fMRI in the Courtroom: A (Very Brief) Overview

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On the evening of May 9, 1991, a postdoctoral fellow named Kenneth Kwong ran a new MRI sequence at Massachusetts General Hospital and, remarkably, "saw a bright blob coming out of the visual cortex" (1). This experiment—the first to use blood oxygenation level-dependent (BOLD) functional magnetic resonance imaging (fMRI) in a human subject—led to a surge in neuroscience research that has not abated since. In forensic psychiatry, some commentators have speculated that fMRI may have a role in detecting lies, determining criminal responsibility, and distinguishing chronic pain from malingering. Others are far more circumspect in their predictions, arguing that these technologies have serious limitations. In this column, we discuss how fMRI works, how the images it produces can be misunderstood (by clinicians, judges, and juries alike), and how fMRI evidence has been used in specific legal cases.

The scientific principles of fMRI are simple: (A) more active brain tissues typically require more oxygen than those that are less active, (B) oxygen-poor blood (containing deoxyhemoglobin) responds differently to a magnetic field than oxygen-rich blood, and (C) differences in oxygenation cause a measurable change in the MRI signal (i.e., the BOLD response; see Reference 2 for further review). Thus, fMRI is a measure of the hemodynamic response—an increase in blood flow to active tissues—rather than direct neural activity. These changes in blood oxygenation are measured across the entire brain at a spatial resolution of approximately one mm^3. The BOLD signal in each of these small, cube-shaped "voxels" (essentially a three-dimensional pixel)—of which the brain has about a hundred thousand—is recorded about every two seconds to capture and demonstrate changes in brain activity over time. By measuring differences in the BOLD signal during experimental and control tasks (a process called "cognitive subtraction"), researchers can deduce which areas of the brain are more or less active during particular cognitive processes. However, what these data may imply about human behavior is anything but straightforward.

In particular, the association between the BOLD signal and a specific action, symptom, or behavior may be quite weak. And the connection to legal or forensic conclusions like truth or falsehood, guilt or innocence, is weaker still. Although dense brain regions often require high levels of oxygenation and yield a substantial BOLD response, they may make only a limited contribution to a specific cognitive or behavioral function. It is generally assumed that such functions result from local neuronal processing; however, it is unclear whether this assumption holds for complex pathways and structures of the cortex (3). Until scientists better understand how the brain functions to produce cognition and behavior, it will remain difficult to use hemodynamic data to reach specific legal or forensic conclusions.

Some limitations of fMRI are attributable to the technology itself. Neuromodulatory effects on arousal, attention, and memory are slow to receive blood flow and, thereby, weaken the spatiotemporal resolution of BOLD signaling (3). Furthermore, the highly vascularized connective tissue and surface of the brain distort the signal of adjacent neural regions (4). In addition, the BOLD signal—a measure of blood flow—is unable to independently distinguish whether increased flow represents excitatory or inhibitory neural activity (4, 5).

Even if all these technical challenges were solved, a key conceptual obstacle would remain: the unreliability of inferences about an individual's cognitive functions from group data. This group-to-individual (or "G2i") problem reflects the high levels of interparticipant variability present in both the BOLD response and the location of voxels. Consequently, group-averaged data cannot reasonably be compared with any one person's data given the high level of variability (6).

Without deeper scientific understanding and broader legal acceptance, the use of fMRI as a modern-day polygraph in court is premature. Nonetheless, the lack of medicolegal consensus has not precluded its use in court, even a decade ago (7). Dr. Steven Laken, CEO of the forensic biotechnology company Cephos, Inc., attempted to introduce an fMRI-based "credibility assessment" in *Wilson v. Corestaff Services, L.P.* (8) and *U.S. v. Semrau* (9). In both cases, Dr. Laken's testimony was excluded.

In *Wilson*, Dr. Laken's proposed testimony involved witness credibility in an employment discrimination case. The court stated, "anything that impinges on the province of the jury on issues of credibility should be treated with a great deal of skepticism," and held that the *Frye* standard (10) was not met.

In *Semrau*, Dr. Laken testified that the defendant's denial of committing Medicare fraud was credible. After an evidentiary motion, the court noted that Cephos' tests lacked ecological validity, stating, "there are no known error rates for fMRI-based lie detection outside the laboratory setting, i.e., in the 'real-world' or 'real-life' setting." The judge utilized both the Federal Rule of Evidence 702 (11) and *Daubert* (12) factors to reach his conclusion. In summary, the court determined that the error rate of fMRI lie-detection in the "real world" is unknown and that this use of fMRI was prejudicial. Dr. Semrau appealed, arguing that the district court erred in excluding Dr. Laken's expert testimony (8). The district court's exclusion of the expert witness was upheld partly due to the lack of "formal research" offered at the *Daubert* hearing.

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(3) Sakurai S. I'm Nonbinary. My Passport Should Show That. ACLU News & Commentary. 27 January 2021. https://www.aclu.org/news/lgbt-rights/im-nonbinary-my-passport-should-show-that/ Last accessed 2/28/2021
(4) Kelly N. 'I felt like I was born again': first non-binary person granted UK refugee status. The Guardian. 30 December 2020. https://www.theguardian.com/world/2020/dec/30/i-felt-like-i-was-born-again-first-non-binary-person-granted-uk-refugee-status Last accessed 2/28/2021
(5) Robinson M. Two-Spirit Identity in a Time of Gender Fluidity. J Homosex. 2020;67(12):1675-1690.
(6) Segal C. Oregon becomes first state to add gender-neutral option on driver's license. PBS News Hour. Jun 15 2017. https://www.pbs.org/newshour/nation/oregon-non-binary-gender-neutral-option-licenses. Last accessed 2/28/021.
(7) Siegel R. New gender-neutral identifiers on IDs signal to nonbinary D.C. residents that they belong. The Washington Post. 21 June 2017. https://www.washingtonpost.com/local/trafficandcommuting/new-gender-neutral-identifiers-on-ids-signal-to-nonbinary-dc-residents-that-they-belong/2017/06/21/43361b80-55e3-11e7-a204-ad706461fa4f_story.html Last accessed 2/28/2021
(8) Katz B. California Becomes First State to Introduce Gender-Neutral Birth Certificates. Smithsonian Magazine. October 20, 2017. https://www.smithsonianmag.com/smart-news/california-becomes-first-state-introduce-gender-neutral-birth-certificates-180965343/ Last accessed 2/28/2021
(9) H.R. 5692. Gender Inclusive Passport Act. 116th Congress (2019-2020). https://www.congress.gov/bill/116th-congress/house-bill/5962/text Last accessed 2/28/2021
(10) Stevens J, Balsamo DN, Tomita KK, et al. Sex and paperwork: The ethics of identification documents that misidentify one's sex and gender. IACAPAP 2020 Singapore Virtual Congress. 3 December 2020.
(11) Richards C, Bouman WP, Seal L, et al. Non-binary or genderqueer genders. Int Rev Psychiatry. 2016;28(1):95-102.
(12) Scheim AI, Perez-Brumer AG, Bauer GR. Gender-concordant identity documents and mental health among transgender adults in the USA: a cross-sectional study. Lancet Public Health. 2020;5(4):e196-e203.
(13) H-65.967. Conforming Sex and Gender Designation on Government IDs and Other Documents. American Medical Association. Last Modified 2019.
(14) Diamond LM. Gender Fluidity and Nonbinary Gender Identities. Child Dev Perspectives. 2020;14(2): 110-115.
(15) Chew D, Tollit MA, Poulakis Z, et al. Youths with a non-binary gender identity: a review of their sociodemographic and clinical profile. Lancet Child Adolesc Health. 2020 Apr;4(4):322-330.
(16) Todd K, Peitzmeier SM, Kattari SK, et al. Demographic and Behavioral Profiles of Nonbinary and Binary Transgender Youth. Transgend Health. 2019 Oct 21;4(1):254-261.
(17) Goshal N, Knight K. Netherlands Sees No Role for Gender Marker on ID Documents. Human Rights Watch. July 8, 2020. https://www.hrw.org/news/2020/07/08/netherlands-sees-no-role-gender-marker-id-documents Last accessed 2/28/2021

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The level of acceptable ambiguity in the BOLD response remains unclear for scientific and medicolegal contexts. At present, there is concern that the capabilities of fMRI in lie detection and other areas of interest in forensic psychiatry have been overstated (13, 14). In fact, the American College of Radiology maintains that fMRI has not yet attained the required threshold of evidence to merit routine testimonial basis in evaluations of traumatic brain injury, post-traumatic stress disorder, dementia, and other neuropsychiatric conditions (15). Therefore, although fMRI seems to be a promising forensic evaluation tool, its practical utility in evaluations remains limited.

References:

(1) Athinoula A. Martinos Center for Biomedical Imaging. Ken Kwong and the introduction of noninvasive fMRI [Internet]; 2016. Available from: https://www.martinos.org/ken-kwong-and-the-introduction-of-non-invasive-fmri/. Accessed December 13, 2020
(2) Aguirre GK. Functional neuroimaging: technical, logical, and social perspectives. Hastings Cent Rep. 2014;Spec No:S8-18
(3) Logothetis NK. What we can do and what we cannot do with fMRI. Nature. 2008 Jun 12; 453(7197):869–878
(4) Turner R. Uses, misuses, new uses and fundamental limitations of magnetic resonance imaging in cognitive science. Philos Trans R Soc Lond B Biol Sci. 2016; 371(1705):20150349
(5) Lee JH, Durand R, Gradinaru V, et al. Global and local fMRI signals driven by neurons defined optogenetically by type and wiring. Nature. 2010 June; 465:788–792
(6) Woodruff, William A. Evidence of lies and rules of evidence: the admissibility of fMRI-based expert opinion of witness truthfulness. N.C. J.L. & Tech. 2014 October; 16(1):105–252
(7) Langleben DD, Moriarty JC. Using brain imaging for lie detection: where science, law, and policy collide. Psychology, Public Policy, and Law. 2013; 19(2):222–234
(8) *Wilson v. Corestaff Servs LP*, 900 N.Y.S. 2d 639, 2010
(9) *U.S. v. Semrau,* 693 F.3d 510 (6th Cir. 2012)
(10) *Frye v. U.S.* 293 F. 1013 (D.C. Cir. 1923)
(11) Title 28 U.S.C. § 702, 2010
(12) *Daubert v. Merrell Dow Pharmaceuticals Inc*., 509 U.S. 579 (1993)
(13) Langleben DD, Dattilio FM. Commentary: the future of forensic functional brain imaging. J Am Acad Psychiatry Law. 2008; 36(4):502-504
(14) Appelbaum PS. Law & psychiatry: The new lie detectors: neuroscience, deception, and the courts. Psychiatr Serv. 2007; 58(4):460-462
(15) American College of Radiology. ACR Appropriateness Criteria [Internet]; 2021. Available from: https://acsearch.acr.org/list. Accessed November 20, 2020

Beyond Yoga

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violations. He also presented some of the common psychological sequelae to professionals who are victims of stalking (10).

References

(1) "Wellness" and "Well-being." Merriam-Webster's Collegiate Dictionary, Edition 10. Merriam-Webster Incorporated, 1999
(2) Eley DS, Leung J, Hong BA *et al*. Identifying the Dominant Personality Profiles in Medical Students: Implications for Their Well-Being and Resilience. PLoS One 5(8): e0160028, 2016
(3) National Academy of Sciences, Engineering, and Medicine. Taking Action Against Clinician Burnout: A Systems Approach to Professional Well-Being. Washington, DC: The National Academies Press, 2019
(4) Najjar D. Are Doctors Really at Highest

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