

A Neurology of Belief

The notion that all mental acts, all mental processes and dispositions have specific neural correlates has become much easier to explore in the past 15 years with the development of PET scanning and especially functional MRI. We can now, for example, demonstrate activity in the visual cortex when a subject views a test object, and we can pick up similar activity if we ask the subject to imagine or make a mental picture of what the object looks like. Functional brain imagery has also been used in relation to more complex mental processes, such as those involved in economic decisions.^{1–3} There have, however, been no comparable studies addressed to the neural correlates of belief in general until Harris, Sheth, and Cohen's pioneering article in the present issue of *Annals of Neurology*.⁴

Harris et al.'s experimental method, both simple and ingenious, was to develop a battery of statements which were presented in written form to subjects while they were in the fMRI scanner. The statements in seven different categories (autobiographical, mathematical, geographical, religious, ethical, semantic, and factual) each were designed, according to the authors, "to be clearly true, false, or undecidable." In the mathematical category, for example, the statements were:

$(2 + 6) + 8 = 10$

62 can be evenly divided by 9

$1.2^{57} = 32608.5153$

Semantic, geographic, factual, and autobiographical questions were equally concrete:

California is larger than Rhode Island.

"Devious" means "friendly."

You had eggs for breakfast on December 8, 1999.

In the ethical and religious categories, the statements were clearly more emotionally charged, but still relatively simple:

It is bad to take pleasure at another's suffering.

A Personal God exists, just as the Bible describes.

Jesus spoke 2,467 words in the New Testament.

The results that Harris et al. obtained are striking. Areas of prefrontal cortex were activated for assent, dissent, or uncertainty in all cases, but so were parts of the limbic system and basal ganglia. The brain areas most engaged in assent included ventral medial prefrontal cortex, consisting of the orbitomedial gyrus and gyrus rectus. In contrast, brain areas most engaged in

dissent included inferior frontal gyrus, anterior insula, superior parietal lobule and dorsal anterior cingulate. The engagement of different brain regions during each of these response types strongly suggests that there are two distinct and dissociable systems for assent and dissent, a remarkable finding in itself.

Behaviorally, too, assent, dissent, and uncertainty were further differentiated by the time it took to generate a response: reaction times were significantly faster for the assent responses compared to both dissent and uncertainty responses.

The ventromedial prefrontal cortex that was most responsive during assent responses is also known to link emotional associations with reward contingencies. The neural anatomy specialized for disbelief, in contrast, tended to engage dorsal structures known for their roles in executive functions and decision making. Thus, Harris et al. suggest that dissent or disbelief emerges from a neural basis specialized for more deliberate and considered responses, responses that require judgment and evaluation. The observation that reaction times are slower for these deliberations is consistent with the engagement of more interconnected processes.

It is striking that judgments of propositional truth or falsity, in areas as abstract and impersonal as mathematics, still activate emotional networks in the brain as well as cognitive ones. It has been evident from fMRI studies of economic decision-making that these emotional areas are especially activated in regard to charged subjects like risk seeking or risk aversion.^{1–3} But Harris et al.'s work raises the possibility that *all* decision-making involves both emotional and cognitive processes. Intriguingly, they note, the strongest emotional reactions were observed in association with dissent or disbelief, which activated bilateral areas of the anterior insula, a region thought to be involved in reactions of disgust. "The acceptance or rejection of propositional truth claims," they write, "appear to be governed in part by the same regions that govern the pleasantness of tastes and odors."

Extending these notions to the levels of experience and philosophy, Harris et al. suggest that belief or acceptance of a proposition as true has a pleasant and rewarding emotional tone. We are reminded of the "thrill" one experiences when solving a mathematical proof. Alternatively, disbelief or rejection of a proposition is often experienced with a feeling of discomfort and urge to avoid the "untruth." Harris et al.'s work contributes an objective validation of these experiences by relating them to specialized neural processes consis-

tent with these polarized experiences, and enhances our understanding of a uniquely human cognitive ability to distinguish the true from the untrue.

Harris et al. note that reactions of assent are significantly prompter than those of dissent or uncertainty. This they take to support "Spinoza's conjecture that the mere comprehension of a statement entails the tacit acceptance of its being true," an almost reflexive, if provisional, assent, to be followed by a more deliberate weighing and assessment. Human beings, in other words, are wired to "accept appearances as reality until they prove otherwise." This seems to us to ring true.

The most provocative suggestion made by Harris et al. relates to their finding that all reactions of assent or acceptance (or belief, if one prefers) are neurophysiologically identical, whether propositional judgments are made in the highly charged realm of ethical or religious issues or the seemingly neutral realm of arithmetical statements. If such results can be duplicated, Harris et al. will have made a fascinating discovery.

But are there different kinds of belief? Is belief in a simple statement whose truth can be checked (such as "Jesus spoke 2,467 words in the New Testament") comparable to forms of belief which we call "faith" or conviction, where assent is given to transcendent propositions which lie beyond the realm of evidence (such as belief in a soul, a god, heaven or hell)?

These are all questions for future research, and one hopes that such questions will now be addressed by Harris et al., as well as by other researchers. Harris and his colleagues have set up an original and elegant series of experiments, and that they have achieved such clear-cut results represents a brilliant beginning to what we hope will be a whole series of ever deeper and more probing studies on the neurology of belief, a crucial aspect of human behavior and identity which has, until now, been beyond the reach of neuroscience.

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References

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A Touch of Increased Pain: Cutaneous Allodynia in Migraine

Allodynia is a hot topic in migraine research, with increasing recognition that it may be a quantifiable clinical marker. The phenomenon of cutaneous allodynia, the perception of discomfort resulting from an ordinarily painless stimulus involving the skin, has long been recognized as a clinical symptom that some patients experience during their migraine attacks. It was formally described nearly 50 years ago when Selby and Lance¹ reported scalp tenderness in a significant majority of migraine patients associated with their attacks. Lipton and colleagues² study in this issue of *Annals* is the first to characterize allodynia at the population level, employing a questionnaire to quantify allodynic symptoms in 11,388 patients. The results solidify cutaneous allodynia as a common clinical symptom in migraine. They also provide interesting new information about the relation between cutaneous allodynia and other features of migraine, and highlight some fundamental questions: What does cutaneous allodynia tell us about migraine pathophysiology? Should it influence our clinical management of migraine patients?

Several interesting and significant findings are reported in Lipton and colleagues² study. First, it finds a prevalence of allodynic symptoms that is similar to that reported in a variety of other studies.^{1,3-7} This is important because most other studies of allodynia have been performed in headache clinics where the severity of symptoms is typically much greater. It indicates that allodynia is a common characteristic of migraine not only in specialized headache clinics but in the general population. The study also finds that the allodynic symptoms are correlated with defining clinical features of migraine, and with headache severity, frequency, and associated disability. There is also an increased number and frequency of allodynic symptoms in patients with increased body mass, and decreased allodynic symptoms in patients with higher levels of education. There is a substantially increased occurrence of allodynic symptoms in patients with migraine with aura as compared with those without aura. Another interesting finding is that patients commonly experience allodynic symptoms that involve nontrigeminal dermatomes, such as discomfort from wearing a necklace.

Lipton and colleagues² study supports the concept that a questionnaire approach can document the phenomenon of cutaneous allodynia without having to do formal quantitative sensory testing, a time-consuming