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RESEARCH ARTICLE

On the viability and potential value of current and emerging neuroscience and technologies to the practice of forensic science

Nathan Skinner[1], Monica A. Leyva[2], James Giordano[3,4*]

[1]Dept. of Forensic Sciences, George Washington University, Washington, DC, USA
[2]Duke Clinical Research Institute, Duke University, Durham, NC, USA
[3]Depts. of Neurology and Biochemistry, and Neuroethics Studies Program, Georgetown University Medical Center, Washington DC, USA
[4]Defense Medical Ethics Center and Dept. of Psychiatry Uniformed Services University of Health Sciences, Bethesda MD, USA

*james.giordano@georgetown.edu

ABSTRACT

As developments in neuroscience and its technologies (neuroS/T) advance, the criminal justice system's consideration of, and interest in the applications of such methods and tools to forensics and legal proceedings are also increasing. In light of these advances, considerations, and interest, it becomes essential to address the pragmatic validity, viability and potential value of neuroS/T to forensics and law. This essay describes ways that implementation of neuroS/T can directly benefit the forensic science community; identifies limitations of, and concerns about forensic use of neuroS/T; and posits the value of an implementation science framework to identify and analyze extant gaps (in both neuroS/T and forensic sciences and law) and offer ways that such gaps can - and arguably should - be compensated, closed or prevented in order to promote ethical interdisciplinary and systemic utility, effectiveness, and efficiency. Based upon these arguments, we propose the following recommendations that may be useful when considering and/or implementing neuroS/T in forensic contexts:

1) NeuroS/T under consideration should be evaluated for its actual capabilities, and constraints/limitations as specific to the needs and charge(s) of the forensic process within legal contexts.

2) NeuroS/T should be determined by consensus of a *representative community of neuroscientists*, to validly and reliably obtain defined results as relevant and applicable to the process(es) and policies of the forensic community.

3) NeuroS/T should corroboratively be determined by consensus of a *representative community of forensic professionals*, to validly and reliably obtain the aforementioned results as relevant and applicable to of the process(es) and policies of the forensic community

4) The extent of consensus should be necessary and sufficient to sate current standards of the Code of Federal Evidence (e.g.- Daubert) or other codification as applicable to the (national) jurisdiction in which these approaches will be utilized.

5) The use of neuroS/T in these ways should be supportive, but not substitutive of, other ratified, accepted methods of forensic investigation and analyses, and relative weighting of neuroS/T-based information should be determined in proportion to the specificity and precision of the technique(s) in comparison to other methods.

Keywords: neuroscience; neurotechnology; forensic science; law; implementation science; neuroethics

Introduction

With continued advancements in and of neuroscience and its technologies (neuroS/T), there is ongoing interest in the possible viability and value of employing the methods and tools of the brain sciences in forensic and legal proceedings.[1] Reflective of such interest, there has been sustained consideration for employing neuroS/T in the criminal justice system, with most common applications being for demonstration/provision of bases for exculpatory evidence.[2,3] While research has addressed the role of neuroS/T in assessing antisocial or criminal behavior, and the viability and validity of using such evaluations in the courtroom,[4-6] fewer papers have focused on the potential value of neuroS/T to the forensic science community.

The biologic disciplines contributory to the forensic science community (pathology, hematology, DNA trace/Firearm analysis, etc.) are engaged toward a unifying telos: the legally sound analysis and presentation of scientific evidence that will aid the court in exonerating or convicting a defendant. In 2009, the National Academy of Sciences (NAS) detailed the relative heterogeneity of the forensic community in the United States, and suggested three important objectives for improvement. First, steps should be taken to help "identify perpetrators with higher reliability." Second, there should be directed effort to "…reduce the occurrence of wrongful convictions." And third, in making such improvements, the forensic science community "will undoubtedly enhance the Nation's ability to address the needs of homeland security".[7] Apropos to these objectives, it is tempting to consider current – and potential – capabilities of extant methods and tools of the brain sciences (neuroimaging, use of neurobiomarkers, etc.) as an affording advantage in forensic analyses. While the validity of context-specific uses of particular neuroS/T approaches is generally well-established, this is not sufficient to sustain the legal probity of their forensic application in legal settings. To wit, the standards established by *Daubert v. Merrell Dow Pharmaceuticals Inc., (1993),*[8] provide defined criteria with which to evaluate the admissibility of expert testimony regarding the use of current and newly emerging methods so as to inform the tier(s) of fact (vide infra; and for overview, see [9]).

This so-called Daubert standard, "attempts to strike a balance between a liberal admissibility standard for relevant evidence on the one hand and the need to exclude misleading 'junk science' on the other".[10] Briefly, the Daubert standard focuses upon the *relevance* of evidence, which has been deemed reliable and valid. By definition, reliability refers to consistency and accuracy of results, and validity describes the soundness of methods used (internal validity), and the generalizability of results obtained (external validity). If either the consistency, soundness, or generalizability of evidence is judged to be insufficient, such evidence is held to be not relevant to the case, and therefore inadmissible to the court.

This prompts questions of whether, and to what extent information acquired through the use of state-of-the-science methods and tools of brain research, if and when deemed valid by consensus of the neuroscientific community, can and should be deemed relevant to forensic analyses in legal proceedings. Herein, we propose that certain methods – and resultant findings – of neuroS/T are relevant in this context, and thus may be at a technological readiness level (TRL) sufficient to allow the utility and admissibility of neuroS/T-derived evidence in courts of law. However, we also urge caution when considering neuroS/T approaches and techniques, given our elucidation of key limitations of these approaches, and in this light, offer recommendations for de-limiting these constraints toward sound implementation and adoption of neuroS/T within the palette of forensic analyses.

How, Why, and What Neuroscience and Technology Can be of Value

When considering how and what specific neuroS/T may be of explicit value to the forensic community, we believe it to be important to posit premises upon which any such use of these approaches could be grounded. At present, if a defendant's cognitive capacity, mental health, and/or personality and behavioral traits and characteristics were to be called into question in a court of law, a defense or state attorney may rely upon a forensic psychologist to provide subject matter expertise relevant to such assessments. A variety of evaluations (e.g.- the Minnesota Multiphasic Personality Inventory or the Wechsler Adult Intelligence Scale; structured interviews, analyses of relevant prior behaviors, etc.) are employed to produce etiological and correlative, if not implicitly causal explanations of the defendant's behavior.[11] For example, over a course of seemingly unexplainable random acts of violence brought about by a single defendant, a forensic psychologist might attempt to elucidate an underlying emotional connection to the crimes that may have culminated over the course of the defendant's life. Depending on the forensic psychologist's assessment, the defense or the state attorneys would then form an argument in their favor.

In recent years, legal and scientific scholars have questioned the relevance and thus applicability of many of these forensic assessments. Issues of self-reporting, the reliability of methods, the temporal latency with which the assessments are conducted, and various biases associated with the tests (e.g., confirmation bias and expectation bias) have led to re-examination of a number of current practices of forensic assessment of neurocognitive function.[12,13] Given this re-examinative stance, inquiry to if and to what extent current neuroS/T could improve regnant forensic approaches, methods and tools. The aforementioned critical issues of forensic neurocognitive assessment notwithstanding, we by no means disparage the overall aims of these methods, and, pro Ward and Wilshire,[11] opine that specific methods of neuroS/T can be of value to "flesh out specific components of, [...] develop, and refine our psychological etiological models of crime-related behavior". Further, we assert that the prudent use of neuroS/T in these ways would fortify a biopsychosocial assessment framework to explain criminal behavior, which has recently garnered support within criminological theory.[12,14]

Given this rationale, it is important to recognize and define the capabilities and limitations (as well as possible de-limiting efforts) of available neuroS/T, to posit a toolkit to best engage particular tasks – and thereby embellish and expand existing approaches - of forensic neurocognitive assessment. There is growing interest in the application of neuroimaging techniques (e.g.- functional magnetic resonance imaging [fMRI], functional near-infrared spectroscopy (fNIRS); and magnetoencephalography [MEG]) to provide evidence of variations in brain structure and/or function that may help explain socially problematic/criminal cognitions and behavior. Despite attempts at using these methods in legal contexts,[15-17] there has been general consensus that these techniques are not yet sufficiently mature (viz. due to lack of reliability and limitations of the technology) to sustain their courtroom applicability, and hence should be viewed with caution (for further discussion, see the following section).[18-20]

However, a recent review of fNIRS supported the viability and validity of using this technique to assess current and/or previous traumatic brain injury (TBI); stating "in general, a high proportion of the assessed papers have concluded that NIRS could be a potential noninvasive technique for assessing TBI, despite the various methodological and technological limitations of NIRS".[21] Other research on the use of biomarkers and their potential to evaluate patterns of cognitive function has determined that "a combination of MRI-based neuroimaging biomarkers, along with other biomarkers from modalities such as EEG and MEG and genetics, can provide a robust framework for diagnosis and prognosis of various mental disorders with high accuracy in a reasonable time".[22] Biomarkers have also been considered for possible detection of certain genetic disorders, (e.g.- a monoamine oxidase-A (MAO-A) gene mutation that putatively has been correlated to predispositions to antisocial behavior).

On the Validity of Neuroscience and Technology

Yet, while these approaches may have a plausible role in legal proceedings,[23] we offer caveat to the broad use of currently available neuro-biomarkers – and any and all methods and tools of neuroS/T - in forensic settings, as we opine that further research should first be undertaken to more substantively ascertain (1) the role and fortitude of individual and group variation in the expression of particular neuro-cognitive and behavioral phenotypes; and (2) the validity and accuracy of techniques and technologies to evaluate such effects.

Cognizant of concerns about the internal and external validity (i.e.- reliability) of extant neuroS/T, we believe that rather than asking the question "what tools can currently be implemented within the forensic community?", a more pragmatic, and prudent query should be, "what underlying cognitive factors of crime could a neuroS/T toolkit validly assess so as to aid current and future forensic approaches?" To this point, Saladino et al. have reviewed literature on possible neurological correlates of empathic cognition, behavior, and violent crime, concluding that neuroS/T-based studies have elucidated a core empathy network, which, if and when compromised, may result in psychopathic traits or violent offending.[24] Saladino and colleagues encourage "interdisciplinary research" at the intersection of neuroscience, psychology, and sociology to establish more bio-psychosocially-oriented insight(s) to criminality.[24]

As well, other research has focused upon putative neural bases of cognitive and emotional elements of crime (e.g.- anger, aggression, anxiety, fear, disgust, etc.), and has implicated or explicated the possible role of neuroS/T-based methods in evaluating the potential roles of these substrates in ways that could be of value to the law.[25,26] Referential to these studies, and any consideration of employing the brain sciences in/for forensic neurocognitive assessments, it is critical (in the literal sense) to emphasize Baum and Savulescu's rather perdurable suggestion that while much of neuroS/T has been scrutinized for inherent limitations and issues of reliability, these problems most often are not intractable, irrecuperable, or permanent.[23] Indeed, concerns about the capabilities and constraints of tools and methods of the brain sciences have not gone unheeded, and ongoing developments in both the science and engineering have been such that it is reasonable to re-evaluate these capabilities and limitations, and in light of persistent gaps in forensic neurocognitive analyses and the needs of the legal system, posit if there is ethical justification to reconsider further advancing specific neuroS/T for "best fit" use (of best available science) in defined forensic contexts and ways (for synopsis of methods of best available science as constituent to informing policy and law, see [27]).

Towards such ends, it is important to more closely address the categorical and specific threats that weaken the relevance of current neuroS/T. Perhaps the most substantial categorical threat is the influence of confounding variables. A confounder affects the observed outcomes of a study, which can greatly skew statistical results and misdirect outcomes and conclusions. A classic example looks at the relationship between an individual's consumption of ice cream and their extent of sunburn; it may well be that these factors are strongly correlated. The confounding variable, however, is the time of year or the hot weather, which surely can affect both variables. From this pedestrian example, it is not difficult to envision the potential breadth of confounders that influence investigations of any relationship between a biological mechanism and human thought, emotion, and/or behavior. Thus, the use of an assessment neuroS/T (e.g.- neuroimaging) might be helpful in demonstrating certain patterns of biological activity relevant to and reflective of token cognitive and/or behavioral outputs but could not provide a stand-alone metric to define direct causality.

Indubitably, neuroscience is a correlational endeavor; not merely because of the ubiquitous "hard problem" of not understanding how mind occurs in brain,[28] but also with respect to the relative uniquity of individual brains, which develop in response and relation to both embodiment in an organism, and embeddedness and experiences of environments over time.[29-31] Therefore, any assessments aimed at establishing relationships of brain structure, patterns of node and network activity, and cognitive and emotional experience and behavioral expressions must acknowledge individual variation (i.e.- both in a given individual over time; as well as between individuals in and across temporal domains), and the issues arising in and from attempts at comparing individuals to groups (viz.- I-2-g contingencies) and groups to individuals (G-2-i contingencies; for overview, see[9]). This becomes problematic for neuroS/T in the forensic setting because most neuroscience studies (and conclusions) are based on group-level inference; thus, individual findings from a forensic assessment may differ significantly from group-level conclusions.[19] Overall, G-2-i comparison issues obtain a more general complication when applying any novel scientific findings to the legal system; we shall refer to this as the "binary/ non-binary" (BnB) problem.[32] The BnB problem establishes that cutting edge science (especially those methods that entail reliability or validity concerns) represents a non-binary system, in that there still exists a gray area laden with debate about, and lack of generalizability of findings. The courts on the other hand, represent a binary system, in which findings and outcomes are reducible to a dichotomous verdict of guilt or non-guilt.

The Viability of Neuroscience and Technology in Forensics

When trying to employ cutting edge science in the courtroom, difficulty can exist in that the court may rule new or novel scientific methods to be at very least inapt (e.g.- not sufficiently well developed or communally accepted within a recognized collective of expertise) for providing knowledge that is relevant to (aspects of culpability, for example) informing the trier(s) of fact (viz.- jury, judge); or at worst, regarded to be "junk science" (i.e.- not valid; contentious), and in either situation, deem the evidence inadmissible (even if some may be relevant to the case). Here, the Daubert standard and criteria (Rule 702 of the Federal Rules Evidence (FRE; as shown in Table 1) figure prominently in United States' legal protocols for planning the implementation and adoption process of scientifically-based information (note too, that other countries have used US FRE 702 as a basis for establishment of committees and procedures for discourse on, and regulation of similar issues, with the United Kingdom's House of Commons Science and Technology Select Committee Forensic Advisory Council being a representative example).[8,33]

Table 1: List of Criteria to Determine for Expert Testimony Adapted from the Daubert Standard and Federal Rule of Evidence 702.[a,b]

Daubert Standard Criteria	Federal Rule of Evidence 702 Criteria
Has the theory or technique in question been tested? If not, can it be?	Will the expert scientific, technical or other specialized knowledge help trier of fact to understand the evidence to determine a fact in issue?
Has the testimony been subjected to peer review and publication?	Is the testimony based on sufficient facts or data?
What is the known potential error rate?	Is the testimony the product of reliable principles and methods?
What is the existence and maintenance of standards controlling the testimony's operation?	Has the expert reliably applied the principles and methods to the facts of the case?
What is the level of widespread acceptance within a relevant scientific community?	

[a]Adapted from Daubert Standard criteria
[b]Adapted from Federal Rule of Evidence 702[33]

Still, the question remains, given ongoing developments in brain science and neuroengineering, as to what approaches have achieved a readiness level sufficient for legal admissibility under Daubert (and/or similar international standards). To be sure, a formal determination of such capabilities of neuroS/T by professional community consensus would be useful, and we believe it important to inform the trier of fact in legal contexts. In other words, we assert that given what (certain types and applications of) neuroS/T can do, it will be important for the forensic and legal communities to define what (1) is needed to enable these methods to have utility in proceedings and procedures of the courts; (2) how and why such methods are not applicable or sustainable in these pursuits; and, perhaps most importantly, (3) what these communities require from the brain sciences. In sum, and to paraphrase the late former United States' President John F. Kennedy, *let us not ask what the current brain sciences can do for the forensics and the legal communities' needs, but instead, what do the forensics and the legal communities need from the future capabilities of the brain sciences?*

Yet, let us presume for a moment that the brain sciences do in fact articulate developments to meet and suit the expressed needs of forensic science and the legal system. What then? With this supposition, it is crucial to recognize ethical and legal issues and implications that are generated by the implementation of neuroS/T in these contexts. For instance, legal scholar and cognitive scientist Nita Farahany speaks of "cognitive liberties" and the relative inviolability of "cognitive space" as a last bastion of identity and autonomy.[34] Similarly, questions of "neurorights" and impositions of civil liberties have been considered when considering an iterative development and use of neuroS/T in legal contexts, inclusive of positing if a person should be forced to "give evidence" through undergoing neuroS/T-based evaluations, or if uses of these sorts constitute violation of their privilege against self-incrimination[35] (for review and further speculation, see [4]). These ideas are not merely future-gazing, but rather reflect contemporary consternation about the use (and misuse) of fMRI-based "lie detection", and attempts at "brain fingerprinting" using EEG to indicate certain patterns of neurological activation that are thought to represent representations of information, or knowledge (e.g.- of a deed committed; intent; etc.).[36]

Let us reiterate the need for technical rectitude: it is very tempting, as we have previously noted, to become enthusiastic (and apprehensive) about current capabilities and new developments in brain science, and their proposed utility in various social applications, including forensics and the law. But we advocate a prudent balance between what philosopher Paolo Benanti has called positions of "neurogullibility" (i.e.all neuroS/T is wondrous and viable), and "neuroskepticism" (i.e.- very few iterations of neuroS/T are valid, viable and thus of any real value),[37] and advocate a stance of "neuropragmatism",[38] calling for deliberation in regarding and employing neuroS/T as bricolage – a combination of "things that work best"; wherein what is best entails both what is technically correct and ethico-legally sound.[31] In this way, it is possible to recognize that older methods may still be the best in some cases, while in others, newer approaches may be optimal, if not essential. Certainly, the use of neuroS/T in forensic settings should be based upon estimations of probable benefit incurred, and the integrity of any such benefit is maintained by mitigation of burdens and risks. We have previously described a risk assessment and mitigation paradigm for use when evaluating intended applications of emerging neuroS/T,[39,40] and again endorse these methods as a first step in any consideration of employing the technologies and techniques of the brain sciences. Going further, exercising this pragmatic balance (of benefit versus burden/risk in the use of extant and/or emerging toolkits) will require posing core questions, and predicate assertions to guide any proposed use of neuroS/T specific to forensic, legal (and, more broadly, public safety and national security) contexts.[41,42]

The Utility of Implementation Science

Putting proposed tools and methods into practice necessitates definition of what we refer to as the "engagement opportunity space", which consists of domains and dimensions of (1) the task(s) at hand; (2) the terrain (i.e.- the stable and/or unstable grounds of opposition, acceptance and opportunity), and (3) the tools available – and those that may be required – to engage and efficiently effect the task upon the terrain and what may be shifts in its tectonics. Methods such as the US Department of Defense Advanced Research Project Agency's (DARPA) Heilmeier catechism can be of use and value to assess and review developmental processes when considering definitions, limitations, and evaluations of the said engagement opportunity space.[43] However, we posit that methods of implementation science (IS), "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practice into routine practice",[44] and more specifically the Integrated-Promoting Action on Research Implementation in Health Services (i-PARIHS) framework, would be useful to facilitate the task of evaluating, and/or developing the tools of neuroS/T for adoption and use in current and near-future forensic cognitive assessment. The aim of implementation science is not to ascertain the impact of a scientific/technological innovation, per se, but rather to identify and understand the dynamics that (positively and/or negatively) affect the acceptance and adoption of the innovation into routine practice.

The i-PARIHS framework, revised from the original PARIHS framework,[45] focuses upon successful articulation of a scientific innovation through facilitation with the recipients (i.e.- stakeholders) in their respective contexts.[46] As an IS determinant framework, i-PARIHS focuses on the causal nature of determinants (i.e.- individual barriers) and how they impact outcomes.[47] Axiomatically, IS frameworks tend to be multidimensional so as to account for varied and interactive influences that affect acceptance or rejection of new approaches. The i-PARIHS framework is used to gain insight to key characteristics of adopters and end-users by identifying the (community-inherent) cultural, constituency, and leadership pediments and barriers to implementation, in order to develop and facilitate methods for successful adoption and integration of a particular innovation within an established system of practice(s).

The facilitation, innovation, recipients, and context(s) (FIRC) facets of the framework are not mutually exclusive, but instead, function synergistically to address, investigate, and mitigate extant obstacles and obstructions to optimal outcomes via the adoptive employment of new - and/or novel approaches to extant – methods within a given context of community practices. The FIRC components of the i-PARIHS framework are discussed in overview, below.

FACILITATION

Facilitation is the core construct of the i-PARIHS framework, which addresses barriers, aligns stakeholders, and integrates the regnant constructs important for the execution of the identified task(s). The facilitation process entails gaining granular understanding of current practices (and outcomes), and developing strategies for possible adoption of new/novel approaches. Facilitation involves obtaining relevant research data, defining contextual barriers, and recognizing domains, dimensions, and need for change. Building upon these evidentiary cornerstones, facilitation involves subsequent modeling those ways that adoption, performance, and sustenance of identified changes would be of benefit to target recipients and key stakeholders.

Table: 2

Table 2: i-PARIHS[a]
$SI = Fac^n(I + R + C)$ · SI = Successful implementation · Achievement of agreed implementation/project goals · Uptake and embedding of the innovation into practice · Stakeholders are engaged, invested and own the innovation · Variation related to context is reduced across implementation settings Fac^n = Facilitation · *I* = Innovation · *R* = Recipients (individual and collective) · *C* = Context (inner and outer)
[a] Successful implementation in the i-PARIHS framework[45]

INNOVATION

Innovation requires applying relevant neuroS/T-based evidence and fitting this information to existing practices and procedures. Roger's Diffuse Innovations Theory describes queries that are important to establish the relative benefit of implementing change.[48] Therein, elemental questions include: what is the underlying knowledge of both the regnant system or process, and how would that benefit (or be burdened by) proposed innovation(s)? Could any such innovations be trialed within the system to assess compatibility, effectiveness, and efficiency? And are such innovations sustainable and adaptable (within the system/community)? These queries, and their evidence afforded by their address are critical to inform and support incorporation (or non-incorporation) of innovation within an existing systemic framework.[47]

RECIPIENT(s)

Recipients refer to the individual stakeholders affected by, and who influence the implementation of an innovation, both at the individual and organizational levels. There is growing evidence to suggest that groups or teams play an important role in influencing acceptance of new knowledge and putting it into practice.

CONTEXT

Focusing on evidence, while necessary, is often insufficient for successful implementation. Certain communities may have difficulty adopting new practices, due in large part to intra-institutional systemic barriers. Context focus enables examination of internal (i.e.- institutional/organizational) and external (i.e.- environmental/social-ecological) factors that promote or impede innovation adoption. Contextual analysis of existing (inner and outer) environmental and cultural barriers and stakeholder engagement enables the prior FIR domains and dimensions of implementation.

Proposed Recommendations

Based upon the core construct that from the notion that neuroS/T should not change the inherent tenor of forensic and legal analyses and procedure(s), but rather that the needs and contingencies of forensic and legal settings should actively guide the development and use of neuroS/T in ways that are directly applicable, serving, and therefore of value, we propose the following recommendations when considering if and how a particular neuroS/T technique or technology is viable, worthwhile and applicable in forensic contexts.

1) Any and all neuroS/T under consideration should be evaluated for its actual capabilities, and constraints/limitations as specifically relevant to explicit needs and charge(s) of given foci of the forensic process operative within explicit legal contexts.

2) Said neuroS/T should be determined, *by consensus of a representative professional community of neuroscientists,* to validly and reliably obtain the aforementioned defined results as relevant and applicable to the scope and tenor of the process(es) and policies of the forensic community.

3) Said neuroS/T should be determined, *by consensus of a representative professional community of forensic professionals,* to validly and reliably obtain the aforementioned defined results as relevant and applicable to the scope and tenor of the process(es) and policies of the forensic community

4) The extent (viz.- depth and breadth) of consensus (as in 2 and 3, above) should be necessary and sufficient to sate current standards of the Code of Federal Evidence (e.g.- Daubert) or other codification as applicable to the (national) jurisdiction in which these approaches will be utilized.

5) The use of any/all neuroS/T in these ways should be considered to be supportive, but not substitutive of, other ratified, and accepted methods of forensic investigation and analyses. However, the relative weighting of neuroS/T-based information should be determined in proportion to the specificity and precision of both the technique(s), as well as in comparison to other methods, based upon the expert evaluation of professional consensus (see 2 and 3, above).

We opine that these proposed recommendations emphasize requisite prudence in order to avoid inapt implementation, and may afford guidelines for consideration, and possible successful implementation and adoption of neuroS/T within practices of forensic science. Further, we posit that these proposed recommendations establish both (1) a position of constructive progressive utility, and (2) a safeguard against unbridled and politicized scientism.

Table: 3

Table 3: i-PARIHS Constructs and for Project Implementation and Analysis [a]	
i-PARIHS constructs and definitions	Comparable constructs and definitions for successful implementation
Fac^n=Facilitation ▪ The key construct that assesses, aligns and integrates the innovation (neuroS/T) to the recipients and context ▪ Subject expert who engages teams and educates on the current neuroS/T available ▪ Engages stakeholders to develop approaches to include new evidence based methods of neuroS/T into the forensic science and legal communities ▪ Project management	**Facilitation processes** We agree with the National Academy of Sciences in that we recommend national oversight towards forensic standards and methods (e.g. National Institute of Standards and Technology (NIST)). However, focusing on a state/regional approach may be easier since most states have existing law enforcement offices (e.g. FLDE) Leaders of the state/regional approach will have a better understanding of specific contextual barriers that their community faces. Facilitation role could be added within existing state-run law enforcement offices (see Appendix): ▪ Help determine relevance of neuroS/T for evidence on a case by case basis (based on innovation) ▪ Promote shared research and education of neuroS/T on a state-wide and national level. (inter/intra-office) ▪ Organize an annual (at least) branch assessment methodology for performance. (regular audit and feedback)
I = Innovation ▪ Content focus of neuroS/T implementation strategies	**Innovation (neuroS/T)** Pinpoint neuroS/T limitations: ▪ Lack of reliability and general consensus of neuroimaging techniques (e.g. fMRI and EEG etc.) ▪ Categorical Threats (confounding variables) ▪ Specific Threats (Group to Individual contingencies (G2i), Binary - non Binary Problem (BnB)) ▪ Neurorights and cognitive liberties Augmenting existing etiological, psychoforensic models with neuroS/T will promote swift implementation ▪ Focus on the question "what underlying cognitive factors of crime could a neuroS/T toolkit validly assess so as to aid current and future forensic approaches?" Continue sharing research across forensic laboratories on a national and local level.

i-PARIHS constructs and definitions	Comparable constructs and definitions for successful implementation
R = Recipients (individual, collective) ▪ Forensic, legal, and court communities ▪ Defendants ▪ Organizational staff and stakeholders who may be directly affected by the innovation (neuroS/T)	**Stakeholders** *(key emphasis: how each is affected by adoption and implementation)* Practitioners, researchers, and educators: New jobs/roles will be introduced under the implementation of a psych/neuroS/T branch. An increased focus on collaboration and communication will lead to higher reliability and successful implementation and adoption. State forensic and law enforcement offices: Adding a psych/neuroS/T branch will require an initial increase of specific standards and methodology which also require time/effort/money. Participants should be provided with appropriate resources, education, and be willing to adopt these standards for successful implementation and adoption. Taxpayers: Taxpayers should understand the weight of this new branch and be interested in public safety, wrongful convictions, etc.; we recommend a focused effort on these public concepts so taxpayers have a clear understanding of the importance and need for psych/neuroS/T tools and resources.
C = Context (inner, outer) ▪ Contextual factors and the potential impact on the implementation ▪ Strategies/ potential solutions to handle them	**Context (National, regional, local, and organizational)** **Inner:** To avoid bias lawyers should use state appointed forensic psychologists Adopting change may be difficult for local law enforcement officers (forensic scientists, lawyers, police, judges, etc.) but proper education and resources should be accepted to minimize organizational barriers. **Outer:** Adopting a forensic psychology/neuroscience branch within existing state-run forensic and law enforcement offices (e.g. FDLE, the courts, etc.) is recommended. The cost of adoption may be undesirable to taxpayers and implementers, but the benefits seem to outweigh the costs (e.g. reducing wrongful convictions, increasing public safety, decreasing bias, improving scientific reliability, etc.) Cost will likely be a barrier to adoption. ▪ Alternative recommendation: education, research, and practice of neuroS/T within the field of forensics (i.e. without creating new branches and using expensive technologies), through existing methods such as using court appointed experts.

Abbreviations: neuroS/T, neuroscience and neurotechnology. FDLE, Florida Department of Law Enforcement. fMRI, functional magnetic resonance imaging. EEG, electroencephalography.

[a] Adapted from i-PARIHS constructs[48,49]

Conclusion

Current (and inevitably, future) advancements in neuroS/T have created excitement, as well as trepidation among forensic and legal scholars, which can devolve into (a) "neurogullibility": failing to address the risks and limitations that current neuroS/Ts possess in turn leading to an inapt adoption process; or (b) "neuroskepticism": a failure to acknowledge the validity and viability of neuroS/T, and the value of its use, in well-defined contexts and circumstances. In proposing a realistic and prudent middle ground, we advocate a deliberate evaluation of those ways that current, as well as modifications and/or new developments in neuroS/T can fortify the processes – and uphold the probity – of forensic analyses in/for legal contexts. This approach, as described and endorsed in this essay, entails and obtains a consensus of needs and capabilities of neuroS/T, as explicitly determined by both the neuroS/T and recipient stakeholder (i.e.- forensic and legal) communities. What is important to note, however, is that positional stasis is an unrealistic, and thus, arguably unethical option, given the pace and extant of neuroS/T development, and both calls for, and concerns about its use in forensic settings. In the words of one of the world's most famous, albeit fictional, forensic scientists, Sherlock Holmes: *the game is afoot.*

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