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Mechanization of Hearing in Chao Yuen Ren's Dialect Research, 1927–1936: Senses, Objectivity, and Observation[1]

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Abstract: When scientific research began in early twentieth-century China, a key issue was the acquisition of reliable empirical information through objective and precise observations. This article examines a specific case where a scientist grappled with such an issue: the linguist Chao Yuen Ren's application of mechanical means in his phonetic studies. In the 1920s–1930s, Chao conducted a series of field and lab studies on the dialects in southern and central China. In contrast to traditional scholars' exclusive reliance on sharp ears and rhyme books, Chao employed mechanical devices to inscribe and analyze the spectrographs of dialectical tones and used phonographs to record the articulations of his subjects. It is demonstrated that Chao's machines not only provided a new method of observation; they also altered the theoretical understanding of certain fundamental categories in Chinese phonology, such as tones. Moreover, Chao did not aim to replace human perception with automatic mechanisms in empirical investigations. Rather, the use of machines in his research called for an active and engaged scientific persona.

Keywords: mechanical objectivity, phonetics, tone, phonograph, Chinese dialects

摘　要：当科学研究于 20 世纪初在中国发轫时，关键问题之一是如何经由客观精确的观察取得可靠的经验数据信息。本文通过具体的个案探究当时如何处理客观性的经验观察这一问题，聚焦于语言学家赵元任在其语音研究中使用的机器装置。赵元任于 20 世纪二三十年代在华中与华南地区进行了一系列包含田野及实验室记音的方言调查。有别于传统音韵学家完全依赖人耳辨音与韵书的方法，赵元任利用机械仪器印刻并分析各种方言

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声调的频谱，且使用留声机记录受访者的发音。赵元任使用的机械装置不只提供新的观测工具，更改变了对中国音韵学的一些基本范畴（如声调）的理解。此外，赵元任并不试图以机器取代观测者在经验研究中的地位。相反地，这些机械装置对研究者的个人特质有新的要求。
关键词：机械客观性，语音学，声调，留声机，汉语方言

1 Introduction

Science has always been a salient feature of modern Chinese society. Yet while intellectuals and technocrats of the late Qing period had systemically translated Western scientific books and begun to erect relevant educational institutions, science as a research endeavor—not just a body of imported knowledge—did not start to take root until the second decade of the twentieth century. By the time of the Sino-Japanese War in 1937–1945, China had a sizable community of scientists actively conducting investigations in a number of areas.[3] These early Republican scientists adopted various strategies to build up research in the modern sense from almost nothing. Some devoted themselves to novel interpretations of conventional wisdom and classical texts—as in the case of traditional Chinese medicine. Some undertook fieldwork to study the country's idiosyncratic physical, biological, and humanistic environments—for example, geology, zoology, botany, and ethnology. Some engaged critically with historical writings and legends by weighing them against new archaeological findings. And some tried to establish research programs with tighter connections to researchers' local networks of expertise and training than to China's geographical or cultural niches—as in the case of physics (Lei 2014; Fan 2007; Shen 2014; Hu 2005).

One strategy pursued an approach distinct from those mentioned above, however. This approach was marked by an attention to the nature of sensory perceptions and their stimuli, as well as by an attempt to define the proper ways of retrieving meaningful information from sensory experiences. In this context, what the Chinese scientists highlighted as indispensable to scientific inquiry had less to do with its topics, subjects, theories, concepts, mathematics, or logic than with its arts of observation. Such a focus on senses and observations not only resonated with the May Fourth intellectuals' general preoccupation with empiricism; it also reflected the practical problems the early Republican researchers encountered in obtaining usable, sensible, and reliable empirical data.

In this article, I examine a case closely related to this concern with senses and observations among early Republican scientists: the linguist Chao Yuen Ren's 趙元任 (Zhao Yuanren, 1892–1982) research on the phonetics and phonology of Chinese

3 For a brief overview of the historical setting of the build-up of science during the Republican period, see Elman 2014.

dialects in the 1920s–1930s. Chao's entire career witnessed a sea change in China's language studies in particular and its development of modern science within transnational contexts in general. Elsewhere I have discussed Chao's theoretical explorations of cybernetics when he was teaching in the US during the 1940s–1960s, and have placed these explorations in the context of his earlier language-related work (Yeang 2017). Here, my focus is on Chao's methods of empirical investigation in his linguistic research in China during the 1920s–1930s. As a research associate of the Institute of History and Philology at Academia Sinica, Chao designed and conducted field surveys and laboratory investigations on the dialects of various regions in central and southern China. In a sense, Chao's work bore the mark of a longstanding cultural heritage of studying sound in the Chinese language. For hundreds of years, mastering the articulation of words from rhyme books had been an integrated part of classics education, and tracing the chronological changes of phones had been one of the most dynamic scholarly fields. Yet some Chinese intellectuals in the early twentieth century, including Chao himself, were increasingly dissatisfied with traditional phonology, which, they believed, could only amount to an antiquated, bookish undertaking that did not help increase the knowledge about spoken Chinese. Their aim was to transform Chinese phonology from a form of literary scholarship into an empirical science of actual utterances.

A primary challenge to this goal had to do with the problems of senses and observations: How to denote and represent sound and voice precisely? How was it possible to record and reproduce sound and voice? To what extent did the methods of denotation, representation, recording, and reproduction assist the analysis of sound and voice? Chao's research in the 1920s–1930s tackled exactly these questions. His solution to these problems was interesting, for he was among the first Chinese language scholars to introduce mechanical instruments to facilitate observations in phonetic studies. In his dialect surveys, he employed various apparatuses and devices, ranging from the sliding pitch pipe to the kymograph and phonograph, to reproduce and inscribe sound. He also designed a number of instruments to automatically record the spectral characteristics of tones in Chinese dialects. Chao's frequent use of instruments in the data acquisition of his dialect research may be conceived of as a way to mechanize hearing. This mechanization of sensory input was consistent with the methods that Western experimenters since the mid-nineteenth century had been adopting to remove personal bias from data recording via automatic apparatuses, which historians Lorraine Daston and Peter Galison call "mechanical objectivity" (Daston and Galison 2010).

Nevertheless, Chao by no means treated his instruments as theory-free artificial sensory organs or automatic data-taking machines free from human intervention. In fact, some of the apparatuses he introduced were not mere recorders but rather analyzers of sound and voice. Specifically, he made significant efforts to invent and improve devices that could measure the frequency variations of tones in various Chinese dialects. To him and his peer phoneticians, devices of this kind brought novel meanings to the millennium-old notions of tones, "clear," and "murky" in Chinese phonology that could meet their increasing demand for precision and objectivity. The automatic instruments thus epitomized a fundamental change in the theoretical framework of the study of Chinese language.

Moreover, counter to the popular belief that humans should be removed from scientific observation, Chao's employment of mechanical instruments marked the emergence of a scientific persona. Throughout his research in the 1920s–1930s, human data collectors continued to play a central part. The machines did not replace the human observers, but rather depended on humans with particular qualifications. His tone spectral measurers required delicate operations and interventions by human data collectors with "musical ears." In addition, he utilized the phonograph in a non-conventional way (by playing the record backward), such that his research assistants could gauge the precision of phonic denotations. The mechanical instruments thus fit together perfectly with the image of an ideal phonetic researcher as an individual with sensitive and musical aural perceptions.

Chao's method of mechanized observations produced several crucial works on Chinese dialectology. In the 1920s–1930s, he and his research team conducted a series of phonetic surveys in central and southern China. These surveys and Chao's other phonetic documentation led to the corpora that comprised detailed phonological reports in distinct regions, transcriptions of non-Han lyrics, and abundant unpublished records. These works, together with a few other reports and scholarly accounts from linguistic surveys on Han and minority peoples by Bernhard Karlgren (1889–1978), Luo Changpei 羅常培 (Lo Ch'ang-p'ei, 1899–1958), Liu Fu 劉復 (Liu Fuh, 1891–1934), and Li Fanggui 李方桂 (Li Fang-Kuei, 1902–1987) around the same time, marked a new page in Chinese phonetics and phonology. The significance of Chao's empirical studies is not that they altered the fundamental theoretical understanding or uncovered important, novel features of the Chinese oral language. Rather, Chao's reports and documentation during this period were critical because they represented some of the first sets of empirical data on Chinese phonetics obtained by systematic, scrutinizing, and machine-assisted means in the framework of modern linguistics.

2 Making of a scholar

Born in 1892 in Tianjin, Chao Yuen Ren came from a clan of literati that had resided in Changzhou, Jiangsu Province for generations. Throughout the eighteenth and nineteenth centuries, the Zhao clan had produced a number of scholar-officials. Yet despite a strong family tradition of Chinese classics education, Yuen Ren was sent to a westernized, modern high school in Nanjing. In 1910, he passed the exam for the Boxer Indemnity Scholarship, from which he got an opportunity to study at Cornell University (Zhao and Huang 1998, 26–65; Levenson 1977, 1–30).

At Cornell, Chao majored in mathematics and took courses in (among other subjects) physics and philosophy. He obtained a BS in mathematics in 1914, stayed at Cornell to pursue a doctoral degree in philosophy, and transferred to Harvard University the next year. He obtained a PhD from Harvard in 1918, visited the University of California at Berkeley with a postdoctoral fellowship, and went back to Cornell as a lecturer in physics in 1919 (Zhao and Huang 1998, 66–97; Levenson 1977, 31–46).

The following decades witnessed Chao's wanderlust, which brought him across China, America, and Europe. He took an offer from Tsing Hua College in Beijing and returned to China in 1920; went back to Harvard to teach philosophy and Chinese in 1921; left Cambridge, Massachusetts in 1924 for an extended study trip in Britain, France, Germany, and Sweden; and accepted an offer in 1925 to become a research professor at the Graduate Institute of Sinology at Tsing Hua, which now became a university. In 1928, he joined the Institute of History and Philology of the newly established Academia Sinica and commuted between Guangzhou and Beijing. He visited the US again in 1932 as director of the Tsing Hua Chinese Educational Mission in America in Washington, DC, and returned to Academia Sinica a year later. When the Institute of History and Philology was resettled in Nanjing in 1934, Chao moved his household to the nation's capital, too. He planned to live there for good and develop a career. Yet the plan was ruined by the outbreak of the Sino-Japanese War in 1937, which forced him to move again (Zhao and Huang 1998, 98–196; Levenson 1977, 47–75).

Chao began to show interest in linguistics as early as his undergraduate years. In his diary in 1915, he stated, "I thought that I am essentially a born linguist, mathematician, and musician," and "I might as well be a philologist as anything else" (Zhao and Huang 1998, 82). At Cornell, he took courses in linguistics and co-wrote a series of articles with Hu Shi 胡適 (Hu Shih, 1891–1962) on "the problem of the Chinese language" (Zhao and Huang 1998, 83). But Chao traced the moment of his final decision to commit to linguistics to 1920, when Bertrand Russell undertook a speaking tour around China and Chao was asked to serve as Russell's translator. On a boat trip with the English philosopher's entourage to Changsha, Hunan Province, Chao met a local person and picked up some of the Hunan dialect from him. When they arrived, he used the newly learned dialect in the oral translation of Russell's lectures. His accent was so perfect that the audience believed he was a native speaker like them. This episode not only revealed to Chao his own talent for learning and speaking Chinese dialects, but also triggered his curiosity to further explore the Han Chinese's geographically diverse oral language. It was about this time that he decided to pursue linguistics as a career (Zhao and Huang 1998, 116; Chao 1976, 13).

3 Transforming phonology

Phonology was not a new subject to educated people in China at this time. For centuries, it had been part of classics and literary education, since knowing how to pronounce words correctly was the first step toward reading and composing prose and poetry. State-issued phonological dictionaries ("rhyme books") such as *The Tang dictionary of rhymes* (*Tang yun* 唐韻) of the eighth century and *The extended rhyme dictionary* (*Guang yun* 廣韻) of the eleventh century had been widely available for the literati to choose words with the right rhythms for their poems. Nevertheless, these dictionaries did not instruct one how to pronounce a word by specifying the positions and shapes of the tongue, teeth, lips, and vocal cords, as modern phonetics does. Rather, they indicated the pronunciation of words by using other words, and grouped together words with the same pronunciation in a system known as the "turning and spelling method" (*fanqie* 反切). The problem was that this phonological system did not correspond to the contemporary spoken language, but presumably to the spoken language of more than a thousand years prior. Consequently, the dictionary guides to pronunciation deviated significantly from people's daily linguistic experience. This discrepancy in knowledge began to be addressed by the leading scholars of the Qing period from the seventeenth to the nineteenth century, who developed the renowned scholastic tradition of *kaozheng* 考證, of which phonology was a substantial part. These individuals devoted much effort to reconstructing the association between the ancient and contemporary systems of sounds by analyzing and revising the existing rhyme systems. Through comparative research into ancient and medieval Chinese texts, they uncovered the historical evolution of certain features of pronunciation and devised the principle of using sonic similarities as a basis for reconstructing the meaning of archaic words. Such major achievements from the *kaozheng* scholarship nonetheless did not alleviate the early twentieth-century Chinese intellectuals' concern that the phonological grouping of words remained a categorizing scheme that was independent of the words' actual oral utterance, and that classical phonology thus became an archaeology of written documents (Chao [1959] 2002, 517).[4] This problem with traditional Chinese phonology became acute for Chao's contemporaries. For instance, Chao's close friend Hu Shi once criticized the work of Gu Yanwu 顧炎武 (1613–1682), a famous scholar of the seventeenth century who found 162 pieces of textual evidence to demonstrate that the ancient articulation of the character *fu* 服 was identical to that

4 For traditional Chinese phonology, especially its development during the Qing period, see Baxter 1992; Wang 1981, 109–172; Zhao 2000, 341–412; Pu 1990, 359–456.

of *bi* 逼. But Gu did not really know how to pronounce the character *bi* 逼 (Hu [1928] 1986, 356).

The situation began to change in the early twentieth century, when a few individuals began to employ the methodology of modern Western linguistics in studies of Chinese phonology. Applying the methods of historical linguistics that Western scholars had used to investigate Indo-European languages, the Swedish sinologist Bernhard Karlgren proposed a reconstruction of the sounds of Old and Middle Chinese based not only on ancient phonological dictionaries but also on a comparison between various Chinese dialects, Japanese, and Vietnamese. His book *Études sur la Phonologie Chinoise* (Studies on Chinese phonology), first published in 1915, opened up a new direction for Chinese phonology and dissociated it from the scholarly tradition of classics studies.[5]

4 Fieldwork and labwork on dialects

This was the intellectual milieu of Chinese phonology when Chao entered the field. Like those influenced by Karlgren, he viewed phonology as an empirical science, not a form of literary scholarship. Getting to know how words were pronounced in a living language involved listening to, recording, classifying, and analyzing how those using that language spoke, not studying antiquated dictionaries or sniffing through ancient texts. Thus, fieldwork became Chao's primary mode of data collection. From 1927 to 1936, he conducted a series of field surveys on the Han dialects across the central and southern provinces of China proper. While he was still teaching at Tsing Hua University in 1927, he conducted a field survey with his assistant Yang Shifeng 楊時逢 (1903–1989) on the Wu dialects in Jiangsu and Zhejiang. Upon transferring from Tsing Hua to the Institute of History and Philology, he surveyed the Yue dialects in Guangdong and Guangxi in 1928–1929. Immediately after the institute was relocated to Nanjing in 1934, Chao made a trip to Anhui with Yang, his colleague Luo Changpei, and his wife Yang Buwei 楊步偉 (1889–1981) (a gynecologist who grew up in Anhui) to study the dialects there. In the following two years, Chao, his colleague Li Fanggui, and his assistants, including Yang, Ding Shengshu 丁聲樹 (1909–1989), Wu Zongji 吳宗濟 (1909–2010), Ge Yiqing 葛毅卿 (1906–1977), and Dong Tonghe 董同龢 (1911–1963), continued the field research on dialects in Jiangxi and Hunan (1935) and Hubei (1936). Although his team also documented vocabulary, phrases, and grammars of local dialects in these surveys, their focus was to record pronunciations (Chao [1975] 1976, 26–33; Zhao and Huang 1998, 145–149, 155–157, 160, 192, 198–199, 203–204, 206–207).

5 For Karlgren, see Malmqvist 2011.

Fieldwork was not Chao's only mode of data acquisition, though. Like some of his contemporary Western peers, he viewed phonetics not only as an observational science but also as an experimental science that could and should be studied in a controlled, instrument-assisted environment. When he toured around Europe in the mid-1920s, he had the opportunity to spend a month at the renowned English phonetician Daniel Jones's laboratory at the University College London in 1924 (Zhao and Huang 1998, 125–126; Levenson 1977, 113–114). From this experience, Chao became familiar with the phonetics laboratory. In 1934, Chao enthusiastically set up his own laboratory at the Institute of History and Philology when it was resettled in Nanjing. He designed the layout of the rooms, purchased soundproofed materials from abroad and had them installed, ordered various recording and measuring apparatuses, and built some of them when they were unavailable or their performance was inadequate. Chao's aim was to make this laboratory the center for recording and analyzing sound and voice in the phonetic studies of Chinese dialects (Zhao and Huang 1998, 190–191).

Instruments played a crucial role in Chao's fieldwork and labwork. He was enthusiastic about introducing new apparatuses to phonetic and phonological research. In his 1927 survey of the Wu dialect, he did not have devices to make voice recordings of how subjects spoke. In addition to using his own perception to recognize the vowels and consonants in syllables and documenting them by hand (using the International Phonetic Alphabet, or IPA), he employed a sliding pitch pipe, a gadget similar to a harmonica, to match the tones of the syllables (see below). In his subsequent surveys, he employed a variety of phonographs as the major apparatuses for voice recording (Tu 2005, 42–43; Chao [1975] 1976, 28–30). In addition to these portable devices for fieldwork, Chao also used heavier and more delicate instruments for his laboratory research, such as the kymograph, a mechanical inscriber for recording vibrations that used a stylus to make indentations on a rotating cylinder wrapped with smoked paper. He learned how to operate a kymograph at Jones's London lab in 1924 and had one of these instruments installed at his own Nanjing lab in 1934 (Zhao and Huang 1998, 125–126, 191; Levenson 1977, 113–125).

5 Instruments of objectivity and their conditions

Clearly, the apparatuses and devices Chao used in his fieldwork and labwork served to make his data acquisition conform to the standards of modern science. They were to help the phonetic investigators overcome the limitations and shortfalls of sensory experience and hence to boost the naked ear's power of observation. Like many scientists since the Enlightenment, Chao employed mechanical instruments to reduce uncertainty, ambiguity, inconsistency, and individual variations among subjects or observers, and thus to achieve the commonly accepted virtues of science at that time: objectivity, precision, consistency, measurability, and clarity (Wise 1995).

Yet the use of mechanical instruments in Chao's research involved more than an improvement on the skills of observation. Here, the arts of observation in dialect studies were closely related to two additional conditions: a fundamental change in the understanding of sound and voice in Chinese phonology, and the emergence of a scientific persona that manifested the qualities expected of a good phonetic researcher. In the following sections, I will use two examples—the attempts to measure tones and the meanings of recording—to illustrate how Chao's methods of mechanically enhancing the human ear intertwined with these two conditions in his research.

6 Measuring tones

Among the major characteristics of the Chinese language, Chao was most intrigued by the tones. Although most languages in the world have intonations, Chinese uses tones to differentiate meanings of words instead of using them to express emotions or intensions, as many other languages do. The classical phonological dictionaries classified Chinese words into groups of four or five tones: *ping* (*yin ping* 陰平 and *yang ping* 陽平), *shang* 上, *qu* 去, and *ru* 入. In the national language officially standardized in the 1910s, based on Mandarin, *yin ping* was the first tone, *yang ping* the second, *shang* the third, and *qu* the fourth. (*Ru* was a short and rapid tone only present in some dialects.) Two words with the same syllable but different tones usually meant entirely different things; for example, *yin* (first tone) might mean cloudy 陰, *yin* (second tone) silver 銀, *yin* (third tone) hide 隱, and *yin* (fourth tone) seal 印. Some southern dialects had more tones.

The formal identification of the tones in Chinese began as early as the fifth century. For a long time, Chinese scholars used analogical adjectives to define the tones. In a well-known verse on the four tones, according to linguist Liu Fu, Chao's contemporary, *ping* was described as "sad and calm," *shang* as "sharp and elevated," *qu* as "clear and far," and *ru* as "straight and short." By the turn of the twentieth century, however, this kind of specification appeared more and more outdated and ambiguous to Chinese phoneticians. They started to use the length of articulation and the pitch of voice to define the tones (Liu 1924b, 86–91).

6.1 Acoustic basis of voice

But even this more phonetically savvy perspective on the nature of tones was unsatisfactory to precision-seeking researchers like Chao. In his view, phoneticians should not only uncover the physiological basis of speech and voice (as they had done since the nineteenth century) but also explore the "physical" (that is, acoustic) elements of phones and sound. He believed that these acoustic elements were more fundamental than physiological attributes and could be used to explain various phonetic features of a spoken language, including the tones. Chao began to develop this view in the early 1920s and articulated it explicitly in a 1924 exposé titled "Physical elements of speech" (Yuyin de wuli chengsu 語音的物理成素), which he wrote for *Science* (*Kexue* 科學) magazine. Chao started this article by pointing out that all the basic units in current phonetics and phonology, such as syllables, vowels, and consonants, were not basic enough. For example, physiological phoneticians had demonstrated that the pronunciation of a sound as simple as "m" required a sequence of complex coordinated actions among speech organs. Even if one separated the sound from its physiological origin, the sound itself was a composite. It could, and should be broken down into its acoustic attributes. Thus, an acoustic phonetics—which he considered to be young but on the rise—was potentially as important as physiological phonetics (Chao [1924] 2002, 103–112, eps. 103).

Chao listed the acoustic components of a phonetic sound: duration, intensity, pitch of fundamental, overtones, and noise. These components would become clear if one treated a sound as a waveform and performed a spectral-temporal analysis: the duration was the overall period of this waveform; the intensity corresponded to its overall or average energy; the pitch of fundamental was its lowest frequency component; the overtones were other discrete frequency components that might or might not be multiples of the fundamental; and the noise referred to the components that did not have apparent periodicity, which corresponded to a continuous spectral region. Chao asserted that the combinations of these elements constituted distinct phonetic features of a sound: duration and intensity specified stress accent; duration, intensity, and overtone demarcated syllables; duration and fundamental (frequency) determined intonation; intensity and fundamental were often confused with each other in a language because of their high statistical correlation (that is, sounds of high volume were often sounds of high frequency in a spoken language, and vice versa) (Chao [1924] 2002, 104–112).

6.2 Liu Fu's kymograph

Analyzing speech in terms of its acoustic elements provided a novel understanding of sound and voice to some Chinese language scholars. To them, acoustics not only facilitated a more precise definition of longstanding notions in Chinese phonology, such as the tones, but also turned them into measurable entities. Chao was not the first to come up with the idea of measuring the tones in Chinese. When the linguist, poet, and songwriter Liu Fu (better known as Liu Pan-nung or Liu Bannong 刘半农) pursued a PhD at the University of Paris (Sorbonne) in 1924, his dissertation project concerned exactly the acoustic measurement of the tones in twelve Chinese dialects. Liu was convinced that tones corresponded to specific patterns of the fundamental frequency's variation over time, and he designed a procedure to measure these patterns (Levenson 1977, 115; Liu 1924a; Liu 1924b).

The instrument he employed was the kymograph (Figure 1). Invented in the 1840s by German physiologist Carl Ludwig (1816–1895), the kymograph comprised a rotating cylinder wrapped in smoking paper and a stylus mechanism. The temporal variation of a mechanical effect, be it blood pressure, pressure in a steam engine, or acoustic vibration, drove the stylus into a corresponding motion. As the cylinder was rotating at a steady rate, the moving stylus would inscribe a trace on the smoking paper, which was a graphical representation of the mechanical effect's temporal variation. By the early twentieth century, the kymograph had become a popular instrument in experimental phonetics.[6] Notice that the kymograph was presumably an automatic mechanical inscriber that did not require the experimenter's sensory input. The phonetician did not really need to hear the voice of his subject. What he did was set up the machine, ask his subject to speak to the mouthpiece connected to the kymograph, and let the stylus record the waveform of the subject's voice on the rotating paper (Liu 1924b, 21–27).

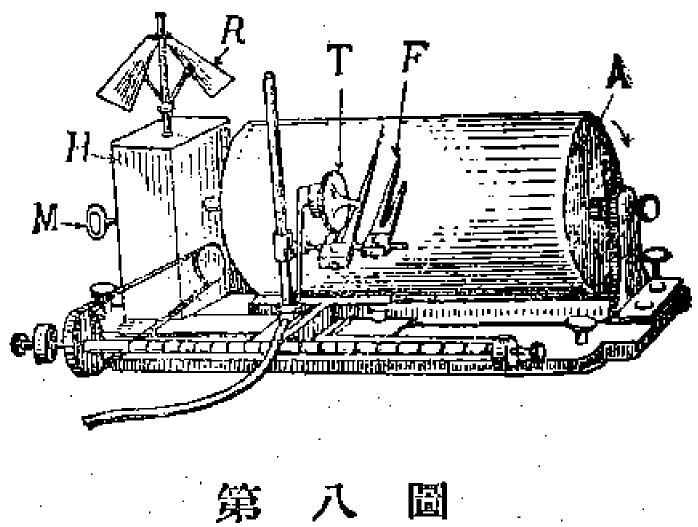
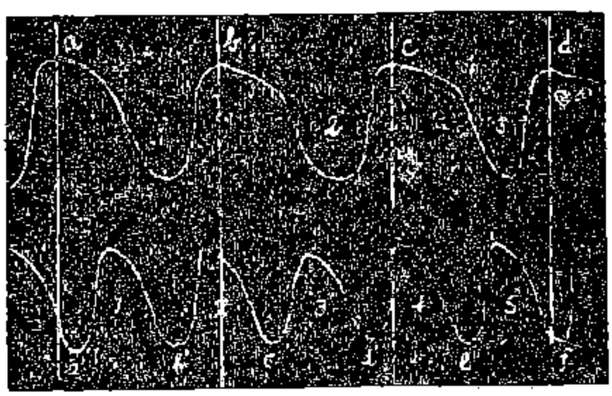


Figure 1: Liu Fu's kymograph (Liu 1924b, 22).

6 For Ludwig's invention of the kymograph, see Borell 1987.

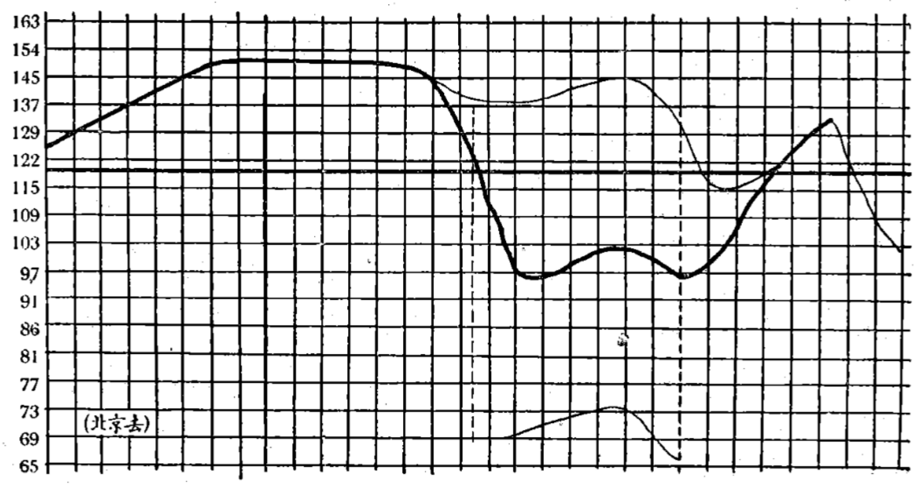
The more complicated work came after the automatic data recording. Since the kymograph directly inscribed the waveform of a voice, not the temporal variation of its fundamental frequency (which was Liu's definition of the tone), an elaborate data analysis was required to determine such a variation (Figure 2). Liu employed two methods to calculate the frequency of oscillation at a specific part of the recorded waveform. One was to overlay the waveform with an inscribed curve produced by a tuning fork with a known frequency, to count and compare the numbers of oscillations for the reference waveform and the waveform to be measured, and to compute the frequency of the latter accordingly. The other method was to measure the length of a single oscillation on the latter waveform; the frequency of oscillation was then obtained by dividing the speed of the kymograph rotation with the value of this wavelength. Repeating the same procedure for different parts of the waveform, Liu got the value of the oscillating frequency at different times. Then he plotted the numerical data on a Cartesian coordinate system. The abscissa represented the elapsed time (calculated from the distance between the part under consideration and the starting point of the waveform). The ordinate represented the perceived pitch of the voice (calculated by taking the logarithm of the measured number of oscillations, for physiologists had demonstrated that the pitch perceived by the human aural sense was proportional to the logarithm of a sound's frequency of oscillation) (Liu 1924b, 28–47). Liu found twelve male subjects, each representing a different dialect (including the ones in Beijing, Nanjing, Wuchang, Chengdu, Fuzhou, and Guangzhou). He then recorded their articulations of chosen words containing the four or five tones (*yin ping*, *yang ping*, *shang*, *qu*, or *ru*) and produced the corresponding curves of frequency variation by following the above-mentioned procedure (Figure 3). To Liu, the patterns these curves characterized represented the physical reality of tones in Chinese (Liu 1924b, 48–85).



b

第 十 九 圖

Figure 2: An example of Liu Fu's waveform (Liu 1924b, 28).



第 三 十 二 圖

Figure 3: An example of Liu Fu's spectral curve for a tone (Liu 1924b, 55).

6.3 Sensory input in Chao's mechanical devices

Chao was familiar with Liu's work. When he visited Paris in 1924–1925, he spent considerable time with Liu discussing the latter's experiment. Chao even audited Liu's thesis defense at the Sorbonne in 1925 (Zhao and Huang 1998, 130–131). Like Liu, Chao held that the curves of frequency variation over time represented the unambiguous physical reality of tones. The most obvious strength of this representation was its independence of any language system. Chao observed that while all the Chinese Han dialects had four or five tones, a tone nonetheless sounded different in different dialects. Knowing which tone was associated with which word in a dialect, as the conventional phonology had achieved, did not really convey the direct sensory experience of that tone in the dialect. By contrast, the curves of frequency variation were a clear physical denotation of the way we actually hear the tone. A case in point was to compare the spectral curves of the four tones (*yin ping*, *yang ping*, *shang*, *qu*) in Beijing and Kaifeng dialects. The four curves in the Kaifeng dialect appeared to be very close to those in the Beijing dialect in a rearranged order (Figure 4). That was the reason why, Chao argued, the four words "hua (*yin ping*) yuan (*yang ping*) hao (*shang*) da (*qu*)" (花園好大) in Kaifengese sounded like "hua (*yang ping*) yuan (*qu*) hao (*yin ping*) da (shang)" (華院蒿打) in Mandarin (Chao [1922] 2002b, 27–36, esp. 33–34).

Chao undertook a quite different approach from Liu's to produce the tones' curves of frequency variation, however. While Liu's kymograph removed the act of hearing from mechanical recording and hence got rid of human intervention at the stage of data acquisition, hearing perception was an integrated part of Chao's instruments for tone measurement. Well before his familiarity with Liu's work in 1924 and his full-fledged fieldwork in the second half of the 1920s, Chao had shown interest in and begun to work on measuring the tones. A device he often employed for that purpose was a sliding pitch pipe, a gadget similar to a harmonica that helped identify the tones of syllables. Specifically, he blew the pipe while sliding it to create a sequence of pitches that sounded similar to the tones of syllables. He then discerned the exact pitches and their durations with the assistance of a standard-tuned musical instrument, like a violin, and recorded such information with musical notes. In addition to the pipe, he also used a *qin*, a string instrument, to simulate the pitch sequences of tones (Chao [1922] 2002b, 33).

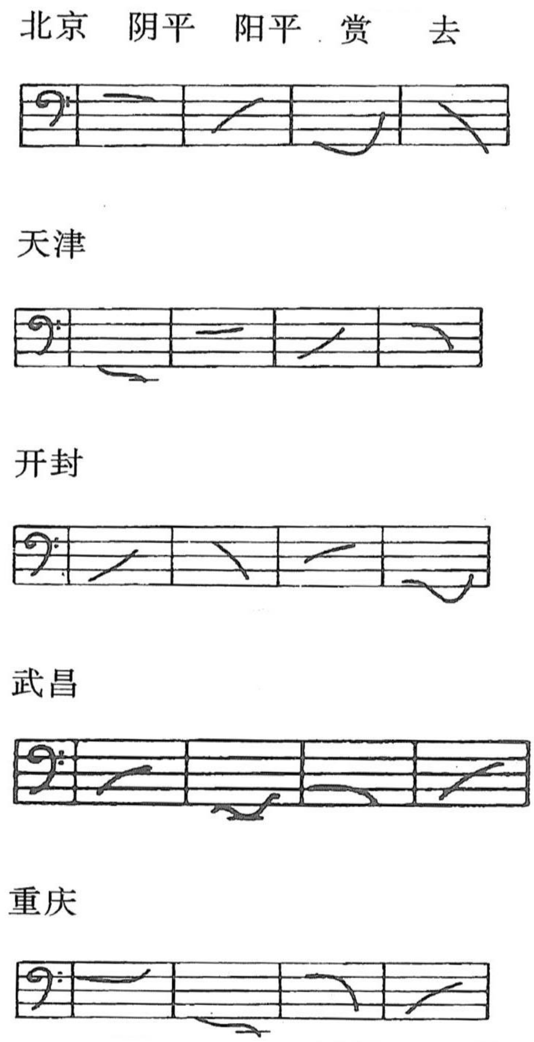


Figure 4: Spectral curves for tones in several Chinese dialects (Chao [1922] 2002b, 33).

Such musical instruments were not handy enough as phonetic experimental devices for Chao, though. In 1922, he designed a more automatic apparatus to produce the curves of frequency variation for the tones. This apparatus comprised a sliding pitch pipe mounted on a gadget similar to the kymograph, with the pipe's piston connected to a stylus that could inscribe on a sheet of paper moving horizontally at a constant speed (via a mechanism like the kymograph). The experimenter would slide the pipe's piston skillfully while blowing on it; this action could presumably produce a sound that imitated a particular tone. Note that the temporal variation of the pipe length, which was equivalent to the position of the piston, represented the temporal variation of the pipe's fundamental frequency, that is, the tone to be measured. (Recall that the dimension of a cavity is inversely proportional to the resonating frequency). When the paper-driving mechanism was turned on, therefore, the stylus would inscribe a curve that corresponded to that temporal variation. To turn the ordinate of the curve from the oscillating frequency to the pitch perceived by the aural senses, Chao set the sliding pipe at musical notes from A to G and used the machine to draw the lines representing the notes. In so doing, he actually cast the curve of a tone on a musical staff (Figure 5) (Chao [1922] 2002b, 31–33).

The instrumental design Chao proposed in 1922 was never turned into a real mechanical inscriber. In his fieldwork and labwork during the 1920s–1930s, he employed three instruments to measure the tones in Chinese dialects: the sliding pitch pipe, the whistle, and the vacuum-tube oscillator (Chao [1933] 2002, 734–749, eps. 739). All of these apparatuses followed the same fundamental principle as his mechanical design in 1922. The sliding pitch pipe and the whistle, suitable for fieldwork, were musical instruments to mimic the tones. The electronic oscillator, more delicate and hence suitable for labwork, could also produce audio-frequency oscillations with time-varying pitches that emulated the tones' spectral patterns. To operate the device, the experimenters also had to change its oscillating frequency in a way similar to playing a musical instrument.[7] The methods of recording the tonic patterns ranged

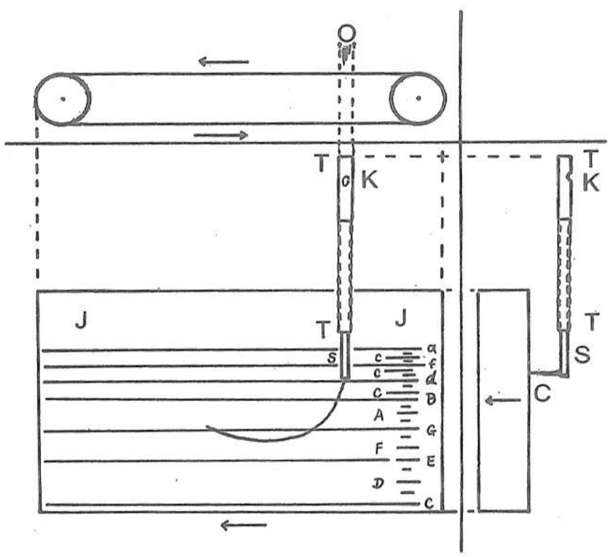


Figure 5: Chao's design of an automatic tone inscriber (Chao [1922] 2002b, 31).

from purely manual (as in the cases of pipe and whistle) to fairly automatic (as in the case of an electronic oscillator), but all of these instruments needed the experimenter to have a "musical ear."

Although both Liu and Chao conducted phonetic fieldwork with a similar

7 For an example of the type of electronic oscillator Chao referred to, see Hunt 1935, and Obata and Kobayashi 1937.

repertoire of tools and schemes for tonal recording, their approaches nonetheless continued to demonstrate the subtle but important difference between mechanical computation and human judgment. Liu kept on developing computational devices for linguistic surveys, including a series of "rulers" for tonal determination (Liu 1934). Using simpler gadgets such as the sliding pitch pipe and whistle to mimic tones, Chao adopted a notational scheme to record the dialectical tones by indicating approximately their variations of frequency over time. In this scheme, the pitch was divided into five scales from 1 (low) to 5 (high). A tone was recorded as a sequence of two or three of such numbers followed by a colon (for example, "42:") marking its pitch change from beginning to end. This set of numbers was often accompanied by the corresponding skeleton of a time-pitch curve. Almost all of Chao's phonetic surveys and transcriptions in the 1920s–1930s employed this kind of tonal recording.[8]

If Liu's kymograph required a relentless human calculator who did not meddle with the data acquisition, then Chao's apparatus demanded an experimenter with sonic sensibilities who could mimic tones with a musical instrument. Wu Zongji, one of Chao's protégés, recalled that when he applied for the position of assistant at the Institute of History and Philology in 1935, the tests comprised not only phonetics but also musical listening comprehension—the examiner played a chord on the piano and asked the examinees to write down its musical notes (Wu 2010). The observer's sensory interpretation was always indispensable in Chao's research on the tones, no matter how automatic his data acquisition scheme became.

7 Phonographic recording

The accurate recording of sound and voice was one of the most important considerations in Chao's dialect research. The systematic and carefully designed schemes of phonetic data acquisition and documentation in his fieldwork and labwork marked a fundamental difference between the traditional phonology as a form of textual scholarship and the Chinese linguistics of Chao's generation in the 1920s–1930s as an empirical science. The phonograph was a crucial instrument for sound recording in Chao's phonetic studies. When he conducted his first field survey in 1927, on the Wu dialects, the phonograph was not yet available to him. He and his assistant Yang recorded the syllables they heard on paper with the IPA. In his Guangdong dialect survey in 1928–1929, he managed to get an Edison-type wax cylinder phonograph and began to perform mechanical recording. When he directed the Tsing Hua Chinese Educational Mission in Washington in 1932–1933, he purchased on behalf of Academia

8 For example, see Chao 1930, 8–9, and Chao and Yu 1930, 1–2.

Sinica a set of more advanced Berliner-type uncoated aluminum disc phonograph recorders. And he put them in use during his subsequent field surveys. He replaced the uncoated discs with coated ones as soon as they became available a few years later. During his fieldwork in Anhui in 1934, he brought a new type of disc recorder manufactured by the Fairchild Company in the US. From this point on, the disc phonograph became indispensable equipment for his fieldwork. In his Jiangxi survey in 1935, he and his assistants recorded 57 dialects on about 80 discs. In his Hunan survey in the same year, 145 plates representing 75 counties were recorded. His Hubei trip in 1936 produced 150 discs. In his Hunan trip in 1936, Chao selected a general helper to accompany him specifically because the man knew how to crank the battery charger (Tu 2005, 42–43; Chao [1975] 1976, 28–31). To prepare the phonographic recording for his Hubei trip, Chao collaborated with a radio company to design a three-stage vacuum-tube amplifier that took the input from a microphone and fed the output to the Fairchild phonograph's recording head (Figure 6). To reduce the echo for recording, Chao and his assistants covered the walls of the temporary recording room with quilts (Figure 7) (Chao et al. 1938, 34–35).

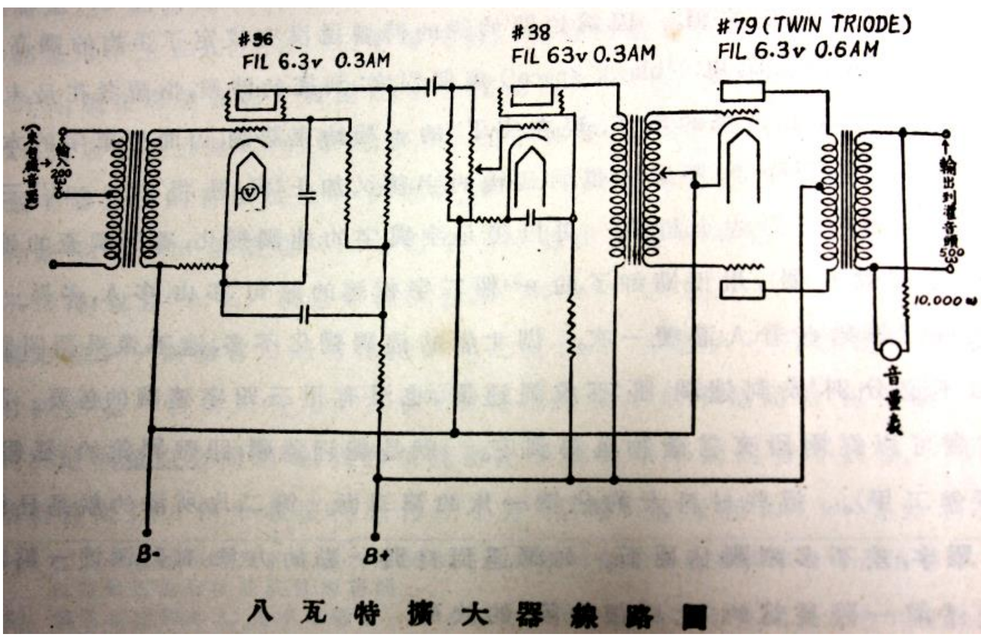


Figure 6: The circuit diagram of the electronic amplifier Chao helped design and employ in phonographic recording for his fieldwork in Hubei (Chao et al. 1938, 34).

Figure 7: Setting up the recording room for Chao's fieldwork in Hubei (Chao et al. 1938, 33).

Phonographic recording played a significant part in Chao's empirical investigations. He employed the phonograph as a research tool in all of his phonetic surveys and transcriptions during the 1920s–1930s except for his earliest fieldwork in Jiangsu and Zhejiang on Wu dialects in 1927. In these undertakings, he and his assistants usually recorded the articulations of his interlocutors on the spot, both in writing (IPA, Latinized phonetic symbols, or Chinese characters of the same sounds) and in phonograph. Then they brought the phonographic records back to their laboratory or institute and listened to them many times in order to finalize their notations for the initials, finals, and tones of words, sentences, and paragraphs.[9] In so doing, Chao's team not only attained a directly verifiable determination of sounds and voices but also created an archive of such data.

Like the camera, the phonograph in the late nineteenth and early twentieth centuries was generally viewed as a powerful instrument to help capture elusive sensory experiences. Inventors, hobbyists, and fieldworkers often talked about the value of the phonograph to *preserve* the sounds and voices of a precious moment, a beloved one, a fading culture, or a non-repeatable sonic sensibility. Ethnographers, historians, and journalists around this time were especially interested in mechanically recording memorable events, rare ethnic musical pieces, and longstanding tales (Stern

9 For instance, see Chao 1930, 1.

2003). In this context, the phonograph was a mechanical substitute for the human ear, and the human did not really have to work with the machine—all he or she needed to do was to turn on the phonograph at the right moment.

It is worth noting, however, that the use of the phonograph in the phonetic research represented by Chao's fieldwork and labwork was saliently different from the preservative, non-intervening character in the above-mentioned context. In Chao's phonetic research, the phonograph neither replaced human recorders nor automated data acquisition. Instead, the researchers played an active part in obtaining data as they interacted closely with the machine. These interactions can be seen clearly in two cases.

7.1 Preparation for recording

First, Chao and his assistants' use of the phonograph in the field was accompanied by significant preparatory work. Before the 1927 survey in Jiangsu and Zhejiang, he and his assistant Yang generated "type lists of words to learn the pronunciation of the initials, the finals, and the tones, 75 items of everyday vocabulary, 56 grammatical and stylistic particles, and finally the story of the North Wind and the Sun" (Chao [1975] 1976, 28; Zhao and Huang 1998, 147). At the field sites, the local subjects were asked to read these items aloud and their voices were recorded. Chao and his assistants maintained the same form of preparation in the subsequent surveys after they started to use phonographic recording. Moreover, Chao and his assistants often learned in advance at least a little bit of the local dialect under study and tried to talk with their subject in this dialect before recording. This warm up, Chao found, was quite effective in reducing their subject's propensity to pronounce words in Mandarin, which was natural for an educated Chinese person to do when he or she was talking to an outsider (Chao [1975] 1976, 28).

What underlined this practice was a notably distinct rationale from that of preservation. Chao did not actually intend to preserve the sounds and voices of individuals. Rather, he wanted to record the *true* and *real* pronunciations of words in the dialects he studied. These true and real pronunciations might not be embodied in the utterances of a single or a few individuals; they were more accurately represented as types synthesized from all the reliable sonic data. Philosophically speaking, Chao was looking for the natural kinds of dialectical articulations, not individual sounds and voices. The aforementioned preparatory work was done exactly to create the conditions that increased the chance for the subjects to produce true, real, and comprehensive articulations of a dialect.

7.2 Reverse recording

Second, Chao came up with a novel use of the phonograph—not for recording, but for testing and training. This use had to do with his preoccupation with the phonetic spelling of Chinese. Chao had paid close attention to the phonetic spelling systems. From Alexander Melville Bell's "visible speech" in the 1860s to the initiation of the IPA in the 1880s, Western language scholars and teachers had dreamed of developing a phonetic system that could be applied to accurately pronounce words in *any* language. Chao had the similar ambition to develop an accurate phonetic system for Chinese, if not for all languages. In the 1920s, he proposed a system of "National Language Romanization" ("Gwoyeu Romatzyh") as an improvement to the existing Wade-Giles system and a scheme to reform Chinese into a genuinely phonetic language.[10] Owing to this strong interest in phonetic spelling, Chao never let the phonograph replace manual voice recording in his fieldwork and labwork. At the field sites or his laboratory, he and his assistants usually documented the articulations in dialects with the IPA, Gwoyeu Romatzyh, or other phonetic spelling systems, despite the employment of mechanical recorders.

Yet how to make sure that a phonetic alphabet system was accurate enough? And how to make sure that an individual investigator had the ability to transcribe sound and voice with sufficient accuracy? In 1930, Chao began to entertain the idea of using the phonograph to address these questions. Here was the procedure. First, he recorded himself speaking an English sentence on a disc. Second, he played this recorded sentence in reverse with a phonograph, listened to this reversed sentence, and transcribed its sound with the IPA or another phonetic spelling system. Third, he read the transcribed sentence aloud and used the phonograph to record it. Finally, he played the second record in reverse. If his listening comprehension and transcription were accurate, then the second record would be the double reverse of the original English sentence and thus sound identical to the original sentence. Later on, Chao tested his assistants under the same procedure, broadened the language from English to Chinese, and extended the length of the recorded utterances. The ability to reproduce a short spoken text through the double-reverse recording was considered an indication of the subject's capability for accurate phonetic denotation, a skill important in Chao's team (Zhao and Huang 1998, 170).

8 Conclusion

In the 1920s–1930s, Chao Yuen Ren pioneered the study of Chinese dialects through a sequence of field surveys and laboratory work. Known as one of the first investigations

10 For Chao's "National Language Romanization," see Chao [1922] 2002a.

of Chinese language using the methodology of modern linguistics, Chao's studies marked a new beginning for scientific research in China. In this article, I have examined a crucial feature of Chao's research program—his employment of various mechanical apparatuses in data acquisition—and explored the meanings and significance of this feature. While his use of these instruments fit scientists' general ethos of mechanical objectivity at the time, the apparatuses nonetheless served more complicated functions than mere data recording: they underlined a fundamentally different way of understanding sound and voice from that of classical Chinese phonology, and they highlighted the demand for a new type of scientific persona in language studies. A close inquiry into two cases—the attempts to measure the tones and the uses of the phonograph—has substantiated the diverse meanings of the instruments in Chao's research beyond mechanical objectivity.

Chao's innovation in the means of empirical observation and data acquisition helped him produce a body of works during the Republican period that documented the phonetic details of various Chinese dialects and (to a much lesser extent) languages of other ethnicities. They included *Studies in the modern Wu-dialects* (1928), *Phonetics of the Yao folk songs* (1930), *Love Songs of the Sixth Dalailama Tshangs-dbyangs-rgya-mtsho* (1930), *Report on a Survey of the Dialects of Hupeh* (1938), *Note on the Zhongxiang dialect* (1939), and unpublished phonetic records of dialects in Guangdong, Guangxi, Anhui, Jiangxi, and Hunan (Chao 1928; Chao 1930; Chao and Yu 1930; Chao et al. 1938; Chao 1939). These works are often regarded as key representatives of the first systematic studies of Chinese dialects' phonetics via the methods of modern linguistics. Linguists decades later have continued to find the relevance and usefulness of Chao's records and data. For instance, Anne Yue discovered in 2001 that Chao's unpublished field notes for the Chao'an dialect in Guangdong confirmed some Western missionaries' phonetic records for the region in the nineteenth century, before the development of modern linguistics. Yue also demonstrated the possibility of tracing the chronicle change of pronunciations in the Chao'an dialect by comparing Chao's field notes with its rhyme book, composed centuries before (Yue 2001).[11]

It is beyond the scope of this article to examine the specific findings in Chao's dialectical research during the 1920s–1930s or to evaluate its significance for the studies of the Chinese language in the twentieth and twenty-first centuries. Rather, our focus here is the novel methods he introduced or developed for empirical observation and data acquisition in his investigations of sounds and voices. The essence of these

11 As far as I know, Chao did not rely substantially on the European and American missionaries' phonetic and phonological records when he designed and developed his research on Chinese dialects. To him, the most relevant work by a Westerner on the Chinese language was Karlgren's *Études sur la Phonologie Chinoise* (1915), which was produced using the methods of modern linguistics. For the purpose of framing and comparing his phonetic and phonological studies, Chao actually found the old rhyme books more useful as a starting point.

methods was to supplement, assist, or enhance the investigators' aural senses and perceptions (which for a long time had been the only resort for phonological inquiries in China) with machines and mechanical procedures in the process of recognizing, determining, documenting, and even analyzing utterances and articulations. Chao's employment of spectrographic machinery for tones and phonographic recording aligned clearly with the mechanical objectivity that prevailed in nineteenth-century natural sciences and early twentieth-century linguistics in Europe and North America, which aspired to attain reliable and consistent empirical information with a minimum of personal equations and individual biases. Yet he never aimed to *replace* the human senses with mechanical means in the process of observation, unlike numerous subscribers to mechanical objectivity who had indeed attempted to do so. The phonograph, sliding-pitch pipe, and even the "automatic" tonal recorder that he designed but never implemented were not mechanical substitutes for human ears. Rather, these gadgets co-existed with sensory perceptions in Chao's research design. He continued to insist on the value of linguists having a "musical ear," and required his assistants to attain and deploy such an ability in his dialectical surveys.

Chao's introduction of machine-assisted hearing in phonetic research provides an interesting case for us to grapple with in considering the nature of empiricism in Chinese science during the early twentieth century. It is well known that the May Fourth intellectuals associated positivistic scholarship with science and justified this association either with the philosophy of logical positivism or with the Qing scholarly tradition. Similarly, the most renowned research activities during the Republican period concentrated on empirical investigations in archaeology, geology, ethnology, botany, and zoology. The episodes in this article nonetheless offer an alternative angle to examine the issues of empiricism in early twentieth-century Chinese science: Instead of focusing on conceptual debates or famous discoveries, Chao's phonetic work reminds us of the importance of examining the techniques, tools, and methods of empirical observations in routine research practice and their implications for understanding the characteristics of objectivity, the roles of sensory perceptions, and the strengths as well as limitations of automation and mechanization in empirical observations among Chinese scientists at the time.

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