Chronos and Psyche – on **Timing** Thought

The human psyche became the object of genuine scientific research for the first time in the closing years of the 19th century. At the time, the key to researching consciousness was thought to lie in the measurement of reaction times with the help of precision instruments. Scientists of the day, among them **Wilhelm Wundt,** *successfully formulated hypotheses that are still considered relevant today. Henning Schmidgen at the* **Max Planck Institute for the History of Science** *in Berlin is an expert on the technical and theoretical demands of such time experiments.*

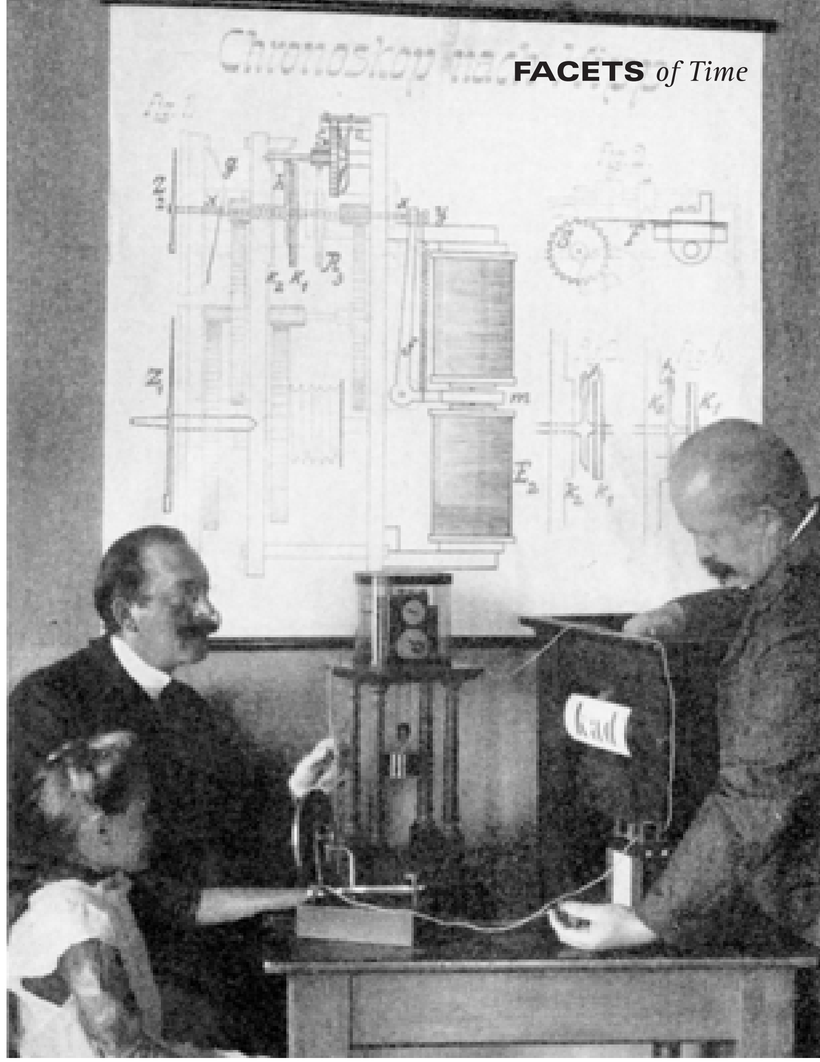
August 21, 7 p.m.; Herr Hamer and Herr Donders at the phonautograph. H. calls, D. answers. Tuning fork = 261 oscillations." This down-to-earth summation of an experiment in 1868 by Dutch physiologist Franciscus Donders is considered to be the birth of the cognitive neurosciences. Donders, along with his assistant, Hamer, hoped to measure nothing less than the speed of human judgment. His timekeeper was a tuning fork, pitched at middle C and vibrating at 261 per second. The experimental procedure was simple: The two gentlemen couldn't see each other, but each was able to hear what the other was saying. Hamer called the syllable "ki" and Donders countered as quickly as possible, likewise with "ki." They repeated this for a while, during which their voices and the tuning fork's vibrations were recorded by a phonautograph, a new invention designed to record speech (see box on page 40).

Donders counted 51.5 vibrations of the tuning fork between the two calls of "ki," equivalent to 0.197 seconds. The next experiment saw Hamer choosing randomly between "ki," "ka" and "ku," whereby Donders' "ki" reply was only to come in response to "ki." This time around, the interval between the two "ki" calls was significantly longer than that between the mere copying reactions of the earlier experiment – 63.3 vibrations, or 0.243 seconds. For the first time in the history of science, the time required for a human decision (deciding between two simple syllables) had been recorded.

Thinking Takes Time

From his laboratory in Utrecht, the news of Donders' experiment spread across Europe like wildfire. In 1850, physiologist Hermann von Helmholtz had already measured the velocity of nervous stimulation in animals and then humans, and it had now become verifiably possible to calculate the speed with which we make decisions and judgments. Finally, it was possible – so it was believed, with a certain amount of euphoria – to investigate the human mind scientifically and to do away with mere speculation. "This marked the beginning of a way of approaching scientific questions that is still being employed today," says Henning Schmidgen, scientific collaborator in Hans-Jörg Rheinberger's department at the Max Planck Institute for the History of Science. Schmidgen is investigating just how much the development of precision timekeepers has influenced the life sciences. This was most strongly felt on the border between physiology and psychology: the end of the 19th century saw the emergence of a new, experiment-based discipline growing out of the old psychology, based on self-observation, collection and comparison.

Watchmaker Matthäus Hipp made the chronoscope into a precision instrument. The picture shows one of the chronoscopes built at the time (ca. 1865).



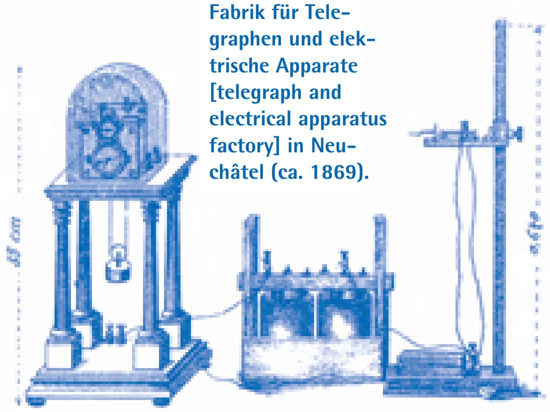
Experimental setup with a chronoscope after Hipp, for pedagogical purposes (ca. 1909).

Source: http://vlp.mpiwg-berlin.mpg.de/lise/lit18171/z0001table1lo.html / Source: Rudolf Schulze, from Experimental Psychology and Pedagogy. For Teachers, Normal Colleges, and Universities, Leipzig, 1912 (German original 1909)

Also in its infancy, the new science of chemistry had discovered that all matter was composed of building blocks, or "elements." With the aid of precision scales, chemists were able to show that the relationships between the elements in a given sample remained constant – even after reactions in which novel substances were formed. This principle could apparently be applied to living objects: in Germany, organic chemist Justus von Liebig reached some successful conclusions about the inner workings of organisms by comparing their "input" and "output" – "even without knowledge of what was transpiring within the body," as Liebig put it. But his approach proved fruitful not only in agriculture and dietetics.

It also seemed natural for scientists of the psyche to look for elementary processes from which higher thought processes could be built, and the key to those hidden processes taking place in the "black box" of the mind was thought to be the reaction times as recorded in the laboratory. The precision instrument of the new psychologist therefore measured, not weight, but time. Experimenters were aware that this would necessitate a change in self-perception. The "founding father" of physiological psychology, Wilhelm Wundt, was a particular champion of a time-based analysis of the phenomenon of consciousness: "Since Aristotle, man has assumed that human thought was structured according to logic, based on the concept of contradiction. We can now show that it is not logic, but time, which structures thought: we measure how long we require to become aware of change ..."

In 1879, Wundt founded a laboratory for physiological psychology in Leipzig that would quickly expand in the coming years. An entire generation of psychologists from both Germany and abroad made a pilgrimage to Leipzig to be educated. While physiologists such as Donders carried on taking measurements with tuning forks, Wilhelm Wundt started using Matthäus Hipp's "chronoscope" (see box on page 38). The Hipp chronoscope was the most up-to-date timekeeper of the day and was supposed to be accurate to within a thousandth of a second. In the years that followed, the chronoscope became something of a "totem" around which the newly formed tribe of experimental psy-



The sketch originates from a price list from Hipp's Fabrik für Telegraphen und elektrische Apparate [telegraph and electrical apparatus factory] in Neuchâtel (ca. 1869).

The Chronoscope

The chronoscope was originally developed and used by the military to measure the flight time of cannon ball shots. Upon firing, the ball broke an electrical circuit, starting the clock, while at the time of impact, another electrical circuit was closed and the clock stopped. Watchmaker and mechanic Matthäus Hipp fundamentally improved the chronoscope by preventing the entire clockwork mechanism from starting and stopping during operation. Only the clock's much lighter hands were coupled and decoupled, greatly reducing the inertial error within the mechanism.
The chronoscope's accuracy was checked before every test by the use of an apparatus containing a falling ball placed at differing heights. The theoretical time taken for the ball to fall was calculated and then compared to measurements taken with the chronoscope operating at different currents until the two values agreed. While the frequencies of tuning forks were calibrated against sirens, the chronoscope's accuracy could be checked using a fundamental law of physics.

Source: Utrecht University Museum, from the Donders estate

Phonautographic recording of speech from an experiment by Franciscus Donders (ca. 1874).

chologists gathered, explains psychology historian Horst Gundlach from Passau University.

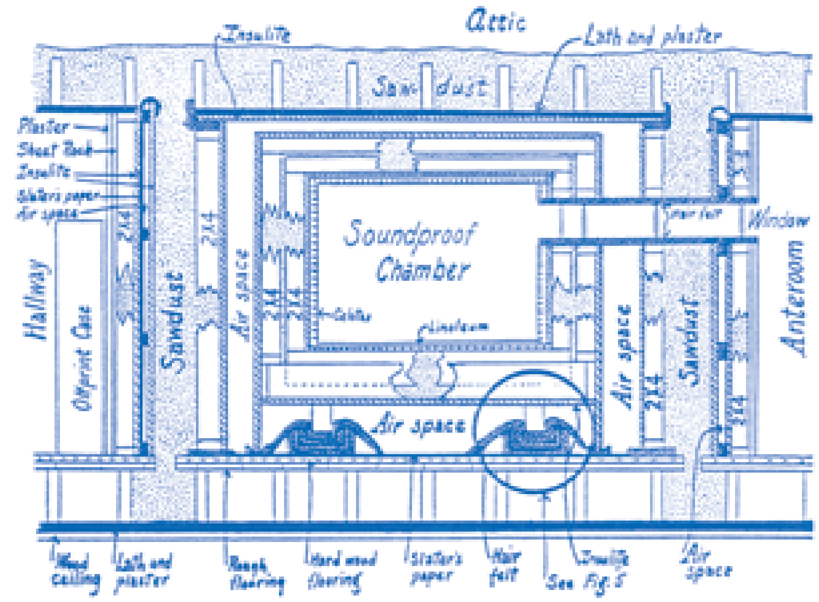
The experiments were, in fact, intentionally monotonous and required great strength of will and concentration. Subjects were required, for instance, to press a telegraph button as soon as they heard a ball hitting the table. The duration of time between the impact and the button being pressed was called the reaction time. Other experiments required participants to react to different colored lights or to geometric forms and numbers.

While, in Germany, consciousness was "dissected" with the help of reaction times, experimental psychologists in France, England and the United States also devoted themselves to researching the supernatural. Nevertheless, Wundt had a relatively restrictive concept as to what constituted psychological experimentation. He refused to recognize colleagues who had dealings with so-called "mediums" as experimental psychologists. Laboratory experiments on "mediums" and "seers" might be of interest, but according to Wundt, they could hardly ever be reproduced. One of the reasons he gave was his skepticism with regard to the self-control of such test subjects.

Speculation between Stimulus and Reaction

But the founder of the Leipzig laboratory was not spared criticism, either. William James, the pioneer of experimental psychology in the United States, was much more open to the idea of the supernatural. He doubted whether research on reaction time was relevant, smugly claiming that such a pedantic way of doing science could only have arisen in Germany. The "chronoscope philosophers" of Wundt's ilk, as he called them, were, in his eyes, nitpickers and accountants: "They mean business, not chivalry."

Indeed, Wundt's inquiries were purposefully modest; the measurable was to be investigated in order to get a view of the immeasurable from all sides. The only phenomena that could be measured were stimulus and reaction – anything between was, for his purposes, worthless. In other words, scientists of the 19th century could approach the cerebral and nervous processes underlying such reactions only indirectly. They therefore extrapolated their knowledge of anatomy and physiology into the times they had measured. It



Source: Karl M. Dallenbach, "The Psychological Laboratory of Cornell University," The American Journal of Psychology, 43 (1931): 295-300, p. 298

Cross-section of the soundproofed room at the Laboratory of Experimental Psychology, Cornell University, USA (ca. 1930).

hardly comes as a surprise, then, that they all arrived at vastly different conclusions. Donders, for example, believed in twelve steps in the process lying between stimulus and reaction, while Wundt thought he was dealing with three physiological and two psychological components.

His subjects' individuality, experience and current state of mind: none of these interested Wundt. They were, rather, obstructions, blocking entrance to the "black box" between stimulus and reaction. Wundt wanted instead to explore that which is common to all of us: consciousness and free will. The theory he developed was as simple as it was apposite: He conceived consciousness to be nothing more than the stage of a theater. Experiences make their entrances much like actors. At first, they merely enter the field of view (perception) where their presence can be registered; only later, when they step into the limelight of our attention (apperception), do they enter consciousness. His laboratory experiments in Leipzig thus showed that simple impressions of color needed far less time to enter consciousness than, for example, six-digit numbers.

As a result, Wundt demanded from his subjects considerable concentration and an ability for self-observation. He chose each of them with a great deal of care and obliged them to undergo what amounted to a course of training, to ensure that their personal weaknesses and strengths had a minimal effect on the final results. Only reliable and healthy people were able to concentrate long enough on the monotonous tasks, to focus their attention satisfactorily, and not be distracted by the "infernal apparatus" of the chronoscope, whose loud operating noise was described by some as "incessant" and "embarrassing."

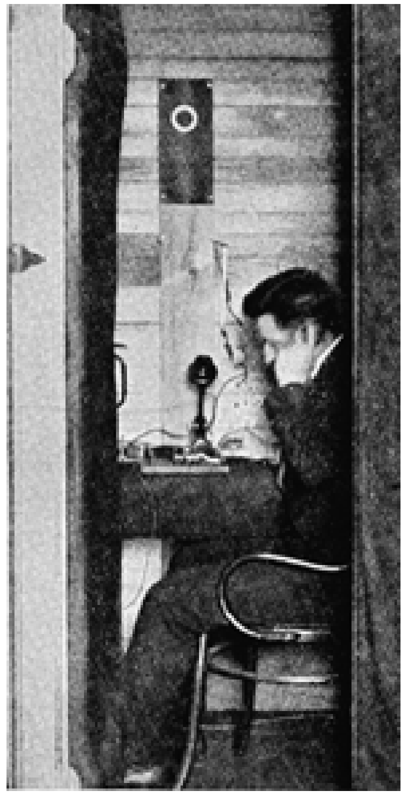
Despite the accuracy of the timekeepers, and fussy control of the test personnel, reliable and reproducible results were not always achieved. The chronoscope revealed itself to be susceptible to variations in electrical supply, was sensitive to changes in temperature and, in addition, disturbed the subjects' concentration. In the end, the chronoscope was rebuilt in a separate room, where it could be telegraphically started and stopped by subjects. The latter were soon seated in complete isolation in a wholly unnatural environment, whose only putative attribute was to be the incoming stimulus. But, even in the soon-to-be compulsory soundproofed rooms of the laboratory, it was possible to be put off by the sounds of one's own body.

Source: Utrecht University Museum

Pioneer of cognitive science: Ophthalmologist and physiologist Franciscus Cornelius Donders (1818 to 1889).

The Chronoscope as a Multi-purpose Apparatus

However, Wilhelm Wundt's results were taken up with enthusiasm over the coming years. France, in particular, boasted a number of modern scientists who rejected research into spiritualism and whose goal was to achieve exact results. Wundt's work was founded on the transparency of his methods, and he arrived at his conclusions without speculation or insinuating his own beliefs. Many renowned psychologists, such as Alfred Binet at the Sorbonne in Paris, ended up buying their own expensive chronoscopes. Soon, however, French researchers started to criticize that, in the extremely artificial labo-

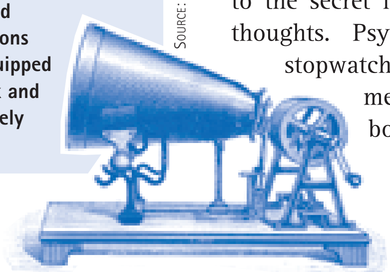


Source: Edward W. Scripture, Thinking, Feeling, Doing (New York: Flood and Vincent, The Chautauqua-Century Press, 1895, p. 41

Subject in a soundproofed room in a Yale University psychology laboratory. The telephone was used for communication with test personnel (ca. 1895).

The Phonautograph

The automated sound-writer, or phonautograph, was initially developed to record human speech. Fascinated by the recent achievements in photography, its inventor, Edouard Scott de Martinville, sought to build a machine that could "mechanically transform a flow of words into a sequence of signs." However, it was to be Scott's collaboration with instrument-maker Rudolph Koenig that turned the phonautograph into a precise piece of scientific apparatus. Its main component was a roll of soot-covered paper on a barrel that could be slowly rotated. Speaking caused the gramophone horn's membrane to vibrate, and a fine needle transferred these vibrations onto the paper. It was Koenig who equipped the phonautograph with a tuning fork and enabled notes and sounds to be precisely timed.



Source: http://vlp.mpiwg-berlin.mpg.de/lise/lit13687/p0077lo.html

The automated sound-writer, or phonautograph, "mechanically transforms a flow of words into a sequence of signs." The engraving shows a device modified by Rudolph Koenig (ca. 1889).

ratory environment, subjects were unable to demonstrate any natural behavior. Instead of measuring reaction times to, at best, simple stimuli, they were keen to investigate complex psychic processes – especially in subjects with unique and individual characteristics.

As a result, researchers ended up sacrificing precision, started relying on small, portable chronoscopes, accurate to at most a fiftieth of a second, and went on to perform home experiments on novelists and piano virtuosi. In an attempt to investigate the process of thought or the facility of judgment, they confronted their subjects with questions such as: "What is the color of snow?" or "Which philosopher is more important: Kant or Hume?" In place of Wundt's general psychology of consciousness, they instituted an individual psychology of the processes of thought.

The measurement of reaction times remained an important technique in psychology. The chronoscope found its way into more than just factories and hospitals, where it was used in the field of applied psychology, in aptitude and employment tests. Sigmund Freud also recorded his own reaction times in self-experiments on "the effects of coca" – with and without cocaine. Shortly after, Carl Gustav Jung used the technique in his "association experiments." The reaction times of a patient hesitating upon hearing words like "mother," but answering spontaneously to "tree," were thought to open a door to the secret inner labyrinth of his thoughts. Psychoanalysts sporting stopwatches seemed to have metamorphosed into laboratory scientists.

In the 1950s, research into reaction times entered a golden age, particularly in the U.S. Many of the first generation of American psychologists had studied under Wundt in Leipzig. After the Second World War, however, his psychology was almost forgotten in America. At conferences on cybernetics organized by psychiatrist and neurophysiologist Warren S. McCulloch from 1946 to 1953, Wundt was all but forgotten – even though reaction times were a frequent subject of debate.

"Free Will" – an Illusion?

Techniques for measuring psychological time had certainly improved greatly, but the same could not be said of the resulting theories. In the words of Henning Schmidgen: "The 'moment-function hypothesis' suggested by cybernetician and psychologist John Stroud postulated that human experience could be dissected into discrete elements, or 'quanta,' which could be isolated from one another by time measurements. This, however, was the principle on which Wundt's psychology was based." Nevertheless, Norbert Wiener was noticeably impressed with Stroud's supposedly new theory. Stroud's reaction time results, taken with soldiers as subjects, converged on a figure of a tenth of a second, in which Wiener saw a further proof for the human brain's central and regular information processing clock. Studies performed with the electroencephalogram (EEG) hinted at the same. For the first time, such experiments were, before the scientists' very eyes, delivering figures on the time scales that characterized how the "black box of consciousness" functioned.

About a century after Wundt's first research into the timing between stimulus, perception and reaction, neurophysiologist Benjamin Libet carried out a now famous experiment: Test subjects stared at a large clock on a monitor, consisting of a glowing green dot that described a circle every 2.56 seconds. Each was asked to make a note of the position of the dot exactly when they decided to move their hand in order to push a button. During the experiment, subjects wore an electrode cap, which measured electrical potentials on the brain's surface, as well as an armband of electrodes to record hand movements.

The result was truly odd: the motor region in the brain responsible for arm movements had already been activated a good 300 milliseconds before subjects consciously planned to press the button. It seemed clear that the subjects were only aware in retrospect of what their brain had already started some time ago. "Free will" had been exposed as a construct of our own minds – a view held by many of today's brain researchers. Wilhelm Wundt would not have been surprised by Libet's results, declares Schmidgen. He would have been impressed by the precise experimental technique, the statistical procedures and, above all, the cutting edge visualization techniques. In contrast, he was familiar with the idea that nervous and cerebral processes are "upstream" of conscious perception and motor reactions. This was precisely what his theater model of human consciousness was designed to show: we become aware of perceptions only when the "spotlight of our attention" is pointed at them. Whether this disproves the human capacity for free will was a question that Wundt nevertheless left open.

Neuroscientists today have at their disposal modern imaging techniques of which previous generations of scientists could only have dreamed. The brain can now be observed "in real-time" during the process of thinking, remembering or dreaming. There are, however, still uncharted regions on the map of human consciousness – even if we are sometimes given the impression that the fundamental questions of brain research on the self and on consciousness have long been solved. This is exactly where Schmidgen sees the challenge facing the history of science. "We don't just study history for its own sake. We also hope to show today's scientists how they can better and more accurately communicate that which is genuinely new and surprising about their research." In his view, the historical context of today's research not only needs to be more exactly analyzed and reconstructed, it also needs to be more effectively disseminated within scientific circles and in the public domain. Even today's experts would probably be surprised how old the history of research into human consciousness based on the measurements of time truly is.

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