



Short Review

The role of neuropsychology in the care of patients with functional neurological symptom disorder

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Abstract

Objective: Functional neurological symptom disorder (FNSD) is a neuropsychiatric condition characterized by signs/symptoms associated with brain network dysfunction. FNSDs are common and are associated with high healthcare costs. FNSDs are relevant to neuropsychologists, as they frequently present with chronic neuropsychiatric symptoms, subjective cognitive concerns, and/or low neuropsychological test scores, with associated disability and reduced quality of life. However, neuropsychologists in some settings are not involved in care of patients with FNSDs. This review summarizes relevant FNSD literature with a focus on the role of neuropsychologists. **Methods:** A brief review of the literature is provided with respect to epidemiology, public health impact, symptomatology, pathophysiology, and treatment. **Results:** Two primary areas of focus for this review are the following: (1) increasing neuropsychologists' training in FNSDs, and (2) increasing neuropsychologists' role in assessment and treatment of FNSD patients. **Conclusions:** Patients with FNSD would benefit from increased involvement of neuropsychologists in their care.

Keywords: Functional neurological disorder; conversion disorder; neuropsychology; cognition; education; integrated care

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Introduction to functional neurological symptom disorder

Functional neurological symptom disorder (FNSD) is a neuropsychiatric condition presenting with various neurological signs/symptoms and associated with neural network dysfunction rather than focal neuroanatomical lesions (Hallett et al., 2022). FNSD is common globally (Kanemoto et al., 2017), on the order of ~100 cases per 100,000 (Asadi-Pooya, 2021). It also has a large economic (>\$1.2 billion annually; Stephen et al., 2021) and public health impact, comparable to that of well-known neurological conditions such as epilepsy (Asadi-Pooya et al., 2021). For example, in functional seizures, > 50% of patients have neuropsychiatric/medical comorbidities (Brown & Reuber, 2016a; Jennum et al., 2019), a majority are unemployed and/or on disability (Salinsky et al., 2018), and mortality is high (Asadi-Pooya, 2021).

FNSD can present with different symptom manifestations, leading to the development of subordinate diagnostic groups that coalesce around the clinical phenotypes. Three of the most common FNSD subtypes with associated cognitive concerns are: functional seizures (FS), functional cognitive disorder (FCD), and functional motor disorder (FMD; Table 1). FS refers to time-limited, paroxysmal motor, sensory, and cognitive alterations that resemble epileptic seizures but lack epileptiform activity (LaFrance et al., 2013); FCD is a cognitive disorder presenting with impairments occurring within a cognitive domain and

inconsistently across situations (Ball et al., 2020); and FMD reflects a family of movement abnormalities that are incongruent with respect to classical neurophysiological mechanisms (Perez et al., 2021).

A major recent advancement in the identification of FNSD has been an improved understanding that FNSDs can be diagnosed via *positive signs*, meaning that they are not simply the end result of having ruled out all other possibilities via a plethora of negative medical tests (Espay et al., 2018). Instead, there are sensitive and specific behavioral and/or physiological features, focusing on neuroanatomic *inconsistency* and *incongruity*, which allow for a “rule-in” determination (Table 1). Critically, when made by experienced clinicians, diagnoses of FNSD tend to be accurate and stable across time (Stone et al., 2005, 2009), with rates of misdiagnosis being similarly low to those of other neurological conditions (Gelauff et al., 2019; Walzl et al., 2019).

Cognitive deficits are a core diagnostic criterion in FCD but not in FS/FMD. However, cognitive difficulties are common in all three FNSD subtypes (~80% of patients with FS/FMD; Butler et al., 2021), and these problems limit treatment gains and reduce quality of life (Jones et al., 2016; Věchetová et al., 2018). For example, some evidence suggests that deficits in processing speed are common in FNSDs (Van Patten et al., *in press*) and may be worse in some FNSDs than in other somatic disorders (De Vroeghe et al., 2021).

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Table 1. Positive clinical features of three common FNDs

FND Subtype	Positive Clinical Signs
Functional Seizures (FS)	Prolonged video EEG monitoring, where the history and ictal semiology are consistent with FS, and the paroxysmal event(s) is/are captured, documenting contemporaneous ictal semiology and a lack of epileptiform activity (LaFrance et al., 2013; Milán-Tomás et al., 2018). Note that the term FS does not include physiologic nonepileptic events (e.g., cardiogenic, autonomic).
Functional Cognitive Disorder (FCD)	Clinical identification of internal inconsistency, where a patient demonstrates impairment in a cognitive domain in some situations but not others (also known as contrasting function/dysfunction; Ball et al., 2020; Cabreira et al., 2023; McWhirter et al., 2020a). Note that for diagnostic criteria to be met, the internal inconsistency itself must occur within a single cognitive domain (e.g., intact memory scores with reported dense amnesia in everyday life), but patients with FCD can also have concurrent cognitive dysfunction in other domains (e.g., executive dysfunction).
Functional Motor Disorder (FMD)	A neurological exam/movement disorders evaluation in which motor evidence of inconsistency/incongruity is demonstrated, such as Hoover's sign or tremor entrainment. In Hoover's sign, one leg shows reduced strength when examined directly, but normal strength when attention is directed to the contralateral leg via a hip flexion movement (Aybek & Perez, 2022; Daum et al., 2014; Perez et al., 2021).

More generally, impaired selective and divided attention has been proposed as a transdiagnostic feature of all FNSDs, possibly driven by excessive interoceptive monitoring, which attenuates the “attentional reserve” available for pursuing external goals and leads to a diffuse and nonspecific cognitive profile (Teodoro et al., 2018; Willment et al., 2015).

Frameworks

Historical models of FNSD focused primarily or exclusively on psychopathology (particularly trauma) as the etiological underpinning (Zepf, 2015). However, not all patients with FNSD have an abuse history, and although mental health is still known to be a critical factor, contemporary frameworks highlight the interplay of etiological relationships, including between neurobiology, adverse life events, emotional processing, and cognitive control (Brown & Reuber, 2016b; Hallett et al., 2022). For example, abnormalities in connectivity between limbic structures and motor control circuits could be partially responsible for symptom expression in some FNSDs (Baizabal-Carvallo et al., 2019; Maurer et al., 2018), while dysfunctional fronto/parietal emotion processing may be related to frequent psychopathology and cognitive symptoms (Pick et al., 2019; Teodoro et al., 2018).

Supplementing advancements in neural associations, the nosology of FNSD has also changed across time. For example, there is some debate about the degree to which FNSD should be primarily conceptualized as a unitary construct versus centering on individual subtypes. On one hand, there is accumulating evidence for shared pathophysiology and underlying cognitive deficits across FS, FCD, and FMD (Hallett et al., 2022; Teodoro et al., 2018), arguing for a so-called “lumping” approach. On the other hand, there is mixed evidence with respect to individual phenotypes, with some data suggesting transdiagnostic presentations (Finkelstein & Popkirov, 2023; Forejtová et al., 2023), and other literature highlighting unique symptom expressions (Kola & LaFaver, 2022; Matin et al., 2017), possibly supporting “splitting.” Currently, many researchers strike a balance, with some attention spent on overlapping characteristics of all FNSD (e.g., functional connectivity abnormalities; Drane et al., 2021; Pick et al., 2019) and additional complementary investigations highlighting nonshared symptoms and treatment approaches (e.g., response to interventions; Goldstein et al., 2020; Poole et al., 2023).

From a clinical standpoint, an important framework that informs the biopsychosocial formulation (Mack & LaFrance, 2022) is that of predisposing, precipitating, and perpetuating factors for FNSD (LaFrance & Devinsky, 2002). Predisposing factors are

longstanding risk factors that increase a person's overall vulnerability to FNSD, precipitating factors are acute/subacute events that represent a “final straw” in the initial presentation of an FNSD, and perpetuating factors are ongoing stressors or experiences that serve as barriers to healing and recovery (Ertan et al., 2022). For example, predisposing factors for FNSDs could include childhood adversity or chronic illness, precipitating factors could be a closed head injury or a reaction to a vaccine, and perpetuating factors may be medical/social stigma or protracted litigation (Chen & LaFrance, 2021; Fung et al., 2023). Within this model, clinicians can identify variables that guide decisions related to neuropsychological assessment (e.g., interview questions, test selection), case conceptualization (e.g., etiology, contributing factors), and treatment (e.g., psychoeducation, treatment planning). In terms of case conceptualization, neuropsychologists and other clinicians can use this biopsychosocial information to generate hypothesized explanations for patients' persistent cognitive symptoms based on the fear avoidance model, which has been applied to FNSDs (LaFrance & Bjonaes, 2018). The model helps explain perpetuating factors for treatment-resistant cognitive symptoms with a focus on negative expectations and catastrophizing in some patients (e.g., believing that a mild TBI will cause severe brain damage; Wijenberg et al., 2020), which can lead to anxiety/worry, avoidance of cognitively-taxing tasks (e.g., work/school), and a corresponding reduction in functional independence. Ultimately, using the biopsychosocial framework to identify and discuss an individualized formulation with a patient and their family is the current gold standard of care in FNSD, particularly in the setting of an interdisciplinary team, where a neuropsychologist can lean upon their relevant foundational skills (Table 2) to offer clinical insights into case conceptualization and treatment planning (Gilmour et al., 2020; Keatley & Molton, 2022; Silverberg & Rush, 2023).

Management and treatment

Iatrogenesis

FNSD is difficult to treat due to persistent/disabling symptoms (Ducroizet et al., 2023; Durrant et al., 2011; Gelauff et al., 2014, 2019), as well as frequent neuromedical and psychiatric comorbidities (Carle-Toulemonde et al., 2023; Jennum et al., 2019). Although poor outcomes in patients with FNSD are partially attributable to inherent symptom severity/heterogeneity, clinicians have also erred (Burke, 2019), as there have been significant problems arising from underrecognition and frequent misunderstandings about FNSD (Keynejad et al., 2017;

Table 2. Alignment of FNSD characteristics with neuropsychologists' knowledge and skills

Aspect of FNSDs	Unique Foundational Skills of Neuropsychologists
Pathophysiology and symptoms that cut across traditional neurological (e.g., seizures, tremors) and traditional psychiatric (e.g., trauma, somatization) arenas.	Integrated brain/behavior knowledge, including neurological syndromes, cognitive functioning, and psychopathology.
Inconsistency in results from subjective and objective outcome measures, possibly resulting in clinical confusion about symptom profiles.	Training in psychometrics and clinical assessment, including the interpretation of discrepancies in results from self-report and cognitive testing.
Confusion regarding differences between FNSDs and factitious disorder/malingering	Knowledge of symptom and performance validity testing, allowing for a well-informed assessment of noncredible performances and invalid data.
Heterogeneity and symptom complexity leading to the need for a comprehensive biopsychosocial conceptualization to informed treatment planning.	Strong background in integrating information from various assessment methods, including review of history, clinical interviewing, symptom inventories, and cognitive testing.
Frequent and undertreated cognitive symptoms.	Ability to characterize and treat cognitive symptoms, via assessment and neuropsychological rehabilitation.

Klinke *et al.*, 2021; McWhirter *et al.*, 2022). That is, confusion stemming from “organic versus non-organic” distinctions (Stone & Carson, 2017), dichotomizing mind/brain conceptualizations (Rawlings & Reuber, 2018), and judgment/stigma about “medically unexplained illnesses” (Foley *et al.*, 2022), has led to a great deal of avoidance and “passing the buck” occurring amongst clinicians (Barnett *et al.*, 2022; Ducroizet *et al.*, 2023).

In one example of a common misconception, surveys of neurologists and psychiatrists have documented beliefs that FNSD is indistinguishable from factitious disorder or malingering (Dent *et al.*, 2020; Kanaan *et al.*, 2011) in spite of a wealth of evidence to the contrary (Edwards *et al.*, 2023; McWhirter *et al.*, 2020). This literature shows that, when a patient with an FNSD has a neurological symptom such as limb weakness or memory loss, the symptom is not purposefully feigned in order to achieve secondary gain and/or attention. Instead, there are impairments in interoception and a sense of agency in people with FNSDs (Drane *et al.*, 2021; Pick *et al.*, 2019), with a complex pathophysiology that leads to a decrement in the volitional control over sensorimotor experiences and that may contribute to FNSD symptom expression (Hallett *et al.*, 2022). Nevertheless, the persistent idea that these patients are faking symptoms is associated with skepticism, frustration, deprioritization, and even discrimination amongst some clinicians, which can lead to iatrogenesis (Foley *et al.*, 2022; Rawlings & Reuber, 2018). This risk for negative outcomes associated with misdiagnosis of FNSDs as factitious disorder or malingering makes the judicious use and careful interpretation of symptom and performance validity tests by neuropsychologists a particularly important clinical function (Table 2; Edwards *et al.*, 2023; Silverberg & Rush, 2023).

Advancements in management and treatment

Multiple efforts have been made to improve outcomes for patients with FNSDs, including (1) enhancements to medical education (Barnett *et al.*, 2022; Rawlings & Reuber, 2018), (2) guidelines for communication with patients (Finkelstein *et al.*, 2022; Rockcliffe-Fidler & Willis, 2019), (3) the development of evidence-based psychotherapeutic interventions (Goldstein *et al.*, 2020; LaFrance *et al.*, 2014), and (4) increased interdisciplinary care (Lidstone *et al.*, 2020; Petrie *et al.*, 2023). Items 1 and 4 are expanded upon below because of their relevance to neuropsychologists. Regarding education, it has become well recognized that many clinicians lack sufficient instruction in FNSD, leading to the knowledge gaps mentioned above (Klinke *et al.*, 2021; Rawlings & Reuber, 2018). In

response, several groups have constructed FNSD-specific teaching initiatives. First, the Functional Neurological Disorder Society ([website](#)) Education Committee has produced a wide variety of interdisciplinary training resources, including content in the form of freestanding webinars, podcast episodes, and an on-demand virtual education course available for continuing education credits. Second, Medina and colleagues (2021) piloted a series of six 60-minute workshops for psychiatry trainees and reported improved knowledge of and comfort with FNSD, including increased confidence in discussing diagnosis and treatment with patients, as well as consensus beliefs that FNSD symptoms are “real” (not faked or malingered). Third, providers from the U.S. Veterans Administration created the Mind Brain Program ([website](#)) to equip clinicians in managing neuropsychiatric disorders. In this program, organization providers utilize online educational platforms and 1-on-1 distance supervision for training clinic programs, which is increasing nationwide access to evidence-based therapy (LaFrance & Clark, 2024).

Efforts to promote interdisciplinary care seek to address the multifaceted nature of FNSD within a biopsychosocial framework that reduces stigma and individualizes the treatment approach (Aybek & Perez, 2022; Gilmour *et al.*, 2020). This movement can be distinguished from a “siloed” model of care, where a patient presents first to a neurologist and then is sent to an outside mental health clinician, without either professional collaborating with the other or assuming responsibility. In contrast, in an integrated model, the patient initially undergoes a thorough neuropsychiatric assessment, which is then translated into a personalized intervention provided by a collaborative team, addressing physical/neurological (Nielsen *et al.*, 2015), mental health (Oriuwa *et al.*, 2022), and social/situational (LaFaver *et al.*, 2021) concerns. To date, positive results have been found with integrated interventions (Jacob *et al.*, 2018; Jimenez *et al.*, 2019; Lidstone *et al.*, 2020), although the role of neuropsychology has been largely neglected, in spite of the prominence of cognitive dysfunction across FNSD subtypes (Carle-Toulemonde *et al.*, 2023; Jones *et al.*, 2016; Teodoro *et al.*, 2018). That is, neuropsychologists can contribute to an interdisciplinary FNSD team with a thorough biopsychosocial clinical formulation, cognitive assessment to characterize strengths and weaknesses, and cognitive rehabilitation targeting the most distressing and disabling symptoms.

Regarding options for cognitive rehabilitation, as yet there are no formal evidence-based treatments specifically targeting FNSDs. However, broad-based compensatory approaches have been

Table 3. Recommendations for FNSD-specific education in neuropsychology training programs

Issue or Topic	FNSD Subtype	Learning Activity	[†] Resource
<i>Foundational Knowledge</i>	FNSD and Subtypes	[†] Watch Webinars from the Functional Neurological Disorders Society	https://www.fndsociety.org/fnd-education
	FNSD and Subtypes	Listen to Podcasts from the Functional Neurological Disorders Society	https://www.fndsociety.org/resources/podcasts
	FNSD Broadly	*Read Seminal Publications	(Finkelstein et al., 2022; Hallett et al., 2022)
	FNSD Broadly	Watch a Webinar from Know Neuropsychology	https://knowneuropsych.org/functional-neurological-disorders/
	FNSD Broadly	Listen to a Podcast episode from Navigating Neuropsychology	www.navneuro.com/108
	FS	*Read Seminal Publications and Textbooks	(Brown & Reuber, 2016a; LaFrance Jr & Schachter, 2018)
	FS	Watch a Webinar from the International League Against Epilepsy	https://www.ilae.org/education/ilae-curriculum
	FS	Listen to a Podcast episode from Navigating Neuropsychology	www.navneuro.com/112
	FS	Watch a Webinar from the U.S. Department of Veterans Affairs	https://www.youtube.com/watch?v=NIX-yNTX86w&list=PL3AQ_JVoBEyzDfAHEptumOPB-PFTH_ya-
	FCD	Listen to a Podcast episode from Navigating Neuropsychology	www.navneuro.com/128
	FCD	*Read Seminal Publications	(Ball et al., 2020; Silverberg & Rush, 2023)
<i>Applied Knowledge</i>	FMD	*Read Seminal Publications	(Lidstone et al., 2020; Perez, et al., 2021)
	FNSD Broadly	Complete a Digital Training from the U.S. TRAIN site	TRAIN online site training in evidence-based therapy https://www.train.org/main/welcome
	FNSD and Subtypes	Engage in a Clinical Case Presentation with Supervisor and Peer Feedback	Local
	FNSD and Subtypes	Complete a Focused Literature Review on a Clinically Oriented Topic in FNSDs	Local
	FS	Read a Treatment Manual from the Treatments that Work Series	Taking Control of Your Seizures: Workbook (Reiter et al., 2015) Treating Nonepileptic Seizures: Therapist Guide (LaFrance Jr & Wincze, 2015)
<i>Clinical Experience</i>	FS	Complete Digital Trainings from the U.S. Department of Veterans Affairs	Talent Management System (TMS) trainings in neurobehavioral therapy: Courses: 131003888, 131003872, 131004533 https://www.tms.va.gov/
	FNSD and Subtypes	Participate in Supervised Neuropsychological Evaluations of FNSD Patients	Local
	FNSD and Subtypes	Observe/Participate in an Interdisciplinary Clinic	Local
<i>Clinic Development</i>	FNSD Broadly	The VA Mind Brain Program	https://marketplace.va.gov/innovations/va-mind-brain-program
<i>Networking</i>	FNSD and Subtypes	Join a Professional Society and Attend a Conference from the Functional Neurological Disorders Society	https://www.fndsociety.org/
<i>Resources for Patients/Families</i>	FNSD Broadly	Browse a Website	https://fndhope.org/
	FNSD Broadly	Browse a Website	https://neurosymptoms.org/en/
	FS	Browse a Website	https://nonepilepticseizures.com/
	FS	Browse a Website	https://sites.google.com/sheffield.ac.uk/non-epileptic-attacks/

*Two example publications are provided for FNSDs and for each of the three subtypes. These examples are not exhaustive and the reader may wish to select many additional papers from the current bibliography in order to begin building a local repository of scientific work in FNSDs.

[†]Many resources provided are online/digital methods of education. There is growing interest in webinars and podcasts as formal didactic tools to assist in the achievement of competencies in neuropsychology (Van Patten et al., 2022).

successfully used in other related disorders (e.g., psychosis, TBI, stroke; Twamley et al., 2012, 2015; Winkens et al., 2009) and are available to clinicians. Until an FNSD-specific protocol is published, neuropsychologists can adapt these general techniques for use in patients with FNSDs in individual clinical scenarios. For example, several case studies have successfully applied

compensatory techniques in FNSDs, including an example of general cognitive rehabilitation combined with psychotherapy that was associated with improvements on memory test scores (Laatsch & Taber, 1997) and an application of techniques to address processing speed, which improved mental slowness and other cognitive symptoms (De Vroeghe et al., 2017).

Table 4. Specific functions of neuropsychologists in the care of patients with functional neurological symptom disorder

Assessment and Diagnosis Oriented	Interprofessional Oriented
<ul style="list-style-type: none">• Clinical evaluations in patients with cognitive concerns (Alluri et al., 2020; Willment et al., 2015).• Delivery of FNSD diagnoses, either as a member of a care team or with appropriate consultation with neurology (Aybek & Perez, 2022; Espay et al., 2018).	<ul style="list-style-type: none">• Consultation with interdisciplinary teams about approaches to management and treatment, given each patient’s unique cognitive profile and mental health symptoms (LaFaver et al., 2021; M. R. Lopez & LaFrance, 2022).
Treatment Oriented	Research and Teaching Oriented
<ul style="list-style-type: none">• Communication with patients about individualized contributing factors and appropriate treatment recommendations/referrals (Bennett et al., 2021; Finkelstein et al., 2022).• Development and implementation of individual or group-based cognitive rehabilitation interventions (Laatsch & Taber, 1997).• Implementation of evidence-based psychotherapeutic interventions focused on FNSD symptoms and relevant contributing factors (LaFrance Jr et al., 2020; Millstein et al., 2023).	<ul style="list-style-type: none">• Contribution to research and scholarship in FNSD (Silverberg & Rush, 2023; Van Patten et al., in press).• Teaching, mentorship, and supervision of trainees centered on FNSD-specific issues (Lehn et al., 2020; Medina et al., 2021; Milligan et al., 2022).• Education of the public about FNSD presentations and brain health (e.g., via development of patient resources and provision of community-based lectures).

FNSD in neuropsychology

As the movement toward interdisciplinary FNSD care has gained momentum (Lopez et al., 2023), a variety of allied healthcare specialties have joined neurologists and psychiatrists as active members of treatment teams. This is reflected in published consensus statements in occupational therapy (Nicholson et al., 2020), physical therapy (Nielsen et al., 2015), speech language pathology (Baker et al., 2021), and general health service psychology (Keatley & Molton, 2022). By contrast, the role of neuropsychology is typically not detailed in discussions of interdisciplinary FNSD care, in spite of the fact that neuropsychologists possess a relevant knowledge base and skillset that would allow for unique insights in many clinical situations (see Table 2).

In order to expand the role of neuropsychologists in the care of patients with FNSD, it is first necessary to: (1) enhance FNSD-specific education in neuropsychology training programs, and (2) advocate for appropriate patient referrals and inclusion of neuropsychologists in interdisciplinary teams. Regarding the former, similar to physicians, many neuropsychologists do not receive consistent/robust instruction on various FNSD presentations (including FCD; Silverberg & Rush, 2023), likely leading to knowledge gaps and clinical uncertainty. Importantly, the field of neuropsychology is ripe for the incorporation of more comprehensive content coverage of FNSDs due to significant ongoing development and innovation in current training models. The changes primarily revolve around the revision of the Houston Conference Guidelines (Hannay et al., 1998), which is instantiated in the Minnesota Update Conference (MNC). One overarching goal of the MNC is to delineate entry level competencies for practicing neuropsychology, linked to strategies for implementation within existing training programs. Similar to that of other highly prevalent disorders with major public health impacts, FNSD education should be integrated across neuropsychology training in the form of coursework, didactics, clinical vignettes, discussions of scientific literature, and other activities (Table 3). And as more neuropsychologists become knowledgeable about and skilled in FNSD-specific issues through educational efforts, it is incumbent upon these professionals to advocate for a role in the care of patients with FNSD (Table 4).

Conclusions

FNSD is prevalent and impactful but has been underrecognized in all healthcare specialties, including neuropsychology. Recent years have seen significant advancements in the FNSD literature that can improve healthcare provision and outcomes for these patients. Multiple specialties have proposed educational programs and guidelines/recommendations for their profession’s role in integrated treatment for FNSD patients. Neuropsychologists have strong foundational brain-behavior skills that would allow for positive contributions to FNSD patient care. To facilitate this progress, the current review provides actionable recommendations for incorporating FNSD education into neuropsychology training and for further integrating neuropsychologists into current clinical care models.

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Competing interests. R. Van Patten has served on the editorial boards of *Archives of Clinical Neuropsychology*, *International Psychogeriatrics*, *Journal of Clinical and Experimental Neuropsychology*, *Frontiers in Neurology*, and *Frontiers in Psychology*.

K. Mordecai has no competing interests.

W.C. LaFrance, Jr. has served on the editorial boards of *Epilepsia*, *Epilepsy & Behavior*, *Journal of Neurology, Neurosurgery and Psychiatry*, and *Journal of Neuropsychiatry and Clinical Neurosciences*; has served as a clinic development consultant at University of Colorado Denver, Cleveland Clinic, Spectrum Health, Emory University, Oregon Health Sciences University and Vanderbilt University; and has provided medico legal expert testimony.

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