Transcranial Direct Current Stimulation Improves Naming Reaction Time in Fluent Aphasia
A Double-Blind, Sham-Controlled Study

Julius Fridriksson, PhD; Jessica D. Richardson, PhD; Julie M. Baker, PhD; Chris Rorden, PhD

Background and Purpose—Previous evidence suggests that anodal transcranial direct current stimulation (A-tDCS) applied to the left hemisphere can improve aphasic participants’ ability to name common objects. The current study further examined this issue in a more tightly controlled experiment in participants with fluent aphasia.

Methods—We examined the effect of A-tDCS on reaction time during overt picture naming in 8 chronic stroke participants. Anode electrode placement targeted perilesional brain regions that showed the greatest activation on a pretreatment functional MRI scan administered during overt picture naming with the reference cathode electrode placed on the contralateral forehead. A-tDCS (1 mA; 20-minute) was compared with sham tDCS (S-tDCS) in a crossover design. Participants received 10 sessions of computerized anomia treatment; 5 sessions included A-tDCS and 5 included S-tDCS.

Results—Coupling A-tDCS with behavioral language treatment reduced reaction time during naming of trained items immediately posttreatment ($Z=1.96, P=0.025$) and at subsequent testing 3 weeks later ($Z=2.52, P=0.006$).

Conclusions—A-tDCS administered during language treatment decreased processing time during picture naming by fluent aphasic participants. Additional studies combining A-tDCS, an inexpensive method with no reported serious side effects, with behavioral language therapy are recommended. (Stroke. 2011;42:819-821.)

Key Words: anomia ■ brain stimulation ■ recovery ■ stroke ■ tDCS
Methods
Participants ranged in age from 53 to 79 years (mean, 68.13 years; SD, 10.40); time poststroke ranged from 10 to 150 months (mean, 58.38 months; SD, 44.60). A computerized anomia treatment coupled with tDCS was administered during 2 treatment phases. Each treatment phase lasted 1 week with 3 weeks separating the 2 treatment phases (A-tDCS versus S-tDCS). The number of treatment sessions (5 consecutive days for each treatment phase), length of stimulation (20 minutes per session), and stimulation intensity (1 mA) was modeled after previous research. A computerized naming assessment of both trained and untrained words was conducted 6 times for each treatment phase (A-tDCS and S-tDCS): twice at baseline, twice immediately after the final treatment session for each phase, and twice at 3 weeks after completion of each treatment phase.

During both A-tDCS and S-tDCS, the anode electrode was placed over the predesignated area of the scalp overlying the left posterior cortex. The reference cathode electrode was placed on the right forehead. To ensure blinding, in-house software switched the tDCS on and off without intervention from the participant or experimenter. For S-tDCS, the stimulator was turned off after 45 seconds; for A-tDCS, stimulation was maintained for 20 minutes.

The self-administered computerized treatment consisted of a spoken word–picture matching task occurring concurrently with the application of tDCS. Beginning 5 minutes before the start of tDCS, this treatment was modeled after tasks used in previous studies that have resulted in improved naming accuracy in participants with aphasia. Separate word lists were used for each treatment phase.

Results
After A-tDCS, the median group change in RT for trained items was −455.57 ms (interquartile range, −672.08 to −393.93) immediately posttreatment and −430.06 ms (interquartile range, −511.63 to −346.83) at 3 weeks posttreatment. Comparable reductions in RT after S-tDCS were −281.17 ms (interquartile range, −516.54 to −241.77) immediately posttreatment and −265.86 ms (interquartile range, −328.25 to 228.62) 3 weeks posttreatment (Figure). To minimize the effect of outliers, all RT values greater than ±2 SD from the mean were removed and the mean recalculated. A Wilcoxon signed rank test (1-tailed) revealed greater reduction in RT during correct naming of trained nouns after A-tDCS compared with S-tDCS immediately on treatment completion (Z=1.96, P=0.025) and also at 3 weeks posttesting (Z=2.52, P=0.006). On immediate posttesting, 7 of 8 participants experienced greater reduction in RT after the A-tDCS compared with the S-tDCS. At 3 weeks posttesting, all 8 participants experienced greater reduction in RT after A-tDCS compared with S-tDCS. The probability that of 16 comparisons, 15 occurred in a direction that favored A-tDCS (7 for immediate posttesting and 8 for 3-week follow-up) was calculated (P=0.0002; based on binomial distribution).

Discussion
This study included 8 participants with fluent aphasia and revealed greater treatment-related reduction in RT during naming of trained items after A-tDCS compared with S-tDCS immediately after treatment completion as well as at 3-week follow-up testing. This treatment effect was not accounted for by unspecific arousal differences (ie, changes in blood pressure, heart rate recordings, etc), differences in comfort level (ie, scalp sensations), or treatment order.

Figure. Reduction in RT after A-tDCS (light gray) and S-tDCS (dark gray). The line in the middle of each box represents the median. The top and bottom of each box denote the interquartile range. The error bars represent the data range; RT is measured in milliseconds.

Differences in stimulus generalization were absent because RTs were similar for untrained items after both treatment conditions. However, the receptive treatment task did not include overt naming, suggesting that greater response generalization occurred after A-tDCS than S-tDCS. This relates to the work of Fritsch and colleagues, who found that the effect of A-tDCS on motor learning is stimulus-driven because A-tDCS in the absence of behavioral training did not improve task performance. Specifically, their study revealed A-tDCS induces secretion of brain-derived neurotrophic factor (BDNF), a protein crucial for new learning. It is possible that increased BDNF secretion in perilesional areas promoted improved naming performance among our participants. Based on Baker et al and the current data, it is reasonable to propose that positive treatment effects may be further enhanced and maintained by coupling language stimulation with A-tDCS applied to the left hemisphere.

The current findings warrant further investigation to evaluate the effect of A-tDCS on aphasia recovery. Clearly, more research is needed to understand factors such as stimulus...
generalization, brain plasticity associated with A-tDCS, the necessary time course of stimulation, and perhaps most importantly, the ecological validity of this method. Our hope is that in the future, research such as this may aid aphasia recovery.

Sources of Funding
Grant support provided by DC008355 (Principal Investigator: J.F.) and DC009571 (Principal Investigators: J.F. and C.R.) from the National Institute on Deafness and Other Communication Disorders and NS054266 (Principal Investigator: C.R.) from the National Institute for Neurological Disorders and Stroke.

Disclosures
None.

References
Transcranial Direct Current Stimulation Improves Naming Reaction Time in Fluent Aphasia: A Double-Blind, Sham-Controlled Study
Julius Fridriksson, Jessica D. Richardson, Julie M. Baker and Chris Rorden

Stroke. 2011;42:819-821; originally published online January 13, 2011;
doi: 10.1161/STROKEAHA.110.600288

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/42/3/819

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/