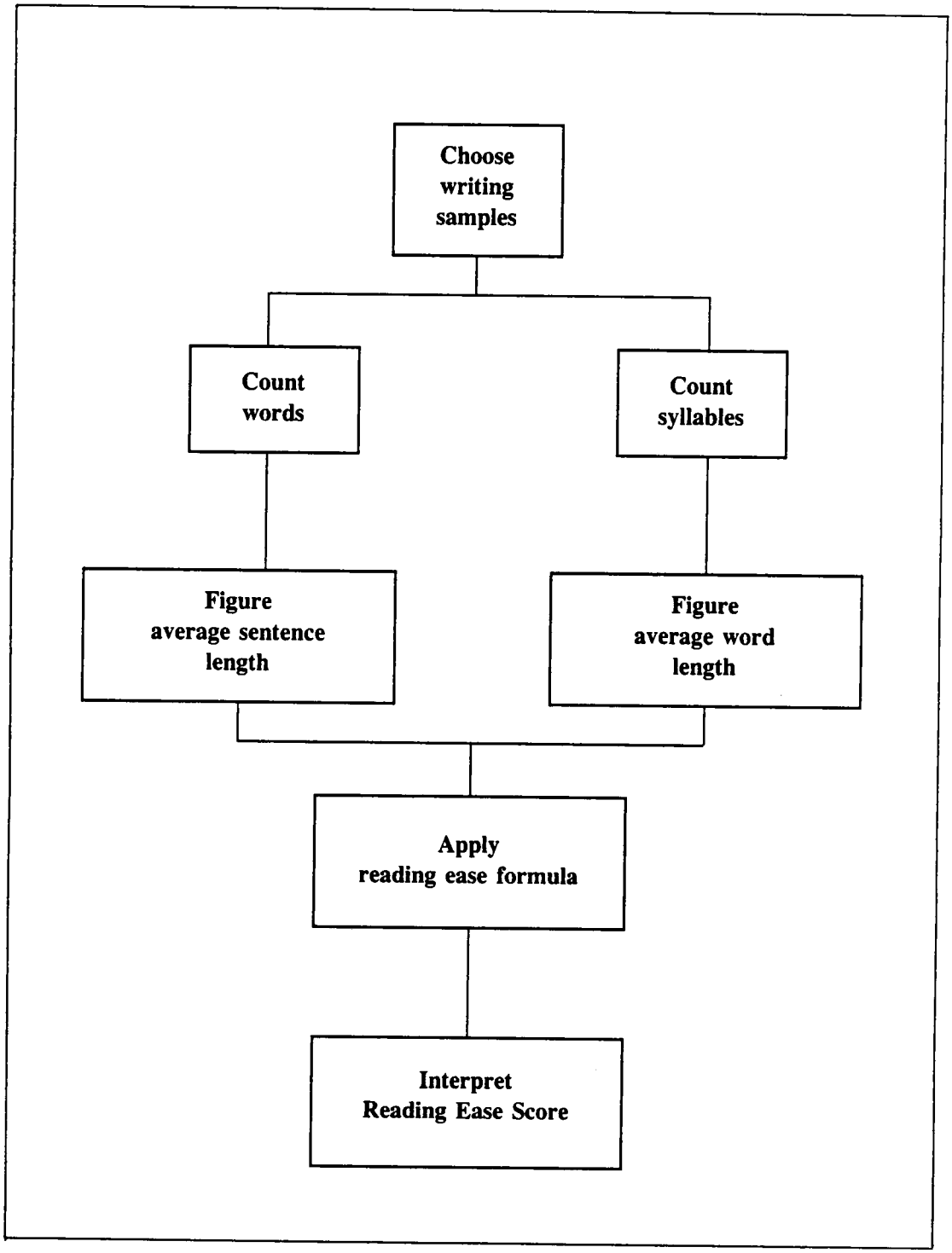

Fig. 1. Procedure to follow in determining Flesch Reading Ease Score.

Count as a sentence each unit of thought that is grammatically independent of another sentence or clause. Judge this count by groups of words that are set off by periods, question marks, exclamation points, semicolons, or colons.

4. How to Count Syllables

Count syllables in words, symbols, and figures according to the way they are normally read aloud: two syllables for $ (dollar), four syllables for 1916 (nineteen sixteen).

5. How to Figure the Average Word Length

Count all syllables in the 100-word samples. Add all the syllables from all the samples and divide by the number of samples. (This will give you the number of syllables per 100 words.)

6. How to Find Reading Ease Score

Use the following formula to calculate readability:

> RE = 206.835 - .846wl - 1.015sl.

RE = Reading Ease
wl = number of syllables per 100 words
sl = average number of words per sentence

Table I illustrates how to calculate the Flesch Reading Ease Score using the average word length and average sentence length of a 100-word passage (Passage One) taken from Asimov's Guide to Halley's Comet.

7. How to Interpret Reading Ease Score

Table II should be used to interpret readability. The scale begins at 0 (practically unreadable) and goes to 100 (easy for any literate person). To translate readability scores into grade levels, refer to Table III.

6.2.2 Selection and presentation of Asimov's writing samples. I had several reasons for selecting an Asimov popular science book to test for readability. I wanted to select a recent popular science book by Asimov that had not been discussed by Neil Goble in his Asimov

TABLE I

How to Calculate Flesch Reading Ease Score
for Passage One from
Asimov's Guide to Halley's Comet

Formula: RE = 206.835 - 0.846wl - 1.015sl
Given: wl = 139; sl = 12.5*

Step	Procedure	Example
1	Multiply the average sentence length by 1.015;	12.5 x 1.015 = 12.687
2	Multiply the number of syllables per 100 words by 0.846;	139 x 0.846 = 117.594
3	Add the two products from Steps 1 and 2;	12.687 + 117.594 = 130.281
4	Subtract the sum of the two products from 206.835;	206.835 - 130.281 = 76.554
5	Your Reading Ease Score is 76.5.	

* RE = Reading Ease
wl = Number of syllables per 100 words
sl = Average number of words per sentence

TABLE II

Interpretation of Flesch Reading Ease Score

Reading Ease Score	Description of Style
90 to 100	Very easy
80 to 90	Easy
70 to 80	Fairly easy
60 to 70	Standard
50 to 60	Fairly difficult
30 to 50	Difficult
0 to 50	Very difficult

TABLE III

Readability Scores Translated to Grade Levels

Score	Grade
90 to 100	5th grade
80 to 90	6th grade
70 to 80	7th grade
60 to 70	8th and 9th grade
50 to 60	10th to 12th grade (high school)
30 to 50	13th to 16th grade (college)
0 to 30	College graduate

Analyzed. I also wanted to choose a popular science book that was written in a technical style, but one that contained subject matter with which the general lay audience was likely to be familiar. Too, I wanted to select an Asimov book that the critics judged to be highly readable and one that they judged to be aimed at the lay audience. Asimov's Guide to Halley's Comet met all of these criteria.

Asimov's Guide to Halley's Comet was published in 1985; therefore, Neil Goble's Asimov Analyzed (published in 1972) did not treat the work. The media has been saturated with news of Halley's Comet for several years, especially in the fall of 1985 and in the early part of 1986 before the comet's close appearance in early 1986. Therefore, the general lay audience was likely to have some knowledge of this scientific phenomenon.

Asimov's Guide to Halley's Comet received good reviews by several critics. One critic believes that no other recent book on Halley's comet "is written with Asimov's distinctive combination of casual, almost conversational style and profoundly detailed knowledge." The critic adds that the book is "information-packed, authoritative, eminently readable" (Bulletin Center for Children's Books 110 w).

A. R. Upgren suggests that Asimov's Guide to Halley's Comet is "intended for those general readers interested in learning about Halley's Comet." Upgren adds: "the book is a well-written and well-illustrated introduction for the casual reader" (Upgren 140).

Hilary King calls the book "fascinating" and records that "Scientific facts and data are presented in clear, readable style; adults and young people alike will become engrossed." King also

believes the book to be an "excellent resource for browsing and/or research" (King 272).

That Asimov's Guide to Halley's Comet is written in a technical style is evident by the illustrations, drawings, and diagrams placed throughout the text. Although the book is indexed, it does not have a bibliography. But for an Asimov book, this is not unusual.

Following Mr. Flesch's suggestions for selecting writing samples, I chose five, 100-word samples from the text. Since the book only contains 118 pages, I arbitrarily decided to select samples from every 25th page, ensuring a representative sampling from the beginning, middle, and end of the text. I did not select the introductory paragraph of any new chapter or division.

The writing samples are marked with "/" to indicate where I judged sentences. Below each sample appear the counts necessary to apply the Flesch Reading Ease Formula: the total words per passage, the total sentences per passage, the average words per sentence (sl) and the number of syllables per 100 words (wl). The five samples appear on the next five pages as Figs. 2-6. I also give the Flesh Reading Ease Score for each passage because these individual scores are later combined to give an average readability score for the entire book.

From the five passages, the average words per sentence were added together and divided by five to get the average words per sentence (sl) for all five passages. Also from the five passages, the syllables per 100 words were added together and divided by five to get the average syllables per 100 words (wl) for all five passages. The Flesch Reading Ease Formula was then applied, which showed an overall readability

PASSAGE ONE

Flesch Readability

From Asimov's Guide to Halley's Comet (1985), page 1

The stars are particularly regular, all moving round and round the sky with a steady, even motion that does not change./ While they do so, their positions relative to each other do not change, either./

The Sun and the Moon are not quite so even./ The noonday Sun drifts slowly higher and lower in the sky as the year progresses,/ and the Moon changes its shape from night to night./ The planets change their speeds and even their direction of motion as time passes./ These changes, however, are regular./ They can be worked out, and the position of these heavenly/ bodies can be predicted far into the future.

*****

Total words: 108
Total Sentences: 7
Average words per sentence (sl): 15.42
Syllables per 100 words (wl): 139
Formula: RE = 206.835 - 0.846wl - 1.015sl.
Flesch Reading Ease Score: 73.6

Fig. 2. Passage One from Asimov's Guide to Halley's Comet (1985), page 1.

PASSAGE TWO

Flesch Readability

From Asimov's Guide to Halley's Comet (1985), page 25

Once Halley's Comet was recognized as a respectable member of the solar system, capable of returning in a periodic and predictable way, astronomers began to look backward to see which of the numerous comet sightings were actually earlier visits of what had now suddenly become the most famous of all comets./

We can start with the perihelion of March 13, 1959, and count backward, through earlier perihelia:/

September 15, 1682./ This was the comet observed by Halley./

October 27, 1607./ This was the comet studied by Kepler, who suggested as a result that comets traveled in straight lines./

August 25,/ 1531.

*****

Total words: 101
Average words per sent. (sl): 14.4
Total sentences: 7
Syllables per 100 words (wl): 183
Formula: RE = 206.835 - 0.846wl - 1.015sl.
Flesch Reading Ease Score: 37.37

Fig. 3. Passage Two from Asimov's Guide to Halley's Comet (1985), page 25.

PASSAGE THREE

Flesch Readability

From Asimov's Guide to Halley's Comet (1985), page 50

Whipple suggested that a comet is essentially a ball of icy substances (a "snowball") that, at higher temperatures, would turn into vapors./ The frozen substances that might make it up include water, of course, and also ammonia, methane, carbon dioxide, hydrogen cyanide and so on./ Embedded in the icy substances would be dust particles and little bits of solid, rocky materials./ (These would make the snowball "dirty.")/ At the core there might be a solid bit of rock, or the comet might be dust and grit embedded in ice all the way through./ The frozen ball might be several miles/ across and would be a small and barely noticeable object as long as it remained frozen.

*****

Total words: 93
Total sentences: 5
Average words per sentence (sl): 18.66
Syllables per 100 words (wl): 155
Formula: RE = 206.835 - 0.846wl - 1.015sl.
Flesch Reading Ease Score: 56.176

Fig 4. Passage Three from Asimov's Guide to Halley's Comet (1985), page 50.

PASSAGE FOUR

Flesch Readability

From Asimov's Guide to Halley's Comet (1985), page 76

There was some question at first as to whether comets broke up into meteor swarms or were formed out of meteor swarms;/ in other words, which came first./ Schiaparelli believed the meteor swarms came first./

The matter was settled by an Austrian astronomer, Edmund Weiss (1837-1917)./ He showed that the Andromedid follows the orbit of Biela's Comet, which had broken up in the 1860s./ On November 27, 1872, when Biela's Comet should have appeared if it had existed, there was instead a heavier than usual shower of Andromedids./ Clearly, that shower was the grit into which the comet had/ disintegrated, and Weiss gave the meteor swarm the new....

*****

Total words: 88
Total sentences: 6
Average Words per sentence (sl): 14.6
Syllables per 100 words (wl): 175
Formula: RE = 206.835 -0.846wl - 1.015sl.
Flesch Reading Ease Score: 43.9

Fig. 5. Passage Four from Asimov's Guide to Halley's Comet (1985), page 76. (Since page 75 consisted of a page of illustrations, I selected a passage from the next page of text, page 76.)

PASSAGE FIVE

Flesch Readability

From Asimov's Guide to Halley's Comet (1985), p. 100

These craters are formed by large meteors (or, if you prefer, small asteroids)./

Comets, of course, are made up of icy matter that is neither as dense or as tough as are the rocks and metals making up meteors, so that a collision with a comet may not seem as fearful as one with a meteor./ That, however, is not necessarily so./

Consider the case, for instances, of an event that took place on June 30, 1908./ On that day a fireball lit the sky in broad daylight over a desolate forested region of eastern Simeria near a place called/ Tunguska.

*****

Total words: 101
Total sentences: 5
Average words per sentence (sl): 20.2
Syllables per 100 words (wl): 146
Formula: RE = 206.835 - 0.846wl - 1.015sl
Flesch Reading Ease Score: 62.81

Fig.6. Passage 5 from Asimov's Guide to Halley's Comet (1985), page 100.

score of 54.9. Table IV shows the counts for total words, total sentences, average sentence lengths, and syllables per 100 words for the five passages. The line graph in Fig. 7 illustrates the wide range of readability scores for each of the five Asimov passages.

6.2.3 Interpretation of Flesch Readability Test. Although Neil Goble's Asimov Analyzed provides a statistical analysis of selections from Asimov's popular science writing, he did not apply any readability measures. Goble reports that his purpose in counting sentences and syllables was "only to describe, and not to judge." He explains: "I have grown a little suspicious of these formulas since discovering they all rate my telephone directory 'dramatic.'" He adds that he had no intention of "grading" Isaac Asimov, for he believes that anyone who has "earned such a reputation for clarity and eloquence, and made so much money, must be doing it the right way" (Goble 41).

I, too, am hesitant to grade Isaac Asimov. But without being judgmental, I simply report that the Flesch Reading Ease Score for Asimov's Guide to Halley's Comet was 54.9. Table I indicates that a Reading Ease Score within the range of 50 to 60 receives a rating of "fairly difficult". This ranking does not seem to coincide with the critics' assessment of Asimov's readability for this particular book (see section 6.2.2).

My preconceived notion about the five Asimov passages (based on the critics' evaluations) was that they would rank "easy" or "fairly easy". Indeed, when Passage One scored a 73.6 (or a "fairly easy" rating), I was not surprised. However, when Passage Two plummeted to 37.3 (or a

TABLE IV

Combined Readability Totals for Five Passages

Passage	Total words	Total sentences	Avg. word length	Syllables per 100 words
1	108	7	15.42	139
2	101	7	14.4	183
3	93	5	18.66	155
4	88	6	14.6	175
5	101	5	20.2	146

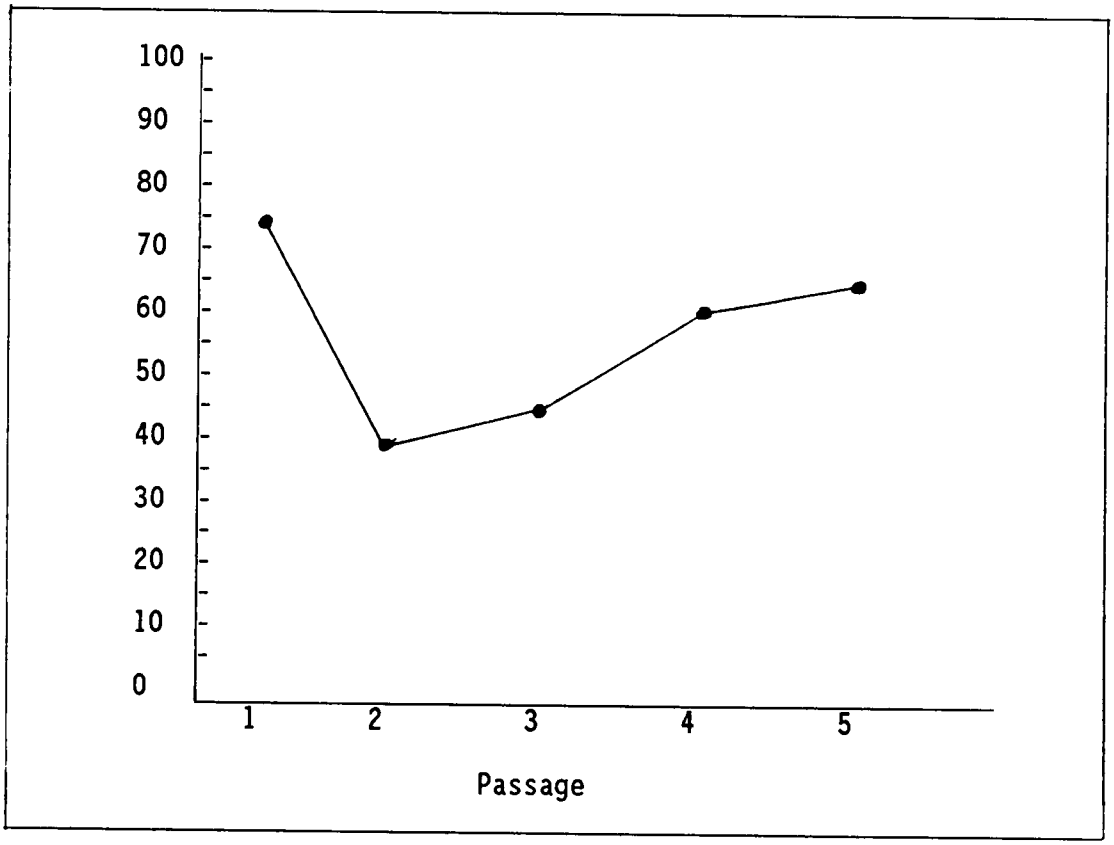

Fig. 7. Individual Flesch Reading Ease Scores for Passages One through Five: 73.6, 37.3, 43.9, 56.7, and 62.8.

"difficult" rating), I began to take notice. Passage Three ranked 56.7 (or a "fairly difficult" rating), and Passage Four ranked 43.9 (or a "difficult" rating). Asimov's readability rose toward the end of the book with a score of 62.8 (or a "standard" rating).

I have made several observations about the application of the Flesh Readability test to the Asimov passages:

(1) Those skeptics who question the validity of readability measures in general will be reinforced in their belief that such measures cannot measure readability. After all, what writer can be more readable than Isaac Asimov, and he rated an overall "fairly difficult."

(2) The results of this readability check may inspire the question, "What criteria do book reviewers use to evaluate the readability of a technical book?"

(3) Several cautions that were made by evaluators of readability measures surfaced in this readability check. For instance, Powell noted that several samples should be taken at random from technical works in order to achieve more reliable readability results. He suggested that technical works have low readability scores when an author explains what he found, whereas the readability is higher when an author explains why something happens.

This observation would seem to be true in Asimov's case. On page 1 (the passage which received the highest readability score--73.6), Asimov tells why comets have frightened people over the centuries (explaining why something happened). On page 25, (the passage that received the lowest readability score--37.3), Asimov tells how

scientists are able to predict the periodic return of Halley's Comet (explaining what he found).

(4) Powell also suggests that readability indexes do not help the technical writer to know when to improve his sentence structure. He suggests that an article which has every sentence ranging from 10 to 12 words may receive the same rating as a second article which has a variety of sentence lengths ranging from 4 to 54 words.

This observation is certainly true of Asimov's style. Passage Two had a wide variety of sentences ranging from 3 to 54 words. Passage Four showed less sentence variety with counts ranging from 7 to 37 words. Nevertheless, both passages had almost identical ratings for average words per sentence: 14.4 and 14.6 respectively.

(5) Flesch warned that samples should not be taken from introductions or introductory paragraphs, for an author writes in a different style for these positions. Although Asimov did not have an introduction in this book, the first chapter could be considered as such. It is probably no coincidence then, that his highest readability rating came from page one.

(6) Although Asimov's average readability for the five passages combined was rated "fairly difficult," when we look at Table II (page 86) and see that a rating from 50-60 translates to grade levels of 10-12th grade, it would seem that Asimov's readability is on target. The general lay audience usually consists of readers with a high school education; therefore, Asimov's readability for the passages selected offer no real surprises.

(7) Finally, the broad variation in scores suggests that I needed a much larger statistical sample. Instead of taking a sample from every 25th page, I could have selected passages from every 10th page. Instead of administering the test to 45 students, I could have used twice that many.

6.3 APPLICATION OF THE CLOZE PROCEDURE TO ASIMOV'S GUIDE TO HALLEY'S COMET

An important consideration in applying readability measures to technical writing is that a single measure tells the evaluator very little about a sample of written communication. Lawrence Frase advocates the use of multiple measures to test more than one variable of readability (Frase 49). In this regard, I will apply the cloze procedure to three of the same Asimov writing samples that I used in the previous Flesch Test. First, it is necessary to give a brief introduction to the cloze procedure. Following the introduction, I will identify the Asimov writing samples and give the procedures used in administering the test. Finally, I will interpret the results of the cloze procedure.

6.3.1 Cloze procedure.

At the heart of the cloze procedure is an attempt to measure the ability of readers to understand written material. Wilson Taylor introduced the cloze procedure in 1953 as a method to measure the readability of communication (written or oral),

but it is not considered to be a readability formula. Taylor defines the cloze procedure as

> A method of intercepting a message from a "transmitter" (writer or speaker), mutilating its language patterns by deleting parts, and so administering it to "receivers" (readers or listeners) that their attempts to make the patterns whole again potentially yield a considerable number of cloze units (Taylor 416).

We have seen that the Flesch Formula is an index for measuring the "difficulty" of written material based on the counting of syllables of individual words and sentence length and applying a formula. The cloze procedure is a tool for measuring the "comprehension" of written material by counting the number of correct answers placed in a series of blanks in a text of 100 words.

According to Jack Selzer, the cloze procedure has gained wide acceptance in the past decade as a reliable way of testing "the comprehensibility of connected discourse" (Selzer 291). Holcomb explains that the cloze procedure is a way of testing the "density of ideas." If Taylor's suggested guidelines are followed for administering the procedure, Holcomb believes it offers a way to "determine the readability level of printed materials in terms of the readers' ability to comprehend what they have read" (Holcomb 8 ff.).

The cloze procedure measures meaning-pattern relationships by asking the reader to fill in deleted passages of text with correct answers (only minor misspellings accepted and no synonyms). Taylor reasons that a piece of written material that is aimed at a specific audience is successful if a member of that audience is able to comprehend a mutilated passage of text. He explains: "if that word really is the same as the one omitted, the person scores one cloze unit for correctly

closing the gap in the language pattern." Taylor outlines seven steps to follow in applying the cloze procedure. Those steps are paraphrased below (Taylor 416 ff).

Step 1 How to Pick Samples

Select several passages of at least 100 words each from a document. It is a good idea to select the passages from the beginning, middle, and end of the document, avoiding any introductory paragraphs.

Step 2 How to Delete (mutilate) Passages

Delete an equal number of words from each passage by some random counting system. Count out each nth word (every fifth one, for example), and delete that word regardless of its function. Delete only words (not numbers). A word is defined by white spaces which separate it from other words.

Step 3 How to Leave Blanks

It is important to reproduce each mutilated passage with a blank of standard length in place of every missing word in order to avoid using length to influence guessing.

Step 4 How to Distribute Passages

Give copies of all reproduced passages to all subjects in a sample group representative of the population in question.

Step 5 How to Give Test Instructions

Ask all subjects to try to fill in all blanks by guessing from the context of remaining words.

Step 6 How to Arrive at Totals

Total the number of times original words were correctly replaced, being careful to total each passage separately. Consider these totals as readability scores.

Step 7 How to Arrive at Scores

Contrast the cloze totals of the various passages. The passage with the highest score is "most readable"; the one with the second highest score is the next most readable, etc.

Because the cloze procedure measures a reader's comprehension, it would seem to be an excellent tool to help an author determine if he is

reaching his intended audience; it also seemed a compatible choice to use with the Flesch test, which measures reading ease (not comprehension). Together, both readability measures applied to the same passages from a specific work should be a fair measure of an author's readability success.

6.3.2 Presentation of Asimov writing samples and discussion of procedures used. I followed Wilson Taylor's suggested steps in selecting the Asimov writing samples. I selected three of the same passages from Asimov's Guide to Halley's Comet that I used in the Flesch Test. Since Taylor recommends selecting passages from the beginning, middle, and end of a work, I used only Passages One, Three, and Five. The mutilated texts given to the students are shown in Figs. 8, 9, and 10. (For answers to the blanks, refer to the Flesh Test passages in Figs. 2, 3, and 6, which give the complete text for these passages.) For the mutilation step, I deleted every fifth word in the hundred-word passages, leaving standard blanks of fifteen spaces for each deleted word.

I gave reproduced copies of the mutilated passages to 45 entering freshmen who were enrolled in two sections of Freshman Composition 1010 at the University of Tennessee, Knoxville. The test was given on their first day of class (September 1986); therefore, they still qualified as a lay audience (readers from the general public with a high school education).

PASSAGE ONE

Cloze Procedure

From Asimov's Guide to Halley's Comet (1985), page 1

The stars are particularly _____, all moving round and _____ the sky with a _____, even motion that does _____ change. While they do _____, their positions relative to _____ other do not change, _____.

The Sun and the _____ are not quite so _____. The noonday Sun drifts _____ higher and lower in _____sky as the year _____, and the Moon changes _____shape from night to _____. The planets change their _____and even their direction _____ motion as time passes. _____ changes, however, are regular. _____ can be worked out, _____ the position of these _____ bodies can be predicted/ [100 words] far into the future.

*****

Number of deletions from this passage: 20
Total number of deletions for 45 students: 900
Total number correct answers from 900 deletions: 326
Percentage of correct answers from 900 deletions: 33.2%

Cloze Score: 33

Fig. 8. Mutilated Passage One administered to 45 Freshmen 1010 students at the University of Tennessee. No synonyms were accepted as correct answers.

PASSAGE THREE

Cloze Procedure

From Asimov's Guide to Halley's Comet (1985), page 50

Whipple suggested that a _____ is essentially a ball _____ icy substances (a "snowball") _____, at higher temperatures, would _____into vapors. The frozen _____ that might make it _____ include water, of course, _____ also ammonia, methane, carbon _____, hydrogen cyanide and so _____. Embedded in the icy _____ would be dust particles _____ little bits of solid, _____ materials. (These would make _____snowball "dirty.") At the _____ there might be a _____ bit of rock, or _____ comet might be dust _____ grit embedded in ice _____ the way through. The _____ ball might be several _____ [100 words] across and would be a small and barely noticeable object as long as it remained frozen.

*****

Total number of deletions from this passage: 20
Total number deletions for 45 students: 855
Total number of correct answers for 855 deletions: 321 Percentage of correct answers from 900 deletions: 35.6%

Cloze Score: 36

Fig. 9. Mutilated Passage Three administered to 45 Freshmen 1010 students at the University of Tennessee. No synonyms were accepted as correct answers.

PASSAGE FIVE

Cloze Procedure

From Asimov's Guide to Halley's Comet (1985) page 100

These craters are formed _____ large meteors (or, if _____ prefer, small asteroids). Comets, _____ course, are made up _____ icy matter that is _____ as dense or as _____ as are the rocks _____ metals making up meteors, _____ that a collision with _____ comet may not seem _____ fearful as one with _____ meteor. That, however, is _____ necessarily so.

Consider the _____, for instance, of an _____ that took place on June* 30, 1908. _____ that day a fireball _____ the sky in broad _____ over a desolate forested _____ of eastern Simeria near _____ place called [100 words] Tunguska.

*****

* Since this fifth word was actually a date, I deleted the next regular word.

Total number of deletions from this passage: 19
Total number of deletions for 45 students: 855
Total number of correct answers from 855 deletions: 420
Percentage of correct answers from 855 deletions: 49.1%

Cloze Score: 49

Fig. 10. Mutilated Passage Five administered to 45 Freshmen 1010 students at the University of Tennessee. No synonyms were accepted as correct answers.

Before administering the cloze procedure, I spent about five minutes introducing my purpose. I explained that Isaac Asimov was the author of over 330 books, many of which were popular science books. I noted that Asimov is considered by many critics to be America's greatest explainer. I read a short passage from page 24 and 25 in which Asimov explains the correct way to pronounce Halley. I did this to call attention to the fact that if each fifth word were deleted, some of the words might be as simple as "a," or "and," or "the." I reminded the students not to let the fifteen-spaced blanks influence their judgement about selecting appropriate words to put in the blanks.

I also reminded students that if they were unable to fill in the blanks, they should not consider it a reflection on their intelligence. After all, the premise of the cloze procedure is that if lay readers cannot fill in the blanks easily, the material is not written for a lay audience.

The test was administered to both classes during the morning of two separate days. One class section was given the test at the beginning of the class. The other section was given the test in the middle of the class. Students were allowed as long as they wished to complete the test, but most finished in 15 minutes. Three students kept the passages until the end of class to linger over choices.

6.3.3 Interpretation of results of cloze procedure. Since the cloze score has no chart to indicate a specific grade level and since there is no scale to determine a rating level of easy to read or difficult to

read, the interpretation of the results of a cloze score can be quite subjective.

The cloze scores for the three Asimov passages were derived from adding all the correct answers together from derived from adding all the correct answers together from students and dividing this number by the total number of blanks. As can be seen in Figs. 8, 9, and 10, the cloze scores for the three mutilated passages from Asimov's Guide to Halley's Comet were 36, 35, and 49, respectively. The bar chart in Fig. 11 shows the fairly even range of scores for the three passages. When these three scores were totaled and divided by three, the overall cloze score for Asimov's Guide to Halley's Comet was 40.

Ideally, if readers are able to predict meaning-patterns relationships, the cloze score should be high. According to Wilson Taylor, the cloze procedure

> "repeatedly samples the extent of likeness between the language patterns used by the writer to express what he meant and those possibly different patterns which represent readers' guesses at what they think the writer meant" (417).

Surprisingly, Asimov's meaning-pattern relationships were difficult for most of the students who participated in the cloze test; the average of the three cloze scores was 40. If we decide that a comprehension level of 50-75% is a desirable range for readability as suggested by Powell, then Asimov's readability is 10% below what is considered a desirable readability score. But Powell suggests "that technical writers should aim for 90-100 percent comprehension, the level at which a student can learn without help" (Powell 43 ff.). Asimov would rank 30-60% below what Powell would consider desirable readability. If we are to believe the critics, Asimov is America's

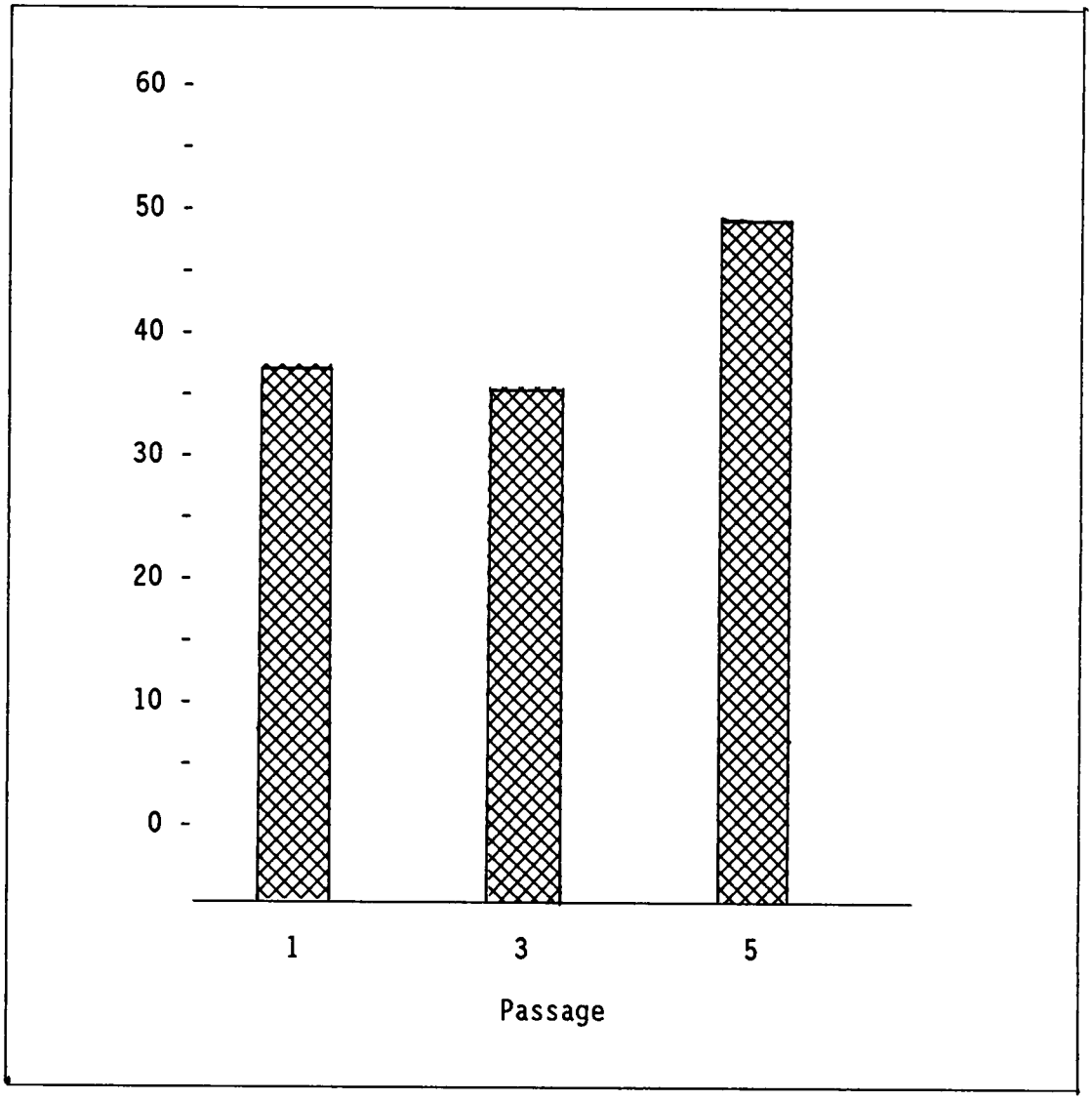

Fig. 11. Percentage of correct answers for mutilated Passages One (score of 36), Three (score of 35), and Five (score of 49) from Asimov's Guide to Halley's Comet.

greatest explainer. His popular science books and articles are a part of the regular science-reading diet of many members of the lay audience (readers with a high school education) and many young people as well. In fact, a review of Asimov's Guide to Halley's Comet appearing in Bulletin Center for Children's Books suggests the book is suitable for ninth graders. Yet 45 entering college freshmen could fill in only 40% of the blanks correctly.

Taylor's only guideline for interpretation of the cloze procedure is that the higher the score, the more readable the passage. This guideline suggests the cloze procedure should be used for comparison purposes rather than being concerned with a readability score.

If we use this yardstick, we find that in a comparison of the three passages, the cloze procedure tells us that Passage Five was the most readable because it had the highest cloze score (49). Passage One was the second most readable passage with a cloze score of 36. Passage Two ranked third in readability with a score of 35.

If we compare the cloze scores with the Flesch scores, we find that the results do not consistently agree. The Flesch Reading Ease score for Passage One was 73.6; the cloze procedure for the same passage was 36. Passage One received the highest Flesch readability score, but it received only the second highest rating under the cloze procedure.

The Flesch Reading Ease score for Passage Three was 48.9; the cloze procedure for the same passage was 35. The Flesch score was the fourth highest score, whereas the cloze procedure gave this passage the lowest score.

The Flesch Reading Ease score for Passage Five was 62.8; the cloze procedure for the same passage was 49. The Flesch test gave this passage the second highest rating; however, the cloze procedure ranked this passage as the most readable among the three passages tested.

Another way of testing Asimov's readability using the cloze procedure would be to select writing samples from other popular science writers such as Carl Sagan, John McPhee, or Lewis Thomas. A comparison of cloze scores could indicate that one science writer was more readable than another. With this type of comparison, the evaluator would have to choose articles that were similar in technical vocabulary, technical content, and subject matter.

I believe Asimov's cloze score would have been higher if I had used a wider span of words between deletions. That is, I should have deleted every ninth or tenth word. The deletion of every fifth word did not allow for much contextual framework for guessing appropriate answers.

I believe Asimov's cloze score would also have been higher if I could have allowed synonyms for correct answers instead of demanding the exact word. For example, many students wrote "celestial" bodies instead of "heavenly" bodies; they wrote "as the year passes instead of "as the year progresses." Even if the cloze procedure allowed multiple choice answers, luck would still be a major factor in selecting the correct answer. I am aware that allowing synonyms could also present a new set of problems. (Who decides what is a proper or accurate synonym?)

Possibly the most appropriate observation about the cloze procedure which applies to Asimov's popular science writing was made by its originator, Wilson Taylor. Taylor acknowledges that the main contribution to the cloze procedure came from Charles Osgood's "dispositional mechanisms" concept that plays a large part in both transmitting and receiving messages. Taylor explains that dispositional language habits evolve when an individual learns to think in a language. He develops many complex verbal skill patterns that stand for many kinds and shades of meanings. These meanings become so automatic that they become habits with each individual. If an individual's set of meanings correspond to others in his culture, he can communicate with no difficulty. But often these language mechanisms differ within the same culture, and communication can become a problem (Taylor 417).

I believe Asimov's dispositional language mechanisms are evident in much of his writing. His habit of composing quickly at his typewriter with little revision is very much like sitting down with an individual and conversing with him naturally. His writing reflects a conversational style; consequently, his meaning-pattern relationship might be less familiar for readers outside his culture to predict with sufficient accuracy. Generally, readers have developed reading habits that are based on a formal presentation of factual information. Thus, when they are asked to fill in blanks that have been deleted from Asimov's work that reflect informal speech patterns, they are unable to anticipate or guess the exact words Asimov uses. Most lay readers have no difficulty comprehending Asimov's writing; it is just that they are

unable to select the exact word to score a cloze unit that reproduces a part deleted from an Asimovian message.

CONCLUDING REMARKS

The work that scientists perform in their laboratories was once considered to be an intellectually detached activity. Scientists were reluctant and often unable to communicate their findings in readily understandable language. However, scientific and technical activities have a great effect on social and political issues that touch the lives of people who have little or no technical or scientific background.

Today, the general public is asking that scientific information be presented to them on their level so that they can sort the facts on socially and politically relevant issues. To be an effective communicator, a technical writer must target the needs of his audience before he begins to write. He must select appropriate rhetorical and stylistic methods to coordinate the technical level of the subject matter between the scientist and the reader. In short, effective technical communicators must develop audience analysis skills.

Technical writers can learn from Isaac Asimov's audience analysis in his role as a popular science writer. Asimov is skilled at expanding scientific and technical information written for experts and technicians to broader definitions for a wider and more general audience. The general lay audience requires greater explication and simplification; Asimov targets those needs by altering his rhetorical and stylistic methods to suit his readers.

Asimov's primary rhetorical device for the lay reader is a highly personal style that does not intimidate but rather draws the reader into his confidence. He generally begins his science essays with

personal anecdotes that pique the curiosity of his reader. After he captures the reader's attention, he slides into his scientific subject matter, maintaining a personal approach throughout the essay. The effect of direct address, the first person "I," the second person "you," and the question-and-answer pattern is that of achieving a conversational tone.

Another rhetorical device for the lay reader is Asimov's subtle humor, which is achieved by plays on words and his gently poking fun at himself and others.

Parenthetical expressions clarify or define technical information, allow Asimov to inject personal comments to maintain his conversational style, give cross references to other works of Asimov that cover similar material, and occasionally add a touch of humor.

Asimov's stylistic devices help him achieve clarity and eloquence as an explainer. Asimov employs a variety of sentence lengths for the general lay audience, whereas most technical documents tend to keep sentences short. He keeps paragraphs to around 100 words. Although most of his sentences are declarative, many of them are complex. He reserves his simple sentences for the juvenile audience.

Asimov's greatest asset as a popular science writer is his ability to explain. An application of two readability measures (the Flesch Readability Formula and the cloze procedure) does not corroborate this claim. The Flesch Reading Ease Score for Asimov's Guide to Halley's Comet was 54.9, a rating of "fairly difficult." The cloze procedure is not a readability formula; it measures meaning-pattern relationships by asking the reader to fill in deleted passages of text with correct

answers. Asimov's average cloze score was 40 (i.e, 45 students were able to fill in 40% of the blanks with correct answers).

I can only conclude that my scientific evaluation of Asimov's readability contained excessive flaws. Results might have been different if I had taken a larger sample. Instead of selecting passages from every 25th page, I should have selected passages from every 10 page; instead of administering the procedures to only 45 students, the number should have been increased to 100 or more.

Future cloze testing should have a broader span between words deleted from the passages; instead of deleting every fifth word, the evaluator should delete every ninth or tenth word. Future cloze testing should also take into consideration the technical vocabulary of the passages. Lay readers cannot be expected to fill in blanks with precise technical vocabulary, whereas they may be able to score more cloze units in narrative prose.

A more acceptable application for the cloze procedure would have been to compare cloze results from Asimov's popular science writing with that of two or three other popular science writers. The comparison should reveal which writer has the most readable text.

Although readability measures have their place in technical writing, they cannot substitute for audience analysis as a method to aid the technical writer in achieving effective communication. Isaac Asimov's audience analysis removes most of the technical noise that burdens scientific explanation. Isaac Asimov's audience analysis makes science intelligible to his lay audience.

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APPENDIX

Periodicals Containing Asimov's Popular Science Essays

(Partial Listing)

Abbottempo

American Scholar

American Legion Magazine

Analog

Boy's Life

Bulletin of Atomic Scientists

Cavalier

Consultant

Dangerous Visions

Diner's Club Magazine

Esquire

Future

Harper's

Holiday

Hornbook

If

Intellectual Digest

Journal of Chemical Education

Ladies' Home Journal

Lithopinion

Long Island Press

Look

Luna

Mademoiselle

National Wildlife

NEA Journal

New York Times

New York Times Magazine

North American Review

Original

Petroleum Today

Playboy

Plays

Popular Science

Psychology Today

Reader's Digest

Redbook

Satellite

Saturday Review

Saturday Evening Post

Science Digest

Science World

Scientific American

Senior Scholastic

Seventeen

Smithsonian

Space World

Technology Week

The Humanist

The Writer

Think

True

TV Guide

Writer's Digest

VITA

Daisy J. Whiting was born in Indore, West Virginia on 4 February 1943. She attended elementary schools in Clay County, West Virginia and junior and senior high schools in Albion, New York, graduating from Albion Central High School in 1961. She did her undergraduate work at Patrick Henry College in Monroeville, Alabama; Mississippi State University in Starkville, Mississippi; and Tennessee Wesleyan College in Athens, Tennessee. She received a Bachelor of Arts degree in English from Tennessee Wesleyan College in 1972, graduating summa cum laude. She began graduate studies in English with a concentration in technical communications at the University of Tennessee in 1984 and received the Master of Arts degree in 1987. She is a technical writer with Science Applications International Corporation of Oak Ridge, Tennessee.