Impaired consciousness in partial seizures is bimodally distributed

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ABSTRACT

Objective: To investigate whether impaired consciousness in partial seizures can usually be attributed to specific deficits in the content of consciousness or to a more general decrease in the overall level of consciousness.

Methods: Prospective testing during partial seizures was performed in patients with epilepsy using the Responsiveness in Epilepsy Scale (n = 83 partial seizures, 30 patients). Results were compared with responsiveness scores in a cohort of patients with severe traumatic brain injury evaluated with the JFK Coma Recovery Scale-Revised (n = 552 test administrations, 184 patients).

Results: Standardized testing during partial seizures reveals a bimodal scoring distribution, such that most patients were either fully impaired or relatively spared in their ability to respond on multiple cognitive tests. Seizures with impaired performance on initial test items remained consistently impaired on subsequent items, while other seizures showed spared performance throughout. In the comparison group, we found that scores of patients with brain injury were more evenly distributed across the full range in severity of impairment.

Conclusions: Partial seizures can often be cleanly separated into those with vs without overall impaired responsiveness. Results from similar testing in a comparison group of patients with brain injury suggest that the bimodal nature of Responsiveness in Epilepsy Scale scores is not a result of scale bias but may be a finding unique to partial seizures. These findings support a model in which seizures either propagate or do not propagate to key structures that regulate overall arousal and thalamocortical function. Future investigations are needed to relate these behavioral findings to the physiology underlying impaired consciousness in partial seizures. *Neurology*® 2014;82:1736-1744

GLOSSARY

CRS-R = Coma Recovery Scale-Revised; **RES** = Responsiveness in Epilepsy Scale; **TBI** = traumatic brain injury.

Impaired consciousness is a major cause of disability in people with epilepsy; however, the mechanisms for loss of consciousness remain incompletely understood. In other disorders of consciousness, patients often show deficits in both the overall level of consciousness and the specific cognitive functions comprising the content of consciousness.¹⁻⁴ In partial seizures, recently termed *focal* seizures,⁵ it is not clear whether loss of responsiveness is usually attributable to selective deficits in contents of consciousness such as language, vision, or memory,⁶ or to a more general decrease in overall level of consciousness.^{7,8}

Prior studies concerning responsiveness in partial epilepsy have relied mainly on retrospective and subjective methods.⁹⁻¹⁶ We recently developed the Responsiveness in Epilepsy Scale (RES), a prospective, standardized tool to assess patients during seizures, including tests of verbal, nonverbal, sensorimotor functions, and memory.¹⁷⁻¹⁹ Of note, initial results using the RES suggested that most partial seizures cause either severe global impairment of cognition or overall sparing and that intermediate or selective deficits are relatively uncommon.^{17,18}

Supplemental data
at Neurology.org

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The goal of this study was to further investigate the precise nature of impaired consciousness in partial seizures. We examined the distribution of impairment scores during partial seizures compared with similar standardized testing in traumatic brain injury (TBI). Common domains of cognition were tested, allowing for direct comparison of performance outcomes of the 2 groups. We found a striking bimodal distribution in the severity of deficits in partial seizures but not in TBI, suggesting that this finding may reflect underlying physiology unique to partial seizures.

METHODS **Standard protocol approvals, registrations, and patient consents.** All procedures were approved by the Yale University Human Investigations Committee. Written informed consent was obtained for all participants.

Participants. Patients with epilepsy were recruited with the following inclusion criteria: (1) admission to the inpatient Yale Epilepsy Video/EEG Monitoring Unit between June 2009 and November 2012; (2) age 7 years or older; and (3) ability and willingness to participate in behavioral testing during seizures. Exclusion criteria were as follows: (1) nonepileptic (psychogenic) events; (2) severe cognitive or motor impairment at baseline that prevented performance of the tasks (in practice, because RES items are relatively simple, this only led to exclusion of 1 or 2 patients per year); and (3) pregnancy. Video/EEG recordings were reviewed by neurologists specializing in epilepsy, and seizures were classified by established criteria.^{5,20} Only partial (focal) seizures were included (table e-1 on the *Neurology*[®] Web site at Neurology.org); primary or secondarily generalized seizures were excluded. Of note, the current cohort included 60 seizures from 26 patients that were previously analyzed through similar but distinct methods.^{17–19} Patients with structural brain abnormalities were included in the seizure cohort, including 8 patients with hippocampal atrophy or increased signal, 7 with cortical gliosis or poststroke encephalomalacia, 5 malformations of cortical development, 4 previous resections, and 1 brain tumor (table e-1).

We also analyzed responsiveness testing in a comparison group with disordered consciousness of a known etiology distinct from epilepsy. Patients with severe TBI were recruited as described previously,²¹ with the following inclusion criteria: (1) age 16 to 65 years; (2) receiving inpatient rehabilitation for nonpenetrating TBI sustained 4 to 16 weeks before enrollment; (3) vegetative or minimally conscious state, as indicated by a Disability Rating Scale score greater than 11; and (4) inability to follow commands consistently and engage in functional communication as assessed by the score on the JFK Coma Recovery Scale–Revised (CRS-R). Exclusion criteria were as follows: (1) disability related to CNS that predated TBI; (2) medical instability; (3) pregnancy; (4) more than one seizure in the previous month; and (5) prior treatment with or allergy to amantadine; or (6) serious renal injury. Neurobehavioral function was assessed for all patients at the time of enrollment (week 0) and again at week 4 and week 6. Patients were randomized to amantadine-treated and placebo groups as described previously²¹; however, for this study, we did not analyze treatment effects because the purpose in this study was only to obtain a group of patients with impaired or recovering consciousness after brain injury.

Standardized testing batteries. The RES is a standardized prospective battery used to assess responsiveness during epileptic seizures.^{17,18} Test items evaluate orientation, receptive and expressive language, visual processing, and sensorimotor function (table e-2). RES test items were derived from the JFK CRS-R, a comprehensive, validated tool for the evaluation of patients with chronic disorders of consciousness.^{21,22} The JFK CRS-R consists of 6 subscales to evaluate auditory, visual, motor, oromotor, communication, and arousal functions.

RES testing was initiated by a trained bedside examiner at the clinical onset of each seizure event, and patients were given 7 to 9 seconds to respond to each item administered in a standard sequence.^{17,18} CRS-R items were also administered by a trained examiner, and patients with TBI were similarly allowed up to 10 seconds to respond to each item. In both RES and JFK CRS-R, subject responses are graded and assigned a score based on level of responsiveness.

Three closely related versions of the RES were used during this study. The original RES¹⁸ was used during the period from June 2009 to September 2011; RES-II¹⁷ was used from September 2011 to September 2012. The 2 versions are generally similar, including many of the same test items, but are administered in a different order to improve efficiency of testing and minimize administration errors.¹⁷ The most recent RES version used from September 2012 through November 2012 contains only minor further revisions consisting of an alternate version of the “Ear” command and interchange of the order of the “Mirror” and “Ball” items in the battery (table e-2).

Data analysis. As described previously,^{17,18} all seizures were scored within 24 hours of testing based on video review and agreement of 2 reviewers. In the original RES, a few items (Memory encoding, Name, Place, Year) were scored from 0 to 5, others (Ball, Mirror) were scored from 0 to 3, and the remainder, as with RES-II, were scored from 0 to 4. To simplify analysis, all items were converted to the 0 to 4 scale using the same criteria as RES-II so that all items were scored consistently (table e-2).

RES testing commenced as soon as possible after seizure onset, with dedicated personnel sitting at bedside during inpatient monitoring, and the sequence of test items was repeated through seizure termination and into the postictal period.^{17,18} For consistency across seizures, we analyzed RES items only from the initial cycle of ictal testing. Items administered after seizure offset were excluded. Seizures often terminated before the completion of the first cycle, resulting in low numbers for some items, so items with insufficient data ($n \leq 5$ ictal scores) were excluded. Therefore, scores from only 13 of the total 16 possible RES items were included in the final analysis.

For the comparison group, CRS-R scores were analyzed for each subject at weeks 0, 4, and 6 after enrollment, as described previously.^{21,22} We analyzed data from 3 of the 6 subscales for which item scoring was as similar as possible to RES, namely, the CRS-R oromotor/verbal, auditory, and motor scales. These scales tested, respectively, verbal responses, motor responses to verbal command, and nonverbal motor responses (table e-2).

Statistics were performed with JMP 9 for Windows (SAS Institute Inc., Cary, NC, 1989–2013). Bonferroni correction was applied using a 2-tailed t test at the $p < 0.05$ level. To determine the relationship between scores on different test items within test administrations in patients with partial seizure and patients with TBI, we analyzed the association frequency between item pairs using MATLAB (R2012a; The MathWorks Inc., Natick, MA) and displayed the results as 3-dimensional histograms. For example, if during an administration of RES a patient scored a 4 on the memory encoding task and a 3 on the pen naming task,

Figure 1 Bimodal distribution of RES scores in partial seizures

Ictal scores from the initial cycle of testing are shown for all partial seizures ($n = 83$). Scores show a bimodal distribution such that scores of 0 (no response) and 4 (unimpaired response) occur most frequently for all RES items. Names of RES test items are shown on the right and included both verbal and nonverbal items (see table e-2 for details). RES = Responsiveness in Epilepsy Scale.

then a point would be added at position 4, 3 on the plot for this pair of items. We then calculated frequency by dividing by all points obtained this way for all item pairs and test administrations and multiplying by 100%.

Figure 2 Behavior on different test times remains consistently impaired or spared in partial seizures

The majority of partial seizures tested received a score of 0 (no response) or 4 (unimpaired response) on the first RES question administered ($n = 75$). Only 8 seizures received an intermediate score of 1, 2, or 3 on the initial item and were therefore not included in this analysis. Initial impairment predicted impairment on subsequent items. The average scores on most questions differed significantly for the 2 groups ($*p < 0.05$, t test with Bonferroni correction). Note that "test item #" refers to the number of items administered from the onset of testing. Only ictal data points were included. Items beyond the ninth item had sample size ≤ 5 in one or both groups and were thus excluded from this analysis. RES = Responsiveness in Epilepsy Scale.

RESULTS Eighty-three partial seizures were evaluated in 30 patients (16 male and 14 female; mean age 35.2, range 15–68 years) using the RES. Demographic and clinical information can be found in table e-1. Onset of RES testing began on average 31 ± 6.7 seconds (mean $\pm$ SEM) after seizure onset. Mean seizure duration was 115 ± 20.5 seconds, and mean duration of the first cycle of RES testing was 106 ± 13.4 seconds so that testing included most of the middle period of seizures. Nineteen patients had more than one seizure, and in this subgroup, there were 3.79 ± 0.55 seizures per patient (mean $\pm$ SEM). Level of impairment was relatively consistent for patients tested on multiple seizures; average RES scores within patients tended to vary by less than 1 point (on a 5-point scale) with an SD mean of 0.71 points. Test items administered in the postictal period were not included in the analysis.

We also obtained data from 184 patients with brain injury (133 male, 51 female; mean age 36.4, range 16–65 years) using the JFK CRS-R. Patients were in a vegetative ($n = 64$) or minimally conscious ($n = 120$) state at the time of enrollment, 4 to 16 weeks after injury.²¹

Partial seizure behavioral test scores are bimodally distributed. During partial seizures, there was a striking bimodal distribution of behavioral performance (figure 1). A large proportion of ictal scores for all RES items showed values of either 0 (no response) or 4 (unimpaired response), with very few intermediate

Table 1 RES scores are correlated between items within seizures

	Mirror	Ball	Money	Wave	Ear	Nose	Watch	Pen	Am I	Year	Place	Name
Mem	0.576 ^a	0.568 ^a	0.438	0.724 ^a	0.506	0.717 ^a	0.790 ^a	0.738 ^a	1.000 ^a	0.826 ^a	0.738 ^a	0.750 ^a
	0.001	0.000	0.103	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Name	0.459	0.456	0.556	0.427	0.605 ^a	0.746 ^a	0.883 ^a	0.836 ^a	1.000 ^a	0.985 ^a	0.887 ^a	
	0.008	0.008	0.016	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Place	0.562 ^a	0.464	0.717 ^a	0.602 ^a	0.684 ^a	0.715 ^a	0.840 ^a	0.882 ^a	1.000 ^a	0.986 ^a		
	0.001	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Year	—	—	—	—	1.000 ^a	1.000 ^a	1.000 ^a	1.000 ^a	1.000 ^a			
	—	—	—	—	0.000	0.000	0.000	0.000	0.000			
Am I	—	—	—	—	1.000 ^a	1.000 ^a	1.000 ^a	1.000 ^a				
	—	—	—	—	0.000	0.000	0.000	0.000				
Pen	0.699	0.792	0.701	0.843 ^a	0.733 ^a	0.777 ^a	0.913 ^a					
	0.008	0.002	0.016	0.000	0.000	0.000	0.000					
Watch	0.671	0.697	0.701	0.778 ^a	0.664 ^a	0.805 ^a						
	0.012	0.012	0.016	0.000	0.000	0.000						
Nose	0.541	0.705	0.809 ^a	0.992 ^a	0.775 ^a							
	0.046	0.012	0.000	0.000	0.000							
Ear	0.416	0.676	0.833 ^a	1.000 ^a								
	0.139	0.012	0.000	0.000								
Wave	0.494	0.698	0.701 ^a									
	0.052	0.002	0.000									
Money	0.326	0.328										
	0.218	0.233										
Ball	0.335											
	0.075											

Abbreviation: RES = Responsiveness in Epilepsy Scale.

Values in each cell are Spearman correlation ρ (top row) and 2-tailed t test p values (bottom row). Only items from the first administration of RES were used for each seizure. Blank cells: item pairs with $n \leq 5$ score pairs were excluded from analysis. See table e-2 for definitions and details of RES test items.

^aItem pairs with $p \leq 0.001$.

values. The severity of impairment thus appeared bimodal rather than graded. The bimodal distribution is also evident when results are analyzed by smaller subgroups of patients classified by temporal ($n = 9$) vs extratemporal ($n = 4$) or by right ($n = 9$) vs left ($n = 6$) hemisphere onset (figure e-1). In addition, this separate subgroup analysis reveals that patients with temporal lobe seizures or left hemisphere onset tended to have more severe impairment, as shown in prior studies.²³ Of note, the RES includes both verbal and nonverbal test items (see table e-2).

Performance tends to be consistently impaired or spared in partial seizures. A bimodal distribution could be attributed to consistently good or bad performance within each seizure, or potentially to behavior switching repeatedly between extremes of good and bad performance from item to item within each seizure. To distinguish between these possibilities, we plotted the time course of scores on consecutive items during

seizures (figure 2). We sorted seizures into those with initially good (score 4) or bad (score 0) performance on the first test item. Seizures showing initial impairment tended to remain consistently impaired throughout the ictal period, and those with spared initial performance usually sustained good performance. Average scores for sequential test items were significantly better for the initially spared group compared with the initially impaired group at most time points during the seizure (figure 2) ($p < 0.05$, t test with Bonferroni correction).

To further examine the similarity between scores on different test items within a single seizure, we performed a correlation analysis (table 1). The pairwise relationship between RES item scores within each seizure was analyzed across all seizures. Most item pairs were highly correlated ($p \leq 0.001$), again suggesting that overall impaired or spared function is consistent across items within a given seizure.

Figure 3 Distribution of CRS-R scores in the patients with brain injury

Testing using the CRS-R testing battery of patients in the cohort with brain injury ($n = 184$) is shown for subscales that closely resemble RES testing items²¹ at week 0 (A–C), week 4 (D–F), and week 6 (G–I) after enrollment. Traumatic brain injury occurred in these patients 4 to 16 weeks before enrollment. In contrast to the bimodal distribution of ictal RES scores (see figure 1), we find a more even distribution of scores in patients with brain injury. For details of CRS-R test items and scoring, see table e-2. CRS-R = Coma Recovery Scale-Revised; RES = Responsiveness in Epilepsy Scale.

Comparison to JFK CRS-R scores in patients with brain injury. To determine whether the bimodal distribution of RES scores might be related to bias intrinsic to the scale, we examined the data distributions in patients with TBI for CRS-R subscales similar to RES (figure 3). In contrast to the bimodal distribution of ictal RES scores (see figure 1), we did not find a bimodal distribution of CRS-R scores in patients with TBI who had impaired consciousness. The distribution of scores at weeks 4 and 6 after enrollment showed some improvement (figure 3, D–I), with more patients showing maximal scores as they recovered, but unlike partial seizures, intermediate scores were common at all time points.

To further compare score distributions in partial seizures with TBI, we generated association frequency plots for both datasets (figure 4). These plots show the pairwise distribution of item scores for seizures (figure 4A) compared with traumatic brain injury (figure 4, B–D) (see the methods section). For a given administration of the scale, each item is paired to each other item (similar to table 1) and represented by a vertical point, so that score pairs

occurring more frequently have greater vertical height. The bimodal distribution of partial seizure scores (figure 4A) is evident given that 4–4 and 0–0 are the most frequent RES item score pairs within seizures. In contrast, the associations between scores in patients with brain injury (figure 4, B–D) are more evenly distributed across different item score pairs. Data for patients with brain injury are shown only for week 0, but similar relatively even distribution plots were seen at weeks 4 and 6 as well (not shown).

DISCUSSION We found that standardized behavioral testing during partial seizures reveals a striking bimodal distribution of impairment, such that most partial seizures either fully spare or severely impair diverse cognitive functions. Furthermore, RES performance was consistent across different verbal and nonverbal tasks within a given seizure, and pairwise analysis of RES items revealed that scores were highly correlated within seizures. These data suggest that most partial seizures can be cleanly separated into those with broadly impaired or relatively spared responsiveness.

Figure 4 Distribution of RES and CRS-R item pairs

Pairwise distribution of item scores for the RES testing in all partial seizures ($n = 83$) and the CRS-R testing in patients with brain injury ($n = 184$) is shown. These association frequency plots show how often any given score on one item is associated with every possible score on a second item within the same test administration. (A) "RES item A" represents the first RES item in the pair and "RES item B" the second item (see table e-2 for details of RES test items). All possible item score pairs were plotted for each seizure. (B-D) CRS-R subscale scores at week 0 are paired in 3 combinations. Each vertical point represents the scores for a single pair comparison, and the percent of total score pairs is given on the y-axis. We found that the most frequent RES item pairs are 0-0 and 4-4 within seizures, while testing in patients with brain injury yields a wide range of subscale score pairs within test administrations. Because all RES items were scored on a scale of 0 to 4, the pairs between different items are displayed on a single plot (A). CRS-R items were scored on different scales (0-3, 0-4, and 0-6), so 3 plots are shown (B-D), one for each pair of CRS-R items. CRS-R = Coma Recovery Scale-Revised; RES = Responsiveness in Epilepsy Scale.

Similar behavioral testing in patients with impaired consciousness after TBI reveals a more even distribution of scores across multiple cognitive domains, consistent with prior studies.^{22,24,25} The cohort with brain injury serves as a reasonable comparison group, because prior studies suggest that complex partial seizures resemble the minimally conscious or vegetative states more closely than coma.^{8,19,26,27} We expect a similar pattern of graded impairment scores in other populations, such as poststroke patients or patients with encephalitis who should be investigated in further studies. Our current results suggest that the bimodal nature of ictal impairment is not the result of scale bias, but rather may be a finding unique to partial seizures and distinct from other disorders of consciousness.

Both the observed bimodal severity and global pervasiveness of deficits could be explained by physiologic properties of seizure propagation to key subcortical arousal structures. Findings from human

neuroimaging,¹⁰ intracranial EEG,^{23,28} and animal models^{29,30} have led us to propose the network inhibition hypothesis,^{8,31} in which partial seizures propagate to subcortical structures and inhibit arousal. Decreased arousal and altered thalamocortical functioning then produces sleep-like slow waves and reduced metabolism in multiple cortical regions, resulting in a unique state of depressed consciousness.^{10,14,15,23,26,30,32} Our present behavioral results in which most partial seizures exhibit either global impaired or spared function are consistent with a model in which seizures either do or do not propagate to critical subcortical structures. As a result, partial seizures often involve a relatively abrupt and global transition between levels of consciousness,³³ whereas other disorders of consciousness tend to impair arousal across a continuum. Of note, there are partial seizures that cause relatively isolated cognitive deficits, such as impaired language or visual processing³⁴⁻³⁶; in these seizures, impairment can be

attributed to localized discharges that do not propagate to key arousal structures.

Although we found that partial seizures can cause broad deficits, it is important to note that these deficits mainly affect higher functions, whereas more rudimentary automatisms are often preserved.⁹ For example, visual tracking, blink to visual threat, or grasping movements are preserved in approximately half of complex partial seizures, but not in generalized tonic-clonic seizures.^{9,19}

We acknowledge that there are limitations to our study. It is important to note that the duration of seizures is brief compared with other disorders of consciousness, such that slower test administration in TBI might allow more gradations in impairment to be detected. Nevertheless, it is unlikely that the bimodal distribution was entirely due to the transient nature of seizures for the following reasons: (1) the allowed response time interval of 10 seconds

for items on the CRS-R for patients with TBI²² was similar to the typical response interval for items on RES of 7 to 9 seconds^{17,18}; (2) scores on even single items, which can easily be administered within the time frame of a seizure, were bimodally distributed (figure 1); and (3) the bimodal spread of scores on successive items was not transient but sustained during the course of seizures (figure 2). Use of different testing batteries including the CRS-R and 3 versions of RES is an additional potential limitation. Although similar items and scoring were used, ideally an identical scale would be used in all cases for future comparative studies. Another potential concern is that RES testing often missed the first approximately 30 seconds of seizures, during which time ictal impairments might have occurred in a more graded rather than bimodal manner. Although this is certainly possible, a minimum of approximately 30 seconds' delay is a clinically realistic time before most patients are evaluated during seizures, making the present data clinically relevant for the majority of patients. An additional limitation includes the heterogeneity of the seizure cohort regarding anatomical localization and etiology, which were not accounted for in this study. Future behavioral testing in a larger population is needed to further characterize impairment by subgroups, including seizure localization and etiology types.

We have demonstrated that standardized and prospective behavioral testing during partial seizures reveals bimodal deficits across multiple cognitive domains, suggesting that partial seizures tend to cause fully impaired or mostly spared responsiveness. These results suggest that it is the level of consciousness that is most often affected during partial seizures. This hints that in partial seizures with impaired responsiveness, it is the disruption of arousal (vs specific cognitive deficits) that usually accounts for the patient's inability to attend to the surrounding environment. Together with recent advances in the physiologic understanding of impaired consciousness in epilepsy,^{10,14,16,23,29,32} these findings support the traditional clinical division between complex partial and simple partial seizures.^{20,37} We believe that this is an important distinction with implications both for patient safety and for improved treatments aimed at preventing impairment in partial seizures.

AUTHOR CONTRIBUTIONS

Courtney Cunningham acquired the data, performed statistical analysis, and wrote the manuscript. William C. Chen, Andrew Shorten, Michael McClurkin, and Tenzin Choezom acquired the data and performed statistical analysis. Christian P. Schmidt, Victoria Chu, Anne Bozik, Cameron Best, and Melissa Chapman acquired the data and participated in data analysis. Moran Furman and Kamil Detyniecki participated in data analysis. Joseph T. Giacino and Hal Blumenfeld designed the study and helped write the manuscript.

Comment: Awareness in partial seizures— Implications for patients and therapies

Consciousness is a complex process, requiring coordination between cortical and deeper subcortical structures to be maintained. Investigations utilizing multiple modalities have led to the “network inhibition hypothesis,” suggesting that partial seizure propagation inhibits deeper subcortical arousal systems.¹ In a more practical sense, for a person with epilepsy, losing consciousness during a seizure carries substantial safety and social implications. The unpredictable loss of awareness leaves patients at risk for injury, impairs their ability to drive, and can affect their employment status.

The Responsiveness in Epilepsy Scale (RES) is a valid measure of awareness during seizures and can be quickly administered at the bedside. Earlier work demonstrated that the RES reliably assesses ictal awareness, with degree of impairment correlating with seizure type and postictal impairment. The scale was modified slightly as the RES-II, with improved accuracy and more expedient testing.² The RES is a scale that allows for gradations of awareness, which could be expected during seizures given varied areas of onset and semiology.

In the present study, distribution of RES scores was bimodal, demonstrating that overall patients either maintained awareness or did not; this was consistent throughout each seizure, and in many cases across seizures in an individual. Though some patients demonstrated partial awareness during seizures, the overall bimodal distribution was striking and unexpected. Comparing ictal results to patients with traumatic brain injuries, the authors were able to show that this bimodal bias was not intrinsic to the test itself but rather unique to partial seizures.³ This “all or none” phenomenon, while not absolute, may allow for insight into a patient's experience during a seizure and provide greater understanding of seizure propagation and consciousness. Perhaps identifying the ultimate mechanism for the loss of awareness in partial seizures can lead to targeted therapies that would improve the quality of life for patients with epilepsy.

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