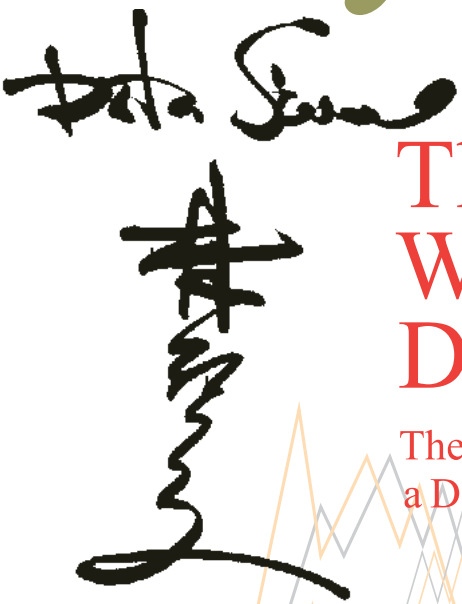
Chikio Hayashi



The Man Who Liked Data

The Life and Work of a Data Science Founder

Kumiko Maruyama

SINFONICA

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Dedicated to Haruo Yanai

O reward after a thought
What a long look at the calm of the gods!

--- Paul Valéry ---
From " The Graveyard by the Sea"

Ô récompense après une pensée
Qu'un long regard sur le calme des dieux!

---- Paul Valéry ---
Extrait de " Le Cimetière marin "

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Preface

Chikio Hayashi (1918–2002) lived during an era when most young Japanese men were drafted to fight in wars. When the nation was defeated in World War II, most of the population had no time to feel lost, but had to earn their living by the sweat of their brow, propelling Japan into becoming an economic superpower. Today, most have forgotten the travails of this era. But for many who lived through it, the circumstances of this country called Japan were important, and these people were proud of the fundamental strength they cultivated in themselves and how the sum total of the strength they demonstrated saved the nation from the crisis it faced.

To a greater or lesser extent, postwar researchers shunned derivative thinking and accepted ways of making things. They were ashamed to be imitators—always valuing original thinking and ideas—and whether others understood them or not, they put their ideas forward boldly, refusing to compromise when faced with counterarguments, believing in their ideas and defending them stubbornly to the last. Chikio Hayashi was one of those who absolutely despised following others in his research. Sometimes he even refused to read other researchers' papers. Once an idea or a concept had occurred to him, he carefully nurtured it, and until his throat was dry and he could no longer hold a pencil, he strove to make his ideas known. He authored a

series of papers and books with a wide range of viewpoints, and his untiring efforts and abilities demand our admiration.

The more people stepped up to argue against his ideas, the more spirited he became. Chikio Hayashi had many opponents. He argued passionately with those who challenged him and devoted all his strength to unearthing the truths hidden in the reams of puzzling data (measurements and observations).

But with a moment's inattention, the black capes of the demons (anomalies or unexpected values) hiding in myriads of data can block the light and make it impossible to see the truths hidden there. Sometimes one must walk in impenetrable darkness, feeling one's way. Those who know this must work hard every day, eyes peeled, to discern the truths hiding in the data. This is the attitude and thesis that Hayashi held most important when approaching data.

Chikio Hayashi's theory of quantification gained widespread attention thanks to his 1959 paper, "Fundamental Concept of the Theory of Quantification and Prediction" which for a time was very influential in the field of marketing. Hayashi developed a series of methods (designated as methods I-IV) for quantification of qualitative data in multidimensional data analysis. People studied thoroughly Hayashi's meticulous social survey methods and sampling theory. Society subsequently began moving gradually away from these sorts of laborious statistical methods toward simple dependence on large computers, but this meant that one could not battle the demons hiding in the data. This is one of the pitfalls awaiting many

researchers who are involved with data science today. It is hardly an overstatement to say that Chikio Hayashi's insistent warnings pointing this out to researchers working with data are one of his principal traits. He succeeded in drawing on the essence of data science by immersing himself in it, seeking the obscured truth and unraveling the complexities of human behavior, and never forgetting his own warnings to others.

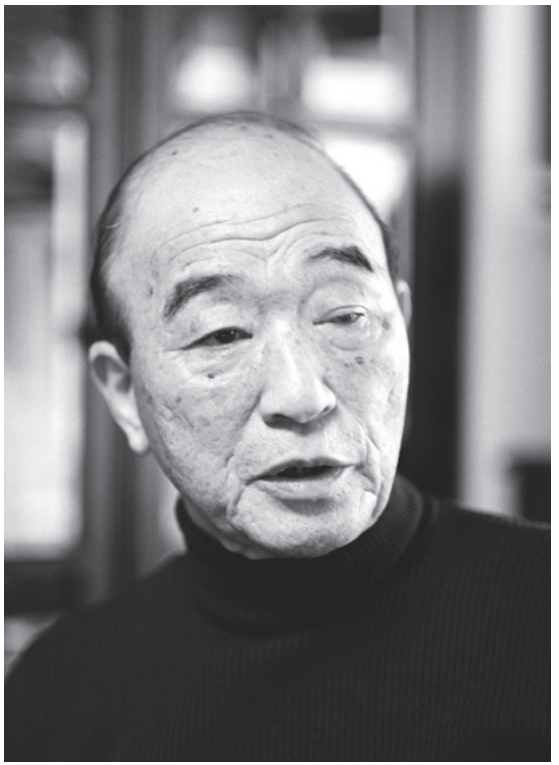
In today's data science, with dramatic development of computers and information engineering, statistical mathematical methodology and data analysis are considered to be merely tools. Generally, there is no concern for the processes taking place in the computer; only the ultimate results are deemed to be important, and there is a strong tendency to be satisfied with them. Modern society is awash in data; people have become entranced and manipulated by it. As time goes on, more and more individuals aiming to become data scientists may not have chance to think deeply about what data is, and as society becomes more data-based, how many will be capable of understanding Chikio Hayashi's earnest approach to data science, searching for the underlying meaning in the given data?

In the current era, young statisticians can write best sellers predicting that society will be ruled by statistics. Indeed, some may envisage that data obtained from the internet will infringe on individual privacy. These developments suggest that now more than ever there is a need to engage sincerely with the basic fundamentals of data science. By doing so, it is certain we will understand naturally the stance that Chikio Hayashi took with

respect to statistical mathematics.

If false data is propagated freely in a society that depends on data as a source of information human beings will inevitably be forced in the direction of their own destruction. Computers intensify human intellectual curiosity to the highest degree, but a pitfall awaits: if there are demons in the data, they can topple a data-driven society into the depths. And because this is just such an era, it is imperative that we understand and engage in the true statistical analysis that was Hayashi's goal.

Why study Hayashi's quantification theory (or simply "quantification") today? To answer this question, it helps to have an overview of his life and an understanding of his ideas, even if only in outline. I invite the reader to learn more about the core ideas of data science by walking in the footsteps of statistician Chikio Hayashi, a towering intellect who covered a vast range of research subjects and laid the foundations of modern data science, worked out its fundamental concepts, ventured out to gather data from the front lines, and followed where it led him.



Chikio Hayashi, 1918-2002
(The Asahi Shimbun / Getty Images)

Chapter One

Boyhood and Young Adulthood

1. The birth of a young visionary

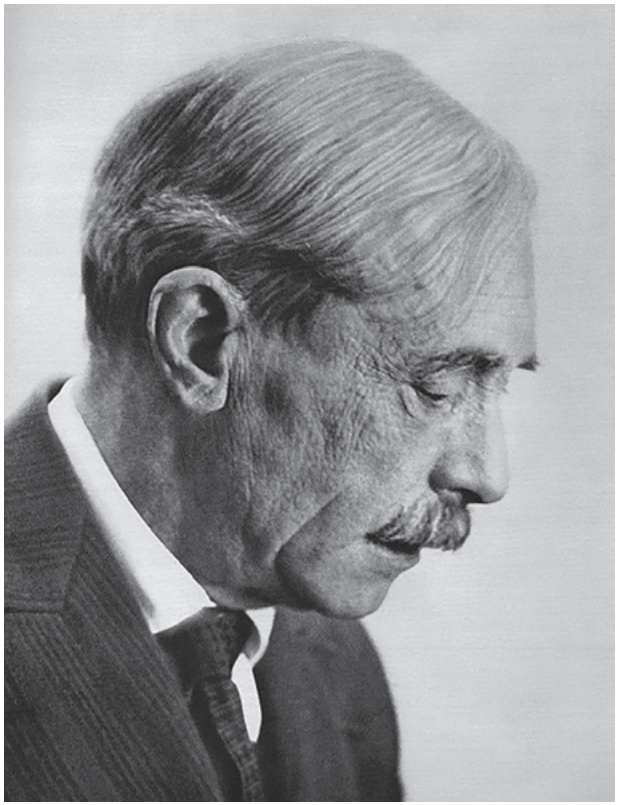
In June 1918, amid the balmy breezes of a fresh summer morning, a son was born to the Hayashi family in Komagome, Hongo-ku, Tokyo City (today's Komagome, Bunkyo City, Tokyo Metropolis). He was preceded by brothers and a sister, but there was a gap in their ages, and the little boy was raised as though he were an only child. His name was Chikio, nicknamed Chiki-chan, and everyone around him treated him with affection. In his early years, he wanted for nothing. When he had completed the local kindergarten and elementary school, he entered Tokyo Kaisei Middle School in Nishi-Nippori. The school was known for developing outstanding boys instilled with a spirit of austerity and fortitude. At the same time, it had a markedly free atmosphere. Young Chikio had a passionate love of books, and he spent many hours immersed in reading.

Hayashi vividly depicts his feelings from this time in "The Pleasures of Reading," an essay he wrote for the school bulletin when he was a third-year student. In it, he repeatedly makes the point that just as one cannot go without food, reading is a pleasure that as a person, he could not forego. Compared with essays written by his classmates, Hayashi's essay is extremely down-to-earth, using a plain style that expresses his thoughts at the time in a forthright manner.

We can discern the early signs of his lifelong devotion to reading. As he grew up, books were a form of sustenance just as important to Hayashi as breakfast, lunch, and dinner—first

of all as a way of gaining knowledge, and then for the spiritual pleasure they afforded. Every time he added yet another book to the pile of those he had read, he writes that he was somehow filled with the pleasure of great accomplishment, as though he had become a great scholar who had made an important discovery. During his years in middle school, his room was submerged in mountains of books, and the joy he felt when he took a new one in hand was a precious moment he would not exchange for anything. Among the authors who left their impressions on him, the most important were Paul Valéry, the French philosopher, intellectual, and poet, and Torahiko Terada, the essayist and professor of physics at the Tokyo Imperial University. Valéry in particular became a lodestar in Hayashi's life.

It must be said that for young Chikio, as a third-year middle school student, to sympathize with and become an ardent admirer of Valéry's recondite world view is highly unusual. But when he encountered the thinking of this esoteric individual, when he touched the depths of the poet's soul and his innermost thoughts, Hayashi, struck with awe, was seized with an impulse to run in circles, crying out as if in an intoxication resembling madness. What he learned from Valéry was not simply to express one's sensibilities in poetry, but to cast his gaze into the sky toward impossibly distant aspirations. Valéry had gained a reputation as a poet when at 20, he felt revulsion toward literature and poetry, abruptly transforming himself into a philosopher and critic. Just as Valéry created the fictional character of Monsieur



Paul Valéry, 1871-1945
(Universal History Archive / Universal Images Group / Getty Images)

Teste, the embodiment of intellect, the lesson that Chikio likely learned from Valéry was the courage to rebel against beautifully tended mathematical theorems as well as poetry and literature, and the need to maintain the penetrating gaze that seeks ultimate truth.

Furthermore, as the young man was drawn to physicist Torahiko Terada's sensibility and sharp eye for observation, he reached the age where he was capable of understanding what he was destined to do. At some point his ears detected the machine-like rhythms hidden in abstract algebra. Might there not be a means of mastering these rhythms? The emotions roiling inside him would drive his subsequent motivation to study mathematics in university. The sensibilities of Valéry and Terada are strongly reflected in the mentality that led him, while feeling the pull of literature, to move as though toward its opposite pole, mathematics. The philosophy of ideas in the natural sciences had been accumulated by traversing a long road, examining reality consistently and unwaveringly. The lessons he absorbed from Valéry and Torahiko Terada penetrated his heart deeply, remaining there without his conscious awareness, exerting a strong influence on the spirit of the man he would become. At age 60, Hayashi recalled his youth this way.

"There are many different ways to arrange one's books on shelves. I keep all my especially precious books in one favorite place. If I was asked to name my favorites among them, I would choose two that suit my temperament perfectly, and reinforced and developed it. They are not properly classic works, but so-

called miscellanea: Torahiko Terada's collected essays from his early and middle periods, and Paul Valéry's anthology, *Variété*. Torahiko Terada's essays consider how the phenomena of 'things' should be understood, and I was very impressed by his original analytic approach. That was as far as it went at the time, but as I began to do my own research, before I knew it I found that his approach was greatly influencing me. When I read research papers, I immediately wonder what things mean, or whether the findings are genuine, before I decide whether or not the paper interests me; I always proceed without artifice, trying to keep before me what is most important. *Variété* greatly influenced my point of view regarding phenomena of the spirit, my attitude toward civilization, and my views concerning human action. From 'La Crise de l'Esprit' and 'Note et digression' to 'Introduction à la méthode de Léonard de Vinci', I found the power of these essays breathtaking, and myself in complete agreement with them (I refer to the Hakusuisha edition, translated by Kenzo Nakajima and Masaaki Sato). Later Valéry compilations are neatly categorized into literary research, philosophical research, quasi-political essays, poetics, esthetics and so on—superficial and not at all compelling. No matter how impressively presented, the finished product is already useless; what is required is the courage and readiness to rebel and start anew. I realized that intellectual and physical reluctance and indolence are the greatest enemies. Don't follow a path laid by others, but blaze your trail yourself. This will strengthen you and build your body, reinforcing your autonomy. This is

the only approach to living in a satisfying way. This is how the argument goes, and it is the impact that *Variété* had on me." (The Nihon Keizai Shimbun, April 16, 1978, evening edition.)

2. Days of immersion in music, sports, and reading

In addition to reading, music—particularly playing the flute—was another boyhood hobby. Not that Hayashi had someone to teach him; he had been entranced when he heard his older brother playing it. He was completely self-taught. He enjoyed playing French impressionist composer Debussy's "Prélude à l'aprés-midi d'un faune," which was inspired by one of the poems of Mallarmé. To the end of his life, Hayashi was a lover of classical music, and was particularly devoted to Debussy. The latter's opera, "Pelléas et Mélisande," was a favorite.

But young Chikio was no introvert, amusing himself with books and music only. He was also active in sports at Tokyo Kaisei Middle School, including track and field, and later swimming, rugby, and sumo. He helmed sailboats to experience the vastness of the sea, and later took part in the National Sports Festival sailing competition. This honed his reflexes and gave him a flexible body. As a youth, he was proficient at all outdoor sports and loved physical activity. As an adult, he climbed mountains and skied, and even in old age he enjoyed scuba diving. His spirit of adventure never waned.

Later he would participate in a survey to count the number of

wild hares living deep in snow-clad mountains, but this was no exuberant winter ski trip. It was the sort of mountain skiing that today would be called cross-country skiing—not the enjoyment of gliding along, but mountain climbing on skis. It was extremely physically demanding, but he aimed for the summits without hesitation and climbed with ease. On his return, he sped down the slopes defiantly, shouting for joy. On a visit to Switzerland, Hayashi often skied in the famous Matterhorn and Eiger areas, logging several kilometers of high-speed skiing every day; and he was past 70 when he enjoyed sailplaning in Hawaii.

Another episode dates to his participation in a 1970 NHK public opinion survey, which required him to travel frequently to Mount Atago. There he discovered the Atago Concerts, performances by amateur musicians that were held twice yearly. He greatly approved of these concerts, and participated for 24 years without missing a single one. At 66, to stretch his capabilities, he switched from flute, which he had played since youth, to the horn, and was so dedicated to practice that he made rapid progress. Hayashi approached this new instrument with the same passion that marked everything he did, and the same commitment to enjoyment.

3. The statistician Richard von Mises

Hayashi graduated from Tokyo Kaisei Middle School in 1936, and enrolled in Seijo High School's Department of

Science under the prewar educational system. The clouds of war were gathering over Japan, and in 1939, when young men increasingly took pride in joining the army or navy, he entered the Department of Mathematics at Tokyo Imperial University's Faculty of Science. As his major, he chose probability theory—a field widely disliked by others because it was not pure mathematics. His academic advisor, Soichi Kakeya, was an authority in the field of analytics, but he allowed Hayashi to pursue probability theory. That a leading light in analytics allowed him to do so had a decisive influence on the rest of Hayashi's life. Kakeya was no imitator, and was not easily influenced by things that interested others; his fundamental stance was to value originality. He was a deep thinker who did not rely on others' academic papers, famous for his superb conceptions, and known for the fact that if he reached the same conclusion as a foreign academic, it would be through original thinking and not due to having read foreign publications.

Consequently, Kakeya practically forbade his students from reading others' academic papers. He told Hayashi to value his own thinking and write papers that took a different stance from the rest. But it was around this time that Hayashi encountered *Probability, Statistics and Truth,* written in 1939 by the highly original mathematician Richard von Mises. Hayashi later recalled "almost weeping with excitement" as he read this work, and without telling Kakeya, he began to seek out other works by von Mises.

Richard von Mises, 1883-1953
(ullstein bild Dtl / ullstein bild / Getty Images)

4. First Lieutenant (Aeronautics), Imperial Japanese Army

In October 1942, Hayashi graduated ahead of schedule from Tokyo Imperial University. In order to join the military, he became a technical cadet at the Imperial Japanese Army's Mito Flying School. Upon graduation, he would become a first lieutenant (aeronautics), and be assigned to the army's air service headquarters. But rather than serve as a technician, he was intent on fighting on the front line as a private second class. Recalling his fervor, he wrote, "I was interested in testing myself, and in strengthening myself. At the root of my attitude was Paul Valéry's idea, which was said to be intellectualism, of ordeal and autoplasty. As a private second class, I wanted to test myself by fighting equipped with nothing but myself, with all my heart" (The complete works of Chikio Hayashi, Bensei 2004, Vol. 10, page 245). This romantic view earned Hayashi a rebuke from military veterans. "Use your knowledge to serve the nation," he was told curtly, and he devoted himself obediently to serving the nation as a mathematician.

During his time at the flying school, Hayashi was ordered by an army surgeon to calculate the appearance of air-to-air ballistic trajectories. Exempt from military drills and training, Hayashi was to produce detailed calculations of how accuracy rates could be enhanced when firing from an aircraft at another aircraft. Each day, Hayashi would visit the surgeon's room, listen to what he had to say, and spend the rest of the day calculating accuracy rates. When Hayashi was finished, the

surgeon, who was a lieutenant commander, took them to a joint Army-Navy aviation research group at the Naval Air Facility in Atsugi, introducing them as "Hayashi's theory."

Hayashi graduated from flying school in February 1943. Though he repeated his request to be sent to the front line, he was assigned to the Research Section of the Imperial Army Air Service Headquarters, General Affairs and Administrative Department. There he encountered the Remington Rand punch card system used for data tabulation. At the time, Hayashi knew only abstract mathematics and probability theory; he had no knowledge of data. This is where his trials began. It was his first step toward recognition as Chikio Hayashi, standard bearer for data science.

The Research Section followed a German model. A Japanese military officer returning from Germany had recommended that Japan establish a similar organization, and the Research Section was assembled with aviation staff officers and fixed-term technical commissioned officers with backgrounds in science and engineering. Hayashi was ordered to gather and organize information relating to the international situation as well as war tactics and strategy, but he was almost completely unable to understand his assignment, and was at a loss. He began by categorizing the flood of information and telegrams coming into the department by type. Once this task was complete, he would have to write a report. A colleague who later became a science journalist taught him how to express his thoughts in writing, concisely and quickly. He created a "Weekly Report" pamphlet with interesting articles about the international situation for

circulation to the entire Army Air Service. This experience taught him the art of organizing information, how to identify key points, and how to build a story around them.

His next challenge was forecasting. His first problem was to forecast Boeing B-29 production and the number of bombers likely to be used in attacks. He projected production rates by calculations based on large volumes of production technology-related information from aviation data and information in dispatches, and curve fitting using historical data. This forecast was later incorporated into plans for defending the Japanese main islands from air attacks. Hayashi had earned a place in the history of the war.

This experience taught Hayashi that data gathered correctly and processed carefully could be of great help in clarifying contentious issues. The experience was extremely eye-opening. Practicing techniques to identify the truth hidden in data could even defend the nation in a crisis. While such a realization seems obvious today, Japanese army officers of the time did not necessarily receive intellectual training; they depended on intuition acquired through military experience to guide their conduct. Hayashi's emphasis on the importance of data dates to this time, and was born from the huge volume of graphic situation reports sent from the front lines of the war. Moreover, he recorded the opinions he derived from the data relating to Japan's air defense strategy and submitted them to the General Staff Office. For these he received much praise, but due to opposition from senior staff officers, his recommendations were

not put in print; the officers did not like the idea of conferring such an honor upon the recommendations of an amateur in military operations. Afterward, Hayashi even thought that if his recommendations had been considered and put into practice, Japan would not have suffered such a terrible defeat. Perhaps it might even have been victorious; his confidence in the correctness of his opinions was that strong. That is how forcefully the raw reality of the data impacted his mind, and this impact remained with him for a long time.

The suicide attacks by Special Attack Unit aviators, which began in late 1944, were so shocking to the Allied forces that they naturally concluded that these aircraft were not piloted by men of flesh and blood, but by robots. For a human being to pilot a fighter plane without the intention of returning alive was suicide. This characteristically Japanese approach to war fighting became known outside Japan as "kamikaze attacks," and it caused much apprehension among Japan's foes.

Hayashi was ordered to carry out more calculations, this time regarding the success rate of the kamikaze strategy. As the young cadet developed the calculation techniques, data analysis, and methods to enhance the accuracy of the attacks, he must have felt a sense of sublime heroism.

And so it was that as a young man, Hayashi grappled with large data sets at the height of war, later creating his unique quantification theory. But without considerable spiritual strength, it would hardly have been surprising if Hayashi had fallen into war neurosis as a consequence of the way the war

consumed his youth, buried him in mountains of data, and forced him to take responsibility for life or death decisions. Instead, Hayashi used his experience as a springboard to hone an almost obdurate spiritual strength.

5. The life-and-death importance of data

People today would be very unlikely to suspect that the foundations of data science were formulated at the height of wartime. They would surely also be shocked to hear, as Hayashi was wont to say, that "from data comes gushers of blood." They might regard this as merely a figure of speech. But each piece of data he was handling was stained deeply with fresh blood and sweat. His paper commemorating his receiving the Medal of Honor with Purple Ribbon in 1981 was titled "Blood is Spilling from Data." The highly sensitive youth who immersed himself in music and reading and excelled at outdoor sports, especially sumo, surely never dreamed that he would soon find himself grappling with data from the front lines of the war, laboring night and day to uncover the truths held within.

6. Decision to become a mathematician

In 1945, with the end of the war, Hayashi returned to the Mathematics Department at the University of Tokyo. Once again, under Kakeya's tutelage, he embarked on probability theory research. Though Kakeya discouraged him from reading

the works of others, Hayashi immersed himself discretely in von Mises's probability theory and von Neumann's game theory, and was excited to see how von Mises's theory related to game theory and was utilized in economics. In the wake of Japan's defeat, the books Hayashi wanted to read had mostly been lost. This meant a series of frustrations for someone as naturally fond of books as he was, and when new books arrived, he hurried to the bookstore as fast as he could. He read all the magazines and books in the Mathematics Department, calculating that if he read 30 pages a day, he could read a thousand pages in a year; in fact, he outpaced his original plan, reading everything in the department in two years. Conditions in Japan were very unsettled at the time, and there were few books he wanted to read in the university's half-destroyed library. Again and again, he read the works of von Mises and von Neumann that had impressed him so much.

At the time of Japan's defeat, the Mathematics Department was holding colloquiums attended by a diverse group of professors who spoke on the latest developments in mathematics. At one of these gatherings, Kunihiko Kodaira gave a talk on John von Neumann and Andrei Kolmogorov's game theory. When Hayashi asked where Kodaira had found such an endlessly fascinating mathematical theory, he was referred to the American Cultural Center near Hibiya Park. Hayashi visited the center immediately, and eagerly read the books he found there in abundance. These books in the center were apparently intended for study by Japanese readers to promote America's

Soichi Kakeya, 1886-1947
(Tohoku University Archives)

democratization of Japan. Whatever the intention might be, Hayashi just devoured the latest mathematical theories available with bloodshot eyes. Today, with bookshops overflowing with books, Hayashi's situation is difficult for us to imagine. More than anything else, he craved knowledge. But Kakeya reproached him for that kind of moratorium, telling him sternly to go back to working on what was important.

The Mathematics Department colloquia, with numerous professors introducing a succession of new mathematical methodologies, gave Hayashi intellectual satisfaction unlike any he had experienced before. He found himself elevated above the realities of everyday life—a society in chaos from the war, with people desperately searching for food to purchase—to a "higher spiritual realm." He believed that his mission was to dare to give himself over to a non-ordinary world; this was how he could best contribute to helping a defeated Japan make a comeback. When Shizuo Kakutani, who had studied at Yale University, began to speak on topological analysis and demonstrated his grasp of the sense and essence of mathematical progress, Hayashi felt as though the scales had dropped from his eyes, and he felt the strength welling up from within to create some mathematical theory of his own. It was then that he decided to make mathematics his profession.

In October 1946, Hayashi joined the staff of the Institute of Statistical Mathematics (ISM) at the recommendation of Soichi Kakeya, who was then serving as the institute's director-general.

Hayashi would spend more than half his life at ISM. Even after he took over the helm there, he maintained a personal research room where he spent his days surrounded by data. He only used the tidy director-general's office to receive visitors, and to talk to research staff who visited him burdened with various human relations problems.

And so it was that through new data-related theories and techniques, Hayashi set forth on the tossing waves of a postwar society in a state of flux. He would move forward vigorously, fighting new battles for truth day by day while experiencing a number of important human encounters.

Chapter Two

The Thrill of Sampling Surveys

1. The National Literacy Survey

In 1948, in line with the US occupation policy, the order was given to conduct a nationwide survey of literacy in Japan. The American military authorities had a one-sided conviction that the Japanese language was difficult, in particular that the Japanese writing system, including Chinese characters, was a peculiar system that could only be understood by a limited segment of the population. The Americans estimated that only around half of the population was capable of writing and reading Chinese characters. Kikuo Nomoto of the National Institute for Japanese Language and Linguistics (NINJAL), later director of that institute, had just recently graduated from the department of Linguistics, Faculty of Literature of Tokyo Imperial University. According to Nomoto, the Americans believed that Japan's use of Chinese characters promoted cultural inequality, which in turn was a factor in the formation of a totalitarian state, and was considering the promotion of a more accessible writing system based on romanization. To test the fixed idea that script reform based on romanization would facilitate democratization, a national survey of literacy would be carried out, with the eventual intention of converting the writing system to Latin letters. Risaku Mutai (Tokyo University of Education) was chosen to head the survey committee, with Osamu Ishiguro (National Institute for Educational Research, NIER), Takeshi Shibata (NINJAL), Kazuo Shimazu (NIER), Kikuo Nomoto (NINJAL), and Chikio Hayashi (ISM) as members.

Around this time, the occupation's Civil Information and Educational Section (CIE) was based in the NHK Building in Uchisaiwaicho, Tokyo. American scholars in sociology and anthropology, schooled in American methods, directed the implementation of public opinion surveys. Everything was carried out according to American methodology. Those involved in public opinion surveys, including ISM researchers, visited CIE daily to study the fundamentals of social surveys.

CIE director John C. Pelzel was charged with overseeing the National Literacy Survey field work. The guidelines he formulated were known as "Pelzel's Constitution" and were treated as scripture. The survey was conducted in accordance with the guidelines, which reflected orthodox social survey methods. Hayashi was responsible for national sampling. With reference to ideas from the field of geography, Hayashi used stratified sampling with three strata. This survey, carried out in 1948, was the first postwar nationwide survey. The American researchers were impressed by the capability and dedication of the Japanese survey team members, which exceeded their expectations to a surprising degree. Many of the best of Japan's younger generation had perished in the war, making the responsibilities of those who survived that much heavier. The Japanese survey members worked fervently and gave their all, carrying out their tasks for the sake of the country.

The survey results were eye-opening. Illiteracy among the population was a very low 1.6%. This meant that the Japanese were far more proficient at reading and writing than the

Americans believed and as a result, the push for romanization was abandoned. The survey can truly be said to have been the salvation of the nation, averting as it did the destruction of the Japanese language. Hayashi, who had never been involved in such a survey, was bewitched by the allure of sampling. The sampling and social survey methods he used would be a precursor to those employed in public opinion and social surveys in Japan, and would become a model in the field. The National Literacy Survey remains a standard for social surveys today. Hayashi gained confidence in handling surveys; he was entranced by the allure of the data gathered, and by the way that surveys could extract meaning from raw data. Freed from the moratoria that were a feature of his student days, he had finally found a "man's life work" he could devote himself to.

It was at this time that Hayashi began to entertain doubts regarding Gaussian distribution (normal distribution) and the Neyman-Pearson statistical testing theory. The Neyman-Pearson standpoint was predicated on the Gaussian distribution, taking it as a basis for judgment. Where data fails to constitute a Gaussian distribution, large amounts of data are collected to more closely approach such a distribution. Hayashi considered this to represent a reversion to the ideas of A. Quetelet's era, because the more data he collected, the more he saw that the Gaussian distribution only applied to a limited portion of the data. Since most testing used the central limit theorem, a representative theorem of the Gaussian distribution, as a foundation, statistical hypothesis testing meant applying the ideas of the Gaussian

distribution. Though a wide variety of distributions had since been discovered, the weakness of statistics in that period was the way it truly harked back to a time when Quetelet's statistics was regarded as almighty.

After the National Literacy Survey, Hayashi next worked on a linguistic survey of Hachijo Island. This was a dialect survey, but what made it different from surveys until then was the way it considered the relationships between dialect, social background, and social circumstances. Though it reached the expected conclusions, the survey resulted in the development of invaluable methodologies that would help establish the foundations of modern social survey methodologies, including sampling, sampling survey strategies, and error evaluation.

From around this time, a large number of documents from international sources were becoming available in Japan. Among these was Methods of Operations Research (Morse & Kimball, 1946), a book that astonished Hayashi. The approaches it described closely resembled those Hayashi had employed during wartime; in particular, its analysis of data relating to suicide planes was virtually identical. Hayashi was becoming increasingly aware of the importance of data and data analysis. He sought to propagate widely the concepts of statistical mathematics, as opposed to mathematical statistics, and with his senior colleague Hiroshi Mizuno, he raised the banner of data centrism, a form of statistical mathematical supremacy. He criticized researchers who persisted in using mathematical statistics, and quarreled with them so heatedly that it seemed

as if they might come to blows. Statistical mathematics or mathematical statistics—it was one or the other, and Hayashi and his opponents were so determined to defend their ideas that they allowed no room whatsoever for compromise. In the wake of defeat, Japan would soon be fired with passion, its people working like bees in a feverish effort to rebuild the nation, and Hayashi was feverish as well, burning with ardour for what he termed "survey science." Together with Mizuno, he laid out a process for design, collection, organization and analysis of data and results, beginning with sample surveys and progressing to statistical mathematics, quantification, multidimensional data analysis, and finally revealing the hidden structure and understanding actual phenomena (natural, human, and social). Today, the general term for these techniques is known as data science. This is how Chikio Hayashi became a data science pioneer.

In Hayashi's view, there was nothing without data. His approach was to devise what was required for data acquisition design and analysis in accordance with concrete considerations: seek to discern the underlying philosophy and devise methods based on that philosophy. Rather than carry out so-called hypothesis testing, he was committed to seeking out the truth in the data and verifying it through investigative data analysis with a quality of hypothesis discovery. He adhered increasingly to a methodology that discovered hypotheses from data and explained phenomena inductively, rather than using the conventional scientific methodology of deducing hypotheses.

2. The first Japanese National Character Survey

Hayashi became known as a "conference crasher." Because he was extremely interested in the work of young researchers, he was usually to be found in the front row of any conference held by an association of which he was a member, arms folded and listening with great attention to the research presentations. And thanks to his fervent criticism of conventional statistics, he was shunned by almost everyone. It is a fact that Hayashi's tough academic criticism made him adversaries. "That Chikio" was regarded as a troublesome fellow, always finding fault, but he was convinced that stating his beliefs in no uncertain terms to a broad audience was the best way to advance the cause of science.

Hayashi opposed the idea that if obvious, common-sense conclusions were derived from data, that in itself indicated that the survey was carried out correctly. He was hostile to the American adherence to operationalism and behaviorism, in which hypotheses were formulated and then tested. His belief that hypotheses should be structured based on survey results never wavered, and he directly attacked the supremacy of statistical hypothesis testing. It was an era when public interest in surveys was increasing; the notion was pervasive that if sampling surveys could be carried out correctly and without error, everything relating to society could be grasped, and support for the idea that natural science was supreme gradually weakened. The 1950s can almost be said to have been an era

when social surveys ruled supreme, and much social survey technology was developed, but Hayashi was a step ahead, promoting survey science and opening the way for a new development that might be called survey philosophy.

In 1953, Hayashi decided that a large-scale survey of the Japanese national character was needed. Conflicting theories concerning Japanese national and cultural identity before, during, and after the war, loss of identity in the wake of defeat, a view of the Japanese as villains—these subjects were in play among Japan's intellectuals, and Hayashi sought to shed light on them. He recalled the "Imperial Rescript on Promotion of National Spirit," promulgated in 1923 at a time of widespread national demoralization, and he called his proposal "A Survey on National Spiritual Trends." Once the survey's budget was approved, he changed its name to "Japanese National Character Survey" to avoid misunderstanding. Since then, this survey has been conducted every five years, developing into a time-series survey and a major ISM project. Hayashi planned the sampling survey, devised the system for carrying it out, evaluated non-sampling errors, worked on probability methods for the questionnaire approach, and carried out a large-scale random-sampling pretest. The form he established for the questions, the lists, and other elements of the survey are in use today.

This survey was a comprehensive exercise in sample survey and social research methods, and along with the National Literacy Survey, became a reference for analyzing the attitudes of the Japanese people. It made it possible for the first time to

achieve a good understanding of who the Japanese people were. Hayashi eventually used these survey methods to carry out detailed research into international attitude comparisons.

Chapter Three

Journey to the Formation of Quantification Theory

1. Parole research

We have seen how wartime ballistics (research to enhance the predicted accuracy of reaching a target) as well as postwar social survey methodology and analytics underlay most of Chikio Hayashi's work. Another episode of importance began in 1947, when Katsuhiko Nishimura, a Ministry of Justice technical officer at the Training Institute for Correctional Personnel (later a professor at Aoyama Gakuin University), visited Hayashi to request that he analyze numerous factors relating to criminal behavior using statistical methodology.

At the time, criminal jurisprudence was divided into two factions regarding punishment methods: disciplinarians and educators. The former advocated reform through strict punishment, while the latter argued for an educational approach to behavior modification. Nishimura was a member of the educator faction. He had reviewed the data used by the disciplinarian faction and found it incomplete. Their analysis used simple calculations only, and was superficial and lacked analytical depth; the approach was rather unfair, even for criminals. It resembled the kind of coercive approach used to educate children in the dark ages, and was education in name only. For the disciplinarians, the crime determined the punishment; individual differences between offenders were irrelevant.

To reform the criminal, the education faction advocated granting parole once the offender had served a third of his

sentence. If he did not re-offend, he would remain free; if he re-offended, he would have to serve out the remainder of his sentence, with time added for the new offense. However, to protect society from harm, it would be necessary to forecast the likelihood of that criminals would re-offend after being paroled. This research would entail heavy responsibility and have to be approached very carefully. Hayashi's role would be to quantify, as much as possible, offenders' individual traits (including developmental and residential histories, family environment, social and psychological attitudes and values, and living, social, and work environments), attitudes toward the crime and the justice system, attitudes and behavior during incarceration, and so on. Based on the results, he would attempt to forecast the probability of a repeat offense as accurately as possible.

Yokohama Prison was chosen as the survey site, and Hayashi's days of commuting to the prison began. As he began to examine the inmates closely, he took notice of a man who was submissive and cheerful. Hayashi was puzzled; why was a person like this in prison, he asked. He discovered that the man was an inveterate repeat offender—dubbed "Prison Joe." In effect, the man had become so accustomed to prison life that as soon as he was released, he would commit another crime. Hayashi thus realized that there were many types of prisoners, and a single standard of measurement would not be applicable to all of them; the problem could therefore not be dealt with in the usual way. In a similar survey carried out in the United States, researchers actually lived in the prison to immerse themselves in

the specific environment, and Hayashi felt he would need to do the same thing—live in the prison to grasp the actual conditions from the same standpoint as the prisoners. But when he made this request to the head of ISM, he was told curtly that the idea was absurd. Hayashi was sure that if their positions had been reversed, he would have granted his enthusiastic researcher's request. Reluctantly, he continued his visits to the prison with Nishimura, and by conducting survey interviews from numerous angles, creating survey forms, and carrying out pretests, he managed to make progress, working diligently to provide useful forecasts of post-parole behavior.

2. Glimmers of quantification theory

Forecasts notwithstanding, there were only two possible outcomes: either the parolee would re-offend, or he would not. Using qualitative data—those who re-offend have these characteristics, while those who do not have those characteristics—Hayashi could calculate forecasting accuracy rates, but to do so, he would need to apply a scale to his qualitative data. The Likert scale is used in the field of psychology. In a simplified approach, reaction categories are scaled from –3 to +3, with 0 as the middle value; prisoners falling on the right (positive) side of the scale were categorized as likely to re-offend, while those on the left (negative) side of the scale were unlikely to do so. The result was a Gaussian distribution centered nearly at 0. Individual categories were

divided by frequency of occurrence, and the average value was used to judge the likelihood of re-offending. The approach was simple, with equal spacing between scale units.

But for Hayashi, who was allergic to Gaussian distributions, this sort of scaling was completely unacceptable. He was fed up with the way that the ghost of Quetelet had possessed statistical analysis in psychology. Such scales were useless; they made it impossible to measure deep truths. What was needed was to return to square one and consider the survey objective seriously, especially given the importance of accurate re-offense forecasting. The importance of raising forecasting accuracy in this case was no less than during wartime, when Hayashi had strived to increase the number of enemy aircraft shot down by even one. From that standpoint, becoming discouraged was not an option, and Hayashi rose to the occasion. He would assign numerical values to his qualitative data so that he could make statistical decisions by adding these values.

First, to carry out an analysis, he had to quantify his qualitative data. He employed the expression $\delta_i(j, k)$; when individual i reacted to category k in survey item j, the expression was assigned a value of 1. If there was no reaction, it was assigned a value of 0. For item category (content) k, he assigned sum X_{jk} ($k=1,\ldots,K_j$; $j=1,\ldots,R$). This is α_i ($i=1, \ldots N$). Using this procedure, for each of the groups with and without post-parole re-offense, it should be possible to calculate a distribution for α_i. If α_i is expressible as a one-dimensional quantity, one can assume that post-parole behavior can be explained one-

dimensionally. If the number of items R is large, it approaches a Gaussian distribution from the standpoint of the central limit theorem. Hayashi assumed that if the two distributions were separate, the forecasts would likely be correct, so he defined a single segmentation point and proposed that forecast accuracy P be maximized if those with an α_i value above the segmentation point were predicted to not re-offend, while those with a value below the segmentation point were predicted to re-offend. Thus, P becomes a metric (yardstick) for measuring forecasting success.

Around this time, John von Neumann's minimax decision theorem was published. Hayashi was surprised to see how closely this rule fit his own thinking; excited, he became confident about his own approach. Von Neumann's minimax theorem has been incorporated into game theory, and was later developed by Abraham Wald into a statistical decision theory.

Hayashi was now free of the Likert scale approach, and he pushed forward with his survey. But even when he had gathered his data and was ready to begin his calculations, he did not have the benefit of modern computers. There were only desktop hand-operated calculators, and calculating a 9 x 9 inverse matrix took two weeks to complete. Yet, though the process was time-consuming without the benefit of computers, which return answers instantly, manual calculation enabled Hayashi to understand the procedure in great detail, and strengthened his numerical calculation abilities. Looking

back, some would later say that ISM's capacity for numerical calculation may have been the best in the world. Working through each step personally gives rise to many ideas. Hayashi's concept of maximizing the square of the correlation ratio η, a foundation of quantification theory, was the result of a repeated, meticulous trial-and-error process of the same kind.

Once the work was complete, Hayashi saw many results that would never have been obtained with the Likert scale. He found that prisoners with both exemplary and very unsatisfactory behavior during incarceration could have high re-offense rates, while those who fell between these two groups had low re-offense rates. Those with whose responses to arrest and trial were neither exemplary nor negative and without special characteristics were the least likely to re-offend. These results had not been verified by previous mathematical calculations. Expected forecast accuracy P increased to 0.95. When Hayashi announced these results at a meeting of psychologists, one of the audience was so moved that he approached Hayashi and shook his hand. This was Juji Misumi, who would later become a noted authority in group dynamics. This young man, who would be one of the early supporters of quantification theory, was then an assistant at Kyushu University.

3. Encounter with Louis Guttman

Around the time Hayashi had completed his parole research—research relating to quantification theory—scale theory was becoming popular, and after telling Hajime Ikeuchi, who would later become director of the Institute of Journalism at the University of Tokyo, about his parole research, Hayashi and Ikeuchi became close friends. Ikeuchi recommended the newly proposed Guttman scale as being superior to the Likert scale.

The Guttman scale was the work of the mathematician and social scientist Louis Guttman. It is a measuring scale based on one-dimensionality and the fact that the items in the questionnaire are hierarchically related. If a positive answer by a respondent to a measurement attribute with high difficulty means positive responses by the respondent to all simpler attributes, one can create a response diagram called a scalogram, which can be used to perform scaling and derive coefficients of reproducibility.

From Ikeuchi, Hayashi also learned about Guttman's method for quantifying paired comparisons. Guttman developed this technique during research aimed at enhancing the satisfaction of American military personnel with the process of demobilization. Total years of service, years of overseas service, number of frontline postings, family status, number of children, and numerous other attributes were compared in pairs. Based on the results, the requirements for accelerated demobilization were identified. The method of assigning values to each attribute

Louis Guttman, 1916-1987
(New York Post Archives / The New York Post / Getty Images)

category was aimed at maximizing the distinction between soldiers to be demobilized rapidly and those to be demobilized slowly. The study's computational approach resembled Hayashi's quantification theory and the maximization of the correlation ratio in his parole research.

Hayashi sensed that Guttman was no ordinary person, and was a kindred spirit, regardless of the name attached to the approach, whether Guttman scale or facet theory. The name of quantification theory itself was inspired by Guttman, with input from Hayashi's mentors Mizuno and Ikeuchi. This was the birth of quantification theory.

4. Developing the theory

Hayashi had led the rebellion against mathematical statistics, and with Mizuno, he had refined the philosophy of statistical mathematics. Now it was time to go on the offensive. This was a conviction he had held since joining ISM, and with help from his powerful ally Mizuno, he proselytized for quantification theory and charted a proper course for data science. The success of quantification theory gave him confidence, and Mizuno's strong personality spurred him to action.

As Hayashi's confidence increased due to such factors as sampling theory, quantification theory that was optimal for qualitative analysis, and the theories' high rates of event forecasting accuracy, he maintained that the centerpiece of statistical mathematics was the analysis of human behaviors,

taking a position that compared to hard mathematical methods, soft methods were more suited to and useful in the analysis of phenomena. His discussions with Ikeuchi as well as Mizuno were bearing fruit.

Hayashi's fundamental notion was that quantity was not inherent to things themselves; instead, it was a tool given to us to do science. In this, his philosophical ideas resembled those of David Hume, the British philosopher who perfected Empiricism; and when Hajime Ikeuchi pointed this out to him, Hayashi read Hume's A Treatise of Human Nature and found himself so much in sympathy with it that henceforth he kept the book close at hand for frequent reference. Equipped with this fundamental concept, the way forward, which until now had been obscured, became plain as day.

Hayashi's philosophical essence was British-style statistical mathematics with Empiricism as its core, and it traced its lineage in the history of statistics less to the German Staatenkunde than to the British Political Arithmetic school. Like the tabula rasa of the British philosopher John Locke, the father of Empiricism, our minds are blank slates, devoid of innate ideas; the source of our ideas is purely experience. We can only perceive things and process that experience. Hayashi's thinking was similar to this philosophical concept. In his case, experience meant data, and social phenomena and the human mind could be understood from data.

Hayashi soon became involved in the field of psychology. In 1955, the Research Society for Quantification in Psychology

was launched under the guidance of Prof. Sadaji Takagi, the head of the University of Tokyo's Department of Psychology.

In addition to standard psychological research in such areas as perception (awareness), learning, and memory, the society conducted research in social psychology and other areas of applied psychology. Takashi Ogawa (psychology of learning, Keio University) served as chairman, and members included Hajime Ikeuchi (social psychology, Institute of Journalism, University of Tokyo), Taisuke Mizuhara (social psychology, Ochanomizu University), Katsuo Sano (cognitive psychology, Keio University), Shunsuke Oshio (cognitive psychology, Tokyo Metropolitan University), Taro Indo (mathematical psychology, Keio University), Yoshitaka Umeoka (mathematical psychology, University of Tokyo), and Chikio Hayashi (statistics, ISM).

In addition, a number of University of Tokyo assistant professors and teaching assistants associated with Sadaji Takagi took part, and the society investigated attitude measurement, scaling and other quantification theory methods. It was through the society that Hayashi encountered Sociometry theory (developed by Jacob L. Moreno and Helen Hall Jennings), which would later become the point of departure for development of the e_{ij}-type quantification method for the National Railway lineman survey. e_{ij} represents the relationship between i and j. This method later developed into the method generally known as quantification method Type IV; even later, the e_{ijk}-type quantification method would be proposed from a changed standpoint.

The society's findings were published in 1955 as Research on Quantification Theory in Psychology (edited by Sadaji Takagi). The preface was extremely interesting; it was penned jointly by Umeoka, Indo, Ikeuchi, and Hayashi, who stated that during their meeting to discuss the text, they found it difficult to agree on an approach. This was because social psychology tends to avoid the hypothetico-deductive methods employed in most perception experiments; properly, phenomena to be investigated are derived inductively from the data. It was only after Umeoka moved to Hokkaido University that the others were finally able to arrive at a decision that psychology research should not emphasize hypothetico-deductive methods but experimentum crucis, that is, repeating experiments and surveys, and while gathering data, analyzing it inductively while discerning the essence of phenomena.

The society conducted a survey of dormitory residents at Japan Women's University. The survey divided the students into two groups—those who preferred French culture and those preferring American culture—and sought to discover characteristics that distinguished them. Today, this approach would be referred to as Quantification Method Type II; it has become routine for categories with external benchmarks. At the time, there was a fixed view that the external benchmark was present/absent. The terminology of Quantification Method Types I to IV dates to 1964 and originated with Hiroshi Akuto (University of Tokyo); it has since become established.

5. The computer era

In 1955, Tatsujiro Sasaki was ISM director-general. Before and during the war, he had been associated with the Aeronautical Research Institute at Tokyo Imperial University, where he had been an aeronautical instruments specialist and a leader in engineering mathematics. Sasaki was also deeply interested in calculators, and before the war he had been building analog devices for such tasks as solving differential equations. He subsequently continued to stress the importance of calculators and had a strong interest in their development.

In an era without automated calculation, computations involved a tremendous amount of effort. Hayashi asked his subordinate, Masatsugu Ishida, to identify a suitable equipment manufacturer, and finally Fujitsu agreed to build a computer. The resulting machine was able to perform computations only slightly faster than they could be done by hand.

Sasaki saw data analysis as critical, and agreed with the views of Mizuno and Hayashi regarding statistical theory. He also shared Hayashi's doubts about Gaussian distributions, and resembled both Mizuno and Hayashi in his tendency to speak bluntly. He valued experiment over theory, and pointed to the dangers of relying on hypothetico-deductive methods. Moreover, this was a time when ISM continued to be divided by the debate—which amounted to an ideological conflict—within statistics ("statistical mathematics" vs. "mathematical statistics"). Seeking to resolve this conflict, Sasaki appointed

himself referee, and pitted his people against each other in a debate that lasted for three days and nights. The losers had to leave ISM.

Through this process, the institute's direction was unified around the importance of data, and the union of computers and statistical mathematics was promoted. The first relay computer was named FACOM 100 and designed to calculate correlation coefficients. This computer was completed in 1954. Fujitsu's next computer, delivered to ISM in 1956, was the FACOM 128A (also known as the TSK general-purpose relay computer). These and many other computers were designed by Fujitsu's Toshio Ikeda, a pioneer in Japanese computer development.

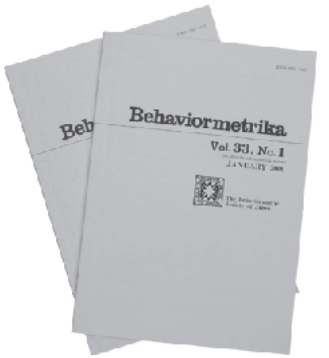
With the delivery of the FACOM 128A, quantification theory calculations became significantly easier, facilitating detailed research into a wide range of phenomena, including election forecasting. With each election, Hayashi became absorbed in projecting the election chances of each candidate based on historical data. The work was thrilling, and the opinion poll section at The Asahi Shimbun was a hotbed of excitement. The editor-in-chief was also passionately involved. No one went as far as setting up an election betting pool, but everyone was on tenterhooks to see what the results of the forecast would be. In the 1960s, there was a strong impression that public-opinion polling methods produced accurate forecasts. Before an election, everyone at ISM was in a festive mood, and getting work done was difficult.

Hayashi had a friend named Ichiro Saito, who worked in the research department of the Bank of Tokyo. Saito enjoyed data analysis and doubled as the director of the Economic Dynamics Research Committee. Saito introduced Hayashi to a rather unusual friend named Keinosuke Sato, who taught at Musashino Art University.

Sato possessed an extremely insightful sensibility and awareness. He and Hayashi must have gotten on quite well from the outset, because he often stayed over at Hayashi's house in Mitakadai, Tokyo, though Hayashi had only recently married. There Sato would sketch, listen to records, and spend time relaxing. Around this time, Hayashi was writing poems in the style of Valéry, and he would discuss poetics and literature with Sato. One day Sato said to him, "I'm designing a product label, but it's proving to be a challenge. What sort of Japanese design do you think would work overseas?" Foreign images of Japan tended toward Mt. Fuji and geisha, which Sato wanted to avoid, but the client insisted that both to be included in the label for export purposes. Sato wanted to know if there was any way he could demonstrate that the client's preference was an indication of poor taste. Hayashi's reply was that data relating to preferences for a wide range of product labels did in fact exist.

Hayashi consulted the data, and after pondering the problem, it occurred to him that label preferences could be plotted along a diagonal line. Sato was impressed with this idea and immediately set about working on the calculations. This was the beginning of Quantification Method Type III (1956). This

The title logo of the newsletter "Behaviormetrics Newsletter", Japanese calligraphy by Chikio Hayashi (1973).
(行動計量学会報)



Cover image of "Behaviormetrika".

Logo of the Behaviormetric Society of Japan. Design by Keinosuke Sato (1973).
K . Sato was a professor of Musashino Art University.

method quantified simultaneous classification based on personal choice patterns. This approach produced good results when fed into the relay computer, and Sato was elated. (The logo for Behaviormetrika, the Behaviormetric Society's English-language journal, is also the work of Keinosuke Sato.)

6. Raising concerns about statistical mathematics in medicine

Around this time, the development of computers was driving their increased use in medical diagnostics. Medical practitioners, whose original purpose was to diagnose and cure disease, were treating the suffering individuals before them as objects of observation, and diagnosis was carried out using scientific methods. Motosaburo Masuyama's theories on inferential statistics *Shosurei no matomekata to jikken keikaku no tatekata* (How to organize limited-case examples and plan experiments) dominated the field of medical statistics, and much data analysis on the medical frontline was carried out with reliance on his work. This infuriated Hayashi, who asserted that limited-case methods for analyzing patient data were outrageous (Hayashi 1973, 1977), and furthermore that treating patients as objects could lead to unforeseen errors. In a sense, the approach involved major hidden dangers, and considerable risk of departing from the true path of medicine. Today, patient-centered medicine is practiced, but at the time, individual patient differences were hardly taken into consideration in medical treatment.

The majority of medical statistical models did not fully treat reaction and question response statistical errors. For example, a certain drug is developed and is said to be effective against a given disease. However, while the drug may be effective in specific patients with specific characteristics, it may not be effective with patients having different characteristics. Why? Because the new drug was aimed at patients with specific characteristics, and the differences between those patients and other patients was treated as a statistical error. In response, Hayashi developed a response error model to enhance the effectiveness of new drugs. The model aimed at identifying patients who had been treated as statistical errors. In a sense, implementing the model required considerable time. The same patient had to be tested repeatedly. This yielded a probability that the drug would be effective on the same patient in the next trial. That probability became the key to forecasting the patient's reaction on the next trial.

The same approach applies to public opinion surveys. One asks the same person the same survey question a second time and measures the distance between responses. The idea is to weight the survey with the resulting Bayesian probability (subjective probability) to obtain a closer approach to the true value. If a patient is administered a new drug every other week and fails to respond, the difference between that patient and those who do respond to the drug will become apparent. This will make the patient's personal variation clear, and may also reveal disease etiology in patients who had been treated as

statistical errors. The problem of individual variation between patients later became an important challenge for Hayashi.

Furthermore, having extended quantification theory to market research, Hayashi applied it to the field of medicine, first in joint research with Eiichi Kimura (Cardiology Department, Electrocardiography (ECG) Research) of Nippon Medical School. The impetus was research Hayashi carried out with Satoki Ninomija (later Professor Emeritus, Aoyama Gakuin University), a member of ISM Research Dept. II, regarding automated ECG measurement. Ninomija asked Hayashi to help him with an inquiry from Kimura regarding what could be discerned statistically from ECG wave shapes, and this led Hayashi to become acquainted with Kimura. After that, Hayashi delegated most of his physical exams to Kimura and his students.

Today, Quality of Life (QOL) is routinely taken into consideration in medical treatment. When Hayashi was doing his research, QOL was not considered at all; today, most large urban hospitals emphasize QOL and patient-centered care. From the perspective of modern medicine, which takes into account the whole person and individual factors when making treatment decisions, medicine at that time was very different. In Hayashi's view, it was extremely dangerous to attempt to understand complex phenomena using theory; complex phenomena must be grasped through data. In 1965, when Hayashi underwent surgery for glaucoma, he experienced that danger personally.

The journey to quantification theory bears the continuous

traces of Hayashi's unshakable conviction and intellectual philosophy, which was always in sharp focus. His stance toward the correct gathering of survey data was stringent and uncompromising. But today, survey data collection has undergone a sea change from Hayashi's era; the excessive regard for personal privacy means surveys cannot be carried out easily. Nevertheless, society is drowning in data. How can methodologies be developed to make Big Data more intelligent? How can the identification of essential aspects of data be optimized to analyze phenomena from data? And how can diverse forms of wisdom be harnessed to extract real data from raw data? Many challenges remain. For Hayashi, grappling with such challenges was a lifelong endeavor.

Chapter Four

Marketing Research and the Multidimensional Analysis Research Group

1. Marketing research efforts

Around 1953, Masao Okemoto of the Asahi Shimbun newspaper's advertising department visited ISM and asked Chikio Hayashi for help in researching how to optimize advertising costs and effectiveness using operations research (OR) methods. OR originated as a tool for military planning, and Hayashi's wartime efforts to enhance the accuracy of attacks on B-29s through data analysis was pure OR. This technique was now to be used to maximize the effectiveness of advertising spending—in effect, to maximize the effectiveness of spending on marketing research.

The Asahi's ad department was very interested in book advertising. It was decided to divide their subscribers into book lovers and non-book lovers and use Quantification Method Type II for the analysis. This was the first example of quantification analysis methods being used in the field of marketing. Moreover, quantification would be used to forecast readership scores for newspaper ads. Takayoshi Murayama, who had been with the paper for less than two years, was assigned to work with Hayashi. Hayashi called his analytic results "factor analysis," though it was actually Quantification Method Type I.

Hayashi worked extensively with Murayama, and in 1964 they co-authored an account of their data adventures, published by the Nikkan Kogyo Shimbun newspaper, titled *Shijo-chosa no keikaku to jissai* (Market survey planning and practice). This was Hayashi's first description of quantification theory

in print, and the book was read widely, not only by marketing professionals. Hayashi was surprised to see researchers in other fields walking around with a copy. As a result, quantification theory made inroads into marketing and related fields, and Hayashi was struck by the widespread hunger to learn more about data analysis methods.

Japan at the time was pouring effort into developing new products, and quantification methods were essential for market surveys. Word spread that Chikio Hayashi from ISM was playing a key role in forecasting potential demand for new products, and requests for help poured in—not only for market surveys, but often in the field of medical research as well.

2. Program rating projections

With the widespread adoption of television, there was a need to forecast program viewership. The methods used to survey and analyze viewership resembled newspaper ad factor analysis. But with television, there was also a need for detailed program content analysis. Also important was the program broadcast. Meiko Sugiyama of NHK's Broadcasting Culture Research Institute was working on this problem. Sugiyama was an enthusiastic convert to quantification theory, and was using it in her analysis. In the early 1960s, she had used Quantification Method Type III to analyze radio program preferences, but gradually she moved into TV program analysis. Her approach involved taking a viewership survey from a particular point in

time and establishing the relationship between factor patterns and ratings. When a new program was broadcast, the projected and actual ratings matched.

Around this time Jun'ichi Komiya, manager of the advertising department at Morinaga, the confectionery manufacturer, was on edge about the ratings of a television program his company was sponsoring. Today, the usual practice is for multiple companies to sponsor a single program, to distribute ad investment risk. But in those days, advertisers felt they should not share their sponsorship, and most programs had a single sponsor. If the program failed to attract viewers, the reputation of the company's advertising department would suffer. As such, there was much more at stake for advertisers than there is today when deciding whether or not to sponsor a new program. Komiya had already gotten Hayashi's consent to use his "sensibility quantification theory" to project program ratings, and the effort had been successful. Hayashi willingly agreed to advise Komiya, and Morinaga continues to use sensibility quantification theory today. The ratings forecasts yielded by the theory have maintained the advertising department's reputation and helped the company maintain its market leadership.

NHK and Morinaga obtained good results from quantification theory, but it was not necessarily the case that companies in every industry understood what they were doing when they used quantification theory to forecast program ratings. In Hayashi's view, the marketing research carried out by people in the advertising industry, people who were uniformly unable to fully

grasp quantification theory and lacked the vision to anticipate the future, was a complete waste of time. That was how shallow their knowledge was when it came to analyzing data of research subjects. Marketing research conducted under such conditions was utterly pointless. As long as no thought was given to the organizational structures needed in order for marketing research to shape management strategy, the effectiveness of such research would be extremely limited.

Looking back on his war experience, it seemed to Hayashi that the military was better organized. The Imperial Army General Staff Office consisted of three departments, with the first handling organization and strategy, the second responsible for information gathering, and the third covering intelligence. Everyone recognized the importance of the liaison representatives who circulated between departments. Although the Office was divided into three departments, officers kept abreast of the situation in other departments through these liaison representatives. The officers in each department listened to their representatives carefully, which enable them to participate in strategy from a shared perspective. But marketing research was not carried out within corporate structures having the same level of commitment. A large company like Dentsu had some very capable people, but it simply lacked enough individuals who were familiar with the kind of surveys and data analysis that Hayashi was aiming for. As such, the required survey systems had to be put in place.

Consequently, survey companies sprang up like mushrooms

after rain—marketing research institutes, research associations, research service providers. These new players were not directly connected to Dentsu or university research units. They were established as the need arose, reflecting the prevailing need for social surveys.

In 1985, at age 67, Hayashi became chairman of the Japan Association for Public Opinion Research. In those early days, university professors conducting joint research projects with Dentsu would send their graduate students to learn on the front lines by participating in research at Dentsu. However, for the students, such work was generally a way to make a bit of money; a student participant might not visit all the households he was assigned to survey, but instead would spend the time in a coffee shop, filling out a stack of surveys himself. When Dentsu's marketing survey team discovered what was happening, they realized they needed rigorous survey methods, and they began visiting ISM on a daily basis.

The rapid propagation of television convinced Dentsu that ratings were important, and they established Video Research. To carry out field surveys, they established another subsidiary, Dentsu Research. (This company would later absorb Dentsu Institute, becoming Dentsu Marketing Insight. In the years that followed, Dentsu would navigate successive turbulent eras, building headquarters in Tokyo's Ginza and Tsukiji. Today, they are based in a massive main office in Shiodome, and are involved in a wide range of marketing industry fields.)

Video Research's challenges included sample design for

ratings surveys, data collection, sample secrecy, data analysis, and the presence of multiple TVs in the home. As they addressed these challenges, Hayashi carried out extensive data analysis at Dentsu and propagated his views. Computers were advancing and spreading quantification methods, market surveys were becoming more sophisticated, and market research-related departments and their research were strengthening. Moreover, there was prevailing dependence on American survey methods. But Hayashi was becoming convinced of the need to develop new, Japanese-style survey methods, to research their effectiveness, and to use those results to carry out a new Japanese National Character Survey.

3. The frontline perspective

When launching a new product, one needs to prepare for the possibility that someday the product will cease to sell, even if it is initially successful. Hayashi visualized this reality in terms of victory or defeat—that is, in terms of armed conflict. During the war, he had been part of what was in effect an operations research unit. There he had dealt with a frustrating amount of news of defeat. When he was consulted by Dentsu's marketing department, he felt as if he were listening to bad news from the front. The process resembled the wartime situation to a surprising degree. In his mind, present and past always seemed to overlap.

Dealing effectively with defeat is extremely important, but

the Japanese spare little thought for it. Such a view strikes them as defeatist and bad for business, and generally they refuse to discuss it. In particular, given the Japanese temperament and their tendency to be influenced easily by prevailing moods, talk of defeat can bring it about, and thus they have a strong tendency to avoid such talk. Because of this, when corporations fall on hard times, much is demanded of those in the company who deal in information. If measures are taken before the situation is serious, problems can be averted. If those responsible for gathering information devote all their efforts to detecting indicators and judging situations, there is much scope for them to act. But once the situation has turned negative, only drastic measures will serve—measures that are beyond their capacity to carry out.

When conditions are favorable, everything goes well, regardless of how marketing is handled. When conditions call for being aggressive, one must be aggressive, but with the understanding that at some point, one will be forced to go on the defensive. Marketing is needed that can discern when that time has come, and can deal with it. This makes it important to detect indications of the change. Then, while conditions remain favorable, one must judge what factors contributed to the success, what actions were taken based on information, and what actions need to be taken now, before they become necessary.

Similarly, during the war, it was important to understand the differences between command structures in Japan and

America. In the case of Japan, the higher the authority, the more commands from that authority tended to be motivational exhortations lacking in specifics. The assumption was that based on the stated general principles, detailed commands would be worked out at lower levels and issued as needed, but the subordinate organizations lacked sufficient personnel capable of this.

When the product is a hit, aggressive marketing can have explosive success. But as the product loses popularity, subordinates are unable to mount a response. Motivational exhortations may come from above to save the situation, but the front line lacks the needed training; they retreat and become progressively weaker as they go down the path to destruction. In America, if every military detail is planned at the top, then subordinates follow the blueprints laid out for them. This strategy is very effective when conditions are unfavorable. One can take the larger perspective, ignore individual frontline aspects, determine a line to retreat to, carry out the retreat, and from there, counterattack to regain lost ground. The exact same path can be taken in management.

In Japan, as noted by Hayashi, the view from the front line is given priority. In the military, no one will listen to anything said by a pale, soft officer unburnt by the sun. The frontline fanatic is a difficult problem in the military as well as in the enterprise. An officer or leader defeated on the field is given a position of importance in view of his frontline experience. This makes him very hard to deal with; he can’t make comprehensive moves,

and the situation gradually deteriorates. Hayashi repeatedly asserted that the same problem continued to plague Japan.

Hayashi mocked the Japanese tendency to think one can understand a situation with extensive exposure to different frontlines. The frontline is important. However, a correct view does not encompass only the intuitive sense one acquires from experiencing a wide range of situations. It also demands considerable scientific expertise. Effecting this change in awareness and belief cannot be accomplished overnight. From an early stage in education, one must cultivate a generalized stance that favors not only beliefs, but taking up and actually looking closely at the real thing, too and absorb something from it. Primary education that creates a craving, welling up from within, to absorbing knowledge is manifestly necessary.

4. The Multidimensional Analysis Research Group

The Multidimensional Analysis Research Group was formed at ISM in 1972, led by Chikio Hayashi and Hiroshi Akuto. The group was fortunate to receive a grant-in-aid for scientific research from the Ministry of Education, Science, Sports and Culture, and as the members debated their first object of research, it was decided to tackle a theme no one had worked on before. This was the start of the “bogey” (Japanese: *obake*) survey. It would attempt to examine and analyze not only bogeys in the narrow sense—evil spirits, ghosts and so on—but also UFO, water sprites, the abominable snowman, the Loch

Ness Monster, supernatural abilities, etc. using multidimensional scales.

Originally, Multivariate Analysis had been used extensively in the field of mathematical statistics. In opposition to this, ISM was using Multidimensional Analysis methods. While the former is a method for analyzing quantitative data multidimensionally, the latter is a method for analyzing qualitative data that is quantified, also multidimensionally. Moreover, this method resembled Guttman’s Smallest Space Analysis (SSA) approach. In response to SSA, Hayashi devised a method of analysis he called Minimum Dimension Analysis (MDA). The similarity of these method names is tricky, but in the next section we will delineate and compare SSA and MDA.

[A] Minimum dimension analysis

MDA is a multidimensional scaling method devised to discern the essence of diverse phenomena, consisting of multiple events, by discarding the elements of those events considered to be unnecessary, in order to characterize the phenomena in terms of the smallest number of variables. That is, the method summarizes phenomena that contain complex foreign elements and uses Occam's Razor (parsimony) extensively to express phenomena succinctly. Since the advent of multivariate statistical analysis, the Minimum Dimension concept, due to the nature of the analytical method, should have been used frequently, and have been a focus of debate.

However, the concept has been insufficiently debated since it was first introduced, and for the most part has been limited to such explanatory concepts as the central challenges of reducing dimensionality, minimum dimensionality, and data reduction.

For example, techniques such as factor analysis simplify complicated data sets, making them easier to understand. They seek to express data as two- or three-dimensional plane surfaces. This sort of spatial expression generally is limited to two-dimensions. Nevertheless, the data is not fully explained in two dimensions. There are as many dimensions as there are variables; these are not mathematical dimensions, but simply empirical class divisions, with the aim of categorizing many variables as efficiently as possible. The basis for ordination is to group things with high mutual correlation, or things that are highly similar, to compare the bases for classification, and to interpret the dimension. Among the variable "items" will be many that have deep mutual relationships, and through ordination, the number of variables required to explain the phenomenon under examination should be reduced. Mutual relationships between variables are considered, and variables are separated into classes to explain phenomena using the fewest possible variables. If group partitioning can be performed beforehand, it may be possible to eliminate this effort, but for most complex phenomena, this is seldom possible. Instead, one must rely on analytic methods such as factor analysis in attempting to elucidate phenomena.

[B] Nonmetric MDS

After Warren S. Torgerson introduced the method of metric multidimensional scaling (MDS), Roger Newland Shepard developed non-metric MDS (nMDS), which can be considered a general solution. As an analytic method for finding minimum dimensions under relatively non-restrictive conditions, it opened the way to MDS in general. As a method, it is somewhat richer in conciseness than factor analysis and Torgerson-style MDS. A target function (normally monotonic) that can maintain a certain minimum dimension is defined; beginning with one dimension and proceeding to higher dimensions, conditions applying to each dimension are considered, with the goal of resolving within about three dimensions. If three dimensions are insufficient, one begins again using trial and error, selecting variables and cross-tabulating to consider such factors as interaction between variables. The approach of Joseph Bernard Kruskal who organized the algorithms used in Shepard's method, begins with more dimensions (typically three) and proceeds by successively reducing the number of dimensions while examining conditions of fit.

With Shepard-Kruskal nMDS, the outlook is meager when one analyzes data that is seemingly complex unless the nature of the data is expected to be clear. Further, where detailed projections for a phenomenon are established from the outset, the results will often be just what one would expect. The reason for this is that the assignment of initial values is a

rather mechanical task that effectively disregards the nature of data itself (Shepard uses vertex coordinates of a regular simplex in which the mutual distance between two points will all be the same value; Kruskal uses all random values), and may not necessarily be compatible with that data. One iterates forcibly and repeatedly to obtain the minimum dimension—and somehow, a result—without assurance that the result will be reasonable. This is where the problem of data reproducibility becomes serious. Furthermore, attempting to explain everything in three-dimensional space means fixing the number of dimensions in advance; the applicable data must therefore meet the prerequisites for resolution in three dimensions. There is thus little possibility that the method would be suitable for things like complex social phenomena.

[C] SSA and MDA

Louis Guttman's SSA and Chikio Hayashi's MDA were revolutionary responses to these challenges in the way they handled assignment of initial values; values were selected to reflect faithfully the nature of the data. To take the nature of the data fully into account beforehand, SSA used facet design to consider data deployment structures and define the factors. For some data, one approach or the other (SSA or MDA) may be effective; it is necessary to consider and analyze the characteristics of the data. Regardless of the superiority of the analytic method, the diversity of social data requires an acute

ability to discern how the suitability of the method depends on the nature of the data. Today, in an era awash in complex data, it is especially important to be fully aware of this; and it is most important to eliminate pervasive data errors, such as measurement error and response error due to response (answers) and non-response. These processes are indispensable for analyzing data scientifically. The divergence between raw data and true data is an eternal challenge. It is natural to look for an analytic method that streamlines and simplifies complicated data, but one must also evaluate the simplified data carefully to determine whether or not it is also the true data, because the true data may be hidden in the raw, impure data that was discarded.

SSA manipulates facet dimensions to order the data, fully taking individual differences into account. MDA partitions groups so as to minimize response error. Around the time MDS, which considered individual differences, was at the peak of its popularity, Guttman's method, and that of Ledyard R. Tucker of the University of Illinois, were widely used. Today, this type of MDS has fallen out of favor. In surveys and experimentation, an emphasis on simplification seems to have become the norm.

Hayashi's MDA was named with a nod to Guttman's SSA. In Hayashi's development of quantification theory, his most pressing task was to verify the so-called KL-type quantification method (based on the computational procedure idea that extends the dimensions). Since the appropriateness of the successive-approximation method, as well as the goal of identifying the

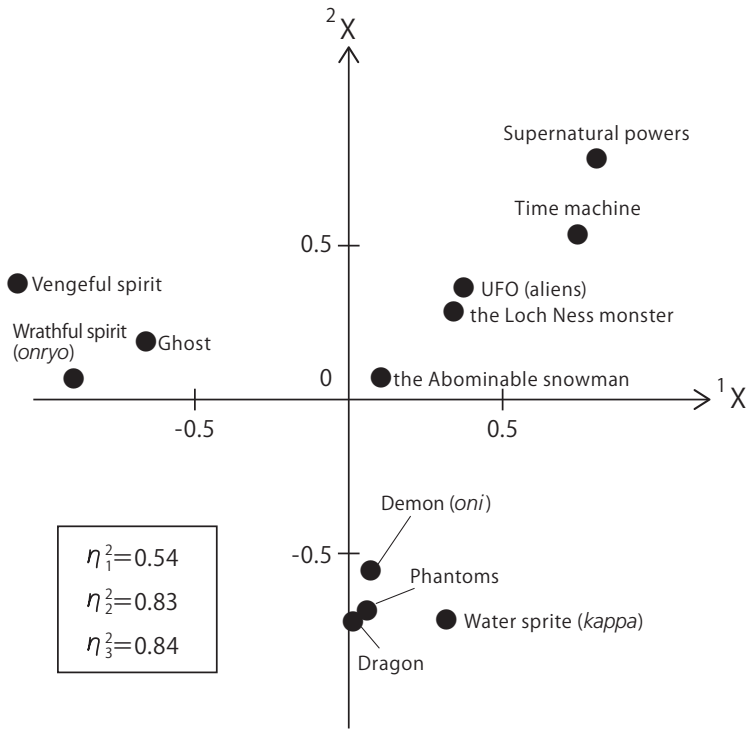


Figure 1

Analysis of bogeys.
Three groups can be seen there.

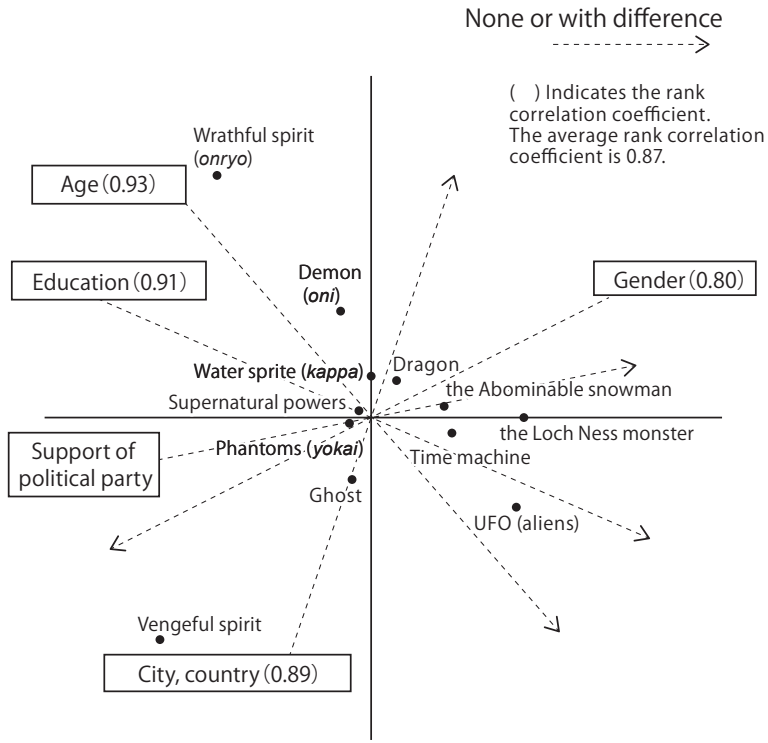


Figure 2

Items, attributes, and relationships.

fewest number of dimensions, were clear, it was when Hayashi was verifying his method by comparing it with Guttman's SSA that he first used the name "MDA." However, because of the nature of the KL-type quantification method as an analytical technique, the limiting terms are stringent, and the method could be said to be more metric than non-metric, or perhaps semi-metric. It therefore has the disadvantage of only being applicable when the data is clearly organized or the number of variables is small. In that sense, one can consider MDA to be a generalized form of the KL-type quantification method. Minimum Dimension Analysis of ordered class belonging (MDA-OR), MDA of unordered class belonging (MDA-UO), and other analytical methods were developed successively, but because they can only be applied to simple, limited data, development of future MDA methods remains a challenge.

[D] The "bogey" survey

In 1976, the so-called "bogey" survey, a research to investigate the foundations of the Japanese national attitude, was finally carried out. The survey was conducted in two locations: Tokyo Metropolis and Yonezawa City in Yamagata Prefecture. The degree of awareness of bogeys was somewhat higher in Yonezawa, but the regional difference was not marked.

Bogeys (mysterious or unexplained objects) were organized into twelve items: the Abominable Snowman (*yukio*), the Loch Ness Monster (Nessy), UFO (aliens), ghosts (*yurei*),

water sprites (*kappa*), phantoms (*yokai*), supernatural powers, vengeful spirits, wrathful spirit (*onryo*), time travelers, dragons, and demons (*oni*).

Since each item could return one of eight different responses, the survey took a long time to conduct, but the subjects found the content interesting. Response categories were: "Do they exist?" (Yes, No); "Do you hope they exist?" (Yes, No); and "[What is your] subjective reaction?" (Afraid, Interested, Uninterested, etc.). The same survey was carried out in 1976 and 1978. The survey also asked about beliefs and awareness of beliefs, specific religious practices, degree of religiousness, daily life customs, conventions, knowledge of the survey items, importance of superstitions, importance of omens, confidence in the existence of bogeys, use of amulets, supernatural phenomena, fortune-telling, use of folk remedies, etc. Details can be found in *Tajigenshakudo kaisekiho—sono yukosei to mondaiten* (Multidimensional scaling analysis methods: effectiveness and challenges) (Saiensu-sha, 1976), and *Tajigenshakudo kaiseki no jissai* (The facts about multidimensional scaling analysis) (Saiensu-sha, 1984). Both titles were edited by Chikio Hayashi and Hiroshi Akuto.

Let us look at the results and consider what the Japanese think about superstitions. It is generally thought that belief in superstition reflects a lack of education. But the survey revealed that the more education a person had, the more superstitious they tended to be. In a sense, the higher the educational background, the less scientific the person's views. In particular,

awareness was high for telekinesis, time travelers, UFOs, the Loch Ness Monster, and the Abominable Snowman.

Even after the survey, Hayashi maintained an interest in supernatural phenomena. He conveyed his thoughts about bogeys in many newspapers and magazines, including the Asahi Shimbun and Surikagaku. Citing Torahiko Terada's essays on monsters, goblins, and ghosts, on uncanny phenomena and bogey evolution, Hayashi argued that some aspects of phenomena, which would seem somewhat rational on the surface, could only be regarded as irrational, and such supernatural phenomena would probably be proven scientifically at some point in the far future. The excellence of the human intellect, Hayashi said, was due to the passion for thorough inquiry, driven by curiosity and the thirst to uncover the unknown.

Torahiko Terada believed that there was something in the human mind called the Old Layer. When triggered, this unconscious component could affect human behavior. In psychological terms, it is typically referred to as the collective unconscious. It causes people to act in incomprehensible ways, creating a world of irrational phenomena that people are compelled to regard as mysteries. This irrational world is an ever-present element of the individual's mind. This primitive world, cultivated over tens of thousands of years through genetic transmission, is the Old Layer, inherited over generations. If it suddenly manifests, operating in unexpected, unconscious ways, there is little room for the law of cause and effect. These

phenomena cannot be accounted for in distinct data, and are simply factored out. It occurred to Hayashi from time to time that if this precious, "irradiated" portion of the data was being ignored, elements required to arrive at true values might be in this discarded data. This sensibility seems to underlie Hayashi's passion for a response error model that would return true values.

Is this primitive, irrational mind something we can simply laugh at and ignore? Hayashi's desire to analyze the existence of "quasi-cause and -effect factors" with multidimensional scaling may have arisen from this murmur deep in the heart.

"My hope is that data science will contribute to the development of a science liberated from the curse of cause and effect, one that through investigation can enhance individual wisdom and broaden individual knowledge while dealing with complicated, ill-defined phenomena." (Chikio Hayashi, *Deeta no kagaku* [Data science], Asakura Publishing Co., 2001.)

Chapter Five

Founding the Behaviormetric Society

1. Measuring human behavior

In January 1947, less than a month after Chikio Hayashi joined ISM, Soichi Kakeya died. Kakeya had been Hayashi's university supervisor and, as the director-general of ISM, his immediate superior. Kakeya had also been serving as chairman of the National Research Council of Japan, and had continued to negotiate with the Allied occupation authorities, resisting American policies aimed at rendering the Japanese simpleminded and ignorant. Perhaps these difficult negotiations exhausted him; in any event, his tumultuous life ended at the age of 60. After an interval of four months, Joichi Suetsuna of the University of Tokyo's Department of Mathematics, Faculty of Science, stepped in as temporary director-general for about one year. For Hayashi, who had just joined ISM, the situation was a source of great anxiety. But in fact, Suetsuna became a second mentor to him, and Hayashi learned much from his new superior.

Years later, in 1971, the author of this book, then an assistant at Aoyama Gakuin University's College of Literature specializing in psychology, was sent to work with Hayashi at the recommendation of Masatoshi Seya, her academic advisor. Seya stated that if he had been a woman, he would likely have fallen in love with a man like Hayashi. With this extremely frank admission of emotion, Seya dispatched his precious student to Chikio Hayashi, as though relinquishing his own child for adoption. As part of my major, I had previously

studied mathematical statistics at ISM; now, unexpectedly, I had become Hayashi's student.

I was majoring in the field of mathematical psychology, which attempts to model psychological phenomena mathematically. Since these phenomena are nonlinear, they require the use of nonlinear mathematics. In addition, spaces populated by human beings are non-Euclidian. Euclidian space is a special case of non-linear space, and elucidating it is a precondition when attempting to reveal psychological phenomena. However, at the time, computers were still relatively undeveloped, and hand-solving non-linear equations was not at all practical. Consequently, I performed calculations for a restricted portion of the data, then attempted to apply the results to the data as a whole. Hayashi told me that I would have to discover the section at which the curve with a single peak (as exemplified by a Gaussian distribution) transitions to a quadratic curve. It was necessary to divide the method into a linear model and a non-linear model, and examine their structures and relationships. Hayashi decided that the results of this research should be presented to the Japan Association for Philosophy of Science, and directed me to do so under the title, "The Problem of Non-linearity in Psychological Measurement." At the time, Quantification Method Type II was widely used to maximize correlation ratios, and ultimately the problem was resolved using that method. But today, with advances in computers, the problem can be elucidated without using that sort of stopgap measure. The non-linear problem arises in the rudiments of

experimental psychology, and the Weber-Fechner Law relating to thresholds (of stimuli and perception) also ultimately returns to this problem. In toxicology as well, toxins sometimes have no effect at all even above a certain level. This problem was treated as an error term in Probit analysis. At the time, as an academic tendency, hardly any researchers adopted the non-linear problem as a research theme.

2. Kinji Mizuno and the founding of the Behaviormetric Society

In 1973, a group of young psychologists asked Hayashi to become the first chairman of the Behaviormetric Society of Japan. The society's aim was to encourage behaviormetric research into human action in a range of specialized areas. It was the first academic society to advocate for interdisciplinary research of this kind. The Japan Association for Philosophy of Science was cross-disciplinary in nature, but it had a wider scope and conducted research into human behavior in general. The Behaviormetric Society included numerous member specialists in psychology, sociology, medicine, and marketing research. Initially the society was presided over by researchers in economics, law, mathematics, and so on, but they never got used to the idea of behaviormetrics and moved out of necessity to the Japan Statistical Society. The offices for both societies were housed with ISM, and in the beginning they were tacitly in conflict, divided, as ISM had been earlier, into warring

factions, one supporting statistical mathematics and the other, mathematical statistics. Hayashi, who had become somewhat dissatisfied with such a work environment at ISM, had been working hard, even before the Behaviormetric Society was established, on the concept of a "Human Behavior Research Center" to further human-related scientific research.

This idea had been under consideration intermittently since 1968. Hayashi had been working to correct the prospectus and revise the concept in a variety of ways, when in 1974, he was appointed as the seventh ISM director-general, and the initiative came to a sudden standstill. Now he was solely responsible for multiple ISM projects, and these kept him running around. Hayashi was the first director-general appointed from within ISM; previously, the position had been filled by professors from the University of Tokyo or a similar institution. Hayashi felt he could not in good conscience refuse the appointment, and he passed the human behavior research center concept to his colleague, Shigeki Nishihira, and the administrative work to Kinji Mizuno.

Mizuno studied visual perception and response theory under Torao Obonai at Tokyo University of Education, and became an assistant at that university. Through his connection with Obonai, who at the time was chairman of the Japan Color Research Institute, he was assisting with color research. He and Hayashi were acquainted, and Hayashi discerned his meticulousness, his scrupulousness, his data sense, and his excellent eye for phenomena. Impressed by his talents, Hayashi waited until

Mizuno's term as an assistant was ending, and recommended him for a position as researcher at the Institute of Behavioral Science. Moreover, several years later, he recommended him for a position as professor in the School of Education at Nagoya University. Such was his admiration for Mizuno's talents.

Haruo Yanai was the Behaviormetric Society's first secretary-general. At the time, Yanai was an assistant at the University of Tokyo's Epidemiology Department, Faculty of Medicine. Consequently, the secretariat was initially based in that department. However, since the society's chairman was based at ISM, and it was the job of the secretary-general to assist the chairman, his presence at ISM was desirable. As such, Hayashi recalled Kinji Mizuno from Nagoya, as he was the perfect person to serve as secretary-general. In October 1975 Mizuno became attached to ISM, and in April 1977 he became secretary-general of the Behaviormetric Society. Beginning in 1991, Mizuno served for three years as the Behaviormetric Society's third chairman.

For five years until 1982, when he went to the US as a visiting researcher, Mizuno devoted himself to his duties as secretary-general of the Behaviormetric Society. He organized the secretariat, which was being run in a haphazard way by young researchers, and put the management of the society on a solid footing. He applied successfully for a grant to enable the society to publish its journal in English, and in close collaboration with the chairman, he worked hard to train young researchers. He was succeeded as secretary-general by Shuichi Iwatsubo,

at which time the society delegated part of its operations to the Center for Academic Societies. To negotiate the transfer of functions, Mizuno accompanied Iwatsubo to the Center on numerous occasions before his departure to the US, and he helped ensure that the various aspects of the handoff between the two organizations proceeded smoothly.

This is the sort of task that requires an experienced individual. Iwatsubo was still young, a researcher in his thirties with a strong sense of justice, and was inexperienced in the ways of the world. He was therefore deeply indebted to Mizuno for the life lessons he learned and the considerable wisdom he gained as a result; for Hayashi, it was as if Mizuno never left. Mizuno later, as ISM director-general Hayashi's right-hand man, devoted himself with all his energy to the development of the Behaviormetric Society. Mizuno's self-sacrifice, and his all-out efforts on Hayashi's behalf, are a lesson for us all.

Mizuno was also a social survey expert. He was involved with all aspects, from implementation, tabulation, to analysis, of the first of the cross-national surveys of national character, which began in 1978 to investigate Japan's rising position in the world. He was also busy with the human behavior research center concept, which had been pending for many years, though ultimately the plan was not realized. Mizuno's labors ended in 1999 when he passed away at the young age of 67. After his death, Hayashi is said to have stood before his grave and vowed to devote the rest of his life to building the science of data.

In 1988, Mizuno penned the preface to Issue 45 of the

Behaviormetric Society's journal. This could almost be considered his last testament to the society. It is also relevant to researchers belonging to the society today in considering where they should be placing their energies. The spirit of the content is very similar to the 2014 statement by society member emeritus Ryozo Yanagihara, titled "Has the Survey Died?" Thirty-two years have already passed since Mizuno wrote his "last will and testament." His passion for behaviormetrics is just as relevant to the society's activities today.

"Do our society's activities have the wind at their back? Are there no challenges as we move toward the future? I believe there is a need for us to review the past.

"First, it is my belief that recent research on analytical methods overemphasizes the numerical at the expense of attention to whether or not the method in question is effective for the actual objective. Might this not be true? If today's new, sophisticated analytical methods are unable to extract new knowledge and discoveries that could not be obtained by traditional methods, they are meaningless. In that case, do we not need to make the effort to develop analytic methods specific to a particular problem and its associated data, however difficult that may be? Perhaps my expectations are high, but I would at least like researchers to have the needed mettle. Second, with respect to the foregoing, I hope researchers will be intensely interested in the phenomena they study. Rarely seen major changes are underway in society today, and a huge number of challenges are waiting to be addressed. Especially in the field of

humanities studies, we must bring diverse and large amounts of data to achieve effective analyses that can elucidate problems. At the same time, while we call our era the "era of information," carrying out a single survey has become difficult when personal data must be kept confidential and managed properly. I therefore hope that researchers will collaborate to meet this challenge with vigor. I think that the sense of aesthetics widespread in Japan is the reason we tend to be drawn to mathematics; however, I believe the quantitative methodologies that are the aim of this society are the scientific, integrated approaches that can solve difficult real problems, even if they might seem rough around the edges compared to mathematical beauty."

What would Mizuno say if he saw the intricate reality of society in the 21st century? Ryozo Yanagihara's essay, "Has the Survey Died?" was based on conversations with Mizuno that he had held in his heart for 20 years. Yanagihara has stated that his title is a testament to Mizuno's passion as well as his despair regarding surveys, which inherently demand straightforward powers of perseverance. This is what drove Yanagihara to write with the feeling that straightforward perseverance of the kind Mizuno advocated continues to be necessary if surveys are to survive.

3. Growth and evolution of the Behaviormetric Society

A year before Hayashi became director-general of ISM, in 1973, the author and Haruo Yanai hosted a "Multivariate

Analysis Symposium" at Gakushikaikan in Hongo, Tokyo. Yanai told me privately that he hoped the symposium would become an academic society with a membership in the range of 2,000, and he wondered whether Hayashi would consent to head the new organization. Both of us were still in our twenties. Today, capable people are encouraged, regardless of their age; back then, however, the idea of young people founding an academic society would have invited contempt. Consequently, though we approached Hayashi with the idea, he dismissed it. When we persisted in approaching him a second time, he generously gave his consent, telling us he expected much from a society founded by young people, and he gave the society its name.

This was the birth of the Behaviormetric Society of Japan. The society named its English-language journal Behaviormetrika, reflecting the influence of Psychometrika (the official journal of the Psychometric Society). The society's goal was to quantify human behavior and elucidate a wide range of such behavior from diverse philosophical perspectives. Rather than collect data only and subject it to mechanical analysis, structures hidden in the data would be extracted to enable phenomena to be observed logically. This was true interdisciplinary research, and researchers from many fields joined the society. The members of the society secretariat worked tirelessly to gather people to join the society. One memorable part of this effort was the publishing of an invited paper in the first issue of the society's English-language journal, Behaviormetrika, by Naoki Komuro, the then-popular, proud, and independent social scientist with

a fighting spirit. Komuro was respected by warriors of the All-Campus Joint Struggle Committees, which had sparked campus activism, as the hope for the movement. He ran an independent seminar at the University of Tokyo, and became popular with the students with his displays of erudition.

It was my job to convince Komuro to write for the journal. I met with him frequently, and he consented finally to contribute a paper titled "On the Concept of 'Marginal Function' Especially in Reference to the Sociology of Law." This proud, independent genius became a member of the Behaviormetric Society, but papers for publication in the journal must go through a screening process, and after certain papers by Komuro became subjects of criticism, he withdrew from the society in resentment. But he was a fervent supporter of Hayashi, and even after his departure, Komuro maintained ties to ISM.

In the beginning, the society was full of passionate energy, perhaps because it was steered by young members. But rapid advances in computer technology drove an increasing tendency to rely on them. As chairman of the society, Hayashi was frustrated by the indiscriminate use of computers and the bootstrap method in data analysis by young researchers. Often and everywhere, he continued to question whether or not behaviormetrics had a guiding philosophy. But this awareness that a problem existed is absent in today's young researchers, and Hayashi's theories gradually lost their influence. Behaviormetric Society membership has largely become

focused on frontline social surveys; moreover, there is little room to debate philosophies and ideas. Investigations of detailed mathematical mechanisms for handling big data are beyond the bounds of the behaviormetrics of the past. Times have changed, and researchers' awareness has changed along with them.

We live in an era when someone who might never have heard of Chikio Hayashi styles him- or herself a data scientist. There are likely also those who think that recalling a time when Hayashi's theories were passionately debated is nothing more than sentimentality. But I would like them to reconsider and remember. Human beings are not robots (unless one contemplates a replication of the human brain). To survive, human beings must, by nature, face existential questions. The various services, and the—likely temporary—shopping conveniences offered through today's internet will eventually become obsolete. Those who seek to amass knowledge through their own efforts will go in search of challenges, climb unexplored peaks, and peer toward far-distant horizons. The gift of human wisdom, which will never be exhausted, is hidden therein.

"It is a pleasure to be moved while reading an academic paper. If I may relate a personal experience, there is one paper I read that deeply moved me, that revealed to me just how fascinating mathematics is. When I was studying probability, I read Richard von Mises's first paper on that subject. I was deeply moved. John von Neumann's "[Zur Theorie der] Gesellschaftsspiele" struck me exactly the same way, as did his proof of his ergodic

theorem. Reading Abraham Wald's proof of the existence of a collective in probability theory, and the first editions of von Mises's Probability, Statistics and Truth, made we want to dance with excitement.

"I knew that probability and statistics were extremely interesting mathematic fields that would be my path in life. I remember spending days where I felt intoxicated.

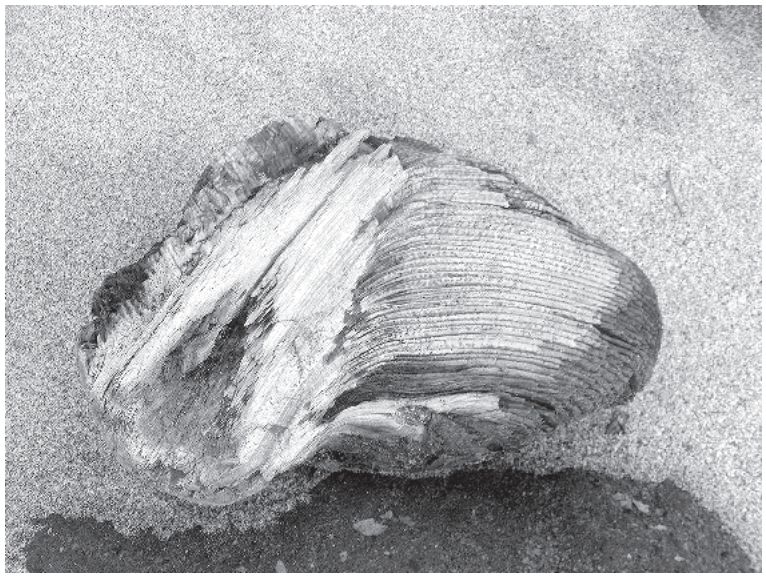
When my teacher told me to study statistics, I read books and papers on the subject. They impressed me as being truly absurd and uninteresting. But when I discovered that the allure of statistics is the unity of knowledge and practice—when I experienced it, and not simply read about it—my heart was moved. Since then, my research has had nothing to do with empty theory. Knowledge and practice are always unified. I concentrate and observe. I do nothing other than that.

"Writing an academic paper is like being the conductor of an orchestra; you want to present superior results in the best way possible. A performance that fails to thrill is a poor performance. Just as a poet may write a poem that brings the poet himself to tears, it is wonderful to be a researcher writing up your results, and moved so much that you leave the tracks of your tears on the manuscript. In today's world of word processors, wouldn't it be lovely if your tears ruined your keyboard?" (Chikio Hayashi, preface to *Nihon kodo keiryo gakkai kaiho* (Behaviormetrics Newsletter), No. 84, 2000)

4. Hopes for behaviormetrics

Today, a researcher is often measured by their number of publications. Regardless of the content, or whether they are empty or meaningless, they only need to pass review. If reviewers are permissive, the output of publications will keep rising, creating mountains of paper. This aspect of Japanese society, and its effect on universities and research institutes, usually hinders high-quality research. Hayashi grieved over the state of research in today's Japan, which ruins superior researchers and prevents superior research from being carried out. He felt that the solution to this problem could only be found in the hearts of individuals. And today, when connections between people have become fragile, there is a world from which we can gaze steadily at reality and elevate the human spirit. It is not only the world of personal computers, nor the world of e-books, but the world of ordinary books—page after page, filled with writing—and our encounters with them. Hayashi prayed that the finely honed sensibility capable of perceiving this reality would arise among young researchers.

"Kappa Paw" stamp from Hayashi's collection
(Maruyama 2015)



Chapter Six

Exploration of Data

1. From the Japanese National Character Survey to the Cross-national Comparative Attitude Survey

The first Japanese National Character Survey was carried out by ISM in 1953. I have noted that since then, the survey has been carried out every five years. When ISM was conducting the survey at its own expense, it was a process of trial and error, and survey staff had to undergo detailed training. Later, work on the survey was subcontracted to a variety of survey companies through competitive bidding.

After the fourth Japanese National Character Survey was complete, Chikio Hayashi began to realize that there was a need for a cross-national comparative attitude survey. A rough idea had been formed regarding the Japanese national character and the people's deeply-rooted temperament and values. Now there was a need for an external perspective on the Japanese. That is, while Japan was small among the nations of the world, it had become the world's second-largest economic power. It was decided that a cross-national survey, by comparing Japan with other nations to identify differences, would bring a clearer picture of the Japanese into relief. But to simply apply the same metrics to the Germans or the French in one large survey and compare the results would not be compelling. Unless the survey took a detailed approach, the results would lack valuable insights. Japanese-Americans living in Hawaii were therefore chosen as the first subject of the cross-national attitude survey.

The survey was conducted in 1971, focused mainly on

Japanese-Americans in Honolulu, since voter registration rolls were available. Through Yasumasa Kuroda, a professor at the University of Hawaii who jointly conducted the survey, an English-language version of the survey questions was prepared by a local expert. The survey results, however, revealed the same degree of difference between the Japanese in Japan and Japanese-Americans as had been seen previously between Japanese living in different prefectures of Japan. It was as though Hawaii were nothing more than another Japanese prefecture. However, while concepts of tradition and culture were common among the Japanese, Japanese-Americans living in Hawaii did not display that tendency. It was here that a foothold for considering differences began to come into view. The conclusion was that Japanese-Americans had no habit of considering behavior in light of tradition and culture, whereas for the Japanese, tradition and culture were always top of mind.

In 1978, not only Japanese-Americans but the entire population of Honolulu was surveyed. Interestingly, the results indicated the presence of opinion differences between Japanese-Americans born in Hawaii and those born in Japan. In turn, the distribution of opinions of Japanese-Americans born in the US and those born in Japan who immigrated to the US could be summarized and highlighted as a chain. This new approach is called Cultural Link Analysis (CLA).

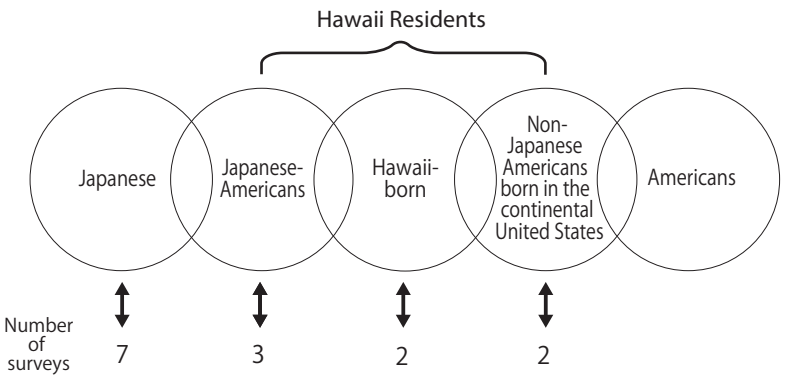
When comparing Americans living on the mainland with the Japanese, with the exception of questions relating to personal relationships, Quantification Method III analysis indicated

similar attitudes in areas common to highly industrialized societies, including the role of trust in human relationships, terms of employment, attitudes toward work, and attitudes toward science and civilization. Japanese-Americans therefore played an important role in the survey, occupying an intermediate position between Japan and the US in terms of attitude differences.

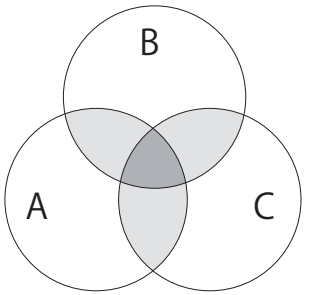
Today, attitudes in foreign countries are still surveyed for comparison with those in Japan; these surveys stand on the results of this first comparative survey of Japanese-Americans in Hawaii, which was critical in demonstrating how such surveys could identify differences in attitudes.

As can be seen from the figure, the survey was also important in forming an understanding of the American temperament. This investigation of the Japanese and American temperaments was carried out in sequence: first, Japanese-Americans in Hawaii; then, non-Japanese Americans born in Hawaii; non-Japanese Americans born on the mainland; and Americans born on the mainland.

Subsequently, the scope of the surveys was widened to include the United Kingdom, Germany, France, the Netherlands and other Western European nations; Thailand and Singapore, Indonesia, Malaysia, and other countries in the Southeast Asian region; and China and Korea, among others. There was a clear difference between national characters in Western Europe and Southeast Asia, with the basic character of the Japanese being



(a) One-dimensional chain



The figure is two-dimensional, but becomes multidimensional as the number of groups increases.

(b) Multidimensional chain

Figure 3 Japan-US survey chain-link

extremely similar to the results found in the latter. At the time, the US was principally a mixture of peoples from Western Europe, and exhibited almost the same attitudinal structures as that found in those countries.

The Japanese people under American occupation barely studied Japanese history and Southeast Asian culture. Instead, they focused on Western culture, literature, and world history. I myself did not begin studying the origins of the Japanese people, Japanese culture and cinema, and Japanese folk beliefs until 1980, when I was a student in the US. At the time, Japan's economy was growing rapidly and was poised to overtake that of America. As such, the Japanese were held in extremely high regard in foreign countries.

Today it seems rather odd, but at the time, many Americans majored in business in order to study Japanese corporations. It seemed difficult to grasp that the Japanese seniority system, and the loyalty that led employees to stay in one company for a working lifetime, could be behind Japan's economic development. In America, the land where meritocracy reigned supreme, works like Max Weber's The Protestant Ethic and the Spirit of Capitalism were held up as proof that those who are capable and work hard should earn a reasonable profit. For the weak, and those who fell through the cracks of the system, there were some charitable groups. Fundamentally speaking, America had to be a strong nation that scorned the weak, because it was this attitude that was encouraged by the pioneer spirit. But eventually America's economy stagnated and the country fell

into a demoralized mood. This had its effect on Japan as well, because for many years, Japanese society has been guided along the path of American values and meritocracy, and the weak have been sacrificed unmercifully. The independent contractor system and other measures have been introduced, and new graduates struggle to find employment. With the economic and social changes, there have been reports of weird and bizarre crimes. Such a society would have been unthinkable during the period of strong economic growth. It seems that now the pain of sacrificing the weak has led Americans to yearn for Japan-style company loyalty and job security.

Hayashi had this to say about the survey results.

"With respect to survey questions addressing issues common to modern society, the Japanese display the same attitudinal structures as Americans. Europe does not, however, necessarily always display the same structures. This aspect of Japan demonstrates the astonishing degree to which Japan has been Americanized. However, Japan and America are poles apart when it comes to human relations, with clear differences between warm Japanese beliefs and dry, impersonal American beliefs in this area. Europe is between Japan and the US in this respect. A tripolar structure is visible that encompasses Japan, the US, and Europe. We are proceeding our analysis to elucidate clearly how similarities and differences emerge in each area" (Hayashi 1996).

2. A leading French classification expert

Chikio Hayashi was active on the international scene. His relationship with Jean-Paul Benzécri of the University of Paris VI—that eccentric, cult-like figure—bears special mention.

In 1975, Hayashi was astonished by a paper written by a Frenchman. The paper included a method of pattern classification that closely resembled Quantification Method Type III. The method of data analysis, called correspondence analysis (CA), was originated by the statistician Benzécri. At the time, the majority of such methods had been devised in the US or UK; Hayashi had not been aware that data analysis was such an active field in France, much less in Germany, which had been defeated in the war. Hayashi made inquiries with a number of well-informed friends, but none was acquainted with Benzécri.

Around 1970, the multi-volume series *Elements of Mathematics* by Bourbaki was translated into Japanese from the French, to widespread acclaim. Hayashi initially assumed that "Nicolas Bourbaki" was an individual, and was duly impressed. In fact, Bourbaki was the pen name of a group of young mathematicians whose aim was to write a series of treatises on mathematics. Apparently, there was a custom in France in which certain cult-like "gurus" in a wide range of fields—for example, in mathematics, the entire range of mathematics including topology, abstract algebra, and so on—put together a team of disciples, who would produce a

huge amount of work to be published under the guru's name, while the guru himself was rarely seen. France seemed to be a nation where astonishing jokes were permitted. In the same way, thought Hayashi, Benzécri rarely showed himself, but his students must be active under his name. "Guru" has a dubious ring, but Hayashi referred to Benzécri as such without irony.

In 1978, a Japanese-French joint research seminar was held at the University of Paris VI under the Japan Society for the Promotion of Science's Bilateral Joint Research Projects/ Seminars program, as part of the society's international exchange efforts. Attendees from Japan included Kameo Matsushita, Shigeki Nishihira, Takeshi Hayakawa, Hirotaka Sakasegawa, Nobuo Inagaki, and Noboru Ohsumi (all from ISM), Yukio Suzuki (University of Tokyo), and Meiko Sugiyama (NHK Broadcasting Culture Research Institute). Daniel Dugué led the French participants. Hayashi was interested in French probability theory, not mathematical statistics, and did not participate in this seminar. However, because Hayashi was curious about Benzécri, he took this opportunity and asked Sugiyama to look into his situation; and she reported back that indeed, Benzécri was a guru-like figure who rarely appeared in public.

In 1979, the 2nd "Data Analysis and Information Science" international symposium was held at a hall near the Palace of Versailles, under the auspices of France's Institut National de Recherche en Informatique et en Automatique (INRIA).

The invited lecturers were Chikio Hayashi and John Tukey

from America.

Hayashi learned how data analysis was practiced in France by attending the symposium. Benzécri appeared before him, smiling and accompanied by his students. The Frenchman was indeed quite eccentric-looking, with a long white beard and a bald head that made him seem like a guru. Impressed by his elegance, Hayashi recalled that this exceptional statistician reminded him of a hermit living deep in the mountains, aloof and proud, or a poet depicting invisible landscapes in words. When they shook hands, it was as if Hayashi was grasping a pale, soft, waxen tentacle of an octopus. Hayashi had requested an appointment to meet Benzécri before he traveled to France. The response, written in a halting English, was almost like a love letter, and Hayashi had laughed out loud as he read it. This is certainly the reason he came to view Benzécri as a kind of poet. Hayashi had never encountered anyone like him. Benzécri's students—they numbered no less than 200—were scattered all over the world, and were influential not only in France but in Italy, the former Soviet Union, Eastern Europe, Africa, and Latin America.

Benzécri stood at the pinnacle, hidden away in his library, with his students active widely. Hayashi realized it was a situation that would be unthinkable in Japan.

3. Benzécri's view of statistics

M. Hill, one of Benzécri's students, introduced his mentor's

data analysis more widely in Europe and America. Hayashi learned of Benzécri from reading Hill's papers, and after that, Benzécri's students often requested copies of Hayashi's papers. Around 1973, they had informed Benzécri of Hayashi's pattern categorization method (Quantification Method Type III). Consequently, Benzécri must have felt perfectly at ease meeting Hayashi.

It was surprising that Benzécri's approach was based on Hayashi's statistical mathematical ideas. Hayashi was deeply impressed, and regretted not having paid attention sooner to French statistical mathematics. That he did not do so may well be due to the fact that after the war, Japan was gripped by the delusion that the world revolved around the US and Britain.

Benzécri's fundamental stance regarding statistics was to raise a banner of resistance against the prevailing US- and UK-style mathematical statistics. His basic idea that "statistics is not probability" startled Hayashi, who had studied probability. According to Benzécri, since 1930, the sophisticated, exhaustive theory of mathematical statistics was based entirely on probability, and as long as one was caught in that exhaustive framework, one would never be able to enter the world of analysis of phenomena. Data is messier, and discovering truth amid that messiness is true statistical mathematics, true statistical analysis rooted in data. It is better to forget that exhaustive framework. Statistical models do not come from conjecture but from data. Today's statistical analysis, in which data is forced into exhaustive models, is not

an entirely accurate approach. Benzécri insisted that statistical models should be inferred from data. Moreover, he preached the barrenness of statistical testing and lamented the way that intricate statistical testing theory led one into confusion, until one's eyes were swimming. He stressed the importance of data, saying that testing is not important; what is needed is useful data that help us construct logical hypotheses. This was the view of the guru of French-style data analysis. Hayashi was astonished, and was immediately captivated by this eccentric-looking individual.

One American statistician shared Benzécri's view: John Tukey, who advocated exploratory data analysis. Nevertheless, Hayashi found that the fundamental concept of quantifying data was absent from the outset. It struck Hayashi that Tukey's sense of the essence of data differed from how Hayashi understood it.

4. Japanese-French exchange in statistics

Once the context for Japanese-French collaboration had been established, Hayashi was eager to invite Benzécri to Japan by any means. However, Benzécri had a rule against flying. Hayashi suggested he take the Trans-Siberian Railway, but Benzécri continued to refuse. Hayashi received only sentimental correspondence via Benzécri's students. Benzécri's stance as a guru in retreat was unshakeable. Hayashi was not so much astonished as impressed, and he was often to ponder this

decisive difference between himself and the "guru" in France.

French-style data analysis was eventually translated into English and quickly achieved recognition, but Japanese quantification theory never achieved the same global exposure. There were too few students of the method, and Hayashi did not spread his theory to his students and from them, across the world, while keeping out of sight himself, as Benzécri did.

Later, at Noboru Ohsumi's initiative, two of Benzécri's students, Maurice Roux and Ludovic Lebart, were invited to visit Japan as researchers by the Japan Society for the Promotion of Science (JSPS). The two men traveled around Japan, lecturing on data analysis as practiced by Benzécri and Hayashi.

Japanese and French statistical mathematicians, having become fast friends through data analysis, held a joint seminar at ISM in 1987.

The seminar, which focused on recent developments in clustering and data analysis, was held with support from JSPS, private enterprise, and other organizations. Nine preeminent experts in data analysis and clustering gave presentations, including organizing committee members Hayashi and Ohsumi representing Japan, and Edwin Diday and Michel Jambu representing France. With around 180 attendees, the venue was filled to overflowing, testifying to the degree of attention data analysis was receiving.

To achieve truly useful data analysis, it is necessary to have a comprehensive understanding of analytic methods as well as

the capacity to develop superior statistical software. In addition to computer literacy, software developers must be thoroughly conversant with the fundamentals of data analysis. Perhaps this attitude is a product of the 20th century, when Hayashi was active. Even with the advanced processing capabilities of 21st-century computers, there are numerous restrictions on data collection, and the capacity to distinguish decent data usable for analysis is not always possible. There was once an era when splendid exchanges with international researchers were frequent; today, data analysis is largely inward-looking and somewhat stale. Despite the broad propagation and use of Hayashi's quantification theory, its fundamental spirit is still not well understood. In the present era, not only data analysis but numerous other aspects of statistics are trapped in a cul-de-sac of confusion and uncertainty, with no clear way forward.

5. The importance of data mining methods

Data science today seems to begin and end with technical manipulations aimed at smartification (classification) of big data. Indeed, with technological advances and revolutions that facilitate big data information summation leading to the development of supercomputers and the internet, there is a conspicuous tendency to value indirect human connection through the internet more than direct dialogue.

Data itself is something that flows back and forth across the internet, not something gathered and handled directly by

human beings. Methods of extracting data for analysis are completely different now. Gathering data in the conventional way, with rigorous population sampling methods, would likely require enormous amounts of money and time.

Previously, social and other surveys were carried out with consideration of sampling, survey design, response error, survey error, and other factors. Today, conducting this sort of social survey is close to impossible. There is no support for surveys requiring extensive care.

Ours is an era when the merest remark on Twitter can turn directly into data and leak, resulting in an unprecedented flooding of data. Some of those who are swallowed up in the flood can even commit criminal acts that shock society. Unintended consequences may lead people to find themselves designated criminals. These conditions are being skillfully used to commit an increasing number of unprecedented crimes. Statistics should be a predictive science that enables us to prevent such crimes before they happen. Flesh-and-blood human beings must be very careful of the negative legacy that advanced civilization is bearing, and look closely to ensure that they do not unconsciously fall into the trap. The fundamental ideas of quantification theory are sounding the warning we need; this must be understood.

In a broad sense, data mining consists of data analysis that aims to sort out or categorize data. However, this is performed using newly developed algorithms that leverage computer capabilities; the mediation of computers makes

slight but unmistakable differences from conventional data analysis in technical terms. Data on the internet has developed dramatically, and it is unclear what form it will assume going forward.

Ohsumi has stated that one key to future directions of data analysis may be, for example, the handling of data gathered through web-based survey methods that have become standard in marketing research and other fields, as well as the analytic methods of the huge amounts of text data found in on social media blogs, Twitter, Facebook, and elsewhere.

Curiosity—the eternal aspiration for the new—is like a mission that human beings must pursue eternally. Old words return to the present in new forms, and "data mining" methods, which have long been with us, seem to have appeared before us for the first time. Moreover, since the Japanese have a weakness for foreign terms, we use the English term "data mining," rather than the Japanese term for data analysis, perhaps creating the illusion that some new and more useful method has been born. Distinguishing the differences between "data mining" and "data analysis" requires the capacity for penetrating observation.

"Social surveys are one method for understanding society. They are truly broad and deep in scope. Data theory forms the foundation of surveying. Actual surveys validate and utilize this theory, but the theory must be applied by none other than human beings. A passion for the data is what we are called

upon to have when we conduct surveys and use them. In that case, what is it that enables us to have a passion for the data? Without conviction, passion is impossible. Therefore, to have a passion for data, one must experience it first-hand and be convinced that data is something truly useful."
(Chikio Hayashi, *Deeta no kagaku* [Data science], Asakura Publishing Co., 2001)

Chapter Seven

"The Fire in My Soul Will Never Be Extinguished..."

1. Final life work

Chikio Hayashi retired in 1986, after forty years at ISM and a professional life spent devoted to research. For the next three years, he lectured in data analysis at the Open University of Japan. Following this he set up an office for research in an apartment building in the Sakuragaoka district of Shibuya City, Tokyo. There he worked vigorously on numerous cross-national comparative research surveys, including surveys of Japanese immigrants in Brazil and on the west coast of the US. He also hosted a morning research seminar roughly every month for an adoring circle of researchers. There was also the "Thursday Association," an evening study meeting attended by numerous practitioners and researchers. This too was originally held approximately every month, but the number of attendees kept rising, and finally the meetings were moved from his office to a room at ISM. These meetings were hosted by Masakatsu Murakami of ISM, with enthusiastic participation from Ryozo Yoshino. Both men provided Hayashi with thorough support.

Also at that time, Shuichi Iwatsubo, an assistant professor at the National Center for University Entrance Examinations, and other young colleagues and associates were holding study meetings at Hayashi's office in Shibuya. Because many attendees were from the Center, issues relating to university entrance examinations were a frequent topic. Themes from many other fields were also subjects of discussion, and Hayashi participated from beginning to end with just as much

enthusiasm as the young researchers. When time permitted, the group would share a meal of tempura at Tenmatsu, a restaurant in the neighborhood, and afterward return for more animated discussion. Eventually, Hayashi's research room became known as "Hayashi's cram school."

2. Promoting international research exchange

In 1983, the study meetings on classification theory and its applications became the Japanese Classification Society, with Hayashi as its first president. The society placed particular emphasis on international exchanges, built close ties with the foremost members of classification societies in France and French-speaking Belgium, and promoted information exchange. Hayashi was eager to create an international classification society in Japan as well. Based on pertinacious, passionate discussions with the principal members of classification societies in West Germany, the UK, Italy, the Netherlands, Poland, Portugal, France, Belgium, the US, Canada, and other nations, as well as Slovenia, which at the time was an associate member nation, the International Federation of Classification Societies (IFCS) was at last established.

The first international IFCS meeting was held in 1987 at RWTH Aachen University in West Germany, the same year that Hayashi stepped down as ISM director-general. The fifth IFCS meeting was held in 1996 at the Kobe International Conference Center in Japan, and as chair of the organizing committee,

Hayashi worked with furious energy. His data science-related presentation at the meeting was an extremely important one. He summarized the fundamental concepts of modern data science and traced the path of its development from data analysis to science. Already around this time, Hayashi was using the term *deeta no kagaku* ("data science").

Starting in 1998 and for the next two years, Hayashi served as president of IFCS. Noboru Ohsumi and Yasuo Baba, both from ISM, worked to obtain the needed funding. Both men were burning with passion to spread recognition of the importance of the new developments and directions that awaited data science in the future, as well as the role and importance of the classification concept, and they provided close assistance to Hayashi.

There is another important matter that should be remembered. Before and after he assumed his post as IFCS president, Hayashi established the Travel Award Program (TAP) for young researchers. He served as chair of the TAP committee, which endeavored to offset a portion of young researchers' research expenses. Despite the severe challenges facing this effort to provide partial funding in place of the government, Hayashi considered it his mission, based on his own experience as a young researcher studying abroad. These grants of aid were later dubbed "Hayashi Prizes."

Hayashi had given thought to somehow creating a Chikio Hayashi Prize during his lifetime. He was eager to subsidize part of the research expenses for outstanding young researchers,

so they could do research in directions of interest to him. This "Hayashi Prize" would be different from the Chikio Hayashi Prize awarded by the Behaviormetric Society, in that it would provide assistance for travel expenses, and was a technical incentive award perfectly befitting the IFCS.

The Behaviormetric Society had administered an achievement prize from the beginning, but after Hayashi died, it was renamed the Hayashi Chikio Award (Achievement Award / Excellence Award). The society's first Hayashi Chikio Award (Achievement Award, 1986) went to Yoshio Takane of McGill University in Canada. Since before the society had been founded, Takane had been a participant in the Multivariate Analysis Study Group, where he had made a presentation on the massive tome on three-mode factor analysis by Tucker of the University of Illinois. That had been at the height of the student movement and the universities were closed. Despite the situation where students could only either participate in the student movement or take a noncommittal attitude, Takane was burning with academic fervor.

After that, it established numerous other awards, including the Hidano Tadashi & Mizuno Kinji Award (Encouragement Award) in 1999, and a publication award (Sugiyama Meiko Award) in 2011. The society adopted a wide range of measures to accelerate the appetite of young researchers for pure research.

After Hayashi retired from ISM, he engaged in large amounts of international information exchange. He set up an office in Shibuya and made frequent trips abroad in order to actively

propagate his research activities, and his quantification theory in particular—a plan that had been difficult for him to carry out during his time at ISM. But now, Chikio Hayashi's name had started spreading around the world.

His last trip abroad, accompanied by his wife Reiko, was in November 2000, to Germany. After his return, he wrote and published *Deeta no kagaku* (Data science). It was his final single-authorship work.

3. Last message

Three months before the events of September 11, 2001, and for no particular reason, Hayashi was seized with feelings of nostalgia. Thinking deeply about the past and the future, he found himself considering carefully the systematization of data science, which he was intending to promote. This was without a doubt a magnificent conception, one that ordinary persons could not grasp.

Deeta no kagaku, published in 2001, discusses the subject of accuracy rates extensively. Hayashi's blood-stained experience during the war had convinced him of the effectiveness of data. After the war, that experience became the motive force for a lifetime devoted to researching data. This was not something he was taught by others. It was something cultivated by the joy of guessing right and the sorrow of guessing wrong. Data science was possible because it was backed by data theory. Discovering the concepts behind Hayashi's data theory requires

a close reading of *Deeta no kagaku* and an understanding of its theoretical methods. In addition, to seek and extract further truths from data that has already been analyzed, one must make extensive use of data mining techniques, look at the data from a higher perspective, and mine the vein of gold to be found there. This will be a task for those he left behind. Hayashi's sincere wish was for young researchers, who occupy a place at the heart of modern society, in which diverse theories relating to data circulate, to share their ideas with each other, and build a more exhaustive theory of data from data science.

Hayashi was to give the keynote lecture at the 29th annual meeting of the Behaviormetric Society, held at over four days at Koshien University from September 13, 2001. But he stayed up all night watching reports of the terror attacks of September 11; the next day, he became ill and had to be hospitalized. His wife called the society and told them he would have to cancel. Hayashi had never missed a lecture under any circumstances, but in this instance, he had no choice.

On May 11, 2002, to make up for missing his keynote lecture, he spoke at a Behaviormetric Society symposium held at ISM. After an introduction from Iwatsubo, Hayashi gave a lecture that was full of fighting spirit. Based on his grand vision, he lectured on the systematization of data science.

He stood at the lectern with a plastic bottle of water in his hand, which was something unprecedented with him, and he began the lecture with an embarrassed chuckle.

"What's different from last year is that I have this [bottle of

water]. The reason is that after I left the hospital, I spoke at a medical conference and my doctor happened to be there. 'If you don't drink plenty of water,' he told me, 'it's bad for your heart. So, you should drink as you lecture.'" (Lecture record, 2003)

He did exactly as the doctor recommended. For a physician, he was the perfect patient; he had respected specialist knowledge in others strongly.

Before a month had passed, his condition changed suddenly, and he was readmitted to the Department of Cardiovascular Medicine at Nippon Medical School Hospital. His physician was a student of his old acquaintance, Eiichi Kimura, a leading authority in electrocardiology who had served as the president of Nippon Medical School. Kimura was no longer alive, but his pupils had learned much from Hayashi concerning data analysis. His initial exam upon admission was overseen by Hirokazu Hayakawa, Kimura's foremost student, and for two months Hayakawa and his own students cared for Hayashi.

Hayashi's heart condition had been worsening, but was not yet able to extinguish the fire of life that burned within him. Hayashi, indifferent to it, was making final corrections to the manuscript of his last work, *Suji ga akasu nihon-jin no senzairyoku* (Numbers reveal the hidden strength of the Japanese), dealing with the true nature of the Japanese as demonstrated by fifty years of national character survey data (published in 2002), so that the writing would be easily accessible to all. The book is a comprehensive summary of 50 years of Japanese National Character surveys and presents

Hayashi's final theories on the Japanese people as extracted from those surveys.

After the defeat in World War II, the spiritual strength of the Japanese, who had never yet experienced defeat, was tested as never before. How did they overcome the long testing period of the postwar era? Hayashi attempted to demonstrate the fundamental strength of Japan's people, or as he put it, their hidden capabilities, as shown by the survey data.

After the war, the Japanese labored like worker bees, pushing development forward until Japan became the world's number two economic power. But the economic bubble collapsed in the early 1990s, and there were many who yearned for Japanese traditions of diligence and frugality. For those born before the war, this national character was taken for granted, but since the end of the war, people had been caught up in living like the proverbial grasshopper. Everyone agreed it was time to start living like the ant, and there were many who were willing to work hard to restore the fundamental character of the Japanese. But for some middle-aged and younger people born after the war, the post-bubble times were difficult to cope with, and Japan's suicide rate rose to the third-highest in the world. Moreover, the nation was totally at a loss faced by a daunting array of political, economic, and diplomatic challenges. The data Hayashi presented was his attempt to provide a spiritual prescription for the Japanese. It was a work of hope, almost amounting to a prayer.

Furthermore, Hayashi invested particular effort in studying

Japanese religious piety. Japanese traveling abroad are often asked what religion they adhere to. Most will say they do not believe in any religion. Some foreigners can only shake their heads dubiously and assume that the Japanese are atheists or uncultured. But on this point, the data demonstrate that Japanese religious piety is truly profound. For many non-Japanese, religion is a matter of belief. According to Hayashi, the Japanese have spiritual leanings that are both subtle and natural, which they possess without being taught.

Whenever Hayashi traveled outside Japan, there was something he pondered. For instance, believers in Christianity say a prayer before each meal; but this must be the result of religious training. On the other hand, before each meal, the Japanese will say "itadakimasu (I receive [this food])" and place their palms together. This is the artless spirituality that is strongly rooted in the character of Japan's people. Moreover, though religious feelings tend to strengthen with age, it is not uncommon to hear that most Japanese seem not to have noticed that they are religious by nature. "The Japanese are often said to lack a religious sense, but they are unique among the peoples of the world for continuing to retain such feelings without any religious education" (Hayashi and Sakuraba, 2002). Using analysis of the data from the Japanese National Character Surveys and the Cross-national Comparative Attitude Surveys, Hayashi penned a heartfelt spiritual prescription for the Japanese of today—a guide showing what they needed to do to recover from an almost complete loss of vigor—and to take

the initiative to enhance international mutual understanding. Hayashi's wish—and he left numerous suggestions as to how this might be accomplished—was for the Japanese to flourish in the 21st century by working for international harmony while valuing their unique qualities, and realizing that from a historical perspective, even with the ordeals of defeat and occupation, few nations had been as fortunate as Japan.

But his time had run out. Even in the intensive care unit, his mind was fully sharp enough to correct the manuscript, but whether or not he was aware that his body was failing is uncertain.

4. The idea and future of data science

While the significance of data science has been a constant refrain, we may roughly summarize it as follows.

Statistics focuses on the collection, organization, analysis of numerical data, as well as drawing conclusions. In particular, the following points are important for the systematic analysis of data: sampling theory, which deals with the organization of data, and sampling theory's survey metrics of universe (the set of all experimental units), population, and sample, or UPS.

Inferential statistical theory initially retained its own scientific adequacy. However, as the theory progressed, it became more mathematically detailed and less grounded in reality. An identical tendency can be seen in the field of experimental design methods. Even the fundamental UPS concept is often

ignored. As such, advanced mathematical statistics (the study of statistics from a mathematical perspective) became progressively irrelevant to the elucidation of phenomena.

Furthermore, some researchers applied the theory without understanding of how data should be organized; others used calculations based on hastily collected data, and tried to fit the data to a simple conventional model. Those without access to data often used the computer-simulated (artificial) data with simple structures to explore the nature of existing theories. That their data analysis methods were inappropriate is obvious, resting as they did on the assumption that the mechanism that gave rise to the data was unknown. Some good predictions were based on incorrect assumptions. Software development is essential to encourage the propagation of data analysis to other domains, but is not always useful for the development of new efficient methodologies and theories appropriate to the studied phenomena.

What, then, is to be done? New paradigms are needed. The "data mining" paradigm is like that of "soft sciences" and "life sciences"—the scope was already present, but the paradigm is new. By creating new paradigms, things that were invisible under existing paradigms become visible. I believe that new scholarly directions and developments require new paradigms.

Data scientists must cope with the oncoming data flood by grasping fully the meaning of what Chikio Hayashi asserted and envisioned. The propagation of the internet and computer infrastructure will cause an unimaginable flood of data, and

society's expectations of data science are growing. The world is waiting for the elaboration of fundamental concepts and the philosophical ideas relating to statistical analysis that will meet those expectations. In a sense, a restructuring of the overall concept of data is probably necessary. To achieve this, the role of data science will likely be essential in an increasingly complex society. We must think deeply about these conditions and work diligently and patiently. Chikio Hayashi yearned for researchers with the abilities to provide an integrated, unified view of theory and practice, in order to achieve knowledge in the constantly evolving data science world.

"To every thing there is a season, and a time to every purpose under the heaven: a time to be born, and a time to die," (King James Version of the Bible, Ecclesiastes 3:1-2) and in the fullness of time, what is needed will come into being. Today's data flood—Big Data—will ultimately pass, in the infinite universe.

5. We will surely meet again in the Pure Land

Hayashi passed away at 8:00 a.m. on August 6, 2002, on the same date as Joichi Suetsuna had died 32 years before. He was 84 years old. Nine days later, on August 15, his final work, *Suji ga akasu nihon-jin no senzairyoku*, was published. His co-author was Masafumi Sakuraba, who had strongly urged him to write it. Fifteen days after Hayashi died, on August 21, the evening edition of the Asahi Shimbun newspaper commented that the book was his final testament.

The then-director-general of ISM, Genshiro Kitagawa, penned a tribute to Professor Chikio Hayashi that was published in Vol. 50 of *Tokei suri* (Proceedings of the Institute of Statistical Mathematics), ISM's official publication.

"[Dr. Hayashi] was a constant advocate for data science, and I heard that just before his passing, he was hard at work on a book. Despite the fact that he was singlehandedly active as a researcher in an incredibly wide range of areas, to die before completing his deployment of a new concept can only be regarded as truly regrettable… Throughout, he promoted the analysis of data based on an investigative standpoint, originating and practicing the research style that became the tradition of ISM. Against the traditional scientific methodology of understanding phenomena through theory, he insisted on doing so through data. That stance was embodied in quantification theory, behaviormetrics, and data science. If I may summarize his approach without fear of misstatement, I would say that it favored data over theory, quantified expression of collective characteristics over cause-and-effect relationships, macroanalysis and an integrated view over microanalysis, and hypothesis discovery over hypothesis and verification. As the realization of a stance that emphasizes real problems in statistical science, two currents came into being at ISM: investigative data analysis and statistical modeling. With his leadership in data analysis and data science methods, he demonstrated particular influence with respect to complex, hard-to-quantify subjects of research such as national attitude, and

contributed to a dramatic expansion in the scope of statistical science and applied fields."

Chikio Hayashi was laid to rest in the cemetery at Keifukuji, a Zen Buddhist temple deep in the mountains in Hinode Town, Nishitama District, Tokyo. Instead of the conventional inscription, "Hayashi Family Grave," the tombstone is inscribed with four Chinese characters—a line from the Sukhavati sutra that means "We will surely meet again in the Pure Land," in Hayashi's own calligraphy. Each year in early August, Hayashi's beloved students gather in that cemetery deep in the mountains, take photographs before the grave, and observe a moment of silence before retiring to Kurochaya, a nearby Japanese-style restaurant, to exchange memories of Chikio Hayashi in bygone days. Might Hayashi perhaps be there next to us, watching these scenes of reunion? One is reminded of how he would often encourage us, in his openhearted, placid manner, saying, "Hey, hey, right there. Here's how you do it. Just like that."

"Just as the fire in my soul will never be extinguished, may you too walk the same path."

We listen carefully for the whispers of Chikio Hayashi's soul in our ears. Under the midsummer sun, in a tranquil setting where the only sound is the distant calling of cicadas, we share a brief interlude over lunch. Somehow it has become a tradition.

There we tell each other of the big problems we are facing, discuss them, share opinions, and then in twos and threes, followed by the clamoring of the cicadas, we make our way home.

Epilogue

The litmus test for a statistician seeking to achieve excellence is the penetrating insight, and the clearly articulated supporting ideas and philosophy, that are required to discern truth in huge amounts of social survey data.

This is why Chikio Hayashi states repeatedly, in *Deeta no kagaku* (Data science), that simply running data through a computer will miss the essence it contains, and lead to incorrect conclusions. Hayashi was a statistical mathematician of global importance who trained himself to develop the insight and sensibility needed to see through the data to its true essence; his focus was always to grasp the phenomena hidden in the data, to discover hypotheses from the data. We have traced how he cultivated this sense by examining his development, the era of social upheaval during which it took place, and his response to that era, as well as his ideas concerning data. Hayashi spent half his life at the Institute of Statistical Mathematics (ISM), where he was known for his responsible, patient, and optimistic nature, and he stimulated and educated numerous young researchers. He had a kind of aura that attracted numerous scientists, marketing professionals, journalists, and others, who would make many contributions to society under Hayashi's influence.

It is rare for individuals to be faced with complex data, wrack their brains and agonize sincerely, burn with passion, and respond with joy when arriving at the truth. Just as Hayashi himself was this sort of individual, all of his students were

baptized and trained in the same way.

When faced with a large data set, Hayashi would rub his hands with anticipation, gaze at the pages of data lists like a puzzle, and exclaim that examining data was his greatest pleasure. He would then settle gradually into a state of deep contemplation, allowing his mind to roam freely and consider all possible ways to capture the truth hidden in the data.

What one might call the "twilight years" never applied to Chikio Hayashi. If they did, it was only a period after his hospitalization on September 14, 2001, and the cancellation of his keynote address.

As stated previously, in 2001, when Hayashi was designated a symposiast of the 29th annual meeting of the Behaviormetric Society, which was held at Koshien University, he experienced chest pains on the way to the conference, and went to the hospital for an examination, which uncovered a heart defect requiring immediate hospitalization. The meeting was thrown into a state of extreme confusion, but managed to continue. Hayashi was probably overwhelmed by the events of September 11, 2001. His own battle with illness began. He managed to recover quickly and gave lecture after lecture. He worked tirelessly with Masafumi Sakuraba to compile the definitive statement on the Japanese national character into a single work that was easy for anyone to grasp. His illness assailed him, yet even in the intensive care unit, he calmly worked to correct the

manuscript. But in the end, this intellectual giant exhausted his strength, and at the age of 84, at the height of summer, his life drew to a close. The cause was multiple organ failure.

A single body with a superior brain, buried and done with. We will surely never again encounter such originality. If an individual with a singular uniqueness identical to that of Chikio Hayashi ever appears again, it will likely take an unimaginable number of years, and then be a special dispensation, a genuine gift from heaven.

But we will not be so blessed. We can only watch, dazed, as Hayashi's soul disappears into an unimaginable distance, like wild dandelion seeds borne away by a strong gust of wind. The potential of the Hayashi's ideas has not been exhausted yet.

Acknowledgments

Haruo Yanai, my comrade-in-arms during our younger days when we shared the travails and joys of founding the Behaviormetric Society, and who urged me strongly to publish this book, passed away in December 2013. I pray for the repose of his soul and dedicate this book to him.

I received encouragement and assistance from many individuals during the writing of this book. I would particularly like to thank my colleagues at the Behaviormetric Society for their kind advice. I would also like to thank my good friend Shuichi Iwatsubo (Professor, Waseda University), who read the draft, and Kazufumi Manabe (Professor, Aoyama Gakuin University), who was generous in providing documents. I would like to express my gratitude to Kazuhisa Takemura (Professor, Waseda University), Fumi Hayashi (Professor, Toyo Eiwa University), and Noboru Ohsumi (Professor, ISM).

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Kumiko Maruyama

March 2021

Appendix

Chikio Hayashi's way of thinking

It is no secret that the past has lessons for the present. Throughout his long career, Hayashi used flow charts and schematic views to illustrate and visualize his way of thinking. New perceptions of the same phenomenon are always possible. For instance, a series of images can tell a story.

Hayashi clearly followed his own philosophy in his work. The intention was not to define every term, but rather to look at them through the perspective of his thought process (multidimensional, dynamic and flexible). Hayashi's work led to the development of many methodologies and analytical techniques. Many scientists felt that his unique style was different from traditional approaches. Some researchers did not share the same understanding of the terms and concepts. There was also a barrier of language. Hayashi considered Data Science as a new concept. It combines statistics, data analysis, their related methods, models and techniques. According to Hayashi, it also includes its results (related to theory, method, methodology, informed decisions and testable predictions). The goal is to understand actual phenomena through data.

He believed that even if there is no underlying theory, the hidden structure (pattern and dynamics) of natural, human and social phenomena can be determined by data analysis.

The behavior of objects is complex and multi-scale in nature. The exact mechanisms or models for a given phenomenon are not always clear. This does not mean that he did not trust the theories of the past. Scientists who advocate the scientific method need scientific wisdom to withdraw the theories they have believed in and create new ones.

In his analysis, Hayashi goes back to the starting point many times. His process is fluid and capricious.

Make and break, rethink and break. In other words, his approach tries to produce accurate and testable understanding of the phenomena without constraints of traditional (formal modeling or hypothesis testing) approach. If the given data set is not enough, one can repeat the process, expand the data set, fill in gaps in the data.

This data-based approach can open new research possibilities, widen the scope of studied phenomena, and lead to the development of new theories and methodologies.

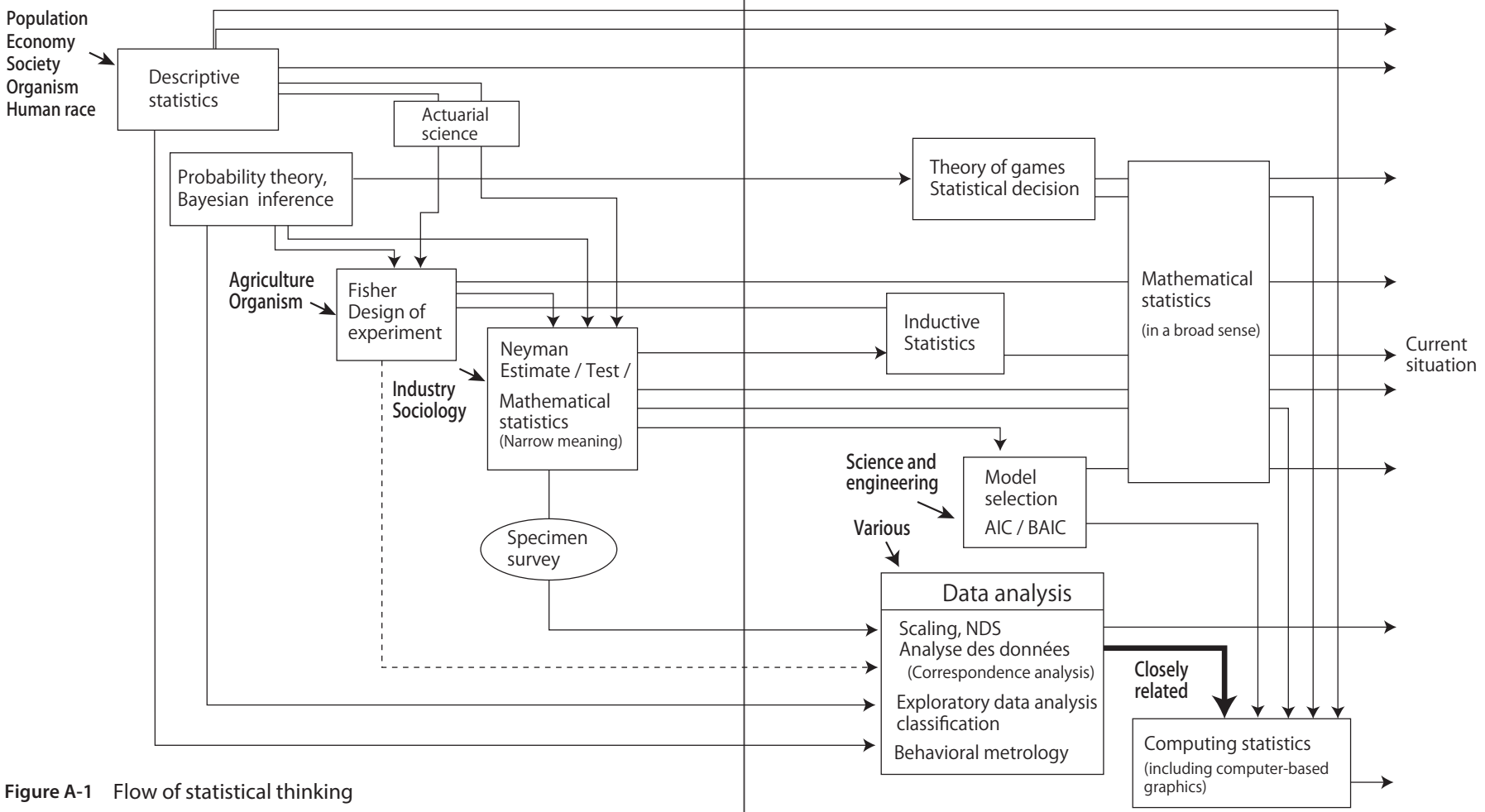

Figure A-1 Flow of statistical thinking

It is based on mathematics, statistics and other fields of study.
Hayashi considered a systematic way of thinking about how we describe a complex world, and make decisions and predictions through the use of data.
Theory (general or abstract principle, or explicit formula) is important.
However, it is not always possible in case of complex phenomena.
Each subject must be studied in the context of data science.
In this way, new horizons will appear.

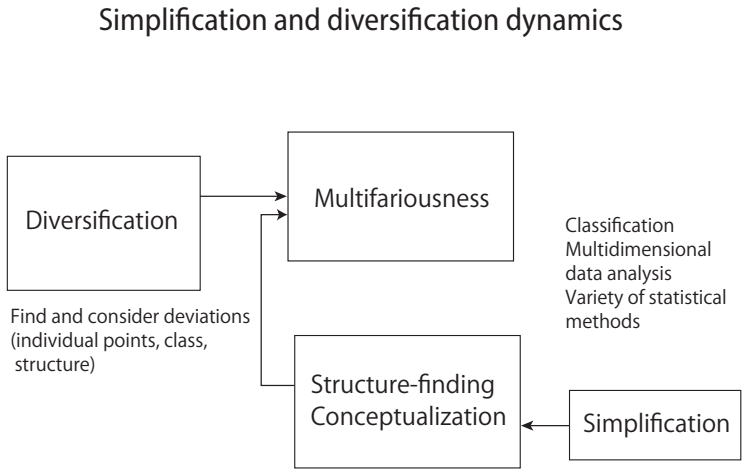

Figure A-2

Hayashi's exploration methodology includes three aspects:
data design, collection, and analysis.
The concept of "diversity" is important. Data is complex and diverse.
Data sets may differ in many ways.
One can not tell what data shows just by looking at the data.
Often, it is very hard to define meaningful categories.

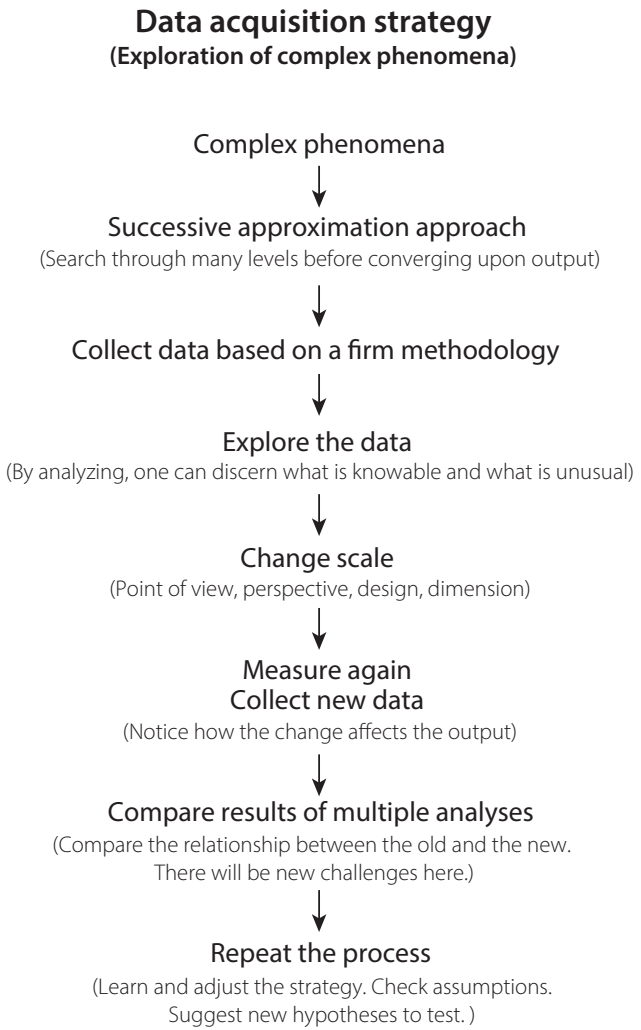

Figure A-3

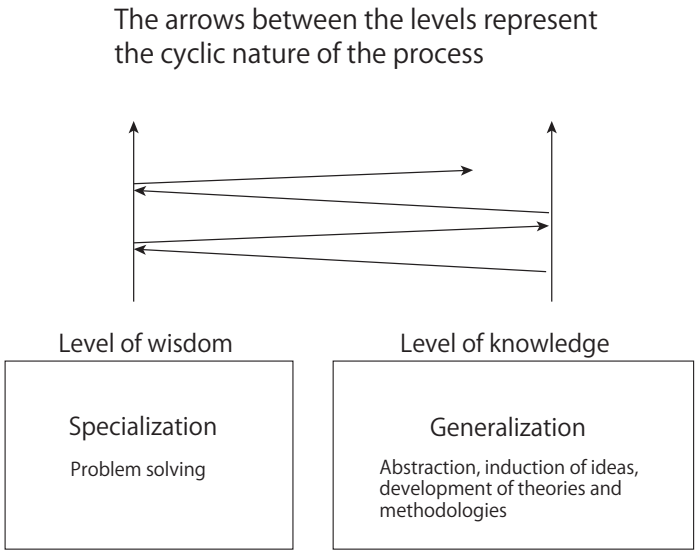

Figure A-4

Data science and the expanding understanding

Seeing things through data is one of the basics of living.
Data is transformed into knowledge.
To solve a problem, we use our knowledge and reasoning.
With time, we generalize knowledge.
We solve new problems.
Then wisdom comes.
This journey may go beyond the limits of human-only wisdom.

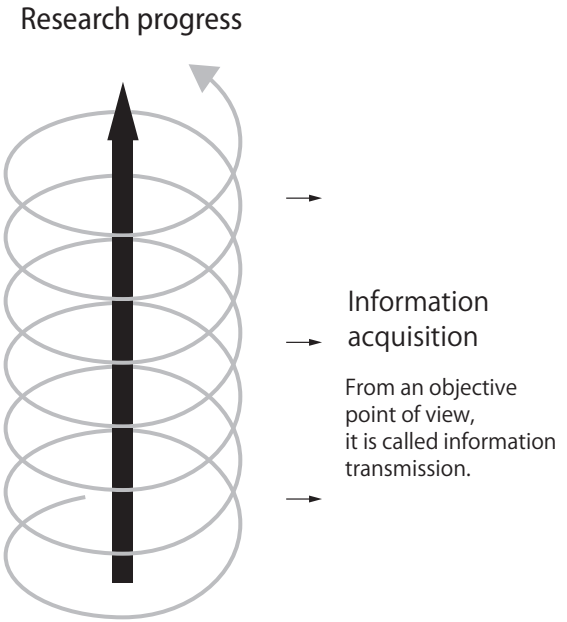

Figure A-5

Research process as an ascending spiral.
As learning proceeds, understanding progresses.

Chronology

1918 Birth
June 7: Born as the fourth son of Ryuichi and Chiyo Hayashi in Komagome, Hongo Ward, Tokyo City (today's Bunkyo City, Tokyo Metropolis).
The family moves to Higashi Nakano 4-chome, Nakano Ward.
November 11: End of World War I.

1923 Age 5
September 1: The Great Kanto Earthquake.

1925 Age 7
April: Enrolls in local elementary school.

1931 Age 13
April: Enrolls in Tokyo Kaisei Middle School.

1932 Age 14
Reads *Variété* by Paul Valéry (translated by Masaaki Sato and Kenzo Nakajima, Hakusuisha Publishing Co., Ltd.) and is deeply moved.

1933 Age 15
His essay titled "The Pleasures of Reading" is selected for publication in the school's bulletin Wakaki kokoro (Young minds), Showa-period edition.

1936 Age 18
April: Enrolls in Department of Science, Seijo High School
December 20: Father, Ryuichi, passes away after illness.
Oldest brother, Hiroaki, takes over management of Ryuichi's steel company, and is joined by younger brothers Fumihito and Naoji.
Hiroaki raises Chikio like a father.

1937 Age 19
July 7: The Second Sino-Japanese War breaks out.

1939 Age 21
April: Enrolls in the Department of Mathematics, Faculty of Science, Tokyo Imperial University, majoring in probability, with Prof. Soichi Kakeya as his academic advisor.
September 1: Nazi Germany invades Poland, leading to the outbreak of World War II.

1940 Age 22
Japan signs Tripartite Pact with Germany and Italy.

1941 Age 23
November 26: The Japanese task force sets out for Hawaii.
December 8: Japan declares war on the U.S. and Britain; Pacific War breaks out.

1942 Age 24
October 20: After graduating ahead of schedule from Tokyo Imperial University, becomes a technical cadet at the Imperial Japanese Army's Mito Flying School.

1943 Age 25
February 20: Graduates and becomes a first lieutenant (aeronautics) assigned to the army's air service headquarters.

1944 Age 26
October 25: Divine Wind Special Attack Unit makes first suicide attacks at Leyte Island.
December 7: Tonankai Earthquake and tsunami.

1945 Age 27
March 10: Firebombing of Tokyo; the family home in Higashi Nakano is destroyed; he moves to a rented house in Meidaimae.
April 8: Assigned to Imperial Army Air Service Headquarters.
August 6: Atomic bomb dropped on Hiroshima.
August 9: Atomic bomb dropped on Nagasaki.
August 15: Radio broadcast of Emperor's announcement of surrender.
August 20: Promoted to captain (technical).
September 2: Japan signs articles of surrender.
October 15: Disarmament completed.
December 28: Begins work as Research Assistant at Faculty of Science, Tokyo Imperial University. Begins practicing the flute on his own.

1946 Age 28
December 16: Joins the Institute of Statistical Mathematics (ISM) as Technical Officer, Ministry of Education.

1947 Age 29
January: Death from pneumonia of Soichi Kakeya, the first director-general of ISM.
May: University of Tokyo Prof. Joichi Suetsuna is appointed as the second ISM director-general (concurrent).

1948 Age 30
April: Suetsuna resigns as ISM director-general, to be replaced for the time being by Toshio Kitagawa.
August: Participates in National Literacy Survey; develops sampling and Quantification Method Type I (to 1951). Begins providing guidance to Asahi Shimbun opinion survey department, participates in election forecasting.
December 15: Ministry of Education instruction officer (concurrent). Begins parole research and development of quantification theory. Develops Quantification Method Type II (to 1950).

1949 Age 31
November 17: Tadahiko Kubota is appointed as the third ISM director-general.
December 15: Ministry of Education instruction officer (concurrent), the research and information section, National Institute for Educational Research (to 1953).

1951 Age 33
June 1: Director, ISM Research Dept. 3 (statistical theories for the social sciences).

1952 Age 34
Participates in research group with Hajime Ikeuchi, Yoshitaka Umeoka, Taro Indo, and others; encounters the Guttman scale. Expands Quantification Method Type II to its current form during a survey of attitudes toward American and French culture; develops Quantification Method Type III during a survey of National Railway line maintenance personnel.
September 1: Tatsujiro Sasaki is appointed as the fourth ISM director-general.
General-purpose relay computer capable of generating tables of random numbers is developed.

1953 Age 35
August: Ministry of Education instruction officer. Begins National Character Survey research.
Family residence in Higashi Nakano is rebuilt; his older brother and his family settle there, while Hayashi moves with his mother and older sister to Mitakadai, Musashino City.

1954 Age 36
October: Receives Ouchi Prize (the most prestigious award in the field of statistics in Japan).

1955 Age 37
January: "Research on Quantification Theory in Psychology" (edited by Sadaji Takagi) is published.
April: Marries Reiko Ohashi of the Ohashi zaibatsu (co-founder of Kurashiki Spinning Works [currently Kurabo Industries]). Takes up residence in a new home next to that of his mother and sister in Mitakadai.
September: Director, ISM Research Dept. (natural and social science theories).

1956 Age 38
January 20–May 15 (116 days): Dispatched to University of London as a foreign research student. Before arriving in London, visits Hebrew University of Jerusalem and the Israeli government's social policy research institute. Attempts to meet Guttman, but the latter is absent; visits Istanbul University, where Richard von Mises and Hans Reichenbach had taught after fleeing the Nazis, before proceeding to London. On his way back to Japan, stops by Sweden, then on to America where he meets Guttman. After a three-month study stay, returns to Japan, where his pregnant wife is waiting. His first child Sachio is born in March; in June, he receives his doctorate in science from the University of Tokyo. His thesis is entitled "Statistical Mathematical Methods for Qualitative Quantification."

1957 Age 39
Development of Quantification Method Type III (during canned goods label design research at the request of Keinosuke Sato); carries out Asahi Operations Research (AOR) mass media contact research; begins joint ECG analysis research with Eiichi Kimura of Nippon Medical School Cardiology Department.
October 18: Tatsujiro Sasaki takes leave of absence from ISM due to illness.
December: Birth of second son, Yukikazu.

1958 Age 40
April: University of Tokyo Professor Joichi Suetsuna is appointed to serve concurrently as ISM director-general.

1959 Age 41
March 31: Joichi Suetsuna is appointed as the fifth ISM director-general.

1962 Age 44
Participates in research relating to circulatory organs and medical examinations.

1963 Age 45
March 30: Opening of ISM computer room.
Member, NHK Broadcasting Culture Research Institute (to 1969).

1964 Age 46
Publishes *Shijo-chosa no keikaku to jissai* (Market survey planning and practice). Quantification theory-based computer program is developed and sold to Morinaga and NHK.

1965 Age 47
Chair, Japan Association for Forestry Statistics (to 1984).
Begins wild hare population survey.
March: Receives NHK Broadcast Culture Prize.
October: Undergoes operation for glaucoma.

1966 Age 48
July: Domestic survey researcher, Small and Medium Enterprise Agency (one term).
Japanese Society for Hares founded.

1968 Age 50
Moves to temporary offices due to new ISM building construction.
June 6: Death of mother, Chiyo.

1969 Age 51
March: Technical advisor, Science Council.
July: Member, Health and Welfare Statistics Council, Ministry of Health and Welfare (to 1971).
October 30: Moves to new ISM building.

1970 Age 52
Member, NHK Broadcasting Culture Public Opinion Research Committee (to 1986).
August 6: Death of Joichi Suetsuna.
September 1: Louis Guttman and his wife visit Japan.

1971 Age 53
February: Technical advisor, Science Council.
In anticipation of first research survey of Japanese-Americans in Hawaii for cross-national comparative character survey, discovers viable approach using Quantification Method Type III (pattern classification); realizes effectiveness of the method.
March 1: Prof. Yoshitaka Kawada, Faculty of Science, the University of Tokyo is appointed as the sixth ISM director-general (concurrent).

1972 Age 54
February: Film production of *Nousagi wo kazoeru* (Counting wild hares) (NHK).
President, Japan Association for Philosophy of Science (to 1984).

1973 Age 55
President, Japan Color Research Institute (lifetime).
Founding of the Behaviormetric Society of Japan, Hayashi becomes the first chairman (to 1988).

1974 Age 56
February: Death of elder sister, Yoshiko.
March 1: Becomes ISM director-general (to 1986).

1975 Age 57
January: Japanese Language Council member (to 1981).
US-Japan seminar on multidimensional scaling analysis and related methods.
Director, Japan Marketing Association.
October: The ISM Research Dept. 6 (statistical theory of behavior) is instituted.
December 1–9: Trip to Philippines.
Observes cultural friction in the South East Asia region.

1976 Age 58
British mathematical statistician D. J. Finney (1917-2018) visits Japan.
Honorary Fellow, Royal Statistical Society (UK).
Technical advisor, epidemiological statistics (to 1977).
Multidimensional scaling research on the basic attitudinal structure of the Japanese people (the "bogey" survey) (to 1978).

1977 Age 59
March 9–22: Trip to the United States.
April: Member, Japanese Language Council (to 1979).
Chair, Arteriosclerosis Prevention Research Association (lifetime).

1978 Age 60
October 26–November 11: Trip to Federal Republic of Germany.

1979 Age 61
February: Chair of Prime Minister Masayoshi Ohira's social policy research group to investigate people's interest concerning life in diversified society (to 1980).
March: Member, Japanese Language Council member (to 1986).
June: Director, Japan Marketing Association (executive director from 1986) (lifetime).
October 15–26: Trip to France and Belgium. Meets French statistician Jean-Paul Benzécri.
Chair, Japanese Society for Hares (becomes the Japanese Wildlife Research Society in 1991).
Plays flute for the Atago Concert (to June 2002).
November: Completion of Information Statistics Research Building.

1980 Age 62
President, Biometric Society of Japan (to 1986).
Director, International Biometric Society, Japan Chapter (to 1986).
Computer Operations Committee is formed.

1981 Age 63
June: Member, Statistics Research Liaison Committee, Science Council of Japan (to 1987).
November: Member of the Board of Trustees, National Institute for Educational Research (to 1985).
Receives Japan Medal of Honor with Purple Ribbon.

1982 Age 64
February: Technical advisor, Science Council (Science Research Budget Subcommittee) (to 1986).
March: Member, Japanese Language Council (to 1984).
September: Member, History and Philosophy of Science Research Coordinating Committee (to 1987).

1983 Age 65
President, Japanese Classification Society (to 1986, 1991–1992, 1992–1999).

1984 Age 66
April: Visiting professor, Open University of Japan (one year).
Chosa no kagaku (Science of survey), Kodansha Bluebacks.
The International Biometric Conference held in Japan.
Switches from flute to French horn.
Studies the instrument on his own while listening enthusiastically to recordings by renowned horn player Dennis Brain (1921-1957).

1985 Age 67
July: Member, Science Council of Japan.
President, Japan Statistical Society (to 1986).
Chairman of the Japan Association for Public Opinion Research (to 1999).

1986 Age 68
ISM professor emeritus; professor, Open University of Japan (to 1996).
Advisor, Japan Marketing Research Association (participation from 1999) (lifetime).
Hirotsugu Akaike is appointed as the eighth ISM director-general.

1987 Age 69
Japan-France scientific joint seminars (1st seminar, Tokyo; 2nd seminar, Montpellier, 1992).
Begins national character study of Japan, the US, Italy, France, Germany, the UK, and the Netherlands (establishes chain-sequence comparative survey analysis method).
Sets up office in an apartment building in Sakuragaoka, Shibuya City and devotes himself to international surveys and analysis.
His office becomes a gathering place for numerous researchers.
October 25: Louis Guttman dies at 71.

1989 Age 71
Receives The Order of the Sacred Treasure, Gold and Silver Star.
Senior editor for the works of Joichi Suetsuna (three volumes, Nansosha).

1991 Age 73
Visiting professor, Open University of Japan (to 1996).
Begins survey of Japanese-Brazilians.

1992 Age 74
Chair, Public Opinion Research Center.
Advisor (lifetime), Institute of Social Research, Institute of Nuclear Safety System, Incorporated.

1994 Age 76
Ryoichi Shimizu is appointed as the ninth ISM director-general.

1996 Age 78
International Federation of Classification Societies (IFCS) conference held in Kobe.

1997 Age 79
Japan Statistical Society Award.

1998 Age 80
President, IFCS (to 1999).

1999 Age 81
Survey of Japanese-Americans on US West Coast.

2000 Age 82
Enjoys trip to Germany with Reiko.

2001 Age 83
June 1: *Deeta no kagaku* (Data science) is published by Asakura Shoten. Hayashi entrusts Ryozo Yoshino to deliver the book to Hiroshi Mizuno, and writes on its cover, “Finally, I came this far.” (Mizuno himself would pass away in September 2003, only a year after Hayashi.)
September 11: Terror attacks on the United States.
September 14: Emergency admission to Nippon Medical School Hospital due to cardiac dysfunction; is forced to cancel his keynote address at the 29th annual meeting of the Behaviormetric Society at Koshien University, his first such cancellation.

2002 Age 84
March 31: Genshiro Kitagawa is appointed as the tenth ISM director-general.
May 11: Lectures on “Data Science and Survey Methods” at Behaviormetric Society Symposium.
June 8: Plays horn (“Memories of the Alhambra" for the Atago Concert.)
July 6: Publishing committee for the complete works of Chikio Hayashi holds its first meeting. (At this meeting, Hayashi’s third admission to the hospital on June 29 was announced. A list of Hayashi’s works, prepared in his own hand writing, is distributed to the committee.) He continues to polish the manuscript while in the ICU.
August 6: Dies of multiple organ failure; posthumously awarded the Senior Fourth Rank (court rank).
August 15: *Suji ga akasu nihon-jin no senzairyoku* (Numbers reveal the hidden strength of the Japanese), co-authored with Masafumi Sakuraba, is published by Kodansha.

2004
November 30: *Hayashi Chikio chosakushu* (The complete works of Chikio Hayashi) in 15 volumes is published by Bensei Shuppan.

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Abbreviations:

AOR	Asahi Operations Research
CA	Correspondence Analysis
CIE	Civil Information and Educational Section
CLA	Cultural Link Analysis
ICU	Intensive Care Unit
ECG	Electrocardiography
ISM	Institute of Statistical Mathematics
IFCS	International Federation of Classification Societies
INRIA	Institute National de Recherche en Informatique et en Automatique
JCS	Japanese Classification Society
JSPS	Japanese Society for the Promotion of Science
MDA	Minimum dimension analysis
MDA-OR	Minimum dimension analysis of ordered class belonging
MDA-UO	Minimum dimension analysis of unordered class belonging
MDS	Metric multidimensional scaling
NHK	Japan Broadcasting corporation
NIER	National Institute for Education
NINJAL	National Institute for Japanese Language and Linguistics
nMDS	non-metric MDS
QOL	Quality of life
SSA	Smallest space analysis
TAP	Travel Award Program
UPS	Universe, population, sample

About the Author

Kumiko Maruyama graduated with a Master's Degree in psychology from Aoyama Gakuin University. She received special training in data science under the guidance of Professor Chikio Hayashi of the Institute of Statistical Mathematics. K. Maruyama became a research assistant at Aoyama Gakuin University, then a special research student at the Division of Educational Psychology, Graduate School of Education, the University of Tokyo. She studied psychometrics at the University of Illinois. Subsequently, she was a professor at Morioka University, then a professor at Seigakuin University, a visiting professor at the University of Cologne (Germany), a visiting researcher at the National University of Ireland and at the University College Dublin, and a professor at Hokuriku Gakuin University. She is currently an emeritus professor at Seigakuin University. K. Maruyama was a recipient of the Chikio Hayashi Award.

Her scientific publications include several articles co-authored with Professor C. Hayashi. K. Maruyama has written several biographies, including *"Hayashi Chikio no Shogai"* (The Life of Chikio Hayashi), Shin-yo-sha, 2015; *"Kitamori Kazoh Den"* (The Story of Kazoh Kitamori, Theologian), Kyobun-sha, 2016; "*Soutou no Washi*" (The Life of Tokiyuki Hojo, Educator, Mathematician), Kosaku-sha, 2018; "*Sakuta Akira no Shogai*" (The Life of Akira Sakuta, Criminal psychiatrist), Seigakuin University Press, 2020.

Notes

Picture credits

p.13: Statistician Chikio Hayashi Interview; TOKYO, JAPAN - JANUARY 11: Statistician Chikio Hayashi speaks during the Asahi Shimbun interview on January 11, 1994 in Tokyo, Japan. (Photo by The Asahi Shimbun via Getty Images). **p.18:** Ambrosio Paul Toussaint Jules Valéry, 1871-1945 French poet, essayist, and philosopher After a contemporary print. (Photo by: Universal History Archive/Universal Images Group via Getty Images). **p.24:** Richard von Mises, 1883-1953 Mathematiker 1883-1953+MathematikerPortrat-1931 (Photo by ullstein bild/ullstein bild via Getty Images). **p.31:** Courtesy of Tohoku University Archives. **p.53:** Professor Louis Guttman, March 24, 1954. (Photo by Anthony Calvacca / New York Post Archives/(c) NYP Holdings, Inc. via Getty Images). **p.61:** Courtesy of the Behaviormetric Society. **p.103:** Courtesy of the author.

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