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Brief communication

Improved proper name recall by electrical stimulation of the anterior temporal lobes

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ABSTRACT

People's names have an embarrassing propensity to be forgotten. This problem is exacerbated by normal aging and by some kinds of dementia. As evidence from neuroimaging and neuropsychology suggest that portions of the anterior temporal lobes play a role in proper name retrieval, we hypothesized that transcranial direct current stimulation (tDCS), a technique that modulates neural transmission, to the anterior temporal lobes would alter the retrieval of proper names. Fifteen young adults received left anodal, right anodal, or sham stimulation of the anterior temporal lobes while naming pictures of famous individuals and landmarks. Right anterior temporal lobe stimulation significantly improved naming for people but not landmarks. These findings are consistent with the notion that the anterior temporal lobes are critically involved in the retrieval of people's names.

Recent evidence has identified the anterior temporal lobes (ATL) as a likely anatomical location for layers within the semantic network that link together person-specific information, including proper names. ATL damage from focal injury, epilepsy resection surgery, or from cell loss in the temporal variant of frontotemporal dementia,[1] can cause a multimodal person recognition deficit (Gainotti, 2007a; Olson, Plotzker, & Ezzyat, 2007). Two distinguishing features of this deficit are that patients' have preserved perception of faces, but impaired recognition of faces, and their deficit extends to non-face recognition cues, such as recognizing people from their voice or name (Evans, Heggs, Antoun, & Hodges, 1995; Gainotti, Barbier, & Marra, 2003; Gentileschi, Sperber, & Spinnler, 2001; Snowden, Thompson, & Neary, 2004). The idea that the ATL represents person-specific semantic knowledge is made more credible by neuroimaging studies reporting increased ATL activations to familiar faces as compared to unfamiliar faces (Gorno-Tempini et al., 1998; Grabowski et al., 2001; Leveroni et al., 2000; Nakamura et al., 2000; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005; Rotshtein, Henson, Treves, Driver, & Dolan, 2005; Sergent, Ohta, & Macdonald, 1992; Sugiura et al., 2001).

In the study reported here we investigated whether stimulation of the ATL by means of transcranial direct current stimulation (tDCS) is effective in modulating the recall of proper names of known people and landmarks (places). tDCS is a technique by which small electric currents are applied to the scalp. These small currents transiently modify transneural electrical potentials, which either enhance or inhibit the likelihood of neural firing. Cathodal stimulation typically reduces excitability in underlying neural substrates (Ferrucci et al., 2008) whereas anodal stimulation can increase the likelihood of neural firing thereby enhancing brain functions (Iyer et al., 2005; Nitsche & Paulus, 2000). The effects typically last 30–90 min and may be mediated, in part, by long-term potentiation or depression-like effects. tDCS has been used in both normal subjects as well as subjects with a variety of brain pathologies (Fregni et al., 2005, 2006) including Alzheimer's Disease (Ferrucci et al., 2008).

In the current study, participants were presented with famous people and places and were asked to recall their names while receiving anodal tDCS over the ATLs. Famous places served as a well-matched comparison condition since they have proper names associated with them but lack the social importance of faces.

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[1] It should be noted here that semantic dementia is associated with a pervasive semantic impairments for which the degradation of person knowledge is but one element. It has been suggested that person knowledge is particularly vulnerable to decline in this disorder because specific levels of knowledge tend to degrade first (Rogers et al., 2004; Warrington, 1975).

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Table 1
Mean naming accuracy in percent correct and reaction times (RT). The bottom row contains % correct for trials in which RTs > 5 s.

	Faces			Places		
	SHAM	L-ATL	R-ATL	SHAM	L-ATL	R-ATL
Accuracy % (all RT)	50	51	53	35	32	33
RT (ms)	3121	3078	3036	3794	3876	3931
Accuracy % (long RT)	**27***	30	**38***	32	29	21

Accuracy rates marked in bold are significantly different (*$p < 0.05$).

The inclusion of this condition allowed us to assess the selectivity/generality of any observed effects.

We reasoned that anodal tDCS over the ATLs may increase proper name recall for people and possibly places in cases when the name is known, but cannot be immediately recalled. Improvements for well-known items may be subject to a ceiling effect because their names are immediately recalled. We hypothesized that tDCS would be most likely to modulate performance when the item is known but recall of the name is slower, similar to a "tip of the tongue" state. In these instances more exhaustive memory search procedures may be performed to activate name representations. This access may benefit from an increase in resting membrane potentials and a resulting increase in the probability of neuronal discharge.

There are two theoretically plausible mechanisms by which ATL stimulation could improve person naming. First, tDCS could modulate access to person-specific semantic information, a stage that is thought to precede access to the name (Bruce & Young, 1986). Second, tDCS could instead directly modulate access to phonological information (=the name itself). The neuropsychological literature suggests that the first mechanism should be more closely associated with the right ATL, the second mechanism with the left ATL (Gainotti, 2007a).

1. Method

1.1. Participants

Fifteen (11 females) neurologically normal subjects between the ages of 19 and 37 (M age = 25.6) participated. All participants had normal or corrected to normal vision and English as their first language. All participants were consented according to the Institutional Review Board of the University of Pennsylvania.

1.2. Stimuli

One hundred sixty-five photographs of famous people and 99 photographs of famous landmarks served as stimuli. These items were selected because normal subjects named them correctly on approximately 50% of trials in a previous norming study. This accuracy level was chosen because we reasoned that in order for tDCS to modulate performance, the items should not be too known or unknown. Fewer places were selected due to the relatively lower familiarity of our cohort with landmarks. In each of the three testing sessions participants were shown 88 pictures (55 faces, 33 places) for a total of 264 stimuli. The assignment of pictures to conditions was randomized for each participant.

1.3. tDCS stimulation

There were three stimulation conditions: anode over the left ATL, anode over the right ATL, or sham stimulation. Anodal electrodes were centered over the ATL using T3 and T4 electrode locations of the international 10–20 system (Jasper, 1958). The cathodal electrode was placed over the contralateral cheek inferior to the zyomatic arch (cheekbone). In the experimental conditions, a 1.5 mA anodal current was applied for 15 min using 5 cm × 7 cm electrodes (15 s ramping, phase in–phase out). In the sham condition, 1.5 mA current was ramped up (15 s) and then down (15 s) with no further stimulation during the task. A Magstim Eldith 1 Channel DC Stimulator Plus was employed.

1.4. Design and procedure

The experiment had a 3 (stimulation condition: left anodal, right anodal, or sham) × 2 (stimulus category: faces or places) design. Experimental treatment was delivered on 2 separate days. On day 1, one of the active stimulation conditions (either left or right anodal; pseudo-random assignment) was delivered. On day 2, the alternate active stimulation condition was administered. Sham stimulation was delivered on the first or the second day and preceded the active condition to avoid carryover effects for sham performance (for a similar design see Fertonani, Rosini, Cotelli, Rossini, & Miniussi, 2010). After the application of the electrodes, the current was turned on and participants received a 2-min training session. This was followed by the experimental conditions, in which the stimulus categories were presented in a blocked counterbalanced order. Each face or place stimulus was shown for 7 s during which time responses were collected. The task was to say the name of the person or place as quickly as possible, followed immediately by a left mouse click. If the name could not be recalled or the stimulus was completely unknown, the right mouse button was pressed. Participants had 7 s to make a response for each trial. Each trial was followed by a 2 s ITI consisting of a blank screen.

Accuracy was the primary dependent measure of interest, and RT was secondary. We expected RTs to be relatively long because (a) RTs for proper names tend to be long (Evrard, 2002); (b) we purposely used difficult stimuli and a recall, rather than recognition task; (c) an open stimulus set was used; and (d) we recorded RTs to the subjects' button press which occurred after naming the item.

2. Results

Correct responses in left anodal, right anodal, and sham conditions were averaged and analyzed separately for face and place stimuli by means of two-tailed, paired t-test ($\alpha = 0.05$). Overall, mean accuracy was higher (faces: 52% correct; places: 33% correct) and mean response times (RTs) faster (faces: 3078 ms; places: 3869 ms) for faces than landmarks (see Table 1 and Fig. 1).

In both face and place conditions the average accuracy of name recall was similar across stimulation conditions and statistical comparisons yielded no significant effects of stimulation. However, we found that in the face condition RTs were 85 ms faster after right-ATL stimulation relative to sham, a difference that approached significance ($p = 0.09$). As we expected that the effects of tDCS would be most apparent for stimuli that were harder to name, we performed a second analysis in which we analyzed accuracy at long RTs, defined as those greater than 5 s. Here we found an 11% increase in face naming accuracy, from 27% in the sham condition to 38% after stimulation of the right ATL ($t(14) = -1.82$; $p = 0.036$;

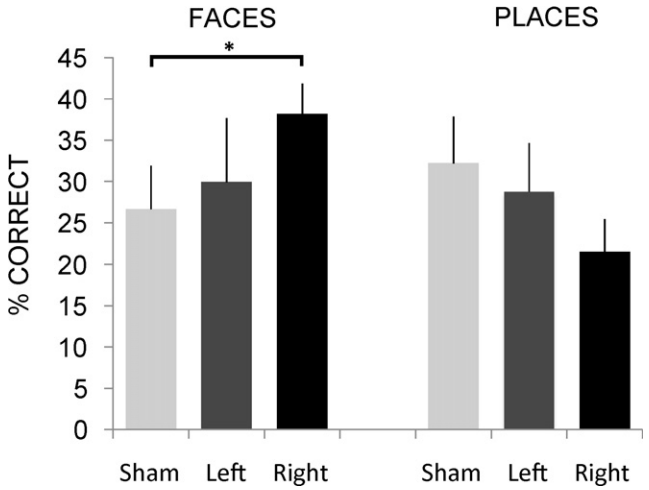

Fig. 1. Average percent accuracy for correct trials with long response times in the face condition and place condition.

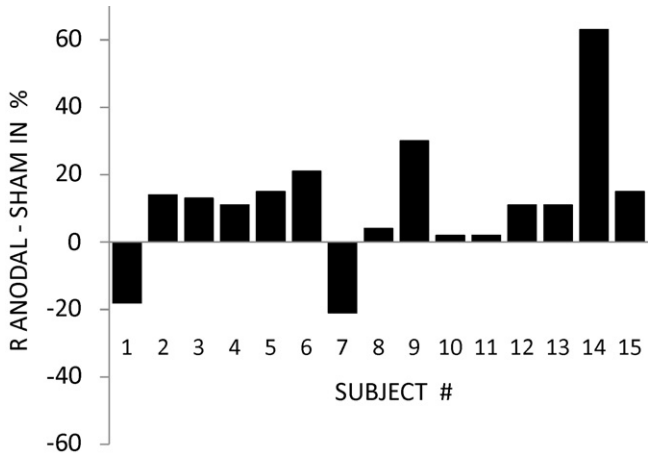

Fig. 2. Percent difference in naming accuracy between right anodal and sham conditions for each individual subject. Numbers on the *x*-axis denote subject numbers.

see Fig. 1). Remarkably, 13 out of 15 participants showed increased naming performance after right anodal stimulation (see Fig. 2). Interestingly, the two participants that showed a decrease in performance were unique in our sample in that tDCS diminished their performance in all conditions.

An inverse trend was apparent in the place condition—an 11% decrease in accuracy after right-ATL stimulation ($t(14) = 1.9$; $p = 0.077$; see Fig. 1). This dissociation was evident in a separate RM-ANOVA [stimulation (sham, left anodal, right anodal) × material (faces, places) × order (1–4)][2] with a significant interaction between factors stimulation by material ($F(2,22) = 5.66$; $p = 0.01$). The RM-ANOVA also revealed that the order in which conditions were delivered did not have a significant contribution to the variance of the dependent variable [$F(3,11) = 0.64$; $p = 0.61$].

3. Discussion

Proper names are difficult to learn (McWeeny, Young, Hay, & Ellis, 1987) and prone to loss in memory decline (James, Fogler, & Tauber, 2008). It has been hypothesized that this is due to their sparse connectivity in the semantic network. We reasoned that tDCS may be effective in enhancing proper name recall when items are more difficult to retrieve. We found that tDCS over the right ATL enhanced recall of names for famous people but not landmarks, in cases when the items were known, but their names not immediately recalled.

The interaction between recall time and enhancement is intuitive because at short RTs the facilitating effect of tDCS is likely to be subject to a ceiling effect—these names are already efficiently retrieved. However, items that are more difficult to name despite being known to the subject, a situation often experienced as a tip of the tongue state in everyday life, are more likely to be modulated by the facilitative influence of anodal tDCS stimulation. Here, the retrieval of well-known information fails even though the retrieval is believed to be imminent (Burke, MacKay, Worthley, & Walde, 1991; Maylor, 1990). Our results suggest that tDCS effects will be more frequently observed in individuals with memory decline such as in older adults or in dementia. Indeed, the "transmission deficit hypothesis" proposes that normal aging is associated with the weakening of neural connections, which in turn results in the loss of access to sparsely connected representations such as proper names (James, 2006; MacKay, 1990). tDCS is therefore a potential tool for neurorehabilitation in these populations, especially in combination with medical intervention (Monte-Silva et al., 2009; Nitsche et al., 2006; Terney et al., 2008).

The trend observed in the landmark condition hints that anodal tDCS to the ATLs may be disruptive for the recall of landmark names. Although a few researchers have implicated the ATLs in the naming of famous landmarks (Drane et al., 2009; Grabowski et al., 2001; Tranel, 2006), landmark naming deficits are not consistently observed after ATL damage (Gainotti, 2007a).

The laterality effects observed in our study are somewhat surprising because of the left hemispheric dominance of language. Studies on focal ATL lesions reveal that right ATL patients tend to loose feelings of person familiarity and access to person-specific semantic information when shown famous or personally familiar faces. In contrast, left ATL damage causes retrieval deficits when names are used as retrieval cues and usually retain feelings of familiarity (Gainotti, 2007b; Gainotti, Ferraccioli, & Marra, 2010). Thus it is possible that right-ATL stimulation affected access to person-specific semantic information, part of the person recognition process, which is thought to precede phonological access of the name (Burton & Bruce, 1992). This neural enhancement of person identification may have affected downstream name recall in the left hemisphere through inter-hemispheric connections.

The recall of proper names is a complex process involving several information processing steps and a network of brain regions (Galdo Alvarez, Lindin Novo, & Diaz Fernandez, 2009). For this reason it is theoretically possible that stimulation of other language regions might yield similar effects to those observed here. There are reports of moderate tDCS effects on reaction times in a picture naming task when applied over Wernicke's area (Sparing, Dafotakis, Meister, Thirugnanasambandam, & Fink, 2008) and the left dorsolateral prefrontal cortex (Fertonani et al., 2010). However the fact that we showed a large accuracy effect, selectively for famous face stimuli, speaks for a prominent role of the right ATL in person naming.

Related to this topic, one could interpret the observed findings as arising from stimulation of the inferior frontal gyrus, rather than the ATL, since tDCS has somewhat limited spatial resolution. The left inferior frontal gyrus is thought to be involved in semantic access (Binder, Desai, Graves, & Conant, 2009). However, the fact that tDCS effects were manifest in the right hemisphere speaks against this notion. Further, tDCS current density decreases substantially even over a relatively short distance from the active electrode (Miranda, Lomarev, & Hallett, 2006; Nitsche et al., 2003; Wagner et al., 2007).

It is possible to interpret our findings within a more general framework termed the "hub account" of semantic processing in the ATLs (see Patterson, Nestor, & Rogers, 2007 for a review). In this view, famous persons and landmarks are highly specific items that are more vulnerable to degradation in semantic dementia than are more general classes of items (Rogers et al., 2004; Warrington, 1975). In support of this notion, Pobric, Jefferies, and Ralph (2007) asked participants to make similarity judgments to basic level or subordinate level words and found that repetitive TMS over the ATL selectively slowed judgments for subordinate level words.

We previously showed that the ATL is more sensitive to social stimuli than non-social stimuli (Olson et al., 2007; Ross & Olson, 2010; Simmons, Reddish, Bellgowan, & Martin, 2009; Zahn et al., 2007, 2009). The different effects in the face and place conditions of this study may therefore reflect the differential sensitivity of this region to social stimuli. In this context the potential applicability of tDCS as a rehabilitation tool may be constrained to specific categories of stimuli which requires that the full range of effects are established before tDCS can be advised for therapeutic purposes.

[2] Please note that we did not have a full factorial design (sham was only delivered over one hemisphere) and therefore could not test interactions between hemisphere and stimulation condition.

References

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cereb Cortex*.

Burke, D. M., MacKay, D. G., Worthley, J. S., & Walde, E. (1991). On the tip of the tongue: What causes word finding failures in young and older adults? *Journal of Memory and Language*, *30*, 542–579.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*(Pt 3), 305–327.

Burton, A. M., & Bruce, V. (1992). I recognize your face but I can't remember your name: A simple explanation? *British Journal of Psychology*, *83*(Pt 1), 45–60.

Drane, D. L., Ojemann, G. A., Ojemann, J. G., Aylward, E., Silbergeld, D. L., Miller, J. W., et al. (2009). Category-specific recognition and naming deficits following resection of a right anterior temporal lobe tumor in a patient with atypical language lateralization. *Cortex*, *45*(5), 630–640.

Evans, J. J., Heggs, A. J., Antoun, N., & Hodges, J. R. (1995). Progressive prosopagnosia associated wiht selective right temporal lobe atrophy. A new syndrome? *Brain*, *118*, 1–13.

Evrard, M. (2002). Ageing and lexical access to common and proper names in picture naming. *Brain Language*, *81*(1–3), 174–179.

Ferrucci, R., Mameli, F., Guidi, I., Mrakic-Sposta, S., Vergari, M., Marceglia, S., et al. (2008). Transcranial direct current stimulation improves recogntiion memory in Alzheimer's disease. *Neurology*, *71*, 493–498.

Fertonani, A., Rosini, S., Cotelli, M., Rossini, P. M., & Miniussi, C. (2010). Naming facilitation induced by transcranial direct current stimulation. *Behavioural Brain Research*, *208*(2), 311–318.

Fregni, F., Boggio, P. S., Mansure, C. G., Wagner, T., Ferreira, M. J. L., Lima, M. C., et al. (2005). Transcranial direct current stimulation of the unaffected hemisphere in stroke patients. *Neuroreport*, *16*, 1551–1555.

Fregni, F., Boggio, P. S., Nitsche, M. A., Marcolin, M. A., Rignonatti, S. P., & Pascual-Leone, A. (2006). Treatment of major depression with transcranial direct current stimulation. *Bipolar Disorders*, *8*, 203–204.

Gainotti, G. (2007a). Different patterns of famous people recognition disorders in patients with right and left anterior temporal lesions: A systematic review. *Neuropsychologia*, *45*(8), 1591–1607.

Gainotti, G. (2007b). Face familiarity feelings, the right temporal lobe and the possible underlying neural mechanisms. *Brain Research Reviews*, *56*(1), 214–235.

Gainotti, G., Barbier, A., & Marra, C. (2003). Slowly progressive defect in recognition of familiar people in a patient with right anterior temporal atrophy. *Brain*, *126*, 792–803.

Gainotti, G., Ferraccioli, M., & Marra, C. (2010). The relation between person identity nodes, familiarity judgment and biographical information. Evidence from two patients with right and left anterior temporal atrophy. *Brain Research*, *1307*, 103–114.

Galdo Alvarez, S., Lindin Novo, M., & Diaz Fernandez, F. (2009). Naming faces: A multidisciplinary and integrated review. *Psicothema*, *21*(4), 521–527.

Gentileschi, V., Sperber, S., & Spinnler, H. (2001). Crossmodal agnosia for familiar people as a consequence of right infero-polar temporal atrophy. *Cognitive Neuropsychology*, *18*, 439–463.

Gorno-Tempini, M. L., Price, C. J., Josephs, O., Vandenberghe, R., Cappa, S. F., Kapur, N., et al. (1998). The neural systems sustaining face and proper-name processing. *Brain*, *121*, 2103–2118.

Grabowski, T. J., Damasio, H., Tranel, D., Boles Ponto, L. L., Hichwa, R. D., & Damasio, A. R. (2001). A role for left temporal pole in the retrieval of words for unique identities. *Human Brain Mapping*, *13*, 199–212.

Iyer, M. B., Mattu, U., Grafman, J., Lomarev, M., Sato, S., & Wassermann, E. M. (2005). Safety and cognitive effect of frontal DC brain polarization in healthy individuals. *Neurology*, *64*(5), 872–875.

James, L. E. (2006). Specific effects of aging on proper name retrieval: Now you see them, now you don't. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*, *61*(3), P180–183.

James, L. E., Fogler, K. A., & Tauber, S. K. (2008). Recognition memory meaures yield disproportionate effects of aging on learning face-name associations. *Psychology and Aging*, *23*(3), 657–664.

Jasper, H. H. (1958). The ten twenty system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, *10*, 371–375.

Leveroni, C. L., Seidenberg, M., Mayer, A. R., Mead, L. A., Binder, J. R., & Rao, S. M. (2000). Neural systems underlying the recognition of familiar and newly learned faces. *The Journal of Neuroscience*, *20*, 878–886.

MacKay, D. G. B. D. M. (1990). *Cognition and aging: A theory of new learning and the use of old connections*. North Holland: Elsevier Science.

Maylor, E. A. (1990). Recognizing and naming faces: Aging, memory retrieval, and the tip of the tongue state. *Journals of Gerontology*, *45*(6), P215–226.

McWeeny, K. H., Young, A. W., Hay, D. C., & Ellis, A. W. (1987). Putting names to faces. *British Journal of Psychology*, *45*, 215–226.

Miranda, P. C., Lomarev, M., & Hallett, M. (2006). Modeling the current distribution during transcranial direct current stimulation. *Clinical Neurophysiology*, *117*(7), 1623–1629.

Monte-Silva, K., Kuo, M. F., Thirugnanasambandam, N., Liebetanz, D., Paulus, W., & Nitsche, M. A. (2009). Dose-dependent inverted U-shaped effect of dopamine (D2-like) receptor activation on focal and nonfocal plasticity in humans. *Journal of Neuroscience*, *29*(19), 6124–6131.

Nakamura, K., Kawashima, R., Sato, N., Nakamura, A., Sugiura, M., Kato, T., et al. (2000). Functional delineation of the human occipito-temporal areas related to face and scene processing: A PET study. *Brain*, *123*, 1903–1912.

Nitsche, M. A., & Paulus, W. (2000). Excitability changes induced in the humanmotor cortex by weak transcranial direct current stimulation. *Journal of Physiology*, *527*, 633–639.

Nitsche, M. A., Liebetanz, D., Lang, N., Antal, A., Tergau, F., & Paulus, W. (2003). Safety criteria for transcranial direct current stimulation (tDCS) in humans. *Clinical Neurophysiology*, *114*(11), 2220–2222, author reply 2222–2223.

Nitsche, M. A., Lampe, C., Antal, A., Liebetanz, D., Lang, N., Tergau, F., et al. (2006). Dopaminergic modulation of long-lasting direct current-induced cortical excitability changes in the human motor cortex. *European Journal of Neuroscience*, *23*(6), 1651–1657.

Olson, I. R., Plotzker, A., & Ezzyat, Y. (2007). The Enigmatic temporal pole: A review of findings on social and emotional processing. *Brain*, *130*(Pt 7), 1718–1731.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience*, *8*(12), 976–987.

Pobric, G., Jefferies, E., & Ralph, M. A. (2007). Anterior temporal lobes mediate semantic representation: Mimicking semantic dementia by using rTMS in normal participants. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(50), 20137–20141.

Pourtois, G., Schwartz, S., Seghier, M. L., Lazeyras, F., & Vuilleumier, P. (2005). View-independent coding of face identity in frontal and temporal cortices is modulated by familiarity: An event-related fMRI study. *Neuroimage*, *24*, 1214–1224.

Rogers, T. T., Lambon Ralph, M. A., Garrard, P., Bozeat, S., McClelland, J. L., Hodges, J. R., et al. (2004). Structure and deterioration of semantic memory: A neuropsychological and computational investigation. *Psychological Review*, *111*(1), 205–235.

Ross, L. A., & Olson, I. R. (2010). Social cognition and the anterior temporal lobes. *Neuroimage*, *49*(4), 3452–3462.

Rotshtein, P., Henson, R. N., Treves, A., Driver, J., & Dolan, R. J. (2005). Morphing Marilyn into Maggie dissociates physical and identity face representations in the brain. *Nature Neuroscience*, *8*(1), 107–113.

Sergent, J., Ohta, S., & Macdonald, B. (1992). Functional neuroanatomy of face and object processing: A positron emission tomography study. *Brain*, *115*, 15–36.

Simmons, W. K., Reddish, M., Bellgowan, P. S., & Martin, A. (2009). The selectivity and functional connectivity of the anterior temporal lobes. *Cereb Cortex*.

Snowden, J. S., Thompson, J. C., & Neary, D. (2004). Knowledge of famous faces and names in semantic dementia. *Brain*, *127*, 860–872.

Sparing, R., Dafotakis, M., Meister, I. G., Thirugnanasambandam, N., & Fink, G. R. (2008). Enhancing language performance with non-invasive brain stimulation—a transcranial direct current stimulation study in healthy humans. *Neuropsychologia*, *46*(1), 261–268.

Sugiura, M., Kawashima, R., Nakamura, K., Sato, N., Nakamura, A., Kato, T., et al. (2001). Activation reduction in anterior temporal cortices during repeated recognition of faces of personal acquaintances. *Neuroimage*, *13*, 877–890.

Terney, D., Bergmann, I., Poreisz, C., Chaieb, L., Boros, K., Nitsche, M. A., et al. (2008). Pergolide increases the efficacy of cathodal direct current stimulation to reduce the amplitude of laser-evoked potentials in humans. *Journal of Pain and Symptom Management*, *36*(1), 79–91.

Tranel, D. (2006). Impaired naming of unique landmarks is associated with left temporal polar damage. *Neuropsychology*, *20*(1), 1–10.

Wagner, T., Fregni, F., Fecteau, S., Grodzinsky, A., Zahn, M., & Pascual-Leone, A. (2007). Transcranial direct current stimulation: A computer-based human model study. *Neuroimage*, *35*(3), 1113–1124.

Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology*, *27*(4), 635–657.

Zahn, R., Moll, J., Krueger, F., Huey, E. D., Garrido, G., & Grafman, J. (2007). Social concepts are represented in the superior anterior temporal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(15), 6430–6435.

Zahn, R., Moll, J., Iyengar, V., Huey, E. D., Tierney, M., Krueger, F., et al. (2009). Social conceptual impairments in frontotemporal lobar degeneration with right anterior temporal hypometabolism. *Brain*, *132*(Pt 3), 604–616.