

Erratum: In the Abstract (line 6) the phrase “especially of footnote 16 in Hitzig’s (1870) report” is incorrect. The phrase should be “especially of footnote 16 pertaining to Hitzig’s (1870 report”.

A Note on the Early History of Electrical Stimulation of the Human Brain

ROGER K. THOMAS
CHERYL DONALDSON YOUNG
*Department of Psychology
University of Georgia*

ABSTRACT. We address inconsistencies in two areas concerning who was first to electrically stimulate a human’s brain. First, Boring (1950) and others attributed priority to Eduard Hitzig based on information mentioned somewhat incidentally in Fritsch and Hitzig’s (1870) classic work using dogs. Others cited Fritsch and Hitzig but attributed priority to Roberts Bartholow (1874). Second, our examination of translations of Fritsch and Hitzig, especially of footnote 16 in Hitzig’s report (1870) of a human case, revealed errors, omissions, and inconsistencies. To aid our inquiry, we requested and received new translations of footnote 16 and of Hitzig’s report.

THIS NOTE ORIGINATED in our discoveries of some interesting inconsistencies in the literature associated with who was first to electrically stimulate a human’s brain. These inconsistencies divide approximately into two categories.

The first category concerns Fritsch and Hitzig’s (1870) article on electrical stimulation of the dog’s brain, a classic in neurophysiology. Based, most likely, on his own reading of this classic work, E. G. Boring (1950) wrote:

This famous joint experiment originated in Hitzig’s observation that the *electrical stimulation of the cortex of a man*, [italics added] led to movement of the eyes. Hitzig verified his observation on a rabbit, and then, with the assistance of Fritsch, undertook a systematic study of electrical stimulation of the cerebral cortex of the dog. (p. 73)

We are grateful to Ms. Petra Hille for providing the translation of Hitzig’s report (1870) and to Professor Ludvig Uhlig for his translations of footnote 16. The authorship of this article is alphabetical, and we judge our creative contributions to be equal.

Address correspondence to Roger K. Thomas, Department of Psychology, University of Georgia, Athens, Georgia 30602-3013 (e-mail: <rkthomas@uga.cc.uga.edu>).

Although some of the most authoritative historians addressing brain stimulation (Brazier, 1959; Krech, 1962; Sheer, 1961) cited Fritsch and Hitzig, they reported that Bartholow (1874) was the first to electrically stimulate a human's cortex. These historians may have been influenced by Bartholow, who, after having reviewed the work of Fritsch and Hitzig, wrote that "nothing hitherto" had been done regarding electrical stimulation of the human brain.

The second category concerns errors and inconsistencies in some of the translations of Fritsch and Hitzig's (1870) article that bear on the question of priority of human brain stimulation. These primarily involve footnote 16, which we examined in some detail, using the following translations: (a) the two complete translations of Fritsch and Hitzig by von Bonin (1960) and Wilkins (1963), (b) translations of excerpts from Fritsch and Hitzig by Cantor (in Herrnstein & Boring, 1965) and by Clarke and O'Malley (1968), and (c) unpublished translations done at our request by Petra Hille and Ludvig Uhlig, two native German scholars.

Overview of the History of Electrical Brain Stimulation

Most historians on this subject, especially in psychology, cite Gustav Fritsch and Eduard Hitzig's report (1870) as the classic study of electrical stimulation of the brain (hereafter, ESB). Often, it is either the earliest dated or the only work cited, which might imply to some that it was the first reported application of ESB (e.g., Glees, 1961, p. 237; Lachman, 1963, p. 18; Misiak & Sexton, 1966, pp. 35, 44; Sheer, 1961, pp. 11–12). Some have stated explicitly that Fritsch and Hitzig's use of ESB was the first (Watson, 1971, p. 251). However, other scholars (e.g., Brazier, 1959; Boring, 1950; Clarke & O'Malley, 1968; Young, 1990) showed that Fritsch and Hitzig were not the first to use ESB, and Fritsch and Hitzig (1870) themselves reviewed prior work.

Walker (1957a) cited Caldini's stimulation of the frog brain (presumably using a stored charge in a Leyden jar) in 1784 as the first use of ESB. Apparently, Luigi Rolando was the first to use ESB with a galvanic current; in 1809, he reported the results of stimulating a pig's cerebellum (Boring, 1950, p. 63; Clarke & O'Malley, 1968, p. 481; Walker, 1957a, p. 437; Walker, 1957b, p. 103).

Fritsch and Hitzig's (1870) predecessors did not resolve the critical question of whether the cerebral cortex was electrically excitable, and Fritsch and Hitzig's demonstration that it was electrically excitable is regarded as one of their major contributions. Perhaps, the greatest importance of their research was its contribution to the theory that functions are localized in the brain. R. M. Young (1990) assessed the general significance of Fritsch and Hitzig's work when he wrote:

The work of Fritsch and Hitzig was a truly epoch-making classical experiment in the sense that all subsequent work in cerebral physiology was done with reference to this single publication. (p. 224)

As noted above, the impetus for the present work was to consider the question of priority in the use of ESB on the human brain, and we return now to that question.

Bartholow's Claim and Observations

Roberts Bartholow (1874), an American physician, cited Fritsch and Hitzig's and Ferrier's (1873)¹ research on ESB before stating:

It is obvious that further observations will be needed to decide the important question of the electric excitability of the cerebral hemispheres. *Nothing has hitherto been done to subject the human brain* [italics added], to a course of experiment in order to determine the nature of its functions. (p. 308)

Regardless of priority, Bartholow's (1874) report appears to be the clearest and most detailed early account. We equivocate because of footnote 16 in Fritsch and Hitzig's study (1870), which cited Hitzig's use of electrical stimulation with a human. We cite this report as "Hitzig (1870)," although it was written by a recording secretary and was based, apparently, on Hitzig's oral presentation before the Medical Society of Berlin on January 19, 1870.² In the Wilkins' translation, footnote 16 included the statement that "a comprehensive work will soon follow" (p. 908). Von Bonin's translation did not include this reference to an apparently more detailed account of Hitzig's human case. We have not been able to locate this work, nor have we seen any reference to it in the writings of the other scholars cited here.

Bartholow's (1874) report included interesting details. One is cautioned to remember that the method and treatment being investigated were extremely new and that Bartholow's intentions were presumably only in the best interests of his patient and the practice of medicine. Bartholow's patient, Mary Rafferty, was a domestic worker, approximately 30 years old. She was said to be of good health until an ulcer appeared on her scalp a little more than a year before she was admitted to the hospital. Mary's ulcer was attributed to the "friction of a piece of whalebone in her wig. . . . [and the] . . . skull is

¹Bartholow did not cite a date for Ferrier's research, but Ferrier (1886/1978) cited 1873.

²A complete translation of Hitzig's (1870) report was done at our request by Petra Hille (Personal Communication, September, 1991), a Research Assistant at the Psychologisches Institut 2, in Munster, Germany. It is obvious from Hille's translation that a recording secretary rather than Hitzig wrote the published account.

eroded and has disappeared over a space of two inches in diameter, where the pulsations of the brain are plainly seen" (p. 308). Portions of both parietal lobes were exposed (see illustration in Walker, 1957b, p. 442).

Bartholow (1874) reported a series of six observations, which we summarize here. During the first observation mechanical stimulation was provided by needle electrodes. Bartholow reported, "No pain whatever was experienced in the brain-substance proper. Mechanical irritation of the cerebral matter produced no results on motility or sensibility of the extremities" (p. 310). About the second observation, Bartholow stated:

When the circuit was closed, distinct muscular contractions occurred in the right arm and leg. The arm was thrown out, the fingers extended, and the leg was projected forward. The muscles of the neck were thrown into action, and the head was strongly deflected to the right. (p. 310)

Observation three involved a deeper insertion of the electrodes and some elicitation of pain. However, Bartholow (1874) reported, "Notwithstanding the very evident pain from which she suffered, she smiled as if much amused" (p. 310). The electrode was then moved from the left to the right lobe and essentially the same observations were made. Bartholow reported:

In order to develop more decided reactions, the strength of the current was increased. . . . When communication was made with the needles, her countenance exhibited great distress, and she began to cry. . . . she lost consciousness and was violently convulsed on the left side. The convulsion lasted five minutes, and was succeeded by coma. She returned to consciousness in twenty minutes from the beginning of the attack, and complained of some weakness and vertigo. (p. 311)

A fourth observation was made (presumably on a later day) with a reduced current and with results less dramatic than those of the third observation. Two days later, a fifth observation was planned to the extent of bringing her into the "electrical room" (p. 311), but it was abandoned because of her worsening general condition. Observation six, which was done the next day, included a description of her "decidedly worse[ned]" (p. 311) condition. The next and last section in Bartholow's account was "Autopsy" (p. 311). Bartholow (1874) concluded his report: "It has seemed to me most desirable to present the facts as I observed them, without comment" (p. 313).

According to Kuntz (1953), the publication of Bartholow's observations resulted in Bartholow's being forced to leave Cincinnati, where he had practiced and served on the faculty of the Medical College of Ohio. According to Walker (1957a), Bartholow was criticized internationally but defended himself in published correspondence in the *British Medical Journal*. Bartholow wrote that his work had been done with the patient's full knowledge and consent and that he thought the technique would not be harmful. Walker quoted Bartholow as saying, "To repeat such experiments with the knowledge we

now have . . . would be in the highest degree criminal" (p. 110). Clarke and O'Malley (1968) reported that Bartholow was able to resume his medical career at Jefferson Medical College in Philadelphia, and that he wrote "widely popular" books on therapeutics.

Was Bartholow the First?

Bartholow's (1874) claim that this was the first case of electrical stimulation of the human brain was iterated by Brazier (1959), who wrote, "The first pioneers to attempt electrical stimulation of the cortex in man (through holes in the skull) were Bartholow in America in 1874 . . . and Sciamanna 8 years later in Italy" (p. 48). Krech (1962) wrote, "The first surgeon to stimulate man's cortex electrically and to observe the behavioral effects was Dr. Roberts Bartholow" (p. 62). Sheer (1961) wrote, "Stimulation of the human cortex was first carried out in 1874, by Roberts Bartholow" (p. 15). All cited Bartholow (1874) as their source, which is interesting because all also cited Fritsch and Hitzig's study (1870), which indicated that Hitzig stimulated a human's brain some time before January 19, 1870.

The following quotation is from Wilkins's translation of Fritsch and Hitzig (1870/1963):

The starting point for these studies arose from observations which one of us had the opportunity to make on man,¹⁶ and which concern the first movements of voluntary muscles that were brought about by *direct stimulation of the cerebral organs and observed on man* [italics added]. He found out that, by conduction of constant galvanic currents through the posterior part of the head, movements of the eyes could be easily obtained which, according to their nature, could have been incited only by *direct stimulation of the cerebral centers* [italics added]. Since these movements occurred only by galvanization of that region of the head, it could be assumed that they were caused by stimulation of the corpora quadragemina, as indicated by some things, or of adjoining parts. However, since such ocular movements also appeared when the temporal region was galvanized and certain techniques were used which increased the stimulation, the question arose whether in the latter method, loops of current, which penetrated up to the base, caused the movements of the eyes or whether the cerebrum, in contradiction to the general opinion, possesses electrical excitability. (p. 908)

The translations of footnote 16 by both Wilkins and Clarke and O'Malley (1968) make it clear that the "one of us" referred to was Hitzig. Von Bonin (1960) translated the same passage to read "I" instead of "one of us"; however, his translation of footnote 16 makes it clear that the "I" refers to Hitzig. As already noted, Boring (1950) also identified Hitzig as the author of the observations on man. Because footnote 16 and the report that it cited (Hitzig, 1870) is critical to the question of establishing priority and because translations of footnote 16 are associated with some curious errors, omissions, and inconsistencies, it is important to address it in some detail.

Footnote 16. What we call footnote 16, was footnote 1 on page 308 in Fritsch and Hitzig (1870). Sequentially, it is the 16th footnote in the original article. Both von Bonin's and Wilkins's translations show it as footnote 16. We found discrepancies between von Bonin's translation and transcription and Fritsch and Hitzig's original footnote. We use the terms *translations* and *transcriptions* because part of footnote 16 in von Bonin's and Wilkins's presentations of Fritsch and Hitzig is translated and part is merely transcribed.

The following series of quotations or translations are related to Footnote 16. First, we show the footnote as it appeared in Fritsch and Hitzig (1870). Next, we show it as it was presented in von Bonin's translation of Fritsch and Hitzig; this is followed by a translation of the German in von Bonin's footnote 16. Finally, footnote 16 is shown as it appeared in Wilkins's translation of Fritsch and Hitzig, and it is followed by a translation of the German in Wilkins's footnote 16.

Fritsch and Hitzig (1870):

Hitzig: Ueber die galvanischen Schwindelempfindungen und eine neue Methode galvanischer Reizung der Augenmuskeln. Verhandl. der Berl. med. Gesellsch vom 19. Jan. 1870 in Berl. klin. Wochenschrift 1870 Nr. 11. Eine ausführliche Bearbeitung wird demnächst erfolgen. (p. 308)

von Bonin's presentation:

Compare my paper: Ueber die beim Galvanisiren des Kopfes entstehenden Störungen der Muskelinnervation und der Vorstellungen vom Verhalten im Raume. (p. 79)

Translation of the German in von Bonin's presentation:

On the disturbances of the muscular innervation and of the perceptions of spatial relations that are induced during galvanization of the head. (Translated by Professor Ludwig Uhlig, Department of German and Slavic Languages, The University of Georgia, July 29, 1991.)

Wilkins's presentation:

Hitzig: Ueber die galvanischen Schwindelempfindungen und eine neue Methode galvanischer Reizung der Augenmuskeln. Verhandl. der Berl. med. Gesellsch. vom 19. Jan. 1870 in Berl. klin. Wochenschrift, 1870 Nr. 11. A comprehensive work will soon follow. (p. 908)

Translation of the German in Wilkins's presentation:

On the galvanic sensations of vertigo and a new method of galvanic irritation of the eye muscles. Proceedings of the Medical Society of Berlin of Jan. 19, 1870 in: *Berliner klinische Wochenschrift*, 1870, Nr. 11. (Translation by Professor Ludwig Uhlig.)

We did not arrange a new translation of footnote 16 as it appeared in Fritsch and Hitzig (1870) because Wilkins correctly transcribed the reference source, and we accept Wilkins's translation of "Eine ausführliche Bearbeitung wird demnächst erfolgen" as "A comprehensive work will soon follow."

To summarize, Wilkins's (Fritsch & Hitzig, 1870/1963) presentation of footnote 16 is most consistent with the original footnote in Fritsch and Hitzig (1870) because it included the title as it appeared in the original of Hitzig's (1870) report of his human case, as well as the translated statement, "A comprehensive work will soon follow." The latter is especially important because it implies that an additional report may exist that might help establish priority of electrical stimulation of the human brain. Von Bonin's (Fritsch & Hitzig, 1870/1960) presentation of footnote 16 mistranscribed the title of Hitzig's (1870) report, omitted the reference to the source for the report, and omitted the statement that Wilkins translated as "A comprehensive work will soon follow." Unfortunately, von Bonin's is probably the best known complete translation of Fritsch and Hitzig because it appeared in his book of translations of classic papers from French and German titled *Some Papers on the Cerebral Cortex* (1960), and because von Bonin is a well-known authority on the cerebral cortex.

Clarke and O'Malley's (1968) partial translation omitted footnote 16 but inserted "[Hitzig, see Berl. klin. Wschr., 1870, 7:137-138]" (p. 508) where the footnote should have occurred. As may be seen by comparison to footnote 16 in Fritsch and Hitzig, Clarke and O'Malley provided correct volume and page numbers that pertained to the footnote but which did not appear in the original footnote. Cantor's partial translation (in Herrnstein & Boring, 1965) omitted footnote 16. However, in their introduction to the selection from Fritsch and Hitzig that was translated by Cantor, Herrnstein and Boring, were apparently referring to footnote 16 when they wrote:

In 1870 it had long been believed that the tissues of the brain could not be excited by direct stimulation, but Hitzig had noted eye movements in a patient whose cortex was stimulated electrically. (p. 229)

A question about cortex. A remaining issue is whether Hitzig stimulated the brain and cerebral cortex *directly*. Bartholow did stimulate the cerebral cortex and that was the precise claim that was reported by Brazier (1959), Krech (1962), and Sheer (1961).

Except for Boring (1950) and Herrnstein and Boring (1965), none of the scholars cited here specified that Hitzig stimulated the cerebral cortex directly. Wilkins's translation (Fritsch & Hitzig, 1870/1963) said that Hitzig stimulated the "cerebral organs" or "cerebral centers," and von Bonin's translation (Fritsch & Hitzig, 1870/1960) used the terms "central organ" and "cerebral centers." The partial translations of Cantor (in Herrnstein & Boring, 1965) and Clarke and O'Malley (1968) read the "central organ." Young's (1990) interpretation seems to agree with Boring's that the cerebral cortex was stimulated. Of course, Boring's and Young's interpretations are reasonably consistent with the translations "cerebral organs," "cerebral centers," and "central organ."

Ferrier (1886/1978) interpreted Hitzig's (1870) report to the Medical Society of Berlin to mean that the stimulation was applied via the mastoid process rather than directly to the cerebral cortex, "central organ," or "cerebral organs." Ferrier's interpretation was confirmed by Hille's translation of Hitzig's report (see footnote 2).

Therefore, priority for electrical stimulation of the human brain may depend on how one considers the point of whether Hitzig's electrodes were in direct contact with neural tissue. Furthermore, until the "comprehensive work" mentioned in footnote 16 has been located and considered, a basis remains for asking whether Hitzig stimulated the brain directly.

Concluding Remarks

Except for the accuracy of the historical record, a question of priority such as this is usually minimally significant to the progress of science. The interest and excitement associated with the development of practical ways to stimulate the brain electrically were widespread, and it was inevitable that the new methods would be applied to many species, including humans. Insofar as the record can be clarified, it is fitting to recognize Hitzig as the first to electrically stimulate a human's brain, even if there is never confirmation that the electrodes were in contact with neural tissue. However, Bartholow's (1874) account was more detailed and was probably more widely noticed and useful at the time, and he deserves recognition for his contributions as well.

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