THE DISSEMINATION OF EINSTEIN'S THEORY OF TIME THROUGH PRINT,

1905-1979

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CHAPTER I

INTRODUCTION

> For what is time? Who can readily and briefly explain this? Who can even in thought comprehend it, so as to utter a word about it? But what in discourse do we mention more familiarly and knowingly, than time? And, we understand, when we speak of it; we understand also, when we hear it spoken of by another. What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not: yet I say boldly that I know, that if nothing passed away, time past were not; and if nothing were coming, a time to come were not; and if nothing were, time present were not.[1]

"For what is time?" This question was posed by St. Augustine of Hippo over 1,500 years ago, yet many still struggle to find the answer. Natural philosophers and scientists have also struggled to find an answer for many years. Some have used the heavens as a way of answering this question, while others have turned to philosophy. Many of the current theories about time come from the realm of physics, and in these theories, time can behave strangely. Despite widespread publication of the latest theories and conceptions of time in textbooks, magazine and newspaper articles, and popular books, few people know of them, much less understand them. Instead, most people understand time as they experience it; uniform and unstoppable. In other words, time is absolute. Time does not begin, end, or change for man or god. It is infinite, yet fleeting, fast but slow. Above all, time simply is.

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[1] St. Augustine of Hippo, *Confessions*, trans. E. B. Pusey (New York: E. P. Dutton & Co., 1907), 262.

The concept of absolute time ruled science for over 2,200 years. Even now, absolute time "is what most people would take to be the common sense view."[2] The reason that so many people hold absolute time to be the common sense view is that it approximates everyday experience so well. In fact, even the most extreme circumstances–such as space flight–in which humans can currently place themselves, absolute time still appears to hold. Currently, it is only in the realm of particle physics, in which particles travel near the speed of light, that scientists begin to observe time behaving in ways that do not seem to be normal.

The Physics Behind Time

While the Greek philosopher Aristotle was the first to put forth the idea of absolute time, Sir Isaac Newton best and most completely developed the view that "one could unambiguously measure the interval of time between two events and that this time would be the same whoever measured it provided the person used a good clock."[3] Many scientists up to the twentieth century considered the Newtonian view of absolute time as definitive because it corresponded so well with everyday experience. No one could argue that time was anything other than constant because of the complete inability to challenge the convention established by Aristotle and cemented by Newton. The technology to confirm or refute absolute time did not exist until the invention of the atomic clock nearly 250 years after Newton published his *Principia*. Furthermore, since no person could travel at speeds that would cause a measurable time dilation, no one could seriously contemplate or defend the idea that time was anything but absolute; the experience necessary

[2] Stephen Hawking and Leonard Mlodinow, *A Briefer History of Time* (New York: Bantam, 2005), 24.

[3] Hawking and Mlodinow, *A Briefer History of Time,* 24.

even to begin to consider variably-flowing time did not yet exist. To this day, the every-day experience of humans is such that time dilation is unnoticeable in all but the most unusual circumstances.[4] To understand better why modern science has failed to make a significant impact on the American public's view of time, it is necessary to understand the two different views of time that science has held and the debate that ensued when Einstein proposed a new definition of time.

Newton's Absolute Time

"Absolute time is that which according to its own nature, unrelated to anything else, flows evenly."[5] Thus time, in Newton's view, is similar to the clock at a soccer match; it continues on at a constant rate without pause. However, unlike a soccer match, all observers can note and measure the passage of time, not just the official on the field. Newton believed that any two observers with accurate clocks[6] would be able to determine how long a particular event occurred. This is possible because Newton believed time to be independent of any and all events or bodies in the universe. Again, this is much like the clock in a soccer match; nothing can influence the game clock during the match and it continues to tick off the passage of time at a regular and constant rate. According to Newton, the passage of time throughout the universe continues at the same rate, a rate that nothing can influence.

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[4] Space travel is the easiest circumstance in which to measure the time dilation, but even here, the effect is only measurable with the aid of atomic clocks.

[5] John Herivel, *The Background to Newton's Principia* (Oxford: Clarendon Press, 1965), 309. The original Latin, "Tempus absolutum est quod sua natura absque relatione ad aliud quodvis aequabiliter fluit," is provided on page 305.

[6] "Clocks" here and throughout this paper refers to any device that can measure the passage of time, such as a watch or the phases of the moon.

The Newtonian worldview held by most scientists came crumbling down in 1905 when a young Swiss patent office clerk named Albert Einstein conceived a revolutionary new view of time. In Einstein's universe, time was not constant and unchanging, but variable and alterable by massive bodies.[7] Einstein actually built upon Newton's study of reference frames[8] in order to develop his new theory of time. However, the majority of the scientific community resisted the acceptance of Einstein's theories of relativity, both special and general.

The Establishment and Crisis of the Ether

Special and general relativity marked a radical departure from Newtonian thinking, and both, initially at least, faced severe criticism and skepticism from many older and more established scientists. However, most of the criticism arose because Einstein abandoned the ether that played such a large role in the Newtonian universe and not so much because of his revolutionary theory of time. While many of the reasons given by skeptical scientists as to why science should not abandon the ether originated in the requirements of the theories that they used to describe the universe, such as James Clerk Maxwell's electromagnetic theories, some of the resistance no doubt came from a reluctance to give up the time-honored theories developed by some of the greatest scientists of all time.[9]

Ether in Newtonian mechanics played a large, almost ever-present role in the functioning of the universe. Scientists theorized that "space [was] filled by an all-

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[7] A massive body is any body that has mass.

[8] Reference frames will be discussed on pages 8-12.

[9] For example, James Clerk Maxwell's work with magnetic fields, which was highly influential in the realm of electrical theory, required there to be an ether through which electromagnetic waves could propagate.

pervading medium having properties unlike those of ordinary matter."[10] This "all-pervading medium" was the ether, through which light and heat propagated through space. Newton, though opposed in principle to the ether, regarded actions and interactions through the void of space as "a great absurdity", [11] and therefore conceded the need for a medium to permeate the void of space. In a 1930 *Science* article, Professor L. B. Spinney provided an excellent analysis as to why the ether became so ingrained in the physics community's thought patterns. According to Spinney, the ether provided an explanation why electromagnetic waves could travel through space according to the prevailing theories of the late nineteenth and early twentieth centuries. Scientists of the time believed that just as sound waves needed a medium through which to travel, so did the electromagnetic waves that composed light. Physicists did not yet understand that electromagnetic waves are not like sound waves and do not require a medium through which to propagate.

Scientists, believing that the ether was necessary to make their theories about the mechanics of the universe work, sought to find the ether in further verification of their theories. However, due the theorized nature of the ether (it did not have properties like normal matter), it would have been nearly impossible to detect directly.[12] Since science could not directly detect the ether, scientists devised a number of experiments to observe the effects of the ether, thus indirectly proving its existence.

The most famous experiment in this area was the Michelson-Morley experiment performed in 1887. This experiment, conducted by Albert Michelson of the Case School

[10] L. B. Spinney, "The Ether Concept in Modern Physics," *Science,* vol. 72 (1930): 303.
[11] Spinney, "The Ether Concept in Modern Physics," 310. Original quote taken from Sir Oliver Lodge's *Ether and Relativity,* pg. 79.
[12] The ether, as theorized by scientists at the time, was unseen and virtually undetectable (directly).

of Applied Science and Edward Morley of Western Reserve University, proposed to observe any variation in the speed of light as it passed through the ether. Ether theory postulated, with firm backing from Maxwell's electromagnetic theories, that although the speed of light was always the same with respect to the ether, an observer moving through the ether could measure a different value for the speed of light. Michelson and Morley devised an apparatus that would take a single beam of light and split it into two separate beams. After splitting, one beam reflected ninety degrees to the other, and both then reflected back to the splitter and recombined. The recombined beam passed into an eyepiece in which an observer could see constructive or destructive patterns of interference. Patterns of interference would arise after recombination because the crests and troughs of the light waves would not be synchronized if one beam were slowed. Michelson and Morley took every precaution with the design and placement of the apparatus so that they could notice even the smallest patterns of interference.

Unfortunately for Michelson and Morley, they failed to find any variation in the speed of light that ether theory said they should have found. No matter which direction they turned the apparatus, no patterns of interference could be detected; the speed of light was the same for both beams at all times. The negative results of the experiment seemed to point to the nonexistence of the ether. In spite of this seeming setback, several scientists proposed new theories to explain why Michelson and Morley failed to observe any differences in the speed of light. Hendrik Lorentz attempted to explain the negative results "in terms of objects contracting and clocks slowing down when they moved through the ether."[13] George FitzGerald suggested a similar explanation. Spinney noted, "[FitzGerald] pointed out that if, as modern theory would indicate, matter is electrical in its nature, it may contract in the direction of motion as it moves through the electromagnetic ether."[14] In general, scientists made a concerted and determined effort to explain the results of the Michelson-Morley experiment in a way that corresponded with the prevailing theories of the time (especially Maxwell's theories of electromagnetic waves), theories that required a medium for electromagnetic waves to pass through. However, there was at least one attempt to use the negative results of the Michelson-Morley experiment, not to rescue, but to do away with the ether.

Special Relativity

Albert Einstein's 1905 paper on relativity concerned only uniform rectilinear motion; motion that is constant (devoid of acceleration) and in a straight line. "Einstein's fundamental postulate of the theory of relativity… stated that the laws of science should be the same for all freely moving observers, no matter what their speed."[15] As Stephen Hawking notes, Newton's laws also required that the laws of science hold for all freely moving observers. But, as shown above, Maxwell's electromagnetic theories allowed observers to measure different values for the speed of light, meaning that the laws of science did not have to hold for all freely moving observers. Einstein's great departure from established scientific thought was that he abandoned the concept of the ether because relativity had no need for it.

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13 Hawking and Mlodinow, *A Briefer History of Time*, 32.
14 Spinney, 307.
15 Hawking and Mlodinow, *A Briefer History of Time*, 32.

Newton understood that a sailor inside a closed cabin of a ship that was sailing on a perfectly calm sea in a straight line would be unable to determine whether the ship were moving at a uniform speed or if the ship were at rest.[16] Furthermore, Newton understood that there was no possible experiment that could determine the motion of the ship. Unfortunately, Newton left his study of reference frames at this point. There is no telling what theories Newton may have developed had he continued with this line of thought experimentation. There is also no way of knowing why he did not continue with these experiments.

Einstein took the work of Newton concerning reference frames one step further. He considered a situation in which two reference frames were in motion relative to each other. Einstein used two trains in this famous thought experiment. The first reference frame (train) contained an observer. The observer in the first train could determine his or her motion by observing a second reference frame, in this case another train. This example is similar to Newton's example given above, but the key difference is that while Newton's second reference frame was the Earth (essentially unmovable with regard to the ship), Einstein's trains both had the ability to move along the tracks relative to the Earth *and* each other. Assuming a completely devoid landscape, it would be impossible for the observer traveling at a uniform speed to tell if his train was moving or stationary if using the second train as a reference. He could tell if he were moving with respect to the other train, but he would have no way to determine if the other train was also moving or sta-

[16] The movement of the ship or lack there of, is in relationship to some other object, such as the port from which the ship sailed.

tionary. The observer's ability to determine if his train or the other train is moving is completely impossible.

This problem arises because, as Newton first noted, there is no way of determining if a uniformly moving reference frame is moving unless the observer can see other reference frames. In the case of the ship, the observer, if in sight of land or with access to the night sky, could infer motion relative to the earth, which he or she could assume to be stationary.[17] However, in the case of the trains, it is impossible to infer absolute motion because the only other reference frame could just as likely be moving. Newton assumed that there was some way of measuring absolutely one's position within space, the stars being the best candidate.[18] The train example helped Einstein to abandon the concept of absolute space because it was impossible to determine if a reference frame were in motion or not.

After Einstein concluded that there was no absolute space and that the laws of science were the same for all freely moving observers, he was now free to argue that there was no need for the ether. Einstein knew from the results of the Michelson-Morley experiment that the speed of light was the same in all reference frames, regardless of motion. Therefore, the measurement of the speed of light did not have to be with respect to the ether, only the observer. In relativity, the ether became unnecessary, and this is why relativity faced so much resistance from the scientific community.

With the abandonment of absolute space came the abandonment of absolute time. Considering the train example will also help to illustrate why absolute time cannot exist.

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[17] Since the Earth revolves around the sun, a fact that Newton did know, it cannot be assumed to be stationary either, hence the flaw in Newton's argument.

[18] Julian Barber, *The End of Time* (Oxford: Oxford University Press, 1999), 64. Newton assumed that the stars did not move, therefore, he could argue for absolute motion.

On the floor of a train specially-modified train there is a laser that points toward the roof, five meters above (Figure 1-1). The laser light reflects off of the roof back to the laser for a round trip of ten meters. To a passenger on the first train, the travel time of the laser pulse is .000000033 seconds (3.3×10^{-8} seconds). A passenger on a second train assumes that his own train is stationary and proceeds to measure the speed of the first train at ten meters per second. The passenger on the second train would not see the laser beam move straight up and down as the passenger on the first train would. Instead, the passenger would see the laser beam move upward at an angle, be reflected, and hit the laser again, but with the laser now a short distance from where it was when the laser pulse was emitted (Figure 1-2).

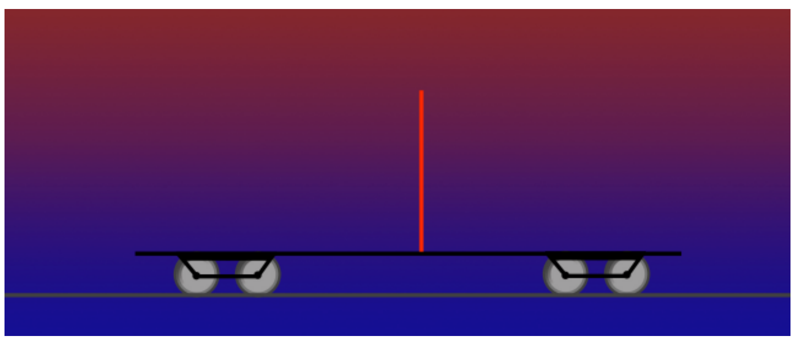

Figure 1-1. View of laser from on board train.

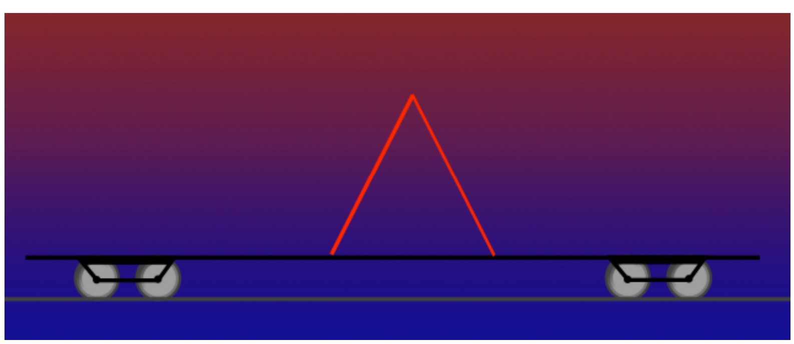

Figure 1-2. View of laser on train from ground.

The passenger on the second train would say that the laser pulse traveled further than the passenger on the first train because the path of the laser pulse would resemble two sides of a triangle, thus the two passengers would be unable to agree on the distance that the laser pulse traveled. On the surface, it would seem that the two passengers should be able to agree on the length of time that the pulse traveled. However, since the speed of light is 299,792,458 meters per seconds ($\approx 3 \times 10^8$ m/s) no matter the speed of the observer or the source of emission, the two passengers must also disagree on the travel time of the laser pulse.[19] This result means that time must be relative since the time measured by each passenger is an equally valid measurement. It also means that time is directly related to the speed of the observers.

An observer watching a train moving relative to himself will always see clocks on that train moving slower than his own. The case is true for any speed, but as speeds approach the speed of light (c) the effect is more pronounced. Einstein modified the equations of Lorentz to show how the passage of time would slow down in a reference frame in relation to the speed of that frame. The equation, as seen in figure 1-3, states in simple terms that time slows as the relative velocity of a reference frame increases. Assuming that a clock in a moving reference frame could reach the speed of light, time would stop for it as viewed by a stationary observer. This effect, known as time dilation, affects all clocks, mechanical and biological. A motorist fond of speeding will find his or her life span increasing but the dilation effect would be so small, that it would be unnoticeable. The equation below helps to illustrate the famous "twin paradox"[20] that arises from the

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[19] Stephen Hawking, *The Illustrated A Brief History of Time* (New York: Bantam Books, 1996), 21.

[20] Also know as the clock paradox.

consequences of special relativity. According to special relativity, if a twin sets out on a long journey in space at a high velocity, he or she would return to Earth having aged at a slower rate than the twin who remained on Earth.

$$t = \frac{t_0}{\sqrt{1 - v^2/c^2}}$$

Figure 1-3. Time dilation equation. The time between ticks of a moving clock a stationary observer (t) measures is equal to the time of the moving clock (t_o) divided by the square root of 1 minus the square of velocity (v) of the moving observer divided by the square of the speed of light (c). Thus, as the velocity of the moving clock increases, the length of time between ticks will increase as measured by the stationary observer.

General Relativity

Einstein understood that special relativity was not the final solution to the questions he was seeking to answer. As explained above, special relativity only deals with uniform rectilinear motion. However, because not all motion is uniform and rectilinear, Einstein realized that he had to formulate a general theory of relativity in which he accounted for non-uniform curvilinear motion.

Einstein used a derivation of Newton's case of the enclosed ship cabin to begin to conceptualize the equivalence of acceleration and gravity and their affect on time. He used the example of a person inside a large chest (Figure 1-4, following page).[21] The chest is placed in space in such a way that there is no gravitational field acting on the chest and its contents and a rope attached to the lid of the chest is pulled with a constant force, i.e. the chest is under constant and uniform acceleration. A person inside the chest

[21] Albert Einstein, *Relativity,* 15th ed. (Norwich: Jarrold & Sons Ltd., 1962), 66.

would be unable to determine if he or she is in a gravitational field or is being accelerated through space and would be correct in assuming either.[22]

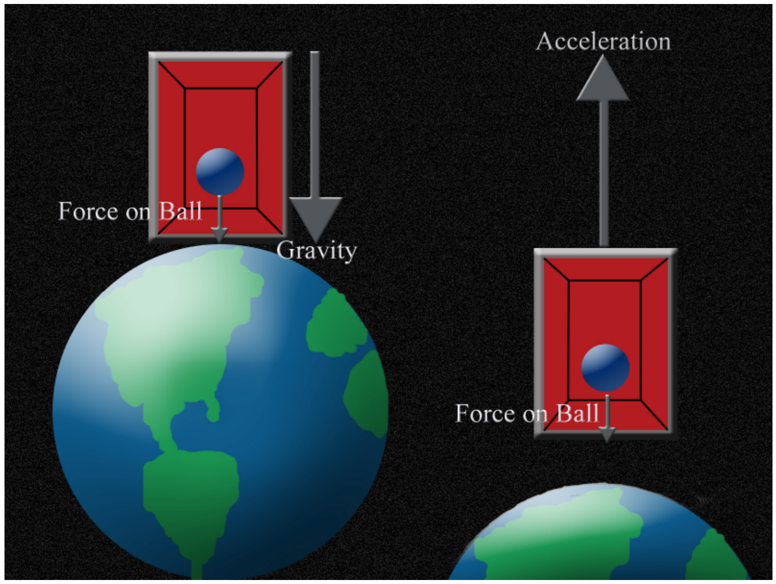

Figure 1-4. The Equivalence Principle. The equivalence of gravity and acceleration as demonstrated by an elevator on Earth and an elevator accelerating through space.

Einstein's next step was to visualize a large plane disk placed in such a way that no gravitational field was acting on the disk and that the disk was rotating about its center uniformly. A person on this rotating disk would feel a force trying to push him or her away from the center. This person, like the occupant of the chest, would be able to assume that there was a gravitational field acting to pull him toward the edge of the disk. The velocity at which a given point rotates about the disk increases the further the point is from the center of the disk, therefore the acceleration experienced at this point also increases. Because it has been shown that acceleration is equivalent to gravity, one could also argue that the gravitational field increased as one moves towards the edge of the disk.

[22] This is called the equivalence principle.

Clocks behave the same if they are accelerating in space or are in a gravitational field. Furthermore, the stronger the gravitational field or acceleration, the slower a clock will appear to run as viewed by an observer in a stationary reference frame. In the disk example above, a clock placed at the center of the disk will appear to run faster than a clock placed at the outer edge because the acceleration of the outer clock is greater than that of the central clock (Figure 1-5). Scientists first confirmed the effect of gravity on clocks in a 1962 experiment.[23] In this experiment, scientists placed two identical atomic clocks on a water tower, one on the top and one on the bottom. The clock on the bottom, under more influence from the gravity of the Earth than the clock on the top of the water tower, "ticked" slower than the clock on top, thus confirming that time slows in the presence of gravitational fields.

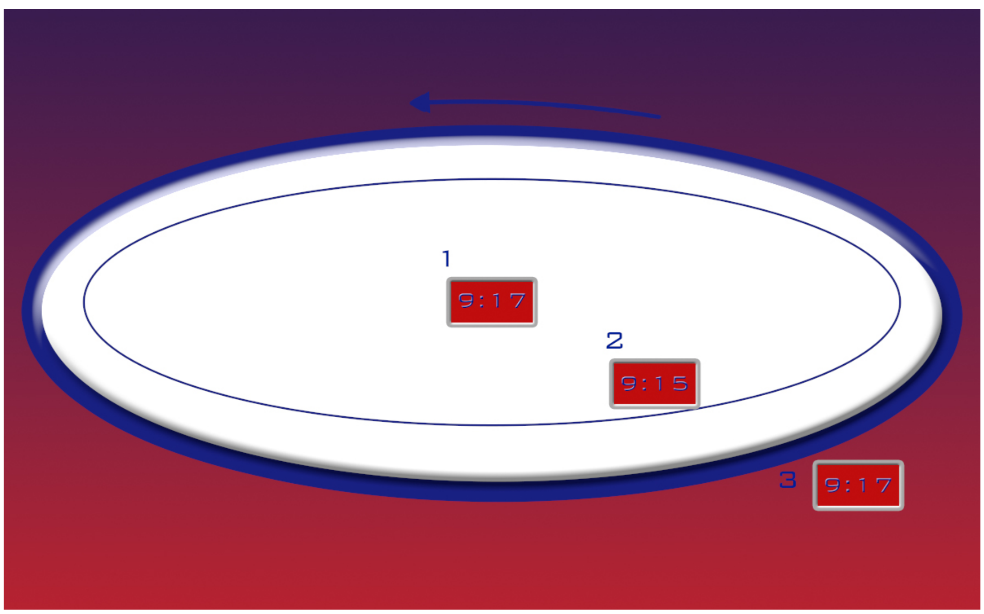

Figure 1-5. Clocks on a rotating plane. Clock 2 ticks slower than Clock 1 at the center of the disk and Clock 3 outside the disk.

[23] Hawking and Mlodinow, *A Briefer History of Time*, 47. There have been numerous other experiments to check general relativity that produced affirmative results.

The Resistance to Einstein and Relativity

Einstein's theories of relativity had some supporters in the United State, but his theories generally did not meet with much enthusiasm. To be sure, much of the resistance Einstein encountered centered on the radical nature of his two theories. Some groups, such as the Woman Patriot Corporation, tried to prevent Einstein from speaking in the United States by attempting to block his entry into the country on grounds that he was a radical thinker and that the government should deny his entry based on the alien exclusion act.[24] Others may have resisted relativity because Einstein was Jewish; anti-Semitism was common in the United States in the first half of the 20th century. During the Depression years of the 1930s, there were those who argued that trying to prove relativity was a waste of time and energy that could be better used elsewhere for more pressing needs. For example, well-known architect Grosvenor Atterbury argued that verification of relativity was "brilliantly useless" and that the money and effort to prove relativity could be used toward the problem of housing people.[25] However, matters more pressing to science formed the basis to the academic resistance to Einstein.

The first reason for resistance goes back to the article by Spinney. He noted that the scientific community had created a system for the workings of the universe that required ether. Without the ether, these long-established scientific principals would collapse, or so they thought. Thomas Kuhn described this type of resistance to scientific change in *The Structures of Scientific Revolutions*.[26] In the book, Kuhn argues, "Each

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[24] "Women Patriots Try New Ban on Einstein," *New York Times*, January 9, 1933, pg. 21.

[25] Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, Mass. And London: Harvard University Press, 1995), 247.

[26] Thomas S. Kuhn, *The Structure of the Scientific Revolution*, 2nd ed. (Chicago, The University of Chicago Press, 1970).

[scientific revolution] necessitated the community's rejection of one time-honored scientific theory in favor of another incompatible with it."[27] Specifically in this case, Kuhn would argue that the physics community resisted Einstein's new theories because they were so radical and because they abandoned a fundamental aspect of the established scientific theory that Einstein was seeking to replace. Even with mounting evidence that the ether did not exist, scientists such as Captain Thomas Jefferson Jackson See of the United States Naval Observatory continued to refute relativity. As evidenced by his letters to the editor published in the *New York Times*, Captain See never ended his quest to find the ether and he never accepted relativity.

Another source of resistance had more to do with a lack of understanding of Einstein's relativity than simple resistance to new ideas. Many American physicists of the late nineteenth and early twentieth centuries did not have a working knowledge of high-level mathematics. Arthur Gordon Webster, a co-founder of the American Physical Society and its president from 1903-1904, lamented that Americans had made "few capital discoveries in physics [because of their generally] insufficient equipment… in mathematics."[28] Relativity contained a high degree of very advanced mathematics that few American physicists of the time could understand. The general ideas of relativity were easy enough to understand, but the mathematics required to understand fully and test the validity of relativity were beyond almost all American physicists of the early twentieth century. John Servos argues that the shift to teaching mathematics in high school at the level required to understand the new theories in physics did not begin in earnest until the 1920s

[27] Kuhn, *The Structure of the Scientific Revolution*, 6.
[28] Kevles, *The Physicists*, 84.

and 1930s, though universities began offering these courses needed for advanced theoretical physics by the turn of the century.[29] It was not until universities and high schools began offering advanced mathematics that American physicists could acquire the skills and tools necessary to understand fully Einstein's theories. Not coincidentally, this new generation of physicists could study the advanced mathematical theories that their predecessors could not, embraced relativity, and worked to test and better understand its many intricacies while many of the older generation only begrudgingly accepted relativity.

General Overview

The debate over the validity and usefulness of relativity by the physics community is well documented; how that debate affected the public is not. In an effort to better understand the impact of Einstein's theories, especially the areas that deal with time, this thesis examines sources that the public could access,[30] such as textbooks, popular books about relativity (Chapter 2), popular and scientific magazines (Chapter 3), and newspapers (Chapter 4). These types of sources are useful because they reached a wider and more representative portion of the American public than physics-specific sources such as trade journals and lectures given at conventions. This thesis will show that despite the long-running and very public debate over relativity in the scientific community, and by extension its appearances in sources accessible to the public, the general public had little knowledge or comprehension of the scientific community's understanding of time

[29] John W Servos. "Mathematics and the Physical Sciences in America, 1880-1930," In *The Scientific Enterprise in America: Readings from Isis*, edited by Ronald L. Numbers and Charles E. Rosenberg (Chicago: University of Chicago Press, 1996), 153.

[30] Not all of the sources would have been easily accessible to certain members of the American public. College physics textbooks, for example, would have been difficult for some Americans because of the financial cost of going to college.

throughout most of the twentieth century. The print sources examined in this thesis had the potential to inform millions of readers about Einstein's theory of time, yet for a variety of reasons discussed in the following chapters, they failed to meet their potential.

The potential impact of all sources will be determined by a matrix that weighs the physical accessibility of the source with the accessibility of the language (linguistic and mathematical) utilized within the source. A source that would have been easy for a member of the public to obtain and understand would have a much higher potential impact than a hard-to-obtain source that required specialized scientific or mathematical knowledge to comprehend. Newspapers were easily accessible to most Americans during the period examined in this paper and used language that was accessible to almost any reader. A newspaper article that clearly explained Einstein's conception of time had the potential for a large impact on the American public. Conversely, a highly mathematical and theoretical article in a magazine with a small circulation would have had much less impact on the average American.

Physics textbooks[31] present a unique source because they were, and continue to be, highly specialized compared to the other sources. The authors of the textbooks designed them for the sole purpose of educating their readers. Also, one can assume that in most cases, the readers of textbooks would have possessed all of the requisite knowledge to understand the contents of the book. However, these textbooks also had a limited audience. Only those attending college physics courses would have had easy access to both

[31] Only college physics textbooks are examined because of their accessibility. Older high school textbooks would be hard to find. However, only a small segment of high school students would have taken physics during the span of this study, especially in the early years, therefore the conclusions drawn from college textbooks can be extended to high school textbooks taking into account the different education levels.

the books and the knowledge contained within them. As will be shown in Chapter 2, some physics textbooks relied extensively on advanced mathematics to explain relativity. Only those students with training in advanced mathematics would be able to understand the information contained within these books. Physics textbooks had a significant impact on those who studied them, but because the number of those who had the means to attend college was small compared with the overall number of Americans, the overall impact of physics textbook on the American public was limited.

Popular books about relativity functioned as a textbook for the masses. These books also attempted to educate the public about relativity. The public could easily access these works at public libraries, or, personal finances permitting, purchase a copy from a local bookstore. The language in these books was usually clear and easy to understand which allowed for many readers to comprehend Einstein's theories. However, at least a few books suffered from poor explanations that could have confused even those readers already familiar with relativity. For those who did read these books, it is likely that many would have come to understand Einstein's conception of time. However, because few members of the public, especially those in the working class, would have had the leisure time to spend reading a book about physics, the readership of popular books would not have been as high as other popular literature, and would have limited the dissemination of relativity.

Magazines (Chapter 3) serve as a bridge between textbooks/popular books and newspapers. Scientifically-oriented magazines (not scientific journals) provided readers with in-depth articles of several pages in which the authors had a sufficient amount of space to explain relativity. The authors of these articles were scientists or had a background in science, though not all were physicists. Popular magazines reached more readers than the scientifically-oriented magazines, but the articles in these magazines were, for the most part, written by nonscientists for consumption by readers with little to no scientific background, thus limiting the ability of popular magazines to disseminate Einstein's theories to readers. Articles in popular magazines did reach more of the public than the scientifically-oriented articles and textbooks and therefore could have had more impact than the previous sources. Also, because the articles in popular magazines relied more on verbal rather than mathematical explanations, the likelihood that readers would understand the article was increased. Although, as will be shown in Chapter 3, magazines of both types did not include explanations of relativity enough to have a significant impact on the public's perception of time, something that no amount of articles or simple language could change.

Newspapers, the subject of Chapter 4, represent the source closest to a "people's forum." Newspapers are interesting and useful precisely because they contain articles written by scientists, journalists, and citizens of varying backgrounds. Newspapers had the highest circulation of any of the other sources (Americans read millions of newspapers in the United States on any given day) and were also the most accessible of all the source types. The articles published in newspapers ranged from feature pieces written by science desk editors or scientists to general news stories written by journalists to letters to the editor written by average citizens. Also, with the use of wire reports, a number of newspapers around the country could use stories from other parts of the world. The articles almost never contained mathematics (some did include scientific terms), which aided in the ease of readability and comprehension. Newspaper articles had the ability to disseminate the theory of relativity and its formulation of time to a substantial number of readers, but a lack of articles on relativity that provided readers with explanations prevented newspapers from reaching as many people as was possible.

Limitations

Textbooks, magazines, and newspapers all had the potential to reach a large number of readers. However, their usefulness was limited by their very nature; they required that a person be literate in order to gain anything of use from their contents. Also, only English language sources have been consulted because they would have had the widest circulation in the United States. While the literacy rates in the United States did rise throughout the twentieth century, there were certainly a number of people living within the United State that did not have the ability to read and comprehend English, including some African Americans and members of the immigrant poor. These sources also required that they be purchased, which excluded those without the necessary disposable income to buy magazines or newspapers or to go to college. Given these limitations, this study must confine its conclusions (and define the general public) as those persons who were English-speaking, literate, and had enough disposable income to gain access to the sources. These limitations in no way reduce the utility of this paper. Rather, they serve to focus the examination and help to avoid the conclusions being extended to those groups who would not have been able to come into contact with and/or understand the content of the sources.

The desire to find the true nature of time did not begin with St. Augustine. Neither did it end with Augustine nor the numerous intellectuals who followed him on the very same quest. Over 1,000 years after Augustine wrote *Confessions*, Sir Isaac Newton published his own views on time–views that corresponded with what he observed in nature. At the turn of the twentieth century, Albert Einstein developed a new view of time that radically differed from Newton. Einstein's theories became an integral part of physics by the middle third of the century. His two theories were so important to science that Vannevar Bush, director of the Office of Scientific Research and Development during World War II, was motivated to push for the federal government's investment in the scientific education of America's youth. His plan, published in 1945 as *Science-the Endless Frontier*, was a cornerstone of scientific education in the 1950s, and is reflected by trends shown in college physics textbooks.

CHAPTER II

COLLEGE PHYSICS TEXTBOOKS AND POPULAR BOOKS

As the United States began considering its post-war policy in the waning months of 1944, Vannevar Bush, the Director of the Office of Scientific Research and Development, convinced President Franklin Roosevelt to write an open letter to scientists asking what the nation's post-war scientific policy should be. Bush delivered his report, *Science–The Endless Frontier*, in July 1945 to President Harry Truman, just as the war was winding down and the political maneuvering with the Soviet Union was heating up. Bush's report called for the federal government to give funding to basic scientific research and scientific training because, as Bush argued, "our defense against aggression demands new knowledge so that we can develop new and improved weapons. This essential, new knowledge could be obtained only through basic scientific research."[1] Through Bush's efforts and post-war political realities, basic scientific research became a cornerstone of America's national defense.

A key component of *Science–The Endless Frontier* was federal funding for scientific education at the college level. Bush described the inability of many individuals in the United States to obtain a college degree as "a tremendous waste."[2] He believed that if everyone had access to higher education, it would assure that the quality of science would

[1] Vannevar Bush, *Science–The Endless Frontier* (Washington, D.C.: National Science Foundation, 1945), 5.

[2] Bush, *Science*, 25.

improve at every level, thus benefiting the nation as a whole. Partly as a result of Bush's influence in the government, and partly because of the looming Soviet threat, the government began pouring federal funds into basic research conducted at universities, allowing more students to partake in scientific education, particularly the physical sciences.

The study of physics played a crucial and central role in the nation's new defense policy because of the new weapons and military technologies that physicists developed during World War II.[3] The battlefield of the 1950s would not have been complete without radar, sonar, jet fighters, and atomic bombs. The American military came to see the value of science in warfare and physicists played a large role in developing and researching new weapons. The importance of physicists to the nation's defense also helped them to gain a new respectability in the American culture. One *Harper's* contributor noted, "No dinner party is a success without at least on physicist to explain… the nature of the new age in which we live."[4] Physics was now implicitly important to almost everyone in the country.

This chapter will explore the different ways college physics textbooks treated Einstein's theories of relativity and the theories' respective treatment of time. An analysis of introductory physics textbooks shows that one cannot draw the same conclusions for textbooks for physical science majors and majors outside the physical sciences.[5] The evidence shows that a very general trend of increasing inclusion of relativity occurred

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[3] Many historians have called World War II "the physicists' war" such as Kevles in *The Physicists*, 302.

[4] Quoted in Kevles, 375. He does not cite the article or the contributor.

[5] Physics textbooks present a unique source in that they targeted a very specific audience, college students taking physics classes. The authors of the textbooks intended them for the sole purpose of educating readers. Also, it can be assumed that in most cases, the readers of textbooks would have possessed all of the requisite knowledge to understand the contents of the book because of prerequisite requirements. However, these textbooks also had a built-in limited audience. Only those attending college physics courses would have had easy access to both the books and the knowledge contained within them.

over the first several decades of the twentieth century for textbooks targeted toward physical science majors. Despite Bush's plea for increased government support of scientific education, a massive influx of funding for basic research, the Soviet threat just after World War II, and the shock of the Sputnik launch in 1957, there were no drastic changes in the number of college textbooks that discussed relativity in textbooks for physical science majors. The inclusion of explanations of relativity in college physics textbooks for physical science majors was a gradual and steady change. The analysis of textbooks shows that no specific event, perhaps other than the Sir Arthur Eddington-led expedition that provided a proof of relativity, had a significant influence on the content of textbooks for physical science majors.[6] Examining the dates in which the authors of these textbooks received their doctorates supports this argument.[7] Authors who received their doctorate after the late-1920s were far more likely to include relativity in their textbooks than authors who received their doctorates before the late 1920s. Therefore, the inclusion of relativity into college-level physics textbooks for physical science majors had more to do with the date in which the author received his Ph.D (this would influence whether and what the author learned about relativity in college) and if they considered a discussion of relativity necessary for their particular audience than any to historical or cultural events except for Eddington's expedition.

The same conclusions drawn about textbooks for physical science majors cannot be extended to those textbooks for general audiences. Rather, as an analysis of textbooks

[6] In 1919, Eddington led an expedition to observe a solar eclipse on Principe near Africa. The pictures he took during the eclipse showed that the positions of the stars were slightly shifted from their expected location. The amount of shift corresponded to the amount predicted by general relativity, which, until this time, lacked concrete evidence of its validity. The results of the expedition did much to raise the status of relativity and Einstein. See Einstein, *Relativity,* 126-129.

[7] An Internet search of the authors was conducted to determine when and where they received their doctorates.

for non-physical science majors suggests, there was a dramatic increase in not only the number of textbooks for general audiences published, but also these books placed a greater emphasis on the explanation of relativity. Unfortunately, due to the limited number of textbooks for non-physical science majors prior to the 1960s, it cannot be argued with certainty that the textbooks did place a greater emphasis on relativity. However, based on the dramatic increase in the number of textbooks for non-physical science majors that were published, the geopolitical context of the Cold War, and the new cultural importance placed on scientific and mathematical education for all students, this conclusion seems reasonable. A more comprehensive examination of the sources needs to be undertaken to allow for more certainty that there was an increased emphasis on the teaching of relativity to students outside of the physical sciences. It would seem that Vannevar Bush's call for an increase in the emphasis and quality of scientific education was answered, at least for non-physical science majors.

This study analyzes seventy-nine college physics textbooks, published from 1917 to 1979.[8] Over half of the books, forty-one, were for majors in the physical sciences: twenty-four textbooks specifically targeted physics majors and fifteen were for science and engineering majors.[9] The remaining thirty-eight books were intended for non-science majors. Within these groups, this chapter will show trends in the inclusion of explanations of relativity and how the textbooks treat the topic in light of their target audi-

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[8] The textbooks were selected by choosing books between Library of Congress call numbers QC21 and QC 24 from the shelves of the University of Akron Science library and the Northeast Ohio Library Cooperative regional depository. Seventy-nine textbooks were procured by this method. There are a total of 620 textbooks on the OhioLink interlibrary network. Therefore, this study examines 12.7% of the college physics textbooks in the OhioLink network.

[9] These books stated that they were intended for science and engineering majors, in effect lumping the two different fields together. See George Shortley and Dudley Williams, *Physics: Fundamental Principles for Students of Science and Engineering* (New York: Prentice-Hall, 1950).

ences–textbooks for physical science majors included relativity earlier and more often than textbooks for non-physical science majors and they also included the use of mathematics more often. In addition, the analysis also includes an assessment of discussions of time according to special and general relativity, and the use of varying levels of mathematics in the explanations.

Textbooks for Physical Science Majors

The first textbook written for physical science majors examined was published in 1917. *Laws of Physical Science: A Reference Book* (1917) did not discuss relativity, but it did mention the ether.[10] As shown in Chapter 1, ether at this time was still a fundamental component of the scientific theories about the universe and the main source of scientific resistance to relativity. Many scientists hoped there were "unifying principles through a physics of the ether" despite the fact that no experiment had up to that time detected the ether.[11] Conversely, science had not established the validity of relativity; relativity remained *just* a theory.

As scientific confidence in the theory of ether waned in the late 1920s, textbooks began to include relativity. J. W. N. Sullivan's *The Bases of Modern Science* (1929), which came ten years after Eddington's expedition, included a lengthy discussion of relativity, both the history of the theory and special relativity itself.[12] In a completely verbal (i.e. non-mathematical) discussion of relativity, Sullivan noted that according to Einstein's theory of relativity, time slows down for an object as its velocity increases. Sulli-

[10] Edwin F Northrup, *Laws of Physical Science: A Reference Book* (Philadelphia and London: J.B. Lippincot, 1917), 165.

[11] Mary Jo Nye, *Before Big Science: The Pursuit of Modern Chemistry and Physics, 1800-1940* (Cambridge: Harvard University Press, 1996), 85. No experiment would ever detect the ether.

[12] J. W. N. Sullivan, *The Bases of Modern Science* (Garden City, NY: Doubleday, Doran, and Co., 1929).

van did not include any mathematics in his discussion and did not mention general relativity.

The use of mathematics to explain relativity would become standard in almost every textbook for physical science majors after the publication of *Bases of Modern Science*. The mathematics the authors generally employed were not difficult, usually nothing more than simple algebra, and most high school graduates would have been able to understand and solve equations such as

$$t_2 - t_1 = \frac{t'_2 - t'_1}{\sqrt{1 - u^2/c^2}}.$$

Most of the mathematical equations primarily functioned to reinforce the verbal explanations of relativity. As many of the textbooks' prefaces note, these introductory works primarily worked to give the students a background in the concepts of physics and not the mathematical and theoretical tools that professional scientists used in their research. The last time that a textbook for physical science majors did not include the use of mathematics in its discussion of relativity came in 1959, though this book, *College Physics*, was only intended as an introductory work and only mentioned relativity in passing.[13]

The use of mathematical formulas in physics textbooks to illustrate scientific discourse increased over the twentieth century. Only seven of the forty-one textbooks for physical science majors did not use mathematics in any way to describe relativity and four were published prior to the end of World War II. All of the textbooks (including textbooks for non-physical science majors) that did not use mathematics were introductory works. This is not surprising because the mathematics required to begin to under-

[13] Robert L. Weber, *College Physics* (New York: McGraw-Hill, 1959).

stand relativity were not being offered in many American high schools until the 1920s. It took several more years before the majority of high schools began to offer introductory courses in theoretical mathematics. While American universities offered this same level of mathematics at the turn of the twentieth century, it was only after the ideological shift from applied to theoretical physics in the American physics community during the 1920s that the use of advanced mathematics in physics was truly appreciated.[14] In the 1920s many American physicists went to Europe to study and there the physics community recognized the importance of the most advanced mathematics, such as Riemannian geometry.[15] Only after these physicists who earned their doctorates after the ideological shift entered physics departments in American universities and wrote their own textbooks would introductory physics textbooks be likely to use advanced mathematics.

Over sixty-three percent (26 of 41) of textbooks used simple equations to help explain relativity, usually employing little more than basic algebraic equations, and relying more on verbal discussions to describe the effects of speed and gravity on time. Only one textbook, *University Physics* (1963), employed basic trigonometry.[16] In this case, trigonometry serves to help the student create constructions for the calculation of length contraction and time dilation as described by the Lorentz-Einstein transformations.[17] Yet

[14] Prior to the 1920s, Americans physicists practiced applied physics. This tradition dated back to at least the founding of the nation and was rooted in the culture of practicality. Theoretical physics seemed too European and elitist for many American scientists. It was not until the 1920s that the shift to theoretical physics became widespread in the United States. Even as late as World War II, the American war effort relied heavily on European immigrants to conduct research in many projects, such as the atomic bombs. For more information see Kevles.

[15] Riemannian geometry is a non-Euclidean geometry and is crucial to understanding geometry in more than three dimensions as required by relativity.

[16] Francis Weston Sears, *University Physics* (Reading, MA: Addison-Wesley, 1963).

[17] This is the Lorentz contraction applied to relativity. See pg. 6.

University Physics relied more on its verbal descriptions than on mathematics to convey the variable nature of time as understood by relativity.

Only seven[18] of forty-one books for physical science students included advanced mathematics (integration, summation, and derivatives), five of which were not introductory-level books, but rather intended for advanced students. The two introductory textbooks that used advanced mathematics were *Elements of Modern Physics* (1971) and *Introduction to Modern Theoretical Physics* (1975).[19] These two books, published in the 1970s, came at a point in American educational history when more advanced mathematics were being offered in high school math classes. The mathematics used in *Elements of Modern Physics* and *Introduction to Modern Theoretical Physics* were available to most freshmen physical science majors during the 1970s, and certainly, those students fortunate enough to have access to more advanced mathematics classes in high school would have understood the mathematics in these two books even as incoming freshmen.

All of the textbooks used explanations based on words rather than pure mathematics to help explain relativity, as well as helped to explain the mathematics. The explanations would have been especially helpful to the students who used the introductory textbooks, as they would not be accustomed to relying on purely mathematical explanations. Verbal explanations would also have been more helpful than pure mathematics in the explanation of new concepts. Not all of the explanations in the textbooks were of the same

[18] Shortley and Williams, *Physics*; J. L. Glathart, *College Physics* (Philadelphia and Toronto: Blakiston Co., 1950); Robert L. Weber, *Physics for Teachers: A Modern Review* (New York: McGraw-Hill, 1964); Floyd Karker Richtmyer, E. H. Kennard, and John N. Cooper, *Introduction to Modern Physics* (New York: McGraw-Hill, 1969); Albert T. Goble, *Elements of Modern Physics* (New York: Ronald Press, 1971); John D. McGervey, *Introduction to Modern Physics* (New York: Academic Press, 1971); Atam Parkash Arya, *Elementary Modern Physics* (Reading, MA: Addison-Wesley, 1974); and Edward G. Harris, *Introduction to Modern Theoretical Physics.* (New York: Wiley, 1975).

[19] Goble, *Elements of Modern Physics*; and Edward G. Harris, *Introduction to Modern Theoretical Physics* (New York: Wiley, 1975).

quality. Many explanations clearly explained relativity and time, however, several suffered from poor explanations that could have left a reader previously ignorant of relativity and relativistic time confused due to the amount of verbal explanation given. A reader could become lost in the details and miss the overall aim of the chapter. [20] This was almost certainly not because the physicists who wrote the poor explanations lacked an understanding of relativity, but more likely because they were not comfortable using written words to describe relativity.

The three textbooks that discussed relativity without the use of mathematics (the other four books that did not use mathematics also did not discuss relativity), *The Bases of Relativity* (1929), *College Physics* (1950), and *Principles of College Physics* (1959) each treated relativity differently.[21] *The Bases of Relativity* provided the reader with a clear and detailed explanation of many aspects of special relativity, most importantly that time slowed for an object as its speed increased: "Regarded from a system at rest the lengths of a moving system are contracted, and the clocks of that system are going slow."[22] This sentence offers in a clear and concise statement of how special relativity treats time. The chapter in *The Bases of Relativity* on relativity also provides a detailed history of the physics that came before relativity (described in Chapter 1) and what events led Einstein to formulate his famous theory.[23] Nearly all that readers could possibly need in a verbal explanation was in *The Bases of Relativity*. Most students would easily under-

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[20] See Chapter 13 of Wayne E. Hazen and Robert W. Pidd, *Physics* (Reading, MA: Addison-Wesley, 1965).

[21] Glathart, *College Physics*; and George Shortly, *Principles of College Physics* (Englewood Cliffs, NJ: Prentice-Hall, 1959).

[22] Sullivan, *The Bases of Modern Science*, 206.

[23] Ironically, *The Bases of Relativity* does not confine itself to just relativity.

stand and retain the information contained within *The Bases of Relativity's* chapter about relativity.

The excellent verbal description found in *The Bases of Relativity* (1929) contrasts sharply with *College Physics* (1950) with regard to relativity, especially time. *College Physics* only discusses relativity in passing and mentions nothing about time. Although intended as an introduction for physics majors, students using this book would have gained little useful information about relativity, and none about time in relativity. The book provides readers with introductory information in a broad range of general physics topics, with an emphasis on Newton's laws of motion. Students of any major could have used and understood this book. Similarly, *Principles of College Physics* (1959) only mentions relativity in passing and does not discuss time at all. As in *College Physics*, the reader of *Principles of College Physics* would not gain any information about time according to the theory of relativity.

In most cases, the books that relied on mathematics to help explain relativity also provided good verbal explanations, though there were exceptions. Some of these books, such as *Physics* (1960) by George Gamow and John M. Cleveland, used verbal explanations as the primary way to discuss relativity.[24] Gamow and Cleveland had to devote space to the explanation of the equations in their book because the book relied on equations partially to explain relativity. They had to make sure that students could understand the equations so that the students could also understand relativity. *Physics* notwithstanding, the majority of books that used verbal explanations as the primary means to explain relativity used simple mathematics and devoted a significant portion of the verbal expla-

[24] George Gamow and John M. Cleveland, *Physics* (Englewood Cliffs, NJ: Prentice-Hall, 1960).

nations to the discussion of relativity. Unlike *Physics*, these books did need to also explain the equations to ensure that students would understand relativity. The reliance on verbal explanation meant that the overall quality of the explanations would not suffer even if students did not understand the equations.

The works that used advanced mathematics devoted more space to the explanation of the equations. They also generally placed more explanatory weight on the mathematics than did the textbooks that used only simple mathematics, but never more than on the explanation of the theories. A typical explanation of a part of relativity in these books would begin with a verbal explanation to set up an example situation, and then proceed with an equation. *Physics for Teachers: A Modern Review* (1964) is a prime example of the increased reliance on mathematical explanations. It describes time dilation in the following way:[25]

> Consider now the effect of relative motion on a clock. Two events occur at a point in coordinate system *S'*: one at time t'_1, the other at a later time t'_2. To an observer in *S* these events take place at different points in space, (x_1, y, z) and (x_2, y, z), as well as at different times, such that $(x_2 - x_1) = u(t_2 - t_1)$. From the Lorentz transformations
>
> $$t_2 - t_1 = \frac{t'_2 - t'_1}{\sqrt{1 - u^2/c^2}} \quad \ldots$$

Unlike the textbooks that used simple mathematics, this equation is an integral part of the explanation of relativity. The verbal explanation provides readers with just enough information to understand relativity and time, but the quality of the explanation suffers without the equations.

As shown in Chapter 1, Einstein's general theory of relativity also discusses time, specifically that time slows for an object under acceleration or in a gravitational field.

[25] Weber, *Physics for Teachers,* 195.

Yet, only thirteen of all seventy-nine textbooks noted this characteristic of general relativity. Just *Physics* (1960) and *Fundamentals of Physics* (1974), both intended for physics majors, included a discussion about time and general relativity.[26] *Physics* notes, "Thus on the surface of the moon, where gravity is weaker than on the surface of the earth, a chronometer should gain time with respect to an identical terrestrial chronometer."[27] Gamow and Cleveland also give other examples of time slowing in the presence of gravitational field, such as a clock on the sun, or the vibrations of atoms slowing. They do not, unfortunately, include a discussion of time slowing down for objects under acceleration, a serious omission because the chapter on general relativity begins with a discussion of the equivalency of acceleration and gravity.[28] A careful reader might conclude that because time slows in a gravitational field, and acceleration and gravity are equivalent, then time must slow for an accelerating object. This omission limits the amount of information about time presented to the student.

Fundamentals of Physics (1974) includes a much more complete explanation of "the effects of gravity on length and time."[29] The chapter actually begins its discussion of time and general relativity by noting that a clock rotating in an inertial frame some distance from the center of rotation–thus undergoing acceleration–would tick slower than either a clock at the center of rotation or a clock outside of the inertial frame.[30] The clock at the center of rotation, while rotating, does not experience acceleration because it is rotating about its own center, while the clock outside the inertial frame undergoes no rota-

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[26] Henry Semat and Philip Baumel, *Fundamentals of Physics* (New York: Holt, Rinehart and Winston, 1974).

[27] Gamow and Cleveland, *Physics*, 321.

[28] Gamow and Cleveland, 315.

[29] Semat and Baumel. *Fundamentals of Physics*, 546.

[30] This is similar to figure 1-5.

tion or acceleration. The forces affecting the three clocks are similar to the forces felt by three children on a merry-go-round, one at the center, one at the very edge, and one standing on the playground. *Fundamentals of Physics* then discusses the slowing of clocks in a gravitational field. The authors note that a useful clock for this type of example is the nucleus of an atom because scientists can measure the vibrations of the atom in gravitational fields of varying strength. Scientists could use their results to verify if this portion of general relativity holds. These two explanations give the reader a much more complete discussion of general relativity than *Physics* (1960).

It is unclear why more textbooks, especially those intended for physics majors, did not include discussions about general relativity and time. Proof for the validity of general relativity had existed since Eddington's expedition in 1919. Further proof, specifically pertaining to the slowing of clocks in general relativity, came in 1938 with Dr. Herbert Eugene Ives' detection of gravitational red shift; the slowing down of atoms' vibration. It is reasonable to expect that few textbooks would have discussed time and general relativity until after Ives' experiment, but no textbook appears to discuss the matter until 1960, twenty-two years after the experiment. There would have been sufficient time for the results of the experiment to disseminate throughout the scientific community and for scientists to write new textbooks or to revise older ones. It is also surprising that textbooks for non-physical science majors would mention time and general relativity more frequently than textbooks for physical science majors. Even the more advanced textbooks and the textbooks that used higher-level mathematics did not discuss general relativity and time. A possible explanation for this is that the authors of the textbooks decided that first- and second-year students did not need a discussion of time and general relativity since they would likely encounter general relativity later in their academic careers. Even the implications of general relativity for space travel, which was a frequent article topic in *Science* after World War II, did not constitute enough of an impetus for the inclusion of this discussion.[31]

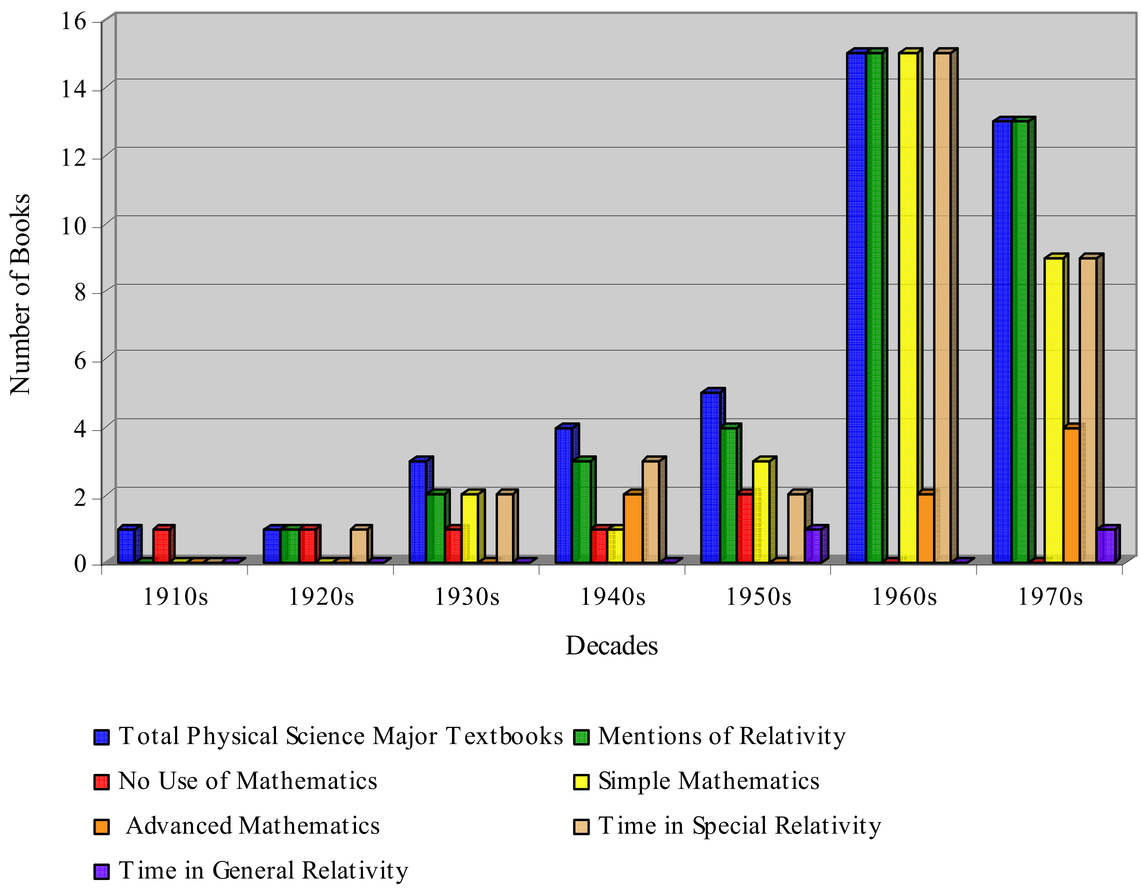

Figure 2-1. Chart for the Analysis of Textbooks for Physical Science Majors

The chapters of textbooks in which the discussion of relativity appeared also serve as a measure of how important such a discussion was to the authors. Likewise, it can also be a measure of how difficult the authors believed relativity to be. If a chapter about rela-

[31] There are two ways of understanding the unstable nature of time in space travel. One method is taking the effects of acceleration into account. The more popular method in textbooks is the "twin paradox" that is described by special relativity. Interestingly, *Physics for Teachers: A Modern Review* (New York: McGraw-Hill, 1964), 201, argues "other predictions of relativity, such as time dilatation, are probably not significant to space travel". Time dilation does have significant implications for high-speed space travel.

tivity appeared early in a book, it could mean that the authors believed relativity to be of primary importance. It could also mean that the authors believed that the readers would have had enough prior knowledge to be able to understand relativity. Which of these two measures applied to a given book depends on the nature of a book. A book about general physics would generally include relativity towards the end after more basic physics were discussed, such as mass, density, and buoyancy. A textbook of a more theoretical and advanced nature would more likely include relativity toward the beginning. However, there does not appear to any definite pattern of where a chapter on relativity would fall within certain types of textbooks. The only trend is that, on average, textbooks in the 1970s tended to discuss relativity roughly eight chapters earlier than textbooks of the 1920s and 1930s.[32] Just as with general relativity and time, the chapter in which relativity appeared seems to have been at the discretion of the author at all points throughout the century, each author having different reasons why he chose to place a chapter in relation to the other chapters.

Textbooks for Non-Physical Science Majors

Textbooks for general audiences in this study, that is, for those students not majoring in one of the physical sciences, did not appear until 1936. Only two books for general audiences were published before World War II, *The Renaissance of Physics* (1936)

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[32] The trend of chapters occurring earlier in textbooks was obtained in the following manner. First, a list of all the textbooks was complied into an Excel spreadsheet in chronological order, oldest to newest. The number of the chapter on relativity was added in a separate column that corresponded to each book. Then, a line chart was created, plotting the chapter number along the y-axis and the year along the x-axis. From one of the commands available with the software, a trend line was established which showed that, on average, textbooks discussed relativity eight chapters earlier in 1979 than in 1929.

and *College Physics*(1938). [33] Two books, *Physics for Arts and Sciences* (1948) and *A Brief Course in Physics for Students of Home Economics* (1949), appeared in the late 1940s, and none in the 1950s. [34] Twenty-one textbooks were published in the 1960s, with a majority coming in the last three years of the decade. There continued to be a profusion of textbooks for general audiences published through the early 1970s, but the trend decreased by mid-decade.

The first textbook for a general audience to mention anything about relativity came in 1960. This book, *Introduction to College Physics*, noted that "Clocks in motion slow down in keeping time."[35] This sentence, at the end of a discussion about Newtonian mechanics, served as a background for the discussion of relativity. The next textbook to mention relativity, *Concepts in Physics*, was not published until 1965.[36] Although most of the textbooks included a chapter on relativity and relativistic implications for time, relativity was not universally included in textbooks for students outside of the physical sciences between 1966 and 1969. For the next decade, 1969-1979, every textbook for general audiences examined in this study contained a chapter about relativity and time.

Nearly sixty-five percent of all textbooks for non-physical science majors that included chapters on relativity also discussed time, compared with just over ninety percent of all the textbooks for physical science majors that contained similar chapters. As noted in Chapter 1, there are no ordinary circumstances in which humans would be able to no-

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[33] Karl K. Darrow, *The Renaissance of Physics* (New York: Macmillan, 1936); and Henry A. Perkins, *College Physics* (New York: Prentice-Hall, 1938).

[34] Luther Grant Hector, *Physics for Arts and Sciences* (Philadelphia: Blakiston, 1948); and Lester Thomas Earls, *A Brief Course in Physics for Students of Home Economics* (New York: Prentice-Hall, 1949).

[35] Rodgers D. Rusk, *Introduction to College Physics* (New York: Appleton-Century-Crofts, 1960), 141.

[36] Reuben Benumof, *Concepts in Physics* (Englewood Cliffs, NJ: Addison-Wesley, 1965).

tice time dilation and thus it is likely that the authors of works without a discussion of relativity and time felt that it was not important for students pursuing a degree outside the physical sciences to understand all of the implications of relativity because it would not be relevant in their future careers. The books that did have chapters on relativity that included a discussion about time tended to come in later years. The authors of these books likely believed that their audiences could understand the concepts of relativity and its implications for time by virtue of the ever-increasing quality of high school education.

All but three textbooks that discussed relativity used simple mathematics (nothing more complicated than basic algebra) to help explain the theory. No textbook for general audiences used advanced mathematics. Most high school students had access to basic algebra, and college students, if they had not taken a course already, could have taken a course in algebra. These courses would have given students sufficient mathematical knowledge to understand the equations that augmented the verbal descriptions of relativity. These texts placed a primary importance on verbal explanations to discuss relativity, and only a secondary importance on mathematical equations to help explain Einstein's theory.

The reliance on verbal explanations of relativity for textbooks intended for those not majoring in the physical sciences is expected. The prefaces of these textbooks note that the books intended to convey some of the principals of physics to the student. While many of the textbooks for physical science majors also intended to provide the reader with some of the principals of science, there is a key difference in the objectives of the authors. In the books for physical science majors, the authors wanted to create a foundation on which students of physics or engineering could build their academic careers. The authors wanted to provide readers with a broad exposure to physics and to give the reader some of the tools that would allow them to continue advancing in their studies. It was the need to provide students with the tools to continue their education that required the authors to place an increased reliance on mathematics to help explain relativity because mathematics was a significant tool of scientists and engineers.

This objective contrasts with the goals for authors of textbooks for general audiences. These textbooks did not need to create a foundation on which students could build a professional career, nor did they need to give the students some of the tools of physicists that the students could use later. Instead, the authors only needed to provide readers with some concepts of physics, but not all of them. These textbooks would likely be the first and last books on physics that an average student would use because college curricula for non-science majors would not have required a student to take more than a year of class work in physics. In the field of physics, these textbooks only need to provide an introduction to the basic concepts of physics, which by the 1960s included relativity.

The reliance on verbal explanations of relativity is also explained by the pedagogical needs of the target audience. Students of math and science are trained to use mathematical expressions in place of words. These students would be comfortable with textbooks that used mathematics as an integral part of explanations. Students in fields other than the physical sciences are not usually trained to think and communicate with mathematics. Instead, they are trained to use words to communicate ideas. Therefore, students outside math or science would be uncomfortable using a textbook that relied on mathematics to help explain relativity. Students not totally comfortable with mathematics would be uncomfortable relying on mathematics to provide part of an explanation for relativity because it is a concept foreign to normal human existence. The authors of textbooks for non-science majors had to use verbal explanations as the primary pedagogical method to ensure that readers would get the most out of the book; the textbooks could only use equations to provide additional information about relativity and could not use advanced mathematics.

Three books relied totally on verbal explanations to explain relativity and time. *Physics for Society, A Course for Generalists* (1971) and *Time, Space, and Things* (1976) both have clear explanations that time slows down for objects in motion.[37] They also contain several examples taken from science, such as muon decay, that scientists previously used to prove relativity. *Modern Physics and Antiphysics* (1970) also uses only verbal explanations, however the explanations are not quite as clear as the other two books.[38] *Modern Physics and Antiphysics* does include a number of thought experiments that Einstein used to formulate relativity, and which provide readers with interesting bits of the history of relativity. However, the heavy reliance on the thought experiments to instruct the reader is at the expense of the clarity and concision found in *Physics for Society, A Course for Generalists* and *Time, Space, and Things*. These three books also stand out because they were published in the 1970s when most textbooks included at least simple mathematics. All of the other books, including the books published prior to *Modern Physics and Antiphysics*, included mathematics to help reinforce the verbal explanations, although mathematics were not integral to the explanations. Also, the quality and level of the mathematics taught in high schools by this time would have ensured that a student

[37] W. B. Phillips, *Physics for Society, A Course for Generalists* (Reading, MA: Addison-Wesley, 1971); and B. K. Ridley, *Time, Space, and Things* (Harmondsworth, NY: Penguin, 1976).

[38] Adolph Baker, *Modern Physics and Antiphysics* (Reading, MA: Addison-Wesley, 1970).

pursuing higher education would have been able to understand the basic equations that the other textbooks used. Concerns about the readers' mathematical understanding should not have been a consideration for the authors of these three textbooks.

The theory of general relativity holds that time slows in gravitational fields. In contrast to the textbooks for physical science majors, nearly twenty-nine percent (11) of the textbooks intended for students in other fields discussed time and general relativity. Only two of the textbooks for physical science majors contained discussions of general relativity and time. This finding is unexpected. It would seem that the percentages should be reversed because general relativity is more difficult to fully understand. A possible explanation would be that the authors of the textbooks for physical science majors believed that the students would learn about general relativity in subsequent classes. Conversely, authors of textbooks for non-science majors may have believed these students would not take additional physics classes. Therefore, textbooks for general audiences needed to include a discussion about general relativity because the students would not likely take additional classes in physics.

The chapters that discussed relativity in textbooks for non-science majors occurred in many different places in the books. As with the textbooks for science majors, the placement of chapters on relativity seemed to depend on whether or not the author believed that students needed other information to understand relativity or that other concepts in physics were more important to learn. On average, these textbooks discussed relativity about ten chapters earlier in 1979 than in 1937, suggesting that the authors of these books believed that the increasing quality of high school physical science and mathematics education allowed the students to understand the advanced concepts found in relativity more easily than they would have in earlier years.[39] The wide range of chapters in which discussions of relativity occurred would seem to indicate that the placement of chapters on relativity relied at least in part on the personal preference of the authors.

Most of the textbooks for non-science majors were intended for all students not in the physical sciences, not a specific audience. Six books, however, did have a specific audience. The earliest two books that targeted a specific audience were published just after World War II and neither *Physics for Arts & Sciences* (1948)[40] nor *A Brief Course in Physics for Students of Home Economics* (1949) discussed special or general relativity. The books assumed that the reader had no knowledge of physics at all. In *A Brief Course,* author Lester T. Earls described time as "a curious concept… It goes on without our volition; we can make it neither go fast nor slow,"[41] a statement that is false. Earls, who received his Ph.D in physics from Michigan in 1935, was a professor at Iowa State University from 1938 to 1975, and professor emeritus until 1996.[42] Earls was part of the generation of physicists that earned their degrees after relativity had become widely known in the physics community, and he probably would have agreed with and understood relativity by 1949. A possible explanation why Earls chose to inform the readers in his book that the passage of time could not change was that he believed his audience–consisting mostly of women–would not have been able to understand the concept of relativity, nor would they have any need to understand relativity as home economists. *Phys-*

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[39] The process of analysis used here is the same as the process used for textbooks intended for physical science majors as discussed in note 29. Physics textbooks did not become shorter, so this would counter any argument that the books became shorter and this is why chapters on relativity came earlier.

[40] L. Grant Hector, et. al., *Physics for Arts & Sciences* (Philadelphia and Toronto: Blakiston, 1948).

[41] Earls, *A Brief Course*, 12.

[42] University Relations, "Inside, November 6, 1998." Iowa State University. http://www.iastate.edu/inside/1998/1106/Death.html (accessed on March 19, 2007).

ics for Arts & Sciences (1948) does discuss the measurement of time, but it does not state anything about its passage other than that clocks can measure the passage of time; it does not misinform readers about time as does *A Brief Course in Physics for Students of Home Economics*.

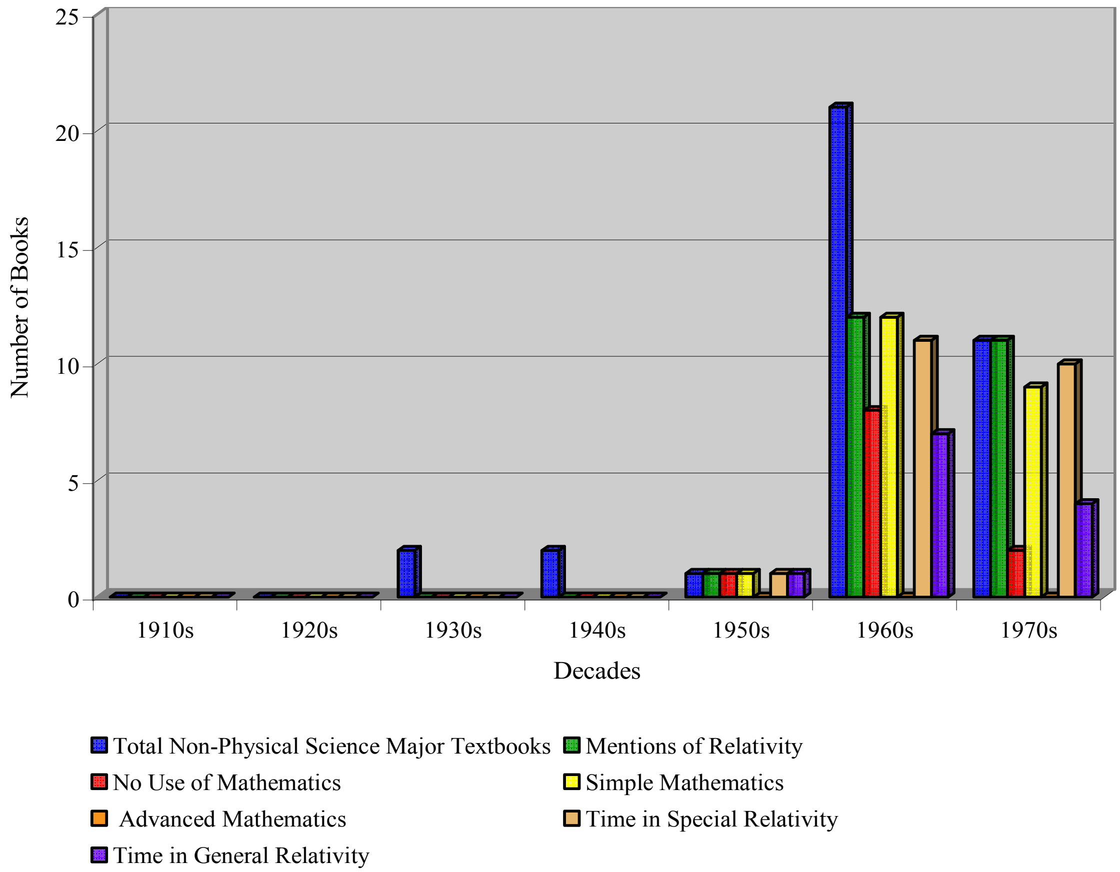

Figure 2-2. Chart for the Analysis of Textbooks for Non-Physical Science Majors

Four other textbooks addressed a specific audience; *The Elements and Structure of the Physical Sciences* (1969)–liberal arts; *Modern Physics and Antiphysics* (1970)–humanities; *Descriptive College Physics* (1971)–liberal arts; and *Invitation to Physics* (1973)–humanities.[43] All discuss relativity and time, using clear and simple language,

[43] Julien Ashton Ripley, *The Elements and Structure of the Physical Sciences* (New York: Wiley, 1969); Baker, *Modern Physics and Antiphysics*; Harvey Elliott White, *Descriptive College Physics* (New

augmented with simple mathematics; two even discuss general relativity and time. These four books and *Physics for Arts & Sciences* (1948) cover similar material and use similar language in discussions of relativity and time as the books that claim no specific audience. Only *A Brief Course in Physics for Students of Home Economics* (1949) stands out because it incorrectly stated that humans do not have the ability to alter time. This explanation would lead a reader, already wedded to the Newtonian concept of absolute time, to further entrench their (incorrect) belief that the passage of time was absolute and unalterable (as mentioned in Chapter 1).

General Analysis

The American physics community received a boost at the turn of the twentieth century when colleges began offering more advanced mathematics courses, which introduced American physics students to some of the most advanced theories and concepts in physics. American physics received another boost in the 1920s when high schools began offering more advanced mathematics courses. Students entering college in the 1920s and 1930s could now understand more advanced mathematical concepts than in previous years, which allowed physics professors to teach their new students more advanced physics, or at least, teach physics in more advanced and mathematically dependent ways than before.

American physics textbooks reflected the enhanced quality of education in mathematics over time. Textbooks used mathematics with increasing frequency as the twentieth century progressed, both for simple and advanced mathematics. This development

York: Van Norstrand Reinhold, 1971); and Ken Greider, *Invitation to Physics* (New York: Harcourt Brace, 1973).

does not automatically mean that the textbooks increasingly relied on mathematics to perform part of the discussion and explanation of relativity and time. Only the books that used advanced mathematics tended to rely partially on mathematics to perform an explanatory function, but even in these works, the reader would gain most of his or her knowledge through the verbal explanations. The few textbooks intended for advanced students did not heavily rely on mathematics to explain relativity and time either.[44]

Though most of the textbooks in this study did not use advanced mathematics by current academic standards, they were advanced for high school and beginning college students in the 1920s and 1930s. The ability of professors to call upon students to use more advanced algebra, trigonometry, and in some cases, calculus, allowed them to move rapidly through the basic concepts in physics, such as Newtonian mechanics, and to arrive quickly at the more advanced concepts of relativity and quantum mechanics.[45] By 1970, all physics textbooks, regardless of the intended audience, contained a discussion of relativity. All textbooks for physical science majors included discussions of time and relativity after 1957 and all textbooks for non-physical science majors contained these discussions after 1969.

The ability of professors to reach the more advanced topic of relativity earlier in course work has also been demonstrated by the trend of textbooks having chapters on relativity progressively earlier through the twentieth century. Physics professors wrote the vast majority of these textbooks. They would not have decided to place discussions

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[44] Textbooks intended for upper division and graduate physics classes have not been examined in this chapter, therefore it is impossible to know whether the observations made for introductory and second-year textbooks would carry over to these more advanced works.

[45] A simple example of Newtonian mechanics would be F=ma, or force is equal to mass times acceleration. This contrasts with the advanced equations given above in the text.

of relativity closer to the beginning of books if they did not believe students would be able to understand the discussions. Atam Parkash Arya, author of *Elementary Modern Physics* (1974), had enough confidence in the students who would be using his book that he placed the chapter on relativity first. Ten other textbooks had chapters on relativity in the second or third chapters. This corresponds with the previous finding that textbooks, on average, included the chapter(s) on relativity increasingly toward their beginnings.

Potential author confidence in students' ability to understand increasingly complicated concepts does not necessarily translate to the successful dissemination of Einstein's theory of relativity and its treatment of time to those same students. The potential impact of these textbooks, like all of the other source types in the following chapters, will be determined by a matrix that weighs the physical accessibility of the source with the accessibility of the language–linguistic and mathematical–utilized within that source. A physics textbook intended for a student majoring in physics could leave a student of music, only taking physics to fulfill a curriculum requirement, quite unsure about relativity. However, a book that does not mention anything about relativity would teach readers nothing about the theory, and therefore be completely useless in the dissemination Einstein's conception of time to the general public.

Seventeen of the seventy-nine (21.5%) books examined in this study do not discuss relativity at all, and twenty-two do not mention that time is variable according to special relativity. While a majority do not reinforce the Newtonian view of absolute time, they also do not disseminate any knowledge of variably-flowing time to readers, and did nothing to alter the reader's understanding of time. Not only does *A Brief Course* *in Physics for Students of Home Economics* (1948) fail to convey any information about relativity and time, but it also works to reinforce the Newtonian view of time.[46]

Only three books (3.80%) specifically state that time is relative (they do not mention that time slows for an object as its speed increases). These textbooks, *Modern Physics: A Second Course in College Physics* (1935), *Physics: Fundamental Principles for Students of Science and Engineering* (1950), and *Physics for Students of Science and Engineering* (1960) all use verbal as well as mathematical explanations.[47] All three books were for physical science majors, but not necessarily as introductory works. *Physics: Fundamental Principles for Students of Science and Engineering* used advanced mathematics. This would not impede the dissemination of relativity because its readers would have taken an appropriate mathematics course as a prerequisite.[48] *Modern Physics: A Second Course in College Physics* and *Physics for Students of Science and Engineering* both used simple mathematics. The mathematics in these books would not have been an obstacle for incoming students studying the physical sciences because they would have taken advanced mathematics classes in high school. The potential for these books to convey the theory of relativity to their readers is high because the language, both verbal and mathematical, was appropriate to the level of the readers. The sole drawback to these

[46] This is the only textbook to reinforce this view. Unfortunately, no information about how many students used this textbook could be found, but it did have at least two printings, the first in 1949 and the second in 1950. While this work was popular enough to merit a second printing, the target audience was very specific so this could have limited the number of students who were taught an incorrect view of time from this book.

[47] G. E. M. Jauncey, *Modern Physics: A Second Course in College Physics* (New York: D. Van Norstrand Co., 1935); and Robert Resnick, *Physics for Students of Science and Engineering* (New York: Wiley, 1960).

[48] It is common for physics courses to require that a student either have already taken a course in mathematics or be taking a course in mathematics that would allow the student to understand the mathematics that the textbook uses.

books is that they left out part of the picture by only teaching that time was relative and not teaching that time can speed or slow depending on one's speed and point of view.

Fifty-four (68.4%) of the textbooks studied in this chapter do mention that time slows down for an object as its speed increases. These books have a variety of audiences and employ differing levels of mathematics. Several books use mathematics at least partly to explain relativity in the manner described above. All of the fifty-four textbooks use audience- and level-appropriate language. As with the three textbooks discussed above, these textbooks would have a high potential to disseminate Einstein's theory of special relativity the students, as well as time in special relativity. Since they also note that time can slow down, they are even more valuable than the previous twenty-five textbooks in educating the public, precisely because they note that time slows for objects as their speed increases.[49] Some of the works provide more details, but all mention this basic and important part of relativity.[50]

Thirteen (16.5%) textbooks discussed general relativity, and thus discussed the other area in which the passage of time can be altered.[51] None of these books use advanced mathematics, which is particularly important because all are introductory textbooks, and all but two were intended for non-physical science majors. The students using these books would have been able to understand the simple mathematics and the verbal explanations of relativity. These books are the most valuable for the dissemination of

[49] The public in this case is defined as those attending college and taking courses in physics.

[50] The most common of these "details" is the twin paradox explained in Chapter 1. This is not discussed in all of the textbooks. This is not a serious drawback for those books that do not include the paradox because it is a consequence of time dilation, not a fundamental part of it. Therefore, it is not problematical if a textbook does not discuss the twin paradox.

[51] Sidney Borowitz and Lawrence A. Bornstein, *A Contemporary View of Elementary Physics* (New York: McGraw-Hill, 1968). These books discussed time in general relativity but did not discuss time in special relativity.

Einstein's theories of relativity, both special and general, because they provide readers wtih a nearly complete understanding of the concepts of relativity with regard to time. Therefore, it is likely that readers of these thirteen books would be able to understand that time can pass faster or slower depending on speed, acceleration, or gravity.

As seen from the analysis above, college physics textbooks varied in their ability to disseminate Einstein's theories of relativity and how those theories described time. Some textbooks, tending to be earlier in the century and intended for non-physical science majors, did not provide any information about relativity at all. Other books, tending toward the middle and later years of this study, discussed some, but not all aspects of relativity and its treatment of time. Consequently they could only provide the student with a partial picture of time, but the student at least would have understood that time was not absolute. Only sixteen and a half percent of the textbooks gave the reader a nearly complete discussion of relativity and time and provided readers with the most information. Also, the authors of these textbooks constructed them to ensure that a wide portion of the college student population would understand and, hopefully, retain that knowledge. Overall, the later a textbook was published, the more it tended to include relativity and mathematics.

This is especially true for textbooks intended for general audiences. While textbooks for physical science majors included discussions of relativity at least since 1929 and in a high proportion of the books, textbooks for non-physical science majors did not include discussions of relativity until the 1950s. Furthermore, in the 1960s, as was seen in Figure 2-2, there was a dramatic increase in the number of textbooks published for general audiences. Textbooks that mentioned relativity comprised over half of the textbooks for general audiences in the 1960s and all in the 1970s. This would suggest that there was an effort to increase the quality, breadth, and the depth of science education at the college level for non-physical science majors. During the late 1950s, many within the Eisenhower administration and around the nation feared the analysis of Soviet education found in John Gunther's *Inside Russia Today*. In his examination of the Soviet education system, he found "that Soviet children crammed into ten years or less what American children did in twelve, and for both boys and girls the 'main emphasis [was] on science and technology.'"[52] Americans, knowing that they faced a deficit in the number of scientists, particularly physicists, began to fear that the American lead in the scientific world was coming to a rapid end. The launch of Sputnik in 1957 only confirmed these fears. Many felt the only solution to the problem was to increase the quality and rigor of science education at the secondary school level in the United States and to do it quickly.[53] The inclusion of discussions of relativity in physics textbooks for general audiences, much like the push to cultivate and educate America's next generation of physicists who were still in primary and secondary school, was driven by the geopolitics of the Cold War and the exigencies it created: Education policy-makers believed that America had to regain its technological superiority over its enemy, the Soviet Union, and better education was the best way to achieve that goal.[54]

The very nature of textbooks limited their ability to disseminate Einstein's view of time to the general public; they were essentially limited to those members of the population that had access to college. At varying times this requirement could exclude the

[52] Kevles, *The Physicists*, 384.

[53] Kevles also makes this point in *The Physicists*, but in reference to secondary school education.

[54] This same conclusion does not easily extend to textbooks for physical science majors because relativity had been included earlier and significantly more often than in textbooks for general audiences.

poor and minorities, and it would always exclude the illiterate. The potential of college-level physics textbooks to disseminate knowledge to the general public increased over time because of rising college enrollments as supported by census data from the United State Census Bureau. Despite increasing enrollment, the number of persons who had attended college never exceeded much more than sixteen percent of the population twenty-five and over during the period encompassed by this study.[55] The percentage of minority groups attending college was much lower. While the number of those who took physics classes was almost certainly higher than the number of those who completed four or more years of college, college-level textbooks could never reach a large portion of the American public and their impact must also be judged as limited.

Popular Books

Popular accounts of relativity are yet another source that attempted to convey the theory of relativity to the general public. There have been numerous works about Einstein's theory by physicists, journalists, and laymen throughout the twentieth century. Some of these books did little to advance the public's understanding of relativity and time. However, many of the popular accounts of relativity did provide readers with a wealth of information. Due to the immense number of popular books on relativity, it would be impossible to examine even a small portion of these works. Instead, this chapter will examine and analyze two of the most popular books on physics. One can assume that a relatively small percentage of the population would have read any one of these

[55] Current Population Survey, March 2006. Historical Tables, Table A-2. Percent of People 25 Years and Over Who Have Completed High School or College, by Race, Hispanic Origin and Sex: Selected Years 1940 to 2006, United States Census Bureau. Accessed at http://www.census.gov/population/www/socdemo/educ-attn.html on March 20, 2007.

types of books. Therefore, any book that underwent numerous editions and printing can be assumed to be popular and widely read. *Relativity* by Albert Einstein and *The ABC of Relativity* by Bertrand Russell were just such books.[56] *Relativity* was in its fifteenth edition by 1952 and *The ABC of Relativity* was in its third revised edition–with several printings for each edition–in 1969. These books are representative of the numerous works about relativity. As with all of the sources in this study, each work will be examined and its ability to convey the theory of relativity and time to the public will be evaluated in the same manner as the other sources.

Albert Einstein's *Relativity* first appeared in 1916, eleven years after he published his theory of special relativity and the same year as general relativity.[57] *Relativity* includes explanations about the theories of relativity and the history of how Einstein developed his conceptions of relativity and time. This background information provided the reader with a break from the sometimes taxing work of understanding relativity and gives them some lighter reading, making the experience more enjoyable. According to the preface of the first edition, the book was intended "to give an exact insight into the theory of relativity to those readers who, from a general scientific and philosophical point of view are interested in the theory, but who are not conversant with the mathematical apparatus of theoretical physics."[58] Einstein goes on to note that the reader would be required to put forth "a fair amount of patience and force of will."[59]

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[56] Bertrand Russell, ed. by Felix Pirani, *The ABC of Relativity,* 3rd ed. (London: George Allen and Unwin Ltd., 1969).
[57] The first edition that was translated into English appeared in 1920.
[58] Albert Einstein, *Relativity*, 15th *ed.*, v.
[59] *Ibid.*

Relativity does not use any advanced mathematics, nothing more advanced than high school algebra and geometry. The use of simple mathematics helped make *Relativity*accessible to a much broader audience than if it had used advanced mathematics. Mathematics play little part in explaining relativity, and instead, verbal explanations provide the bulk of explanations. Einstein's explanations are quite clear for a topic that no author had explained well, let alone a physicist unaccustomed to writing lengthy written works for the general public. He also uses a number of simple diagrams to help illustrate his explanations. These diagrams also help the reader to understand relativity because they do not have to rely solely on their ability to picture complex ideas in their minds. Einstein constructed the book in a logical order with each chapter drawing upon information from previous chapters; at no time does the reader have to wonder about what a term means. Also, Einstein revised *Relativity* throughout the years to include the most up-to-date scientific information about relativity.

Relativity, as evidenced by its publication information, was a popular book. Popularity is a key component to a source being able to reach a wide audience, but it is not the only factor. *Relativity* was also easy to read and understand, advanced mathematics did not appear, mathematics did not perform a significant explanatory function, and the verbal explanations were clear. Importantly, *Relativity* would have been easily available to a large number of people, either at local libraries or for sale. The fact that one of the most famous scientists of the time wrote the book did not hurt either. All of these factors ensured that *Relativity* could have reached a large audience.

Bertrand Russell's *ABC of Relativity*, originally published in 1925, does not explain relativity and time as well as Einstein's *Relativity*. The main problem with *ABC of*

Relativity is the way in which Bertrand Russell writes; it is very cumbersome and could easily leave a reader very confused. This issue of readability was not lost on Benjamin Harrow who wrote the *New York Times* book review for *ABC of Relativity*. He begins his review, "If this is the A B C of relativity, then the sooner we stop thinking about Einstein the better."[60] Harrow turns around Russell's quote, "It is true that there are innumerable popular accounts of the theory of relativity, but they generally cease to be intelligible just at the point where they begin to say something important,"[61] and said "Such, in fact, is precisely my criticism of Russell's book."[62] This is an important insight into how much *ABC of Relativity* impacted the general public. Benjamin Harrow, a biochemist at City College of New York, had problems understanding Russell's work. It would be logical to assume that contemporaries of Harrow, but not in the sciences, would also have trouble understanding *ABC of Relativity*. This would point to *ABC of Relativity* not having much impact on the general public. However, the fact that the book was still being published in 1969 and had undergone numerous printings and several editions would seem to contradict the previous statement. Russell did not use advanced mathematics, at least by the 1969 edition, and he did use a few diagrams. The limited use of diagrams helped make *ABC of Relativity* easier to understand, but there were too few, and Russell's writing too inelegant, to help the reader. In almost all other cases, the use of verbal explanations helps a work to potentially reach more of the public, but in this case, it may actually have hurt the book's chances.

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[60] Benjamin Harrow, "Bertrand Russell on Relativity," review of *ABC of Relativity*, by Bertrand Russell. New *York Times Book Review,* January 10, 1926.

[61] Russell, *The ABC of Relativity*, 3rd ed., 9.

[62] Harrow, "Bertrand Russell on Relativity."

The potential ability of *ABC of Relativity* to widely disseminate relativity and time to the public, according the rubric used for the other sources, is limited. However, this cannot easily be reconciled with the indisputable proof that the book remained in publication for at least forty-five years. It is possible that many people turned to *ABC of Relativity*because Bertrand Russell wrote it and the title made the book seem li ke it would be easy to understand, but that they did not understand relativity and time by the end of the book.

Popular books had the potential to widely disseminate Einstein's theories because they were written to cater to the educational limits of the general public and because they were easily accessible. The profusion of books on this subject also points to these books as being an important component in the dissemination of relativity and time. The ability of individual books lay in the ability of the author to understand relativity, to write clearly, and to use diagrams when possible and appropriate. Both *Relativity* and *ABC of Relativity* had a very large potential to reach and inform a large audience about relativity and time. *Relativity* succeeded, but the final verdict for *ABC of Relativity* is much harder to determine.

Conclusion

Popular books, particularly those written by well-known authors, have always had more ability to capture the public's imagination and attention that far exceeded college textbooks. These books, such as *Relativity* and *ABC of Relativity*, were very popular and would have reached a diverse audience. College textbooks were limited to reaching those persons with access to college, necessarily limiting the diversity of the audience, especially in the early twentieth century. Physics books for college students had an advantage in the educational attainment of their readers. Any person with several dollars could have bought a book on relativity, but it did not guarantee that the reader had the educational background to understand its contents, nor was it likely that the reader would have ready access to a person who did understand relativity. Also, because a degree in physics was not a requirement to have a book on physics published, especially during the beginning of the twentieth century, the information contained with a popular book could be incorrect and would do nothing to further a reader's understanding of relativity. The audience of a college textbook, whether physics of another subject, would have been able to understand the concepts in the book either because of prior knowledge or from the instruction given in that class making for a means of communication far more effective than popular books. However, college textbooks were limited in the audience they could reach because of the economic requirements in order to gain admission to college; popular books on relativity suffered from a lack of readers with sufficient knowledge to understand the contents of the book. In the final analysis, neither college physics textbooks nor popular books could have reached a significant portion of the American population.

CHAPTER III

MAGAZINES

As Americans in the early twentieth century filled their free time with ever more leisure activities, magazines found that they had to change their styles to meet with the increasing activity in readers' everyday lives. Magazines desired increased readership and profit, and certainly a number of magazines met this goal, but they also had a profound influence on the American public as "millions of Americans [got] their ideas about life at home and abroad from these journals since they began."[1] The impact of magazines on the patterns of thought and conceptions about the world of the American public should not be underestimated. Unlike physics textbooks that had a very limited audience–especially in the first few decades of the twentieth century–magazines had a much larger and, on average, less educated audience. However, because of the intended audience of magazines, the majority of their articles were far less technical than in textbooks. Also, the intended audience of magazines, particularly in the two magazines chosen for analysis in this chapter, was broad because the magazines were fairly inexpensive, were easy to access, and written in a way that many literate Americans could understand without extensive training in specialized fields. For these reasons, magazines had the potential to

[1] John Tebbel and Mary Ellen Zuckerman, *The Magazine in America, 1741-1990* (New York and London: Oxford University Press, 1991), 304.

broadly and effectively disseminate Einstein's theory of time, more so than college physics textbooks.

This chapter will serve both to discuss and analyze the content of articles in *Science* and *Time*while looking for larger trends. While the analysis will not be discursive or textual in the strictest sense, the examination of the content of the articles will seek to answer the following questions:

1. Is the article supportive of or resistant to relativity and relativity's impact on time?
2. If known, what is the background of the author and how would this serve to influence his support or refutation of relativity?[2]
3. Does the article explain relativity and time in a clear and easy-to-understand way, or does it use scientific or mathematical terms?
4. Is the article effective in explaining relativity and time to non-scientists?
5. Does the article explain in-depth relativity and time, or are they mentioned only in passing?

These questions, when used for all of the articles, will help determine how well *Science* and *Time* conveyed information about relativity and time. The first question serves to help illustrate the scientific community's acceptance of relativity. For example, if an early article shows resistance to relativity, but later articles show acceptance, then it can be argued that the scientific community has changed its position regarding relativity. However, if articles of resistance and acceptance appeared without showing a steady trend, it can be assumed that the debate over relativity had not been settled by that time. The second question, when utilized in conjunction with the first question, will also help to establish the level of acceptance of relativity within the scientific community. This question is also important because, as was shown in the introduction, the level and type of education of the scientists was a factor in their willingness to accept relativity. The

[2] "His" is used here because all of the authors of the articles discussed this chapter were male.

third and fourth questions are related. Articles that depend heavily on using advanced mathematics and scientific language are not likely to be easy to understand for the average American. Articles that are not easy to understand or that do not provide clear explanations are not likely to have a significant impact on the reader. The fifth question, when used in the proper context, can assist in determining the overall saturation of relativity into the public's general knowledge. Though not a perfect or definitive marker, a mention-in-passing of relativity could show that the average reader is at least familiar with the theory if not its details. Using the question in this way is problematic in the analysis of *Science* since the intended audience is scientists. However, in the analysis of *Science*, the fifth question would also serve as an indicator of the level of familiarity with, and acceptance of, relativity within the scientific community.

Time magazine, founded in 1923, built itself upon the idea that its stories would be quick to read and easy to understand. The idea was that if an article were easy to read, the reader would be able to understand and digest the material much easier than an article that took time to understand and read. *Time*editors wanted the reader to get something out of their articles and to retain at least a small amount of the information that they had read. As a result of this editorial formula, *Time*had an initial circulation of 30,000 by early 1924, and 70,000 by year's end.[3] While the overall circulation numbers were not very high for the time (the *Saturday Evening Post* had 2,000,000 readers by 1917[4]) the rapid growth in circulation and the fact that *Time*had on ly been published for a year make them more impressive.

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[3] Tebbel and Zuckerman. *The Magazine in America, 1741-1990*, 164.
[4] *Ibid*, 41.

Scientific magazines also found expanded readership throughout the twentieth century, though not of the scale of the popular magazines such as *Time* Prior to World War I, “there were only limited audiences for scientific, technical, and trade journals.” However, because of increasing “scientific education in schools and the interest generated by the great number of important new inventions provided a broad general readership.”[5] These magazines generally continued the same formula that they had used for many years: scientists would write articles laden with scientific terms, mathematics, or both, on a topic of specific interest to other scientists. Some of these articles would have been inaccessible to the general reader due to the advanced knowledge required to read and understand them. However, ease of reading for the general public was almost never a concern. *Science* published many articles that readers with at least some scientific training could understand. This no doubt contributed to its wider popularity. Both popular magazines and scientific magazines helped to educate and inform the American reading public about the latest advances in science, relativity included.

Science and *Time* have been chosen for two reasons. First, in a work of this length, it would be impossible to examine all, or even most, magazines. Certainly, there are types of magazines left out, such as entertainment magazines. The second reason that these two magazines have been chosen is because each magazine had a national audience and both were well respected during the period of this study. Thus, *Science* and *Time* serve as representatives of two types of magazines, the scientific magazine written by scientists or journalists with scientific training with the sole intent of disseminating scientific news to a wide number of readers and the popular magazine written by journalists

[5] *Ibid.*

without much scientific training to inform the general public about a wide variety of events in the news.

Science

Science magazine, founded in 1880 "on $10,000 of seed money from the American inventor Thomas Edison," has become one of the world's premier scientific journals.[6] *Science* is unlike most scientific journals, however, in that the content is broad-based–not confined to a single field of science–and numerous readers outside of the scientific community know of it. *Science* is perhaps the most scientifically oriented journal that has an extensive readership outside the scientific community. These facts make *Science* of particular interest to this study; *Science* is simultaneously a journal with articles written by scientists and a popular periodical. Thus, *Science* serves to bridge the gap between science textbooks (discussed in the previous chapter) and newspapers. This section will analyze the articles from *Science* that contain information about time as it is understood through the lens of relativity.

The first mention of Einstein's relativity came in the September 26, 1913 issue. That article, "Continuity II,"[7] presented the transcript of Sir Oliver Lodge's address to the British Association for the Advancement of Science. Lodge, educated in British universities in the 1870s and 1880s, spoke out against relativity, claiming that relativity would reduce the dependence of inertia and shape on speed "to a conventional fiction."[8] Lodge

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[6] Science/AAAS, "About Us," Science/AAAS, http://www.sciencemag.org/help/about/about.dtl#section_about-science (Accessed on February 25, 2007).
[7] Sir Oliver Lodge, "Continuity II," *Science*, vol. 38 (1913): 417-430.
[8] Lodge, "Continuity II," 417.

held to the Newtonian belief that time and space were unchangeable.[9] The article itself confined the mention of relativity to a single paragraph and only cursorily examined time and relativity. However, Lodge's defense of the ether required an entire page.

The article gives very little explanation about relativity, and no reader would be able to discern what the theory of relativity stipulated from Lodge's mention. It is possible that Lodge did not discuss relativity in more detail due to his own ignorance of special relativity because Einstein had only published it in 1905, just eight years earlier. The argument that Lodge spent so little time discussing relativity because he was giving a speech can be dismissed because, as stated above, Lodge spent over a page discussing the theory of the ether and thirteen pages discussing other topics. Lodge clearly did not think that relativity was much of a scientific theory–he called it "The so-called non-Newtonian mechanics"[10]–and it is likely that he was not very familiar with the theory at that time. The article's significance to this study rests with it being the first appearance of relativity in *Science.* Lodge's view at this time was similar to that of a great number of scientists, and likely that of the vast majority of Americans. All subsequent articles, with a single exception, would work to counter Lodge's article and demonstrate to the American public that relativity was in fact a credible theory.

The second article to support the ether and dismiss relativity came exactly seventeen years after Lodge's, on September 26, 1930. This article, "The Ether Concept in Modern Physics,"[11] gave a detailed history of why the ether was needed in theories about the universe. This is curious given that relativity was becoming more established within

[9] Lodge would later admit that Einstein was correct in his formulation of relativity.
[10] Lodge, "Continuity II," 417.
[11] L. B. Spinney, "The Ether Concept in Modern Physics," 303-310.

the scientific community at this time. L.B. Spinney, a professor at Iowa State College, noted that in relativity, "time and space are… not absolute concepts, but are relative only."[12] Spinney clearly understood relativity well enough to argue why it was not able to answer all of the questions about the universe that the ether could answer. However, Spinney did not totally dismiss relativity as Lodge had seventeen years earlier. Spinney did not dispute relativity's stipulation that space and time were relative. Instead, Spinney took issue with relativity's complete dismissal of the ether, a trend that would continue for at least several more years in the scientific community, though not by all members of the scientific community. All subsequent articles, and one previous one, ranged from outright support for relativity to mentioning relativity without much explanation.

Science published the first article in support of relativity, "Modern Concepts in Physics and Their Relation to Chemistry,"[13] in the October 25, 1929 issue. Irving Langmuir, in a discussion about some of the (then) latest advances in physics, provided a fairly decent explanation of relativity and how time is treated within it. Langmuir, a scientist at General Electric, mentioned how time and space are linked and also the relativity of space and time. He did not, however, note the implications of time being relative. Langmuir's discussion of relativity appears to be that of someone in awe of his topic. Part of this can be attributable to Langmuir's admitted lack of understanding about relativity despite his being a physical chemist who would win the Nobel Prize for chemistry in 1932. Langmuir was part of the first generation of American scientists who were able to understand the advanced mathematics involved in relativity, of which Riemannian ge-

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[12] Spinney, "The Ether Concept in Modern Physics," 307.

[13] Irving Langmuir, "Modern Concepts in Physics and Their Relation to Modern Chemistry," *Science*, vol. 70 (1929): 385-396.

ometry is a key component.[14] The theory of relativity could not effectively be communicated to the American public until scientists were willing to accept relativity as legitimate and key to this was the scientists' ability to understand the mathematics behind relativity.[15] This article marks a turning point of sorts in the dissemination of the theory of relativity in a positive tone and with explanations that easily could be understood by the public. With the sole exception of Spinney's article the following year, all of the remaining articles would support relativity in some way, either by directly coming out in support of relativity or by mentioning relativity in a way that showed relativity's acceptance by the scientific community.

Two articles offered outright support for relativity, "What Does Einstein Mean?,"[16] and "The 'Clock Paradox' and Space Travel."[17] Both of these articles were written at times when there was debate over the validity of relativity. In the case of "What Does Einstein Mean?," Jacov Il'ich Frenkel[18] was giving a speech to the Minnesota chapter of Sigma Xi in order to remove "some of the prejudices which [had] arisen in connection with [relativity]" so that his audience might also accept relativity.[19] Edwin McMillan[20] wrote "The 'Clock Paradox' and Space Travel" after a debate that had

[14] Langmuir received his PhD from Göttingen University, the same institution where Riemann received his doctorate and later became a professor.

[15] For more information see the introduction, p.14.

[16] Jacov Il'ich Frenkel, "What Does Einstein Mean?," *Science,* vol. 74 (1929): 609-618.

[17] Edwin Mattison McMillan, "The 'Clock Paradox' and Space Travel," *Science,* vol. 126 (1957): 381-384.

[18] Frenkel was a well-regarded physicist in Russia. He was also a Jew, which may have contributed to his support for relativity. Some scientists of the time resisted Einstein and his theory because he was Jewish and for no other substantive reason.

[19] Frenkel, "What Does Einstein Mean?," 609.

[20] McMillan, who won the Nobel Prize for Chemistry in 1951, received his doctorate at Princeton in 1932, the same year that Einstein would accept a professorship there.

erupted in the journal *Nature* over the validity of the "clock paradox," otherwise known as the "twin paradox" explained in Chapter 1.

Both of these articles provided excellent discussions of relativity and time as understood by relativity. Frenkel's article used mathematics sparingly and used scientific terms that would have been familiar to college physics students at the time he gave his speech, as shown in Chapter 2. McMillan combined an excellent written explanation with advanced mathematics, and the scientific terms in the article would have been easily understandable by other scientists, but not necessarily the general population. The written explanations these articles provided would likely have been understood by a non-physicist with some college-level education in physics or at least some reading from any one of the numerous books published with the sole purpose of educating the public about relativity. The mathematics that McMillan used would not have been accessible to anyone without advanced college mathematics. However, these two articles provided the college-educated reader with very informative explanations of relativity and Einstein's conception of time. The reader without a college education in physics might have had a hard time understanding McMillan's article since it is laden with scientific terms, but almost any reader with a decent college education would have easily understood Frenkel's article.

Science also included an active debate among its articles. The same Dr. Herbert Dingle that Edwin McMillan discussed in "The 'Clock Paradox' and Space Travel" wrote an open letter to the editors of *Science* to defend his theory against an attack by

McMillan. In his letter,[21] Dingle reargued the points that McMillan described in the previous article, and provided a fairly decent explanation of relativity as he interpreted it. The editors of *Science* thought that it would only be fair to give McMillan a chance to respond before they published Dingle's article. McMillan responded to Dingle, but he did not offer any more explanations than he made in his earlier article. This debate does not provide the reader with many useful explanations about relativity and time, though it did provide some basic information. Neither author used mathematics or scientific terms that would have been difficult for a reader to understand. However, due to the lack of clear explanations directly concerning time, as understood by relativity, this exchange does not provide the reader with much additional information as compared with McMillan's article only a few months prior.

"A New Theory of Relativity,"[22] part of a supplement to *Science*, also explained relativity in the context of a debate. This news article related some of the details of a new theory of relativity, developed by the Oxford-trained Indian mathematician Sir Shah Sulaiman, that he claimed was more accurate than Einstein's. The article did not pass judgment on either Shah's new theory or Einstein's older one. However, the article did give a decent explanation of relativity at the end, noting, "Relativity denies the absoluteness of space, time and motion."[23] This article also described the twin paradox, though in only the most basic way. "A New Theory of Relativity" provided clear explanations and did not use advanced scientific terms or any mathematics. The way in which the author

[21] Herbert Dingle and Edwin M. McMillan, "The Clock Paradox of Relativity," *Science*, vol. 127 (1958): 158, 160-162.

[22] Science Service, Washington, D.C., "Science News: A New Theory of Relativity," *Science*, vol. 80 (1934): 13a-15a.

[23] Science Service, Washington, D.C., "Science News: A New Theory of Relativity," 13a.

described relativity would have been accessible to almost any reader of that time, regardless of educational attainment. That is not to say that they would have been able to figure out why the twin who made the journey would have returned younger than his brother who stayed on Earth, to paraphrase Max Born's explanation in the article, but they would have been able to understand that he would return younger and that time itself was relative. The explanation of relativity in this article was far from adequate to allow the reader to understand fully the concepts of special relativity,[24] or the difference between Einstein's and Sulaiman's theories of relativity, but it would have at least allowed the reader to begin to think about time in the manner prescribed by relativity.

The influence of relativity on the scientific community at large can be seen in articles that reference relativity but were written by those outside of physics, astronomy, or mathematics. "Science and the American Press,"[25] written by Scripps-Howard science editor David Dietz, only mentioned relativity in passing, noting, "Everyone wanted to know about the Einstein theory."[26] The article gave no explanation of the theory; Dietz assumed that the readers already knew about relativity, partially because of the articles that they would have read in the newspapers in which Mr. Dietz contributed articles. Likewise, D. Ewen Cameron, a psychiatrist, wrote "The Current Transition in the Conception of Science".[27] Doctor Cameron, a professor at McGill University in Montreal, also only mentioned relativity in passing. He wrote, "The theory of relativity has fertilized our thought to the liveliest growth. Under its stimulus we have outgrown and de-

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[24] The article explains special relativity, though it does not mention special relativity by name. Any effects described in general relativity are not mentioned, such as gravity slowing time.

[25] David Dietz, "Science and the American Press," *Science*, vol. 85 (1937): 107-112.

[26] Dietz, "Science and the American Press," 108.

[27] D. Ewen Cameron, "The Current Transition in the Conception of Science," *Science,* vol. 107 (1948): 553-558.

stroyed the old concepts of time and space."[28] Cameron did provide a brief note that relativity banished the old concepts of space and time, but he did not describe either the old or the new concepts, assuming the reader has an understanding of relativity. However, any reader that had no knowledge of relativity would have been left wondering what Cameron was referencing. This article serves to show that relativity had an effect on fields outside of physics. However, because the audience Cameron had in mind was fellow members of the psychiatric community, it says nothing about how well the general public, college-educated or otherwise, understood relativity. Those outside of the physical science community wrote both of the above articles, and because both mentioned relativity only in passing, the reader would need to have a prior knowledge of relativity in order to gain anything from either article. Neither article provided an explanation of relativity. However, even a trained mathematical physicist could write an article that mentioned relativity, yet provide little to no explanation of what relativity was.

At an address given before the ninth annual meeting of the West Virginia Academy of Science, H.P. Robertson, professor of mathematical physics at Princeton, discussed some concepts about the expansion of the universe.[29] Robertson, a scientist familiar with the mathematics and physics in relativity, nevertheless provided the reader with a poor explanation of relativity, though slightly better than the two preceding articles. Robertson noted that an observer in Einstein's universe would split his universe into three spatial dimensions and a time dimension, just as one would in Newtonian physics. Robertson explained that the difference between the two conceptions of space and time

[28] Cameron, "The Current Transition in the Conception of Science," 553.
[29] D.H. Robertson, "The Expanding Universe," *Science*, vol. 76 (1932): 221-226. The article is a transcript of his speech.

occur because relativity required that the observer use a local time rather than the absolute time envisioned by Newton. Robertson also briefly mentioned that Einstein incorporated gravity into space-time with general relativity, but he did not explain any consequences of gravity interacting with space-time. The article provided very little information about relativity and did not provide enough information for a reader unfamiliar with relativity to gain any sort of understanding of the theory. This is likely for several reasons. The first possible reason is because Robertson, a physicist, would not have been a trained speaker, and therefore would have provided the listeners of the speech with an ineloquent talk. The second possible explanation is that the person who transcribed the speech did not commit every word to paper. The final possible reason is that Robertson assumed that his audience, fellow scientists, did not need every detail about relativity.

By the 1950s, relativity had become another widely known and used tool at the disposal of scientists. As articles from the 1950s and 1960s attest, there was little need to explain relativity in detail since so many scientists understood the concept so well. In the April 11, 1958 issue, *Science* published the reports of two different committees that both put forth recommendations for the direction of the United States' space program. Both the Killian Advisory Committee[30] and the Technical Panel on the Earth Satellite Program[31] recommended that the space program[32] of the United State perform tests to validate general relativity's hypothesis that time would run faster for an object that is in a reduced gravitational field. Both committees recommended that the United States place a

[30] Killian Advisory Committee, "Space Program Offered by Killian Advisory Committee," *Science*, vol. 127 (1958): 803-805.

[31] Technical Panel on the Earth Satellite Program, U.S. National Committee for the International Geophysical Year, National Academy of Sciences, "Research in Outer Space," *Science*, vol. 127 (1958): 793-802.

[32] Neither report mentions NASA because NASA was not established until July 29, 1958.

small atomic clock on board a satellite orbiting Earth. According to general relativity, the clock should run faster than an identical atomic clock on the surface of the earth. Both articles provided the reader with one of the posits of general relativity[33] and both explained in clear language what the scientists expected to find in the results of their experiment. Neither article discusses any other aspects of relativity, however both articles are important in that they explained at least one tenet of relativity in language that any average reader would have been able to understand.

Relativity was just another tool to Sebastian von Hoerner as well. In "The General Limits of Space Travel" von Hoerner discussed how time dilation could be used in interstellar space travel.[34] Von Hoerner used a number of advanced mathematical equations in his discussion of time dilation with respect to interplanetary and interstellar space travel. The equations would have been inaccessible to any reader without at least some college-level mathematics courses. Fortunately, von Hoerner provided clear written explanations of the dilation effects of high-speed space travel that almost any reader could have understood. Von Hoerner also noted that time slows for objects in motion and that the effect increases as the speed of the object increases as observed by a stationary observer.

The articles in *Science* spanned some forty-nine years, from 1913 to 1962. There was a clear break in articles during World War II–there were no relevant articles[35] about relativity from 1937 to 1948, a span of eleven years. This gap is not wholly unexpected as most of the physics community would have been either working on matters of national

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[33] These articles are the first to mention general relativity specifically and only a few of the articles differentiated between the two theories, most lumped the two together under the title "relativity."

[34] Sebastian von Hoerner, "The General Limits of Space Travel," *Science*, vol. 137 (1962): 18-23.

[35] "Relevant article" refers to any article that contained relativity and time.

importance for the government–and working within the constrains of war-time imposed secrecy–or they would have been teaching the next generation of physicists. Scientists would have to wait until the war's end before they could again devote significant time and resources to prove those areas of relativity that had not yet been proven, such as time slowing in gravitational fields.

The articles in *Science* tended to be directly or implicitly supportive of relativity, with only a few exceptions–all but one occurred before World War II. With the exception of the one article before and one article after the war and Sir Oliver Lodge's 1913 article, all of the articles contained scientific terms that would have been familiar to readers with a science class that had a physics component, but the majority of these articles also contain scientific terms or concepts that would have been familiar to only those with some college-level physics background. Only three articles contained mathematics of any sort, though the mathematics used in them was college-level. The articles prior to World War II concerned the theory in a general sense, while the ones after the war, except the 1948 article, all dealt with relativity and the space program, either how scientists could test relativity or how relativity would be of use to the space program. This focus on the space program mirrors the popular culture's interest in the space race. Therefore these articles would have had some level of cultural importance for the readers, making these articles more appealing to the average reader as compared to the articles prior to World War II.

Time

Briton Hadden and Henry Luce created *Time* in 1923 to "serve the modern necessity of keeping people informed."[36] *Time* was interested in "not how much it [included] between its covers–but in HOW MUCH IT [GOT] OFF ITS PAGES INTO THE MINDS OF ITS READERS."[37] The sole purpose of *Time*, in the minds of Hadden and Luce, was to inform the reader of the latest news in a format that was easy to read and, more importantly, easy for the reader to understand and retain, which is a very important attribute to have when attempting to educate readers. Professional journalists, likely with little to no advanced scientific training, wrote the articles examined in this paper. Unfortunately, since *Time* did not include bylines with any of these articles, it is difficult to learn anything specific about the educational background of the authors. Being that professional journalists wrote the articles in *Time*, and that *Time* was a news magazine, not a scientific journal, the articles refrain from explicitly passing judgment on relativity or relativity's treatment of time more often than *Science*.

The fact that *Time* reported about relativity when it became newsworthy allows one to begin to see how deeply relativity had penetrated the thought of average Americans: *Time* only (consciously) reported news about relativity when it became news, not when a scientist was trying to make a point. Therefore, *Time* magazine represented a more mainstream view of relativity and its importance when compared with scientific journals, such as *Science*. This is not to say the *Time* exactly mirrored the American pub-

[36] Isaiah Wilner, *The Man Time Forgot: A Tale of Genius, Betrayal, and the Creation of* Time *Magazine* (New York: Harper Collins, 2006), 85-86.

[37] Wilner, *The Man Time Forgot*, 86. Caps in source.

lic with concern to the importance of scientific matters, but *Time*, by its very design, would attempt to follow the concerns of the American public as closely as possible.

The first mention of relativity came in *Time*'s second issue. "Einstein Made Easy"[38] discussed the film "Relativity" that was playing in movie theaters around the country in 1923. The author described different scenes in the film, most of which have nothing to do with time. The article gave many examples of relativity in a general sense; there are very few references to any of the consequences of relativity. The film worked more to introduce the viewers to the idea that much of what was thought to be absolute was actually relative. Only in the last sentence did the author mention that "Time itself is relative." The article did not use any scientific terms or mathematics, making it easy to understand the concepts being discussed. However, since the treatment of time in the article was so general and so weak, it left the reader only with the knowledge that time is relative. Given that the article never completely discussed relativity in a scientific sense, the reader would be left wondering to what was time relative.

A little more than half of the relevant articles in *Time* about relativity provide equally poor discussions of relativity with concern to time. "A Layman's Complaint"[39] told of Robert Duffus' difficulties understanding relativity. Duffus, then a writer with the *New York Globe*, argued that scientists could not say that they had discovered truths until they explained their findings in language that all people could understand. The article made no direct reference to relativity, and no references to time at all, but the article assumed that the reader would have at least a passing knowledge of relativity, if not some

[38] "Einstein Made Easy," *Time*, vol. 1, no. 2 (1923).
[39] "A Layman's Complaint," *Time*, vol. 1, no. 8 (1923).

basic understanding of the theory. The article would have left a reader unfamiliar with relativity without any useful knowledge. As it was, the article only discussed the difficulty that many, even those with college educations, had understanding relativity; it did nothing to actually help the reader understand relativity any better.

"Einstein Again"[40] also mentioned relativity, but only in passing. This article discussed Albert Michelson's latest experiment to detect the ether. Although this article was about four times as long as the previous two articles, it only gave a poor explanation about a single aspect of relativity, and did not mention anything about time. The article did spend most of its length discussing the experiment that Michelson was to carry out. Because the article's title was "Einstein Again," and that it only mentioned relativity in the last paragraph, shows that the article's author and the *Time*editorial staff believed that the American public had a sufficient familiarity with relativity to feel comfortable with not giving a good explanation of Einstein's theory. In a publication with a limited amount of space, an author would not include information that he felt was unnecessary. Given that there had been several articles published in newspapers prior to this article that did provide the American public with good explanations of relativity, it would be hard to argue that the author of this article did not have sufficient knowledge of relativity and that was why he did not include any explanation of relativity.

"Einstein Improving"[41] and "Atom Time"[42] also mention relativity only in passing. "Einstein Improving," about how Dr. Norbert Wiener published an article arguing that relativity was comprehensible, makes no reference to time at all. This article, pub-

[40] "Einstein Again," *Time*, vol. 4, no. 6 (1924), 21.
[41] "Einstein Improving," *Time*, vol. 13, no. 19 (1929), 48.
[42] "Atom Time," *Time*, vol. 53, no. 3 (1949), 43.

lished in 1924, also assumed that the reader had some knowledge of relativity for the same reasons given above. "Einstein Improving" contributed nothing to the public's knowledge of relativity other than to perhaps encourage the uniformed reader to inquire about relativity from another source. "Atom Time" is even less useful in that it doesn't even mention relativity by name despite the fact that it was published twenty years after "Einstein Improving." The only mention of anything related to relativity is the first line: "Time, the fourth dimension of the world man lives in…"[43] Because relativity was not even mentioned by name in this article, an uninformed reader would not be likely to even inquire about "the fourth dimension" because it was a clause that appears to add nothing to the story. Like "Einstein Improving," "Atom Time" contributed nothing to the general public's knowledge about relativity and time. "Where Time Runs Backward"[44] and "Those Baffling Black Holes,"[45] published in 1966 and 1978, respectively, each mentioned some aspect of relativity in passing, but offered the reader little information about relativity and time.

The first article to support relativity outright appeared in the March 16, 1936 issue. "Einstein's Reality"[46] glowingly described Einstein and his theories of relativity, but offered little in the way of explanation or examples. The author seemed far more concerned with building up Einstein's public image than he was with discussing relativity. To the author, relativity had become a cultural marker of the scientific wonders of the age. It is interesting that this article appeared after Einstein had come to the United States to escape persecution in Nazi Germany. "Einstein's Reality," some could argue,

[43] "Atom Time," *Time*, vol. 53, no. 3 (1949), 43.
[44] "Where Time Runs Backward," *Time*, vol. 88, no. 11 (1966), 57 -58.
[45] "Those Baffling Black Holes," *Time*, vol. 112, no. 10 (1978), 50 -59.
[46] "Einstein's Reality," *Time*, vol. 27, no. 11 (1936), 72, 76.

was an attempt to show the superiority of American science to the American public.[47] American sentiments toward Germany had already begun to turn negative by 1936 as Hitler's worldviews and personal beliefs became better known. It is not hard to imagine that the author of the article was, though only by allusion, arguing that the United States was somehow superior to Germany because Germany was too shortsighted to see the genius of Einstein and that Einstein chose to come to the United States. There is no reason that this article could not have appeared even a decade earlier, and it is the timing of the article that seems to point to the author having an ulterior motive for the article. Relativity is not so important–there is a brief note that relativity makes time relative–as Einstein's genius.

The first article to earnestly attempt an explanation of relativity was in 1929, "Einstein's Field Theory."[48] This article, over a page long in total, was concerned with describing Einstein and the scientific foundations that he had built upon to formulate relativity. The article provided the reader with a decent overview of special and general relativity. It also noted, "Albert Einstein proved that objects change with time, that time itself is not a definite thing. It is different according to the viewpoint. Your hour is not my hour."[49] This explanation did not provide the reader with an explanation that would allow him or her to understand that the passage of time is connected to one's speed relative to an observer. In this respect, the article failed to convey much of the scientific understanding of time to the reader. However, with the type of magazine that *Time* was, the author likely did not want to provide the reader with details that did not pertain directly to

[47] This would assume that the country had already come to (informally) adopt Einstein as an American. The article mentions only once at the beginning that Einstein was German.
[48] "Einstein's Field Theory," *Time*, vol. 13, no. 7 (1929), 38-40.
[49] "Einstein's Field Theory," *Time*, vol. 13, no. 7 (1929), 39.

the main point of the article, in this case to give a general overview of Einstein's accomplishment with relativity and to give some background information on the theory. The descriptions of relativity that do appear in the article are all related to how Einstein came to formulate relativity, both special and general.

The first article to give a good explanation of relativity and its conception of time did not appear until nearly ten years later. "Atomic Clocks"[50] discussed the results of Dr. Herbert Eugene Ives's experiment with spectra and how he used relativity to explain his results.[51] The author wrote, "If two observers are moving relative to each other, *each one*, would find, checking by his own timepiece, that the other's clock was running slow."[52] This was the first time that a complete explanation of special relativity's treatment of time appeared in *Time.* The explanation was short, easy to understand, and provides an accurate description of the flow of time to moving observers. The article also noted that fast moving atomic clocks (glowing particles of hydrogen in this case) showed a change in their frequencies that indicated that the "clocks" were running slow. The potential impact of this article on the general public's perception of time would have been quite high. This article used no advanced scientific terms, nor did it use any mathematics. A reader could easily understand and retain the information contained within the article.

"Slow Time,"[53] which appeared in 1954, offered the first explanation of what happens to time according to general relativity. It stated, "One of the bizarre predictions of Einstein's General relativity is that time runs more slowly in a strong gravitational

[50] "Atomic Clocks," *Time*, vol. 31, no. 19 (1938), 51.
[51] Likewise, the experiment can also be seen as further proof of relativity.
[52] "Atomic Clocks," *Time*, vol. 31, no. 19 (1938), 51.
[53] "Slow Time," *Time*, vol. 63, no. 21 (1954), 63.

field."[54] This article clearly stated one of the key points of general relativity with concern to time. Any reader would be able to understand this fact and would be able to easily retain it. It is interesting, and telling, that the author chose to describe the gravitational slowing of time as "bizarre." This shows that the author clearly believed that this phenomenon was outside the realm of commonsense. It also reaffirms that *Time* was closer to mirroring the level of public knowledge, at least with respect to the information published within its arti cles, than *Science*.

The consequences of general relativity also appear in "Another Check for Einstein,"[55] though the reader would have had to make a bit of an intellectual leap to realize that the article is discussing general relativity since the article only mentions Einstein and not relativity. The article noted that signals sent to a probe near Venus would slow as they passed near the sun. The reader would have to know that the passage of time is related to the speed of light, otherwise he or she would not know that the slowing of a signal would also relate to the slowing of time. This article contributed some to the public's understanding of general relativity and very little to its understanding of time.

The best explanation of relativity, both special and general, came in "A Matter of Overtime (1969)."[56] The article used very clear explanations to inform the reader that time slows down for an object as its speed increases and that time speeds up for an object as the effects of gravity decrease. Any reader would have been able to understand these consequences of relativity. Furthermore, since the article came in the context of the space race–the Apollo 8 mission specifically–readers would be even more likely to read

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[54] *Ibid.*
[55] "Another Check for Einstein," *Time*, vol. 85, no. 2 (1965), 52
[56] "A Matter of Overtime," *Time*, vol. 93, no. 10 (1969), 42.

the article. This article would have had a very large potential impact on the readers of *Time* since it combined easy-to-understand language, very little mathematics (the only equation was simply for show), and a short explanation. "A Matter of Overtime" would likely have contributed much to the public's understanding of time.

"A Question of Time"[57] and "Clocking Einstein,"[58] which appeared in the following three years, were both about the Hafele-Keating experiment that tested relativity. In this experiment, Hafele and Keating took two atomic clocks on board an airplane on a circumnavigation of the world, and left two other atomic clocks in Washington, D.C. as controls. The experiment was to determine if the clocks in the plane would be different from the clocks on the ground. "A Question of Time" provided the reader with several easy-to-understand examples about how time would either speed up or slow down depending on whether the flight was eastbound or westbound, respectively. "Clocking Einstein," which related the results of the Hafele-Keating experiment, noted that time passes more slowly for an object in motion than for an object at rest. It also mentioned and clearly explained the "twins paradox." Both of these articles would have likely informed a number of readers about some of the consequences of relativity with respect to time. They, like "A Matter of Overtime," also employed simple explanations and no mathematics. A reader would have been able to easily understand how time behaves in relativity.

The final relevant article about relativity was "The Year of Dr. Einstein."[59] This article provided the reader with an excellent history of Einstein, including his personal life, his political beliefs, and his science. This article contained the most thorough expla-

[57] "A Question of Time," *Time*, vol. 98, no. 16 (1971), 63.
[58] "Clocking Einstein," *Time*, vol. 99, no. 13 (1972), 66, 70.
[59] "The Year of Dr. Einstein," *Time*, vol. 113, no. 8 (1979), 70-79.

nation of relativity found in all of the articles in *Time* It included excellent discussions about the slowing of clocks at high speeds, the "twin paradox," and many other aspects of special and general relativity not directly related to time. However, the discussion about relativity could have been lost on some readers since the discussion fell into a much larger biographical study of Einstein, about two columns in a ten-page article. Any reader could easily understand the explanations given in "The Year of Dr. Einstein," but they might lose the information about relativity in the mass of other information contained within the article.

The sixteen articles in *Time* spanned fifty-six years, from 1923 to 1979. As occurred in *Science*, there was a clear break in relativity articles during World War II, between 1938 and 1949. This gap can be explained in a fashion similar to *Science*, but with a key difference. Unlike *Science*–whose articles were the published works of scientists–*Time* had to wait for newsworthy science to occur before publishing a scientific article.

Similar to *Science*, most of the articles in *Time*supported relativity. Only a si ngle article reported any negative sentiment, and another journalist expressed that opinion. There were no scientifically based articles in *Time* that were against relativity. A total of five articles gave neither support nor resistance as they simply reported a news story about relativity in an unbiased fashion. All but the lone negative article used scientific terms that would have been familiar to any reader with a basic understanding of physics, and only five articles included advanced scientific terms or concepts that only those with some college-level physics background would understand. Mathematics only appeared in a single article. Though the equation was advanced, the author only included the equation as a demonstration as to the types of calculations scientists made when working with relativity.

The first articles in *Time* mentioned relativity, but gave no explanations about the theories. A reader ignorant of relativity would find no information that would aid his or her understanding of the subject. The next several articles discussed relativity in general terms, such as a scientist supporting relativity. A majority of the articles, from 1938-1965 and 1971-1972, all dealt with experiments that provided support for relativity. Only a single article concerned the space race, a marked difference from the articles in *Science*. Two of the later articles only mentioned relativity and did not provide any explanations about relativity and time. The final article, from 1979, was an article about Einstein, but did provide the reader with a good overview of his theories and his life. Unlike *Science*, the relativity articles in *Time* did seem to mirror, albeit unintentionally, the cultural interests of American society of the time.

General Analysis

As seen from the above articles, magazines had a huge potential to convey information about time and relativity to their readers. However, in many cases, the articles required too much requisite knowledge from the readers to be as effective as was possible in educating the American public about relativity and time either because of scientific terms, advanced mathematics, or because of only passing references to relativity. Had the magazines included explanations, such as found in "A Matter or Overtime," they would have been much more effective in disseminating the theory of relativity to American readers. Furthermore, as shown in figure 3-1, neither the scientifically oriented *Sci-*

ence nor the popular *Time* discussed time with respect to relativity very often. Relevant articles on relativity and time only appeared in *Science* once every 7,473.46 articles, or about 0.013 percent of the articles (the word "relativity" appeared in about two percent of all of *Science*'s articles from January 1, 1905 to December 31, 1979).[60] In contrast "quantum" made just over 4,000 appearances in a slightly shorter time span.[61] Relativity fared worse in *Time*, with relevant articles appearing in one out of 12,967.88 art icles, or only 0.0077 percent. "Relativity" appeared in only 293 articles (0.14 percent) from *Time*'s first issue on March 3, 1923 to December 31, 1979.

	Science	*Time*
First Appearance	September 26, 1913	March 10, 1923
Total Number of Articles in Each	97,155	207,486
Number of Appearances of Relativity	1,927	293
Number of Appearances of Quantum	4,010	182
Total Number of Relevant Articles	13	16
Average Number of Relevant Articles per Year Since First Mention to 12-31-1979	0.197	0.268
Ratio of Total Articles to Relevant Articles	7,473.46:1	12,967.88:1

Figure 3-1. Analysis of Magazine Articles in *Science* and *Time*

As the above figures show, comparatively few articles about relativity made their way into the pages of either *Science* or *Time* As was to be expected, relativity appeared more times in *Science* than *Time*, and it composed a larger percentage of articles than in *Time* as well. *Science*, being a scientific journal, would have included relativity more (as a percentage of articles) than *Time* because it did not also include articles unrelated to science in general. Interestingly, "quantum" appeared significantly less frequently than relativity in *Time* than in *Science*. This could show, as corroborated by the textbook

[60] All numbers have been taken from each magazine's online archive. The total number of articles was figured by performing a null search from January 1, 1905 to December 31, 1979, the range of the study.

[61] Quantum mechanics was not formulated until the about 1920.

analysis, that quantum physics seemed to be more popular in the scientific community than relativity. Certainly, quantum physics was far more difficult to understand due to its highly theoretical and statistical nature, and this may have contributed *Science* giving more pages to quantum physics than relativity. Likewise, since relativity was not as theoretical or statistical as quantum physics, readers would not have to have as much advanced knowledge about relativity to understand and retain the information in an article as they would if reading an article about quantum physics. This would also explain why "relativity" appeared in more articles than "quantum" in *Time*.

As has been shown above, *Science* and *Time* each informed the American public about relativity and time. The articles in *Science* usually contained better explanations than in *Time*, but these articles also usually contained more scientific terms and mathematics, both serving to restrict the number of readers that would have understood the articles. Also, *Science* would have had a smaller readership than *Time*, and those already interested in science, either professionally or recreationally, would likely have composed the majority of readers. *Time* benefited from having a larger circulation than *Science*. However, due to it being a popular magazine, the articles contained within *Time* generally suffered from poor explanations, thus limiting the dissemination of relativity and time to the readers. When the *Time* articles did include explanations about relativity and time, they were clear, easy-to-read, and easy to comprehend and understand. These few articles would have almost certainly conveyed their information to the readers. The main limiting factor on the level of dissemination of these articles, aside from that which has been discussed above, was due to the overall lack of articles. The magazines included articles on relativity and time infrequently, further limiting the dissemination of Einstein’s theory. The number of articles that provided explanations that could have reached a large number of readers was even less frequent. Had more articles about relativity and time appeared within the pages of *Science* and *Time*, more of the American public could have potentially come to understand time as scientists had come to understand it.

CHAPTER IV

NEWSPAPERS

Daily newspapers have been part of the American landscape since before the founding of the nation. By the early twentieth century, "the daily newspaper was universally accepted as one of the foundation stones of American social life."[1] Those who read newspapers throughout the twentieth century in the United States came from all walks of life; these readers were bank presidents, scientists, doctors, teachers, and common laborers.[2] A newspaper provided a connection to the outside world for its readers. They were able not only to read about the most recent events, but they could also travel to ancient Mayan ruins, walk in the halls of government, or be on the frontlines of battle defending the world from tyranny and oppression. Newspapers have always done more than just provide readers with news; they have connected countless millions to the rest of the world.

Because newspapers include a variety of different articles about many news stories and popular interest articles, and because they cater to a varied and diverse audience, with differing educational, social, and economic backgrounds, newspapers must make an effort to be able to reach as many readers as possible. Therefore, news articles in news-

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[1] George H. Douglas, *The Golden Age of the Newspaper* (Westport, CT: Greenwood Press, 1999), ix.

[2] Newspapers have the widest and least specialized audience of any of the source types examined in the study. Physics textbooks, examined in Chapter 2, have the narrowest, but most educated audience. Magazines fall between textbooks and newspapers in terms of the number and educational level of readers.

papers have traditionally been as short as possible, but without losing pertinent details, to allow the readers to quickly read and internalize the information. The language these articles used and the construction of sentences and paragraphs also tended to be as simple as possible so that the widest number of readers may understand the contents. Interest articles can be longer because they are discussing a specific topic to inform readers as possible on a particular topic, and thus the aims of these articles include trying to ensure that the reader can read it as quickly as possible and still be able to understand at least the generalities of the article. Yet, even in these longer articles, the language and constructions are also simple. Regardless of the subject or type, newspaper articles have attempted to be accessible to the lowest common denominators of society. This is more of an economic motivation than genuine altruism–editors want to sell as many papers as possible and running articles that a portion of the literate public cannot understand could hurt circulation numbers and profit.

The *New York Times* began publication on September 18, 1851 under the direction of Henry Jarvis Raymond and George Jones.[3] In 1896, the *Times* had a daily circulation of 9,000.[4] After editor Adolph Ochs dropped the cost of the paper to a single cent in 1898, circulation nearly tripled, from 26,000 to 76,000.[5] Circulation numbers continued to rise throughout the early and middle parts of the twentieth century, and again in

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[3] New York Times Company, "*New York Times* Timeline, 1851-1880," *New York Times*. http://nytco.com/company-timeline-1851.html (accessed April 6, 2007).

[4] Edwin Diamond, *Behind the Times: Inside the New* New York Times (New York: Villard Books, 1994), 40.

[5] New York Times Company, "*New York Times* Timeline, 1881-1910," *New York Times*. http://nytco.com/company-timeline-1881.html (accessed April 6, 2007).

the late 1970s after several years of decreasing circulation.[6] The *New York Times*, like any other large newspaper in a big city, had the ability to reach hundreds of thousands of readers each day. This is far greater than either college physics textbooks or magazines. Also, because newspaper articles were intended for a wide audience, readers could easily understand most of the articles the newspaper ran. The potential to disseminate Einstein's theory of time was far larger for newspapers than any other print source, and the number of people reached increased almost every year. However, despite a total of 9,014,803 articles between January 1, 1905 and December 31, 1979 in the *Times*, there were only 141 articles that discussed relativity and time substantively (i.e. not just mentioned them in passing).[7]

First Appearance	November 11, 1919
Total Number of Articles since First Appearance	8,024,385
Number of Appearances of Relativity	1,529
Number of Appearances of Quantum	1,332
Total Number of Relevant Articles	141
Average Number of Relevant Articles per Year Since First Mention to 12-31-1979	2.35
Ratio of Total Number of Articles to Relevant Articles	56,910.52:1

Figure 4-1. Appearances of Relativity in the*New York Times*

The articles in this chapter are broken into four different categories depending on certain, specific criteria. General articles are standard news articles; they attempt to con-

[6] Diamond, *Behind the Times*, 40, 48, 49, 146. The average daily circulation was 400,000 in 1935, 455,000 in 1941, 538,000 for Sundays in 1947, and 814,000 in 1971. Diamond notes that there was drop down to 814,000, so the actual circulation would have been higher in the late 1960s.

[7] Relativity appeared in 1,529 articles beginning on December 2, 1919. The 1,38 that are not relevant only mention relativity and time in passing, they do not discuss relativity, or use relativity in another way, such as cultural relativity. Because these other articles do not discuss relativity, they do not have the ability to educate the public about the theories.

vey quickly information to readers in a manner that is easy to understand and digest. As would be expected, these types of articles are the most common, with a total of ninety-three (65.5%) articles of the 141 total examined.[8] The next most numerous type of appearance is letters to the editor.[9] These articles, in which any member of the public could express his or her views on a matter, composed over thirty-four (24.1%) of the articles. Because the authors of these letters were diverse, the language also varied, yet none of the articles utilized language that most readers would have been unable to comprehend. Some of the arguments in these articles referenced scientific debates that the general public would not have known about,[10] but the language and construction of the letters was always easy to understand. Book reviews, constituting only twelve articles (8.51%), presented an interesting way for newspapers to educate the public. In the process of reviewing books about relativity, the reviews necessarily discussed some of Einstein's beliefs, disseminating information about relativity to the public. The book reviews did not discuss every aspect and argument of any book, but they provided enough information to start readers thinking about relativity and provided them with information about a source that could answer their questions on the subject. The final article type is the editorial. Editorials, only two of 141 articles (1.42%), provided space for the newspaper's editorial staff to present their own views on relativity.

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[8] Due to the immense number of articles culled from the *New York Times*, it would be impossible to discuss each article individually as the magazine articles were. Rather, general trends will be discussed and several individual articles will be provided as examples of these larger trends.

[9] Not every letter to the editor would have been published. However, this does not present a problem because a letter that did not appear would have no impact on the public if they could not read it.

[10] There was a running debate over the possibility that Einstein stole relativity from Arvid Reuterdahl. While it is unlikely that the general public knew of Mr. Reuterdahl's work, the letters are easy to understand. See the April 21, May 13, July 15, and August 12, 1923 editions.

Letters to the Editor

The first letter to the editor, and the first *New York Times* article to discuss relativity, appeared in the November 29, 1919 edition. This letter, a special cable from the *London Times*, expressed the view that it could not understand an explanation of relativity given by Einstein. The only information that the reader would have been able to glean from the article about relativity, other than it was quite difficult to understand, was that gravity was relative and not absolute. Expressions of the difficulty of understanding relativity would be a popular theme in letters to the editor through the 1930s. As shown in figure 4-1, they were the second most common type of letter in the 1920s and the most common in the 1930s. However, letters that expressed difficulty in understanding relativity were not the only type of letter to the editor, and in fact there were four basic types of letters: expressions of difficulty, support, resistance, and explanation, in addition to the combinations of these letter types.[11] Letters to the editor in particular allow for the tracking of public interest in relativity and its treatment of time better than textbooks and magazine articles–even other newspaper articles–because these letters are a direct expression of the authors, regardless of background. Because the majority of these authors were highly educated males–a significant portion of the population was thus left out–an accurate picture of the overall impact of relativity on the general public cannot be constructed using only letters to the editor. Instead, all of the different kinds of newspaper articles must be considered together in the same fashion as the other source types in order to un-

[11] In Figure 4-1 DS corresponds to letters that expressed difficulty and support, DE were letters of difficulty and explanation, and so on, taking the first letter of the four basic types of letters.

derstand what sort of role and how much impact newspapers had in the dissemination of Einstein's theory of time.

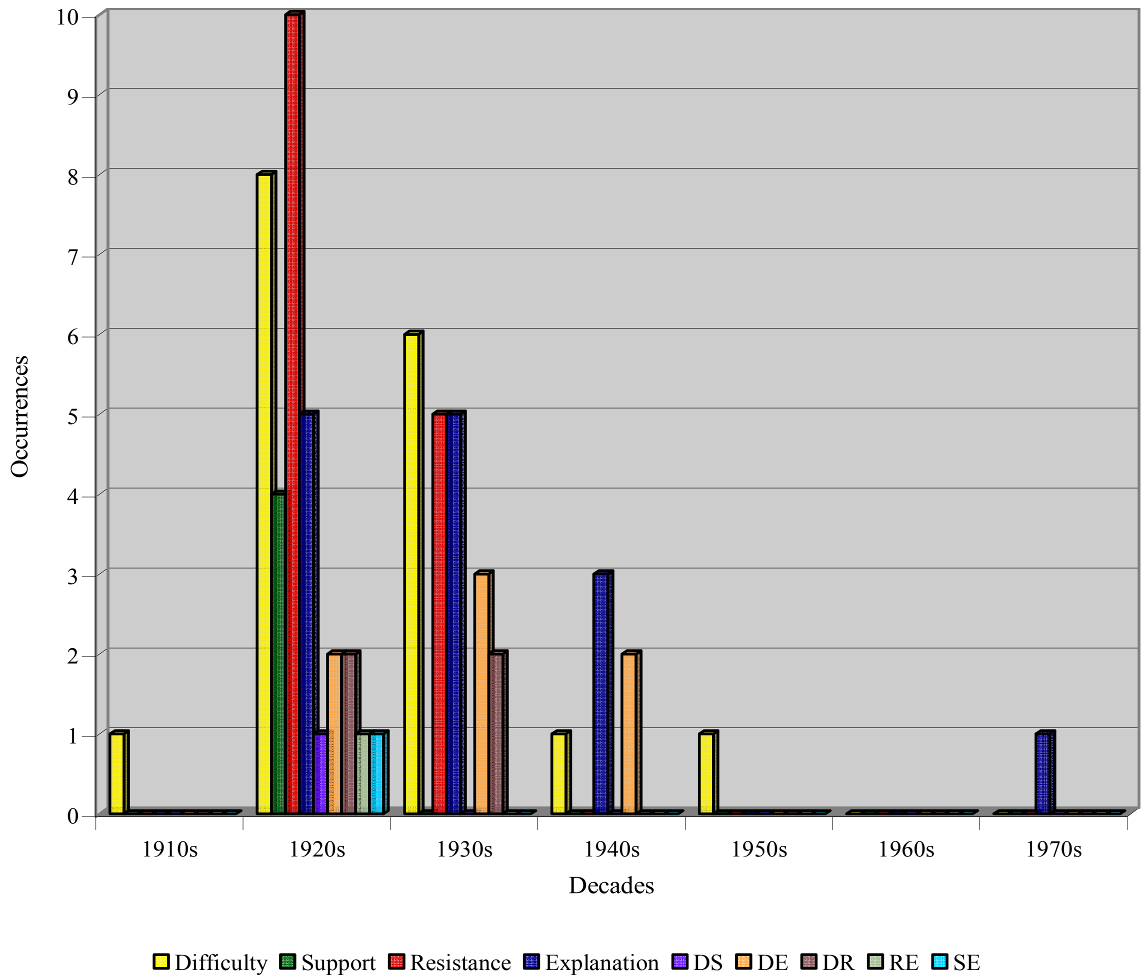

Figure 4-2. Number if Expressions of Difficulty, Support, Resistance, Explanation, and Combinations Thereof in Letters to the Editor in the *New York Times*, 1910-1979.

Letters to the editor that conveyed the difficulty of understanding relativity comprised seventeen of the thirty-four total letters (50%) making these types of articles the most common type of letter to the editor. The timing and frequency of publication of these letters corresponds with the other letter types; there is a peak in the 1920s, a slight downward trend in the 1930s, an even sharper decline in the 1940s, and a complete disappearance of letters conveying the difficulty of relativity after the 1950s. The last letter to the editor that expressed difficulty came in the March 14, 1954 edition. The author of this letter confessed that the theory of relativity "changes our lives, but the equations on which it depends are beyond the ordinary grasp."[12] This sentiment corresponds with the conclusions of Chapter 2 and falls in line with Chapter 3: despite the existence of opportunities for the general public to be exposed to relativity and time, Einstein's theories failed to penetrate deeply into the collective knowledge and understanding of the American people.

While the first four letters to the editor to appear in the *New York Times* all were in the 1910s or 1920s and letters that conveyed the author's difficulty in understanding Einstein, the majority of the letters in the 1920s showed the resistance to Einstein's theories that was prevalent in the United States at that time. The majority of these articles were written by learned men (they were not exclusively physicists) and expressed the idea that another scientist had already anticipated the theories of Einstein (such as the May 28, 1921 letter by Edmund Noble) that Einstein stole the theories of others (exemplified by Frederic Drew Bonds July 15, 1923 letter, "Reuterdahl and the Einstein Theory") or that Einstein was simply wrong in his theory (shown by the several letters written by Captain See of the United States Naval Observatory).[13] These letters are the most virulent of any source type, including textbooks and magazine articles. Dr. Harris A. Houghton, MD, argued, "the time is still not yet ripe either to conclude that Einstein's

[12] "Dr. Einstein's 75 Years," *New York Times*, March 14, 1954, Section E, page 10.

[13] Einstein usually did not respond to those who accused him of stealing theories from other scientists. He did, however, occasionally respond to Captain See's attacks at a talk or convention, although Einstein was always more congenial with his response than See was with his attacks.

theory is correct or that Professor Einstein should receive much credit for calling something by a different name from that by which it has been previously designated."[14]

Letters to the editor that showed resistance to Einstein and relativity, comprising fifteen of the thirty-four total articles, peaked in the 1920s with fully two-thirds of this type of letter coming in this decade. In the 1930s only five letters were published, and none afterwards. This corresponds with the growing acceptance of relativity and its understanding of time in the academic community throughout the first half of the twentieth century. The authors who resisted Einstein were of a previous generation of scholars who were unwilling or unable to understand the universe in a way that was different from the established and very-well tested theories of Newton. As astronomer Charles Lane Poor bluntly explained, "The scientists who have thus accepted the theory [of relativity] on faith do not wish to admit their error."[15] The resistance offered by these scientists would die out only as the scientists themselves died out.

The second most common type of letter to the editor, behind both letters expressing difficulty and resistance, were those of explanation. The authors of these fourteen letters (41.1%) often combined an explanation with another expression, such as difficulty, support, or resistance. These "combi**a** tion" articles totaled nine of the fourteen articles that attempted an explanation of relativity. The letters that showed support also followed the pattern seen with letters that expressed resistance and difficulty of understanding. Five letters were published each in the 1920s and the 1930s, while the 1940s saw a drop

[14] Harris A Houghton, "A Newtonian Duplication?," *New York Times*, April 21, 1923, page 10.

[15] Charles Lane Poor, "Einstein and Gravitation," *New York Times*, September 5, 1926, section 7, page 14. Poor received his doctorate in 1892 from Johns Hopkins and was thus part of a generation that was trained before relativity. The importance of when a scientist received his doctorate and how he viewed relativity has been discussed in Chapter 2.

to only three letters. Supportive letters break from the other patterns with a single letter published in the 1970s. This letter was also the last letter to the editor that dealt with relativity and time prior to 1979 and also the first letter in over twenty-five years (March 14, 1954 to March 25, 1979).

Many of the letters that did not state outright that they supported relativity nonetheless tacitly supported the theory. The explanations found in these letters, while usually only giving a single example, generally were clear and able to pass at least a piece of relativity on to the reader. Even Frederic Drew Bond, who resisted Einstein, provided a good explanation. This shows that he understood relativity enough to be able to provide some sort of argument against Einstein's theory. Unfortunately, readers would not be able to get a clear picture of relativity and its treatment of time because these articles usually only give one or two explanations of relativity. Even if a reader were to examine all of the letters to the editor that gave an explanation, he or she would still not be able to understand the basic tenets of relativity. Likewise, readers would also not be able to understand how time is treated in special and general relativity because the authors only discussed how time slowed as an object's speed increased; no author discussed how gravity affected time. Sixteen letters mentioned time, but only five provided an explanation that time slows for an object as its speed increases. The dearth of letters that explained time only served to limit the dissemination of Einstein's theory of time according to special relativity to the general public and no member of the public would have learned anything about time and general relativity.

The final and least common type of letter to the editor showed outright support for relativity. These supportive letters, only four in all (11.8%), were published in the 1920s.

These letters did not provide readers with explanations of how relativity treats time. Rather they simple argue that Einstein was right and that those who doubted him were mistaken, but offered no proof, experimental or otherwise, to support their assertion. The authors of these letters should not be chastised too severely for not providing proof in their articles that Einstein was correct because there was a limited body of scientific work confirming relativity from which these could draw.

It is interesting that these letters only appeared in the 1920s. It is understandable that no letter to the editor in support of relativity appeared prior to news of Eddington's confirmation of relativity because very few educated men would stake their intellectual reputation by supporting a theory that many felt overthrew the old way of understanding the universe that had yet to be proven in a scientifically sound fashion. However, it is interesting that no articles supporting Einstein appeared after the 1920s. The knowledge of Eddington's expedition had time to spread to the general public, and it would be expected that educated members of the American public would have read about Eddington's results. By the late 1930s there existed a much broader body of confirmation, thereby nearly eliminating the possibility that Einstein was wrong and that any supporter of Einstein would lose credibility. It is also possible that many of those who would have written letters to the editor would have agreed with Einstein and that the need to support him had diminished among this group. Another possibility is that during the 1930s, Americans had more pressing needs, brought on the by Great Depression, to worry about and did not have the time to debate relativity. As seen above, letters that articulated resistance to relativity ceased after the 1930s and it is possible that, in addition to the hardships caused by World War II, the supporters of Einstein felt no need to defend the scientist during the 1940s and afterwards.

Decade	Discussions of Time	Total Letters	Percentage
Pre-1920	0	1	0.00
1920s	7	20	35.0
1930s	6	9	66.7
1940s	3	3	100.0
1950s	0	1	0.00
1960s	0	0	--
1970s	1	1	100.0
Totals	17	36	47.2

Figure 4-3. The Number of Letters to the Editor That Discussed Time

The same basic explanation for the skewed distribution of articles holds for the other three types of letters to the editor as well. Interest in Einstein's theory, as shown by letters to the editor, peaked in the 1920s after newspapers and magazines began reporting about the theory. Interest in relativity began to wane in the 1930s, possibly because of the conditions created by the Depression. Interest was further diminished in the 1940s due to World War II and the need to apply the educational abilities of Americans to the war effort. What cannot be explained by a simple waning of interest is the lack of letters to the editor after the 1940s. As was seen in textbooks and magazines, interest in relativity seemed to increase as these two source types discussed relativity more often in the decades that followed the Second World War. The trends observed in newspaper articles of all types, not just letters to the editor, are in direct opposition to the trends observed for textbooks and magazine articles. Judging solely by letters to the editor (the trend is nearly identical for all newspapers article types), public interest in relativity peaked in the 1920s and decreased over the next five decades.[16]

With a single exception in the 1950s, letters to the editor discussed time with more frequency over the course of the twentieth century, comprising over forty-two per-cent of all the letters to the editor. The lone letter published prior to 1920 expressed difficulty in understanding Einstein, but mentioned nothing about being unable to understand his conception of time. Five of the seven letters to the editor that appeared in the 1920s were published in 1927 or after, but only three give explanations of time. Of the two that do appear in the beginning of the decade, one only briefly mentions time, but the other does give an explanation of time dilation. Two-thirds of the letters to the editor in the 1930s mentioned time, but none attempted to give an explanation of how time behaved in special or general relativity. The three letters published in the 1940s all appeared after World War II, but, like those letters that came in the 1930s, all mentioned some aspect of time according to relativity, but none explained the concept. The letter to the editor published in the 1970s (March 1979) did discuss time and it provided a good explanation of how time slows down for an object in motion.

General Articles

General (or news) articles, like letters to the editor, convey support or resistance, express the difficulty in understanding, or attempt an explanation of relativity. However, because these articles are not the direct expression of the author's personal beliefs on the subject, news articles must be viewed differently than letters-to-the-editor, but can none-

[16] This is not to say that the public's knowledge and understanding of relativity decreased, only its outward interest.

theless still be used to judge popular sentiment toward Einstein's theory. Whereas letters to the editor provided a focused look at how some members of the general public–most likely educated members–viewed relativity, general articles provide a much broader, but more generalized view. Individual general articles in themselves cannot provide enough information as to how the public perceived time, but the number, frequency, and completeness and preciseness of explanation of all the articles can offer insight into how deeply Einstein's views of time had settled into the American mind. In this way, general articles must be analyzed in the same basic manner as magazine articles, but in a more general way.

The first general article to discuss relativity came in the November 11, 1919 issue of the *New York Times*, just after Eddington's expedition. This article, concerning a statement given by Brown University astronomer professor Dr. Clinton Currier that the results of Eddington's work with the solar eclipse provided proof for general relativity, does not mention time, but it does discuss general relativity in very clear terms and provides the reader with several easy-to-understand examples. It would seem interesting that a newspaper article would discuss general relativity before discussing special relativity, especially in light of the pattern of discussing special relativity first as seen in both textbooks and magazines. However, because this particular article, based on Dr. Currier's statement, came just months after Eddington's confirmation of the procession of Mercury's perihelion–information that this article would have been able to draw upon–was also a confirmation of general relativity. It therefore makes sense that an astronomer would have discussed general relativity shortly after the theory received a major confirmation. It is for this reason that the first article to appear in the *New York Times*, and perhaps other major papers around the country, discusses general relativity prior to discussing special relativity.

The timing of this article is consistent with the observation noted in Chapter 2 that textbooks would have only discussed relativity *en masse* after some tenet of relativity had been confirmed. As mentioned in Chapter 2, Eddington's expedition provided the first scientific confirmation of Einstein's theory, and his observations were also the first event that was newsworthy. This article is the first among many articles published within the next two decades (sixty-three general articles were published between 1919 and 1939) to discuss relativity. Much like the publishing frequency of letters to the editor, the number of general articles was low prior to the 1920s, but then peaked in that decade with a total of thirty-four articles published. The 1930s saw a decline in articles, down to twenty-four, and an even steeper decline during the 1940s when only nine articles appeared. However, unlike letters to the editor, general articles found a resurgence in the 1950s, with a number of the articles referring in some manner to space, much like the articles published in *Science*. The 1960s saw a significant decline in the number of articles published (only two), but six articles were published in the 1970s.

Decade	Discussions of Time	Total Articles	Percentage
Pre-1920	2	5	40.0
1920s	14	34	41.2
1930s	12	24	50.0
1940s	7	9	77.8
1950s	11	13	84.6
1960s	2	2	100.0
1970s	6	6	100.0
Totals	54	93	58.1

Figure 4-4. The Number of General Articles That Discussed Time

Discussions of relativity and time appeared in just over fifty-eight percent of the general articles that were published. The percentage of articles that discussed or mentioned time increased between every decade throughout the course of the century. The increase in the percentage of articles that discussed time is likely due to the increasing ability of scientists to harness new technology that allowed them to measure time dilation. For example, a number of the articles in the 1950s discuss the proposed plans to send a satellite carrying an atomic clock into space to measure time dilation. The articles that discuss time in the 1960s and 1970s also discuss new technologies that allowed scientists to more accurately measure time and the effects of time dilation. This is in contrast to the articles that appeared earlier. The articles that discussed time that were published prior to the 1950s tended to discuss the (then) theoretical view that time would slow in various circumstances. They did not have a large body of scientific work to draw upon, and only Dr. Ives' 1938 experiment was published in any of the periodical literature prior to the 1950s examined in this study. Also, the instances in which time was discussed in these earlier articles tended to be included in an article that provided an explanation of relativity and time to readers.

Only two of the five general articles published prior to 1920 mentioned time, and only the last article, published on December 7, 1919 explained that time slows for an object in motion. In fact, R. D. Carmichael intended for this article, "Given the Speed, Time is Naught," to provide readers with an explanation of relativity, including time.[17] A total of fourteen articles from the 1920s mentioned time, particularly that Einstein

[17] R. D. Carmichael, "Given the Speed, Time is Naught," *New York Times*, December 7, 1919, page 18.

“fused” time and space together creating a four-dimensional universe. However, only three of these articles actually discussed time beyond a simple mention. The 1930s saw an increase in the percentage of articles that mentioned time, fifty percent, but only two of the twelve articles explained time. The majority of these articles discussed how time was relative and not absolute. The percentage of articles in the 1940s that explained time rose slightly to over twenty-eight percent. The introduction of atomic clocks and space flight in the 1950s brought a rejuvenated interest in how time behaved at high speeds and in low gravity, and the articles published in this decade reflect this. Eleven of the thirteen articles from the 1950s mentioned time and ten (90.9%) gave explanations of time dilation. The 1950s also saw the first discussion of time and general relativity, and this is almost certainly due to science’s ability to verify general relativity’s assertion that the passage of time increases in decreased gravitational fields by sending atomic clocks into orbit around the earth. Both articles from the 1960s discussed time and provided an explanation of time and relativity. One article discussed general relativity while the other talked about special relativity. All six articles published in the 1970s discussed time and provided readers with explanations. Also, the articles from the 1970s discussed the treatment of time according to special and general relativity.

As would be expected, the articles printed prior to 1920 tended to talk about the newness of relativity. All five articles were about talks given by scientists, including Einstein, in which they attempted to explain or refute relativity. These articles also showed the caution many scientists of the time showed toward accepting such a radically new theory of the universe and the difficulty involved for many even to understand Einstein’s theory, much less use it.

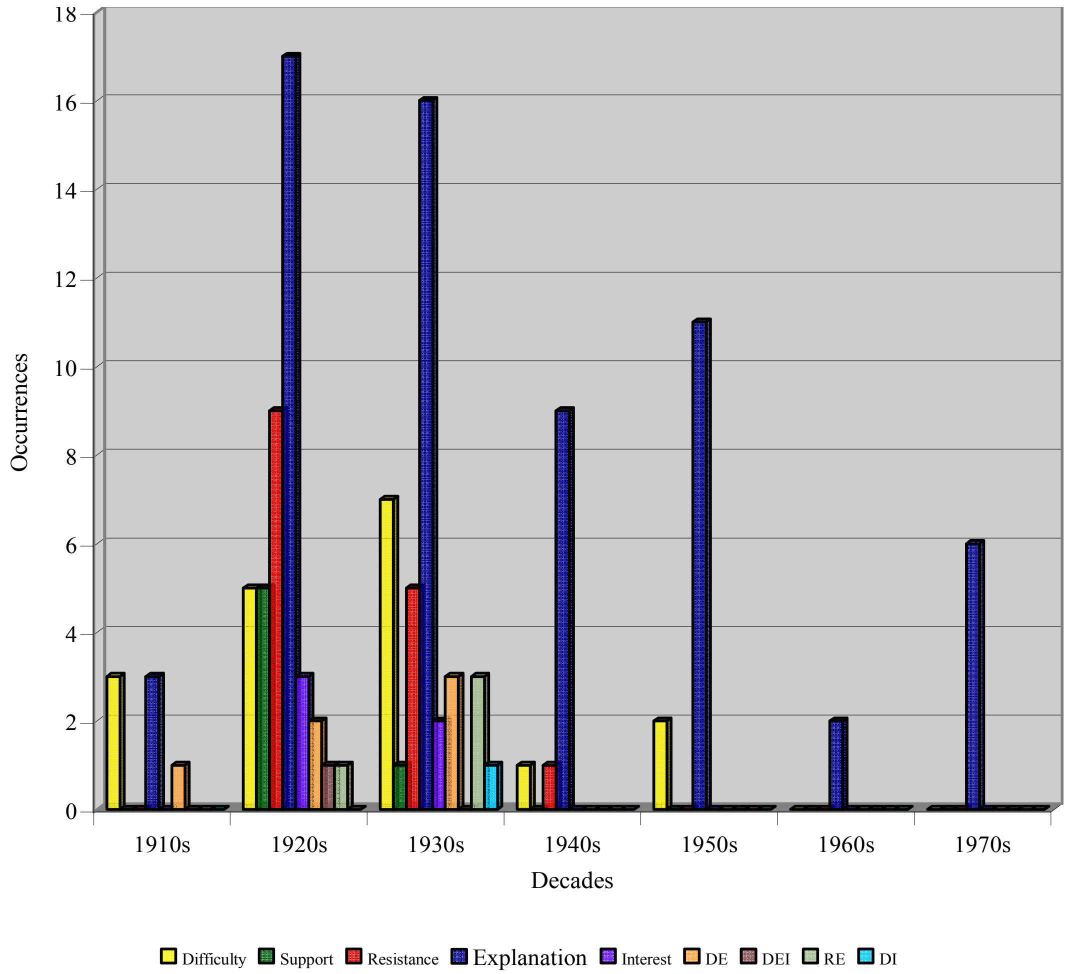

Figure 4-5. Number of Expressions of Difficulty, Support, Resistance, Explanation, and Combinations Thereof in News Articles in the *New York Times*, 1910-1979

The debate over relativity within the scientific community reached its zenith in the 1920s, and the articles of this decade tend to reflect this. The majority of the articles were concerned with the statements of various scientists, including Einstein. Of the thirty-four articles published during the 1930s, exactly half provided readers with an explanation about time. Only one article that provided an explanation also expressed a scientist's doubt about relativity. More articles expressed scientific resistance to Einstein's theory than showed the support of scientists. This is not unexpected because few confirmations of relativity existed during this decade, and at least some scientists questioned the validity of the results of those observations. As observed from news articles during the 1920s, relativity was a hotly debated topic.

As the scientific community increasingly accepted relativity in the 1930s, the articles published in the *New York Times* correspondingly showed this increase in the acceptability of relativity by scientists. Many of the articles from this decade show how scientists began to increase their understanding of relativity beyond the simple knowledge of what the theory stated to being able to use the theory in scientific work. There were still several instances in which scientists expressed their belief that Einstein was wrong about relativity, particularly Captain See. While only a single article expressed outright support for relativity, the majority of the articles showed scientific support tacitly by demonstrating how scientists used relativity in their work.

The articles of the 1940s exhibited a number of different ways in which the public was exposed to relativity. All nine articles gave readers an explanation of some aspect of relativity. Several of the articles showed how scientists planned to probe relativity in upcoming experiments, and one even mentioned how some of Professor Einstein's manuscripts were sold to help the war bond drive. However, unlike the previous three decades, there was no significant unifying theme or themes to the articles. The varied nature of these articles can likely be attributed to the wartime requirements placed on many scientists: they had more pressing matters to attend to than trying to prove relativity.

The Space Race between the United States and the Soviet Union provided a unifying theme for the general articles published in the 1950s. While the first three articles (all published before 1957) discussed a range of topics concerning relativity, the ten articles published in 1957 and after all discussed how relativity could be proven in some manner relating to space. The inclusion of a number of articles that concerned relativity, time, and the Space Race corresponds with the articles the *Science* magazine published in the 1950s. This also mirrors the American fascination with all things that related to the space and the Space Race during the 1950s. Just as the articles in *Science* that also dealt with space would likely have impacted readers greatly, the articles published in the *New York Times* would also have likely had a significant impact on readers.

There were only two articles in the 1960s that discussed relativity and time. The first article (more of a carry-over from the 1950s)[18] also was concerned with putting an atomic clock into space to check the validity of general relativity. The second article, coming in the second half of the decade, discussed Professor John Wheeler's theory that time would cease to have meaning at the quantum level. The lack of articles published during the 1960s is difficult to explain. The Space Race was still ongoing and there was no lack of scientific research that attempted to prove or disprove relativity's understanding of time.

All of the articles published in the 1970s discussed experiments to test Einstein's assertion that time would increase in diminished gravitational fields or slow with an increase in speed. Three of the six articles discussed the Hafele-Keating experiment, and also gave explanations about how time behaved according to special and general relativity. The other three articles discussed various other experiments that also aimed to test

[18] Technically, the first article was published in the 1950s (September 10, 1960). However, because of the dates that encompass this study and the timing of the articles–the first was published in 1919 and the last in 1979–it made more sense from a methodological standpoint to begin decades with years ending in a zero rather than a one, such as 1950 rather than 1951. In reality, the dates assigned to decades will always be arbitrary.

relativity. While there was an increase in the number of articles published about relativity and time in the 1970s as compared to the 1960s, the articles only discussed four events. Part of this lack of articles (when compared to the 1950s) is likely due to fewer scientific experiments conducted or proposed dealing with time. By the 1970s, there had been a number of experiments that confirmed both special and general relativity, thereby limiting the need for scientists to conduct additional experiments. There were fewer articles about time and relativity published because of a lack of ground-breaking experiments to test relativity that newspapers editors deemed newsworthy.

Book Reviews

Book reviews only constituted eleven of the 141 relevant articles published in the *New York Times* between 1905 and 1979. This small percentage (7.80%) would seem to argue that there is little reason to include book reviews in this analysis. Despite the small number of reviews that were published, however, they nonetheless exposed readers to relativity and time. Furthermore, book reviews exposed readers to books that would provide them with much valuable information about time. Thus, if a review did not tell the reader about time, the book that was reviewed very well could–assuming that the reader also read the reviewed book.

The first book review–actually a review of five different books–appeared in the pages of the *New York Times* on October 29, 1922. It is not surprising that a review did not appear before this date because relativity was still a fairly new concept. This first review is in the form of a review essay and attempted to guide readers through the still new and unfamiliar landscape of relativity. It provided several examples of different relativistic effects, but none concerning time. The review served as a primer course for understanding relativity and gave readers five books from which they could further their knowledge of relativity. None of the other reviews function as reviews essays, and only reviewed a book or books individually.

Most of the books reviewed attempted to explain relativity in a way that the average reader could comprehend, and this is not unexpected. Even to this day a number of books about relativity provide readers with an explanation of relativity. Reviews of explanatory books were always the most common type of reviewed books in every decade that reviews appeared, and were thus the most common type of book review. Reviews that discussed books about the difficulty of understanding relativity or resistance to Einstein's theory were a very distant second in the number of reviews that appeared in the *New York Times*. The two reviews of books that expressed difficulty in understanding relativity both were published in the 1920s. This is not surprising because relativity was still a new idea, and it also corresponds with trends for expressions of difficulty seen in letters to the editor and general news articles. Two reviews in the 1930s discussed books that showed resistance to relativity.[19] The appearance of these two reviews corresponds with the trend seen in general news articles, but comes one decade after the peak of resistance seen in letters to the editor. This seeming incongruity between the trends in general articles and letters to the editor is not a concern. Scientists would have been able to produce a short letter to the editor in a much shorter time span than a book. Likewise, an expression of resistance by a scientist likely would have taken several years to be put into

[19] There were three book reviews in the 1930s. However, the final review examined two works, one that explained relativity and one that expressed resistance. Because the two works were so different, and each one was treated separately by the reviewer, this review counts as two reviews for analytical purposes, but only a single article.

book form, thus the reason why the only two reviews of books that expressed resistance appeared in the 1930s and at no other time. A single book, about the psychology of time, shows interest in relativity in a field outside of physics or astronomy.

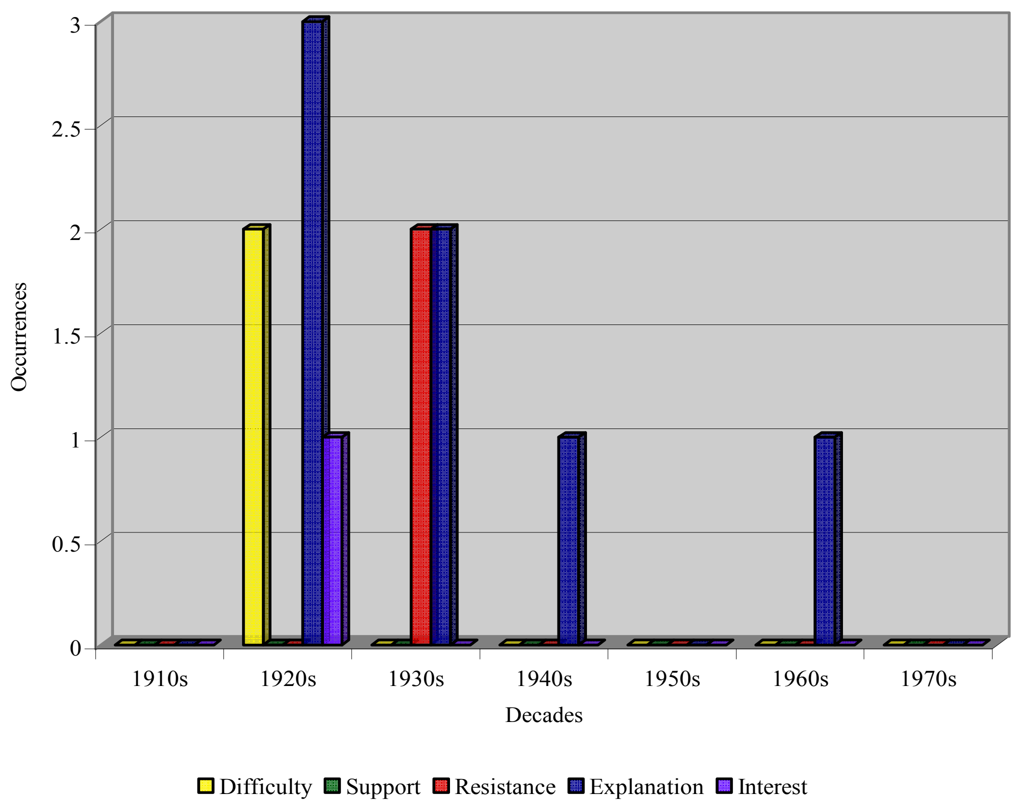

Figure 4-6. Number of Expressions of Difficulty, Support, Resistance, Explanation, and Interest in Book Reviews in the *New York Times,* 1910-1979

The trends seen in Figure 4-6 closely approximates those seen for letters to the editor (Figure 4-2) and general news articles (Figure 4-5). This reaffirms that there was more interest, at least from the perspective of a major American newspaper, when relativity was, in effect, a new frontier that required further exploration. The immediacy of the Great Depression may have impacted the number of books published about relativity, but the scope of this work does not cover reasons why books were or were not published.

The only review during the 1940s did not appear until January 1949. This is certainly due to scientists taking part in the war effort, an effort that left little time to publish books about relativity. The only book review in the 1960s looked at book intended for high school students. Overall, the types of books reviewed in the *New York Times* that were about relativity were not surprising, that is, they corresponded with the prevailing climate in the American scientific community at the time they were reviewed.

Whereas the books reviewed in the *New York Times* likely discussed at least some aspect of relativity and time, the reviews themselves generally did not. Only three of the reviews discussed time. The first review to mention time, "Bertrand Russell on Relativity," from the January 10, 1926 edition of the *New York Times*, mentions time, but does not discuss it, nor does it give any examples of time and relativity. The final two reviews to appear, the January 30, 1949 "Explaining Dr. Einstein" by John E. Pfeiffer, and "Space and Time" by Robert E. K. Rourke from May 14, 1961, both provide excellent explanations of what happens to time at high speeds.

Decade	Discussions of Time	Total Articles	Percentage
Pre-1920	0	0	--
1920s	1	6	16.7
1930s	0	3	0
1940s	1	1	100
1950s	0	0	--
1960s	1	1	100.0
1970s	0	0	--
Totals	3	11	27.3

Figure 4-7. The Number of Book Reviews That Discussed Time

Editorials

Editorials allow newspaper staff to express their views and the views of the paper to the readers of the newspaper. The *New York Times* ran two editorials that discussed relativity. Both editorials appeared in the second half of the 1960s. The first, "Physicists Muse on Question Of Time Running Backward" by acclaimed science writer Walter Sullivan, appeared on January 30, 1966. This editorial updated readers on the latest debate over the nature of time. Sullivan gave readers several explanations about simultaneity, but he did not give examples of the passage of time increasing or decreasing according to speed or gravitational fields. Within the columns of the editorial, Sullivan also provided the reader with his own opinion on some of the research and scientists; he did not attempt to draw a conclusion of his own about the nature of time. The second editorial, "Was Einstein Wrong?," was published in the February 1, 1967 edition of the *New York Times*. This editorial discussed the latest challenge to general relativity, this time by Robert Dicke. The aim of the editorial was not to side either with Einstein or Dicke in this dispute, but rather to show that even the greatest scientific minds and the most revered and "proven" scientific theories could be removed from their pedestals by a single contradictory discovery. This editorial did not discuss, nor even mention time.

General Analysis

Newspapers linked many thousands of readers to the latest events in the world, and the *New York Times* was no exception; it published "all the news that's fit to print." However, as seen in Figure 4-1, news articles were not printed very often, just over two per year. However, that figure is skewed because the majority of the articles appeared in the 1920s and 1930s. When compared to the total number of articles published between the date when a relevant article first appeared in the *New York Times* and December 31, 1979, the relative importance of relativity and time is diminished even further. When compared to *Science* and *Time*, relativity is barely noticeable. However, the *New York Times* did have other areas that it had to cover everyday, such as local events, sports, and world events, something that neither magazine had to do. Therefore, the *New York Times* should not be condemned for failing to report about relativity and time. It reported about Einstein's theory the most when the most scientific debate about relativity occurred, and coverage only waned when fewer newsworthy stories about it occurred. Editorial decisions and space requirements also played a role in the number of articles about relativity in the paper. When a newsworthy story about relativity took place–and other more important stories did not occur at the same time–it was published. It was the increasing lack of important developments in the area of relativity that primarily kept it out of the pages of the *New York Times* and likely not a conscious decision on the part of the editorial staff to dismiss one of the most important scientific theories of the twentieth century.

Time and relativity were mentioned or discussed in over half of the relevant articles published in the *New York Times* between 1919 and 1979. Articles or letters that provided explanations of time and relativity occurred less frequently, but not in the same manner for all of the article types. Time and relativity were mentioned more often as a percentage of the total articles published in a given decade in letters to the editor between 1919 and 1979, but explanations were included less frequently over the same period. The letters themselves do not reveal why this occurred, nor can a plausible and provable explanation be formed. The most important years for letters to the editor concerning the dissemination of relativity to the general public occurred in the 1920s and the 1930s because there were more letters published and these letters tended to provide more explanations than did letters that appeared in later decades.

General articles discussed time and relativity more often than letters to the editor, but followed the same trend of mentioning the two concepts with increasing frequency in articles over the course of the twentieth century. However, unlike letters to the editor, general articles also provided readers with explanations of relativity with increasing frequency during the century. While the percentage of articles that did provide explanations remained at or below thirty percent prior to the 1950s, the 1950s saw an explosion of articles that included explanations. This is due to the importance of the Space Race and scientific education–and science in general–at the start of the Cold War. Scientists developed a number of experiments, most of which in part relied on emerging space technologies, during the 1950s to test Einstein's theory. It was also only beginning with the 1950s that many of these experiments could have been conducted. These articles would likely have had an impact on readers who–already fascinated with all things pertaining to outer space–would have been drawn to articles that featured satellites and atomic clocks. The trend toward articles that discussed experiments continued in the 1960s and 1970s, and all of these articles contained explanations of relativity and time. The articles from the 1950s would have had the most impact on readers because the subject matter of these articles fit the climate of the times more closely than did any other articles. The articles prior to the 1950s dealt with distant scientific figures, while the later articles discussed the cold and impersonal world of scientific experiments conducted in sterile laboratories. Neither set of articles would have appealed to a wide and diverse audience.

Book reviews would have had a very limited role in the dissemination of Einstein's conception of time, but not just because of the small number of articles. The most significant reason why the book reviews would not have reached many readers is because only three reviews mentioned time, each about two decades removed from the other reviews, and because only the last two reviews included explanations. Furthermore, it seems likely that only the more educated and wealthier readers would have read the book reviews; less educated and poorer readers would not have had as much leisure time to spend reading books about a subject with which they may have had limited knowledge. The real impact from books reviews came not from the views themselves, but from the possibility that they might encourage readers to read the books being reviewed, thus gaining significantly more knowledge about relativity than a book review, or any newspaper article, could provide.

Editorials had the potential to reach a large number of readers, and certainly many editorials in the *New York Times* did reach many thousands of readers. However, the same cannot be said about the editorials that mentioned relativity and time. The main drawback of the editorial was the almost complete absence of relativity, only two in over seventy years. Of the two editorials that did mention time, only one provided an explanation, but this explanation did not discuss what happens to time in relativity. Thus, editorials in the *New York Times* would have had almost no impact on the general public and virtually no role in the dissemination of Einstein's theory of time to readers.

Overall, newspapers had the potential to inform a vast number of readers about relativity. Newspapers, by their very nature, were accessible to a large number of people, both in terms of economics–newspapers were affordable to almost anyone–and intellectually. However, as shown by the *New York Times*, newspapers increasingly did not mention relativity and time. The articles did, on average, provide more explanations, but this is outweighed by the increasing lack of articles on the subject. The influence of newspapers to disseminate information about Einstein's theory peaked in the 1950s with articles that incorporated the culturally significant Space Race. The influence of the letters to the editor peaked in the 1920s and 1930s, but the limited number of letters would have hampered the dissemination of relativity and time to readers. As with textbooks and magazines, the illiterate would have found newspapers totally inaccessible, and therefore would have had no direct impact on their understanding of relativity and time. However, unlike textbooks and magazines, non-English speaking members of the American public might not have been barred from learning about relativity and time through newspapers. There were a number of foreign language newspapers around the country that served specific ethnic groups. Unfortunately, the extent to which Einstein's theories appeared in those papers has thus far been left unexplored. In all, newspapers had the highest potential of all the source types to disseminate Einstein's theory of time to the general public, and likely had the highest impact. But, like the other sources, newspapers ultimately did not fully utilize their power to inform the public because there were too many other news stories that took priority over relativity and time.

CHAPTER V

CONCLUSION

Einstein's theories of relativity were revolutionary concepts in the early twentieth century and helped to form the current scientific basis for the understanding of the universe. However, not every scientist rushed to congratulate Einstein on his new achievement when special and general relativity were first published in 1905 and 1916, respectively. Because his theories were so new and, in many instances, contradicted common sense, Einstein initially met much resistance within the scientific community. Yet, as the century progressed and new observations and experiments seemingly conformed relativity, Einstein found he had an increasing number of supporters, and by the late 1970s, very few scientists challenged relativity.

The debate over relativity that occurred within the scientific community spilled over into the pages of the popular media and academic presses. Newspapers, popular books, magazines, and textbooks related the latest news about relativity and worked to provide readers with knowledge about the subject. Each of these sources had the potential to influence a large number of the American public, but as the preceding chapters demonstrate, none of the sources met their potential to disseminate one of the most important set of scientific theories in the twentieth century. Many people knew of Einstein and relativity, but, as the evidence has shown, it is unlikely that many people understood the scientist's theories.

The first source type examined in the study were college physics textbooks. Text books provided readers the most in-depth examples and explanations of relativity as compared to the other sources types. In a number of books, the explanations were clear and concise, which made it more likely that readers would not only understand, but retain the information they were being taught. Also, the target audience for textbooks, in this case college students, would have had the prerequisite knowledge to grasp the concepts of relativity, something that cannot be said of the other sources. Therefore, it can be concluded that college physics textbooks had the highest rate of dissemination for it target audience.

Despite the success of textbooks to disseminate relativity to college students, their success in educating large numbers of them American public was, and remains to this day, severely limited because of the restricted nature of college education in the United States. Prior to the end of World War II and the GI Bill, few Americans, mostly confined to white males,[1] had the opportunity to obtain higher education because of the cost of college and the prevalence of job opportunities that did not require a college education. The rate for attaining a college education for African-Americans was just over one percent in 1940 and certainly even lower earlier in the century.[2] College textbooks are not easily accessible outside of a university setting, and this serves to greatly limit the number of

[1] Current Population Survey, March 2006. Historical Tables, Table A-2. Percent of People 25 Years and Over Who Have Completed High School or College, by Race, Hispanic Origin and Sex: Selected Years 1940 to 2006, United States Census Bureau. Accessed at http://www.census.gov/population/www/socdemo/educ-attn.html on March 20, 2007.

[2] The Census Bureau did not keep statistics for other minorities until the mid-1970s.

persons that would have been able to read from them. Also, some of the background knowledge required to understand the explanations in the textbooks would not have been available to those without at least some college-level classes: to understand information in textbooks beyond introductory one required college-level training.

Popular books such as Albert Einstein's *Relativity* and Bertrand Russell's *The ABC of Relativity* had a large ability to inform the general population about Einstein's theories because they were written with the purpose to educate readers who may not have been fortunate enough to have obtained a college education. Also, average Americans could either purchase these books at a book store or else check one out at the local public library. Popular books were not as easy to access as newspapers, and certainly cost more than an issue of a magazine (assuming that the book was to be purchased), but the books provided the average reader with the most educationally appropriate explanations. Thus, a well-written popular book about relativity–that is a book that provided readers with clear and easy-to-understand explanations–would have greatly informed its readers.

However, popular books may have suffered from a problem of having a great number of readers who knew little or nothing about relativity. It is probable that the readers of these books would have already been interested in the subject. This would mean that the impact of popular books would be mitigated at least somewhat if their readers already knew about relativity.[3] Another possible hindrance to the potential of popular books to reach large portions of the American public, but one that this study did not explore, would be issues of race, class, and gender. It would seem that early in the

[3] A popular book cannot be counted as having influenced a reader if that reader already understood relativity. In effect, a person cannot be "double counted;" only the first source type to educate a reader can be counted as having provided that reader with knowledge of relativity.

century, minorities, the working class, and women would not have read these books in significant numbers. Jim Crow impeded the ability of African Americans to access public libraries, particularly in the South. Members of the working class had very little leisure time to allow for the reading of books on a topic that would have had no impact on their daily lives. Somewhat ironically, newspapers would have been easier to access and more likely to have been read by the lower classes.[4] Women would have been discouraged by American culture from reading about science, particularly a new and very difficult to understand theory, because of the gendered educational expectations that existed in the American educational system, and that still continues to this day (though to a much lesser extent). Because these issues were not explored, they must remain as hypotheses. The final conclusion about popular books remains mixed: they were perhaps the most appropriate tool for the American scientific community to disseminate Einstein's conception of time to the general public, but a number of reasons beyond the control of the author or publishers likely had a negative impact on the ability to reach a significant portion of those living in the United States.

Scientifically-oriented and popular magazines, such as *Science* and *Time*, provided subscribers and occasional readers with easy-to-read and understand articles. The magazines, like all other sources, were at their most effective when they included culturally significant and important elements into their articles, such as the space program in the 1950s and 1960s. When the articles that discussed Einstein's theories about time did

[4] This is ironic because newspapers did not succeed to a great degree in disseminating the theory of relativity.

appear, they would have informed readers in a way that would have likely left a lasting impression.

The main drawback to magazines disseminating relativity was the lack of articles. Very few articles appeared in either *Science* or *Time*, and this would have severely limited the number of readers informed about relativity. Articles about relativity and time appeared only about every four or five years on average for the two magazines. This is clearly not frequently enough to have a significant impact on the general public. Even when the articles did appear, they often suffered from poor or non-existent explanations. There were few articles that gave readers a clear and concise explanation of how time behaved in different relativistic situations. Readership levels were another area in which magazines suffered in their ability to disseminate relativity to the population of the United States. *Science*, which usually included better explanations than *Time*, also had a lower readership. Its articles also used mathematics and advanced scientific terms more often that *Time.* Both of these would have hindered its ability to inform the American public. *Time's* main drawback was that its articles tended to have explanations of poor quality. Mentions of relativity and some aspect of time were far more common than good explanations. Magazines in general failed to achieve their full (theoretical) potential to disseminate relativity to readers, but because these magazines also included a wide variety of topics, it is understandable that they did not include good discussions of relativity more than they did.

Newspapers had a very large audience, especially those in large cities, and consequently had the power to reach and influence a large number of people. The power of newspapers to sway the public's knowledge of a particular subject or topic was perhaps most starkly and powerfully demonstrated by the "yellow journalism" of the 1890s that persuaded many Americans to despise the Spanish treatment of Cuba which led American government to declare war on Spain in 1898. While this instance represents perhaps the most malicious use of newspapers in American history, it also shows how wide of an audience that newspapers could reach. Part of readers' attraction to news articles was their simple language and construction. The aim of articles was to inform readers about a subject as quickly and simply as possible.

The different types of articles each had their own strengths in disseminating knowledge to readers. Letters to the editor were an expression of individual readers' points of view of a subject and usually were easy to understand, while editorials gave the paper's staff the opportunity to express their and the paper's opinion on a subject. General news articles provided readers with (theoretically) unbiased articles about some sort of newsworthy event. Book reviews provided some information about a subject, but their real value lay in their ability to lead readers to a book or books that could impart them with a great deal more information on that subject. Each type of article could, in its own unique way, disseminate knowledge about Einstein's theory of relativity to the public very effectively.

Unfortunately, newspapers did not effectively communicate knowledge about relativity to the American public. Despite a number of articles published about relativity, almost two-and-a-half articles per year on average, newspaper articles about relativity would have almost certainly been lost in the vast flood of articles that did not discuss the subject. Articles about relativity made up only one out of every 63,934.77 articles published in the *New York Times* between December 2, 1919 and December 31, 1979. Another serious problem with newspapers was their lack of good explanations about time and relativity. Less than one quarter of all the article of each type provided readers with an explanation. General articles and book reviews tended to include explanations of relativity with increasing frequency as the twentieth century progressed, but this was somewhat cancelled out by there being fewer articles published toward the later years of the century. As with magazines, newspapers did not meet their full possible potential in the dissemination of Einstein's theory, but they also were forced to make space in their pages for news stories that were more pressing to the American public. With a limited number of pages to work with, editors would often choose a more sensational story over a scientific story. The fact that fewer newsworthy events concerning relativity also did not help in relativity making it into the pages of America's newspapers.

Overall, print sources did a poor job disseminating Einstein's conception of time to the American public. College physics textbooks often provided readers with very good explanations and they had the benefit of the readers (students) having access to an instructor who could help them understand difficult concepts. However, for a number of reasons, few Americans went to college in the first eight decades of the twentieth century and therefore a small number of people would have had access to textbooks. Magazines had the potential to reach a large number of readers and to provide them with the latest information about relativity, but they rarely did. Newspapers had an even larger potential to reader a significant number of Americans, but they too did not print many articles with respect to the total number of articles published. When newspapers did print articles about relativity, they usually did not provide explanations about time.

Popular books often provided readers with excellent explanations that did not require a college-level education to understand. They also potentially may have had the largest role in the dissemination of relativity and time to the American public. Although popular books likely were affected by societal and cultural factors that served to limit the number of readers, they almost certainly would have strongly influenced those Americans who were able to read them.

The question must be asked: Could print sources realistically have done more to disseminate Einstein's conception of time to the American public? The most likely answer is no. College textbooks suffered from a limited audience, but universal college education would have been almost completely unfeasible in both economic and academic terms. Periodical sources, magazines and newspaper, could not afford to take up space with the latest (and smallest) bit of news about research in relativity. Newspapers and magazines were intended to sell copies and had to in order to bring in the required advertising dollars that helped to keep papers financially in the black. Only the most significant developments that related to relativity were worth publishing. It would have been possible to a niche periodical, such as a trade journal, to keep with relativity's latest developments, but they would not have reached a large audience. In the final analysis, print sources generally did not effectively disseminate Einstein's theories of relativity and their conceptions of time to the American public because they often failed to meet their full theoretical potential. However, there was little that could realistically be done to alter that constraint.

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APPENDIX

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