Defending Sleepwalkers with Science and an Illustrative Case

Rosalind D. Cartwright, Ph.D., F.A.A.S.M.¹; Christian Guilleminault, M.D., D.Sc., F.A.A.S.M.²

¹Rush University Medical Center, Graduate College, Neuroscience Program, Chicago, IL;

²Stanford University, Sleep Medicine Division, Redwood City, CA

Objective: To test whether laboratory-based research differentiating sleepwalkers (SW) from controls (C) can be applied in an uncontrolled forensic case as evidence the alleged crime was committed during an arousal from sleep in which the mind is not fully conscious due to a SW disorder.

Methods: A PSG study recorded 8 months after the defendant was charged was analyzed independently by spectral analysis. Slow wave activity (SWA) and cyclic alternating pattern (CAP) rates were computed. Clinical interviews and police records were reviewed for data re: the defendant's sleep prior to the event and use of drugs, alcohol, and stimulants.

Results: The SWA distribution was abnormally low and flat, significantly lower than published controls; in the first NREM cycle, CAP rate 55 was above normal. Two weeks of prior sleep

deprivation was confirmed from interviews and defendant's observed daytime sleepiness. Caffeine intake the day before the event was calculated at 826 mg over 14 hours. Snoring and a mild breathing disorder were present in the PSG.

Conclusion: Testimony based on spectral analysis of PSG recorded following an alleged criminal event supported a SW explanation for the non-rational behaviors charged. The defendant was acquitted of all charges and has been successfully treated.

Keywords: Sleepwalking, spectral analysis, slow wave activity, sleep deprivation, caffeine

Citation: Cartwright RD; Guilleminault C. Defending sleepwalkers with science and an illustrative case. *J Clin Sleep Med* 2013;9(7):721-726.

INTRODUCTION: BACKGROUND PRIOR TO 2000

In 1987 and 1997, two highly publicized cases of first degree murder occurred in which there was no doubt the accused was the one who committed the crime.^{1,2} Nonetheless, a question was raised: were they guilty under the law? The question of guilt is based on the principle of *mens rea*; was the person's mind conscious at the time? In both cases, the aggression took place following an arousal from sleep and was followed by profound amnesia and regret for what had happened. In both cases, the defense argued the accused was in a non-conscious state due to a sleepwalking (SW) disorder. One case was acquitted the other convicted. Since then, both prosecuting and defending lawyers have sought the advice of Sleep Medicine specialists for their opinion asking: is this a case of non-conscious behavior due to a sleep disorder? This has prompted a strong push-back from some in the Sleep Medicine community, denying there is a valid basis in sleep science for an opinion in such cases.³⁻⁵

Sleep Medicine was then relatively new as a clinical profession. The research supporting a diagnosis of several major sleep disorders was strong enough that experienced clinicians, supported by data from the polysomnogram (PSG) revealing the presence of specific sleep abnormalities, could make a diagnosis and recommend a treatment with confidence. An exception was a group of disorders that, although common in young children, were rarely sustained into adulthood, and so escaped systematic attention. These are the non-rapid eye movement (NREM) parasomnias. A landmark study by Broughton⁶ identified a number of their common features. Primary is that these arousals occur early in the major sleep period, prior to REM, when the PSG

shows sleep to be in slow wave sleep (SWS), (also called delta sleep or stages 3 and 4 sleep). It is one of this class, SW, that has been the focus of concern about Sleep Medicine clinicians testifying in legal cases of adults. The basic issue is that SW is episodic; therefore, there can be no certainty that an individual, even one genetically vulnerable to such events,^{7,8} was sleepwalking at the time of the offence.

In fact, prior to 2000, the PSG was of limited value in differentiating an adult SW from a normal sleeper. Although SW have more frequent arousals from SWS than normal sleepers,⁹ this sleep instability had been observed in patients with other diagnoses such as obstructive sleep apnea (OSA).¹⁰ Therefore, once the many other possible diagnoses that might account for an alleged non-conscious episode of a defendant had been ruled out,¹¹ sleep experts pre-2000 had to decide for themselves if this case likely to be one of sleepwalking or not. Most often the cases that came to trial were those involving aggressive behaviors inflicted on another person. More recently, persons charged with non-consensual sexual behavior (sexsomnia)¹² have also become court cases, as have others in which the charge was unlawful entry with intent to commit robbery or rape.¹³ Other activities common during a SW such as sleep eating, protecting others, and exploring are unlikely to result in a criminal charge.

Without a clear diagnostic sign in the PSG, sleep experts acting for the defense were likely to base their testimony on their judgment of the accused's truthfulness during a pre-trial interview, a history of prior witnessed SW, and the similarity of their behaviors before, during, and following the event to those in published case studies. Some of these characteristics were based on formal research, such as early SWS arousal with long lasting confusion and amnesia following,⁶ while others were extracted

Figure 1—Example of CAP incidents prior to a sleepwalking event.

(Courtesy of C. Guilleminault).

from a review of published case reports, showing non-rational behavior during the episode, amnesia, perplexity, and regret afterward.¹⁴ These became the basis of the formal clinical diagnosis of SW for the American Academy of Sleep Medicine¹⁵ and of the American Psychiatric Association.¹⁶

Sleep experts who acted for the prosecution were more likely to base their testimony on their judgment that the accused's actions were premeditated; motivated by a prior negative relationship with the person attacked; or, in the case of sexual behaviors, that the accused took advantage of an opportunity that presented itself. In some cases the prosecution's sleep expert argued the act was not sleep-related but planned during wakefulness and carried out while the accused was fully conscious.¹⁷ If the accused had been drinking alcohol prior to the event, the prosecution's expert held that this was a voluntary behavior and therefore the accused was legally responsible for any aggressive or sexual acts that took place subsequently, even if these followed an arousal from SWS.¹⁸

SLEEP SCIENCE POST 2000

This difficulty concerning proof of SW changed in 2000 with the publication of two independent studies reporting new PSG findings in sleepwalkers not found in age- and gender-matched controls.^{19,20} A third study reporting the same major findings followed in 2001.²¹ These studies were carried out by independent investigators in different laboratories, in dif-

ferent countries. All three reported the same two significant differences.

SW demonstrated more disrupted sleep, whether reported as microarousals, wake after sleep onset (WASO), arousals, awakenings, or an abnormal amount of cyclic alternating pattern (CAP A2 and A3).²² This sleep fragmentation was significantly higher in the SWS of the SW than in the C groups. **Figure 1** shows CAP episodes preceding a SW event recorded in the Stanford laboratory. Difficulty maintaining sleep in the first third of the night could now be considered a characteristic of a NREM parasomnia, as it was observed in all three studies to be significantly higher in SW than in C subjects only in the first third of the night, when most SW events occur. Those who arouse from REM sleep, REM behavior disorder (RBD), may also be aggressive but differ in demographics and PSG characteristics from NREM SW, and none have to date become published forensic cases.

The second finding is a difference in the amount of SWA. This is lower throughout the night in SW than in matched controls and is significantly lower in the first NREM cycle. The analysis of the PSG responsible for this finding is not the Rechtschaffen and Kales (R&K)²³ delta percent but the more precise spectral analysis scoring (fast Fourier transform [FFT]) yielding the count of SWA in each NREM cycle.

These new findings did not, however, settle the concern expressed about sleep experts testifying in court, as stated in a recent publication, "...there is absolutely no after-the-fact poly-

somnographic finding that could possibly have any relevance as to whether the accused was sleepwalking at the time of the event in question.²²⁴ This overlooks the extensive literature that spectral analysis scoring shows high reliability within individuals to reproduce their profile of the frequency of the various EEG wave forms across non-consecutive nights, including the delta power, under normal and sleep deprivation conditions.²⁵⁻²⁸ The objective of this study is to test the SWA in a forensic case to determine if it was significantly low in the first NREM cycle and if that indicated the presence of a predisposing condition and possibly a sleep problem which could be treated.

AN ILLUSTRATIVE CASE

In 2007 a patient, CD, on advice of his lawyer, presented to a sleep laboratory for an evaluation of SW. He was turned down as a patient because his SW was the issue in a pending legal case. The patient then applied to the Sleep Disorder Service at Rush University Medical Center where he was seen by two senior clinicians, both boarded in Sleep Medicine, a neurologist and a psychologist. The patient's wife (LD) also attended the intake interview.

The initial exam showed CD to be a 39-year-old Caucasian male, height 70 inches, weight 187 pounds, with body mass index (BMI) = 26.8, married for 10 years and father of 3 children. He gave a childhood history of frequent episodes of SW, as did his elder brother. These were witnessed by both parents and by each other (as they shared a bedroom). The patient reported his SW persisted into his adult years, with frequent episodes witnessed by his wife and by her parents. Another witness, a physician, observed CD during a SW episode when they shared a hotel room during a trip to attend an athletic event. Although the episode was benign, CD walked about muttering to himself in a confused state, the physician reported that episode to their local police as a safety precaution. LD reported her husband rarely walked outside prior to the episode for which he was now charged. No violence was involved in any of his episodes. His usual behavior was described as patrolling the house after having been aroused by a noise not heard by others. He sometimes moved objects in a non-rational manner. For example- before the expected third child was born, CD placed a clock into an empty cradle and tucked it in tenderly. Most often he looked out of windows searching for possible intruders. These appear to be motivated to protect the family from unrealistic dangers. This is one of five common types of behavior characteristic of adult sleepwalkers.¹³

Background of the November 2006 Event

The events that led to the charges against CD occurred on 11/25/06. The family was visiting her parents shortly before the expected birth of third child. The baby arrived during that visit. The family stayed on another week; then CD, whose work required his presence, returned home alone. This was Thanksgiving weekend; neighbors on either side of his house were away and had asked him to check on their homes as he usually did during their absence turning on lights to discourage intruders. CD performed this task the evening following work. Because he was responsible for a special program from 6 to 9 PM, he did this later than usual. CD rarely drank alcohol and had none that day but did drink many caffeinated beverages. He explained his

unusually high caffeine intake by his need to stay alert at work following his considerable sleep loss the week before and the week following the birth, when he took over responsibility for the nighttime care of his 3- and 5-year-old children. The 5-year-old had multiple medical problems and difficulty sleeping requiring nighttime attention and medication.

On the Rush Sleep Center intake forms, CD listed he consumed ten large caffeinated drinks the day of the alleged SW event: two mugs of coffee at breakfast, two additional coffees between 9 AM and 11 AM, and two Diet Cokes in the afternoon; and during the evening program he drank "large tumblers" of Diet Pepsi. The total caffeine consumption was estimated to be 826 mg over a 14-h period.²⁹ Studies of the effect of 600 mg of slow-release caffeine show it promotes wakefulness following sleep deprivation and improves vigilance.³⁰ As caffeine blocks adenosine receptors, it inhibits sleep onset and sleep maintenance and reduces the amount of slow wave sleep and SWA in the first sleep cycle.^{31,32} High caffeine intake has been implicated in SW with violence.^{2,33}

The (Alleged) Sleepwalking Event

A reconstruction of the event presented at the trial was based on the detectives' interviews of CD, the complainant, the daughter (EF) of the family living opposite him and her boyfriend. CD recalled having difficulty sleeping that night. He remembers arising at about 3 AM and again later on hearing a noise. On looking out a window, believed he saw lights on in the house facing him and the front door standing partly ajar. He felt duty-bound to investigate. He crossed the street and entered through the unlocked front door. He then wandered from room to room checking for intruders. He believes he turned off the kitchen light then looked into the master bedroom. The room was very dark, but he heard EF whisper and then shout to the sleeping boyfriend to turn on the light. When the light came on CD ducked down at the foot of the bed but then arose and identified himself as her neighbor. She told him to get out. He left but wandered into the kitchen. She then got up, guided him to the door, watched while he crossed the street and entered his house. He stated he then went back to sleep, woke in the morning with no memory of the incident, and went to work. EF reported that she awoke feeling someone stroking her abdomen under the covers. She confirmed that he wandered into the kitchen, and she then led him out via the front door and went back to sleep. She did not call 911, did not tell her boyfriend about the "touching," and was not afraid of CD when guiding him out. When her mother returned next morning, EF told her about the intruder. She described the touching as a tickling sensation, then as soft stroking under her pajamas but not under her panties. Her mother phoned the police who contacted CD to get his statement. He was surprised to hear that he was reported to have made a sexual attack, which he repeatedly denied. He waived his Miranda rights and told the police that he was not near her when the light came on. The boyfriend reported his impression of someone feeling his bedcovers. CD explained that he was being a Good Samaritan, wanted to apologize for the intrusion, and about his history of sleepwalking. The police had the physician's report of CD's previous event. CD believed that would be the end of it. Instead he was charged with criminal trespassing, criminal sexual abuse, and a felonious attempt to commit rape. His lawyer advised a sleep study.

Figure 2—Hypnogram and distribution of arousals in PSG of CD

The PSG Performed at Rush Sleep Center

Two nights of recording were ordered; the first a standard clinical night to rule out obstructive sleep apnea (OSA), as CD had a history of loud snoring. That study, performed on 8/16/2007, was scored according to the criteria of Rechtschaffen and Kales,²³ and the arousals by the American Sleep Disorders Association Atlas³⁴ (**Figure 2**). The scoring was approved by the attending neurologist. His report in summary read: “The study and clinical history is consistent with mild positional obstructive sleep apnea syndrome.” The sleep efficiency was low (60%) and sleep latency long (31 minutes); SWS% was low (3.6%), and arousals per hour moderately high (18.1). The oxyhemoglobin desaturation nadir was normal at 93%, and apnea+ hypopnea index 4.1 occurred only when supine. No periodic limb movements were recorded. The second night was to have CD undergo 25 hours of sleep deprivation while matching his reported excessive caffeine followed by 7 hours of recovery sleep. This would mimic the conditions the night of his intrusion event and maximize the possibility he would exhibit a SW episode in the laboratory. However, this plan required approval of the University Research Committee, and CD and his wife could not wait for this approval as the trial date was imminent.

The defense attorney requested the senior author, who had previous experience at SW trials, to act as a sleep expert for the defense. In the absence of further data, she reviewed the data in hand against the criteria for sleepwalking. The one central to the diagnosis—that the arousal typically occurs from SWS within the first or second NREM cycle—could not be confirmed. CD had no episode during his diagnostic night and was not able to state conclusively his bedtime on the night of his event. His best guess was that this was later than usual as he had worked late and checked both neighboring houses before entering his home. He thought this was probably sometime close to or after midnight. Given the amount of caffeine he reported drinking that day, it was not possible to estimate the time to sleep onset nor the amount or depth of sleep he achieved before his behavioral arousal. CD’s wife was not able to report definitively whether his SW episodes typically took place early in the night or later, as she frequently slept separately due to his loud snoring. The

best evidence of the time the intrusion occurred was given by the complainant, EF, who checked the clock when she awoke feeling she was being touched. It was between 4:30 and 5 AM. CD’s estimated bedtime around midnight and an awakening at 3 AM and another later, might suggest that his confusional arousal was at 4:30 from the second NREM cycle. However, that was too speculative to serve as evidence.

To help clarify whether the arousal was from SWS, the second author, who had conducted one of the first studies to use spectral analysis scoring of SW, was asked to score the clinical night using the same software and criteria as used in the 2001 publication.²¹

Independent Blind Scoring of SWA

A disk of the digitized sleep study was sent to Stanford where it was scored by three physicians; first by the second author, then by a visiting assistant professor of neurology and by a visiting research fellow who scored the record for the CAP frequency. Their final report received on 3/03/08 read: “Here are the data from the patient you can use as the official report. The delta power was calculated to determine the total per sleep cycle. The FFT was performed on the C3/A2 signal with a Hamming window applied. Two second windows were averaged over 30 epochs. Artifacts were first rejected. The results are clearly abnormal in distribution and with low delta power during the first sleep cycle. This is similar to what has been described by Gaudreau et al.¹⁹ and what we ourselves found in sleepwalkers (Guilleminault et al.²¹).” Attached were the data in graphic form (**Figure 3**). These data points were plotted against those reported in the Gaudreau study (**Figure 4**). Additional findings were “The CAP rate was abnormally high at 55. The rate for normals in our lab is 32-35 for those of similar age.”

The report confirmed CD had abnormally low SWA in the first NREM cycle. Espa et al.²⁰ hypothesized that a low SWA results in an overt SW arousal if two further conditions are met: (1) there is pressure for more SWS (as follows sleep deprivation), and (2) there is a concurrent stimulus for increased arousal from SWS. This may be from a medication or substance³⁵ such as excessive caffeine,^{2,31,32} from an untreated breathing disorder.

Figure 3—Total delta power for four NREM cycles in CD

der, or an external stimulus such as noise, auditory tone,³⁶ or a touch.³⁷ These two conditions were present in CD's history—the two weeks of prior SD and excessive caffeine still actively affecting his sleep. This provided the grounds for the senior author to agree to be a sleep expert for the trial.

The trial began on 10/24/08. The defense lawyer was able to have **Figure 4** admitted into evidence and copies distributed to the jury while he questioned the sleep expert about how this related to the SW disorder that was the alleged cause of the event. This figure showed the distribution of the average SWA across the four NREM cycles for 15 sleepwalkers and 15 age- and gender-matched controls in the Gaudreau et al.¹⁹ study and for CD. Both he and the SW sample had significantly lower SWA in the first NREM cycle than the C group. Given the reliability of SWA within a person between nights, it is highly probable that CD's low SWA and high CAP constituted a predisposing condition in his sleep prior to his intrusion into the neighbor's home. His history indicated he met the two additional conditions needed to initiate a SW event.²⁰ Sleep deprivation, which was the priming condition, and the excessive caffeine and mild OSA²² both may have precipitated the arousal into a non-rational state of mind. The jury listened attentively. The prosecuting attorney cross-examined to clarify whether CD was fully conscious when he responded to the light being turned on by first hiding then identifying himself. These points were addressed, citing CD's continued mental confusion and failure to recall the event on waking. The jury returned a verdict of not guilty on all counts.

DISCUSSION

Laboratory-based research identifying SWA as differentiating SW from normal sleep using spectral analysis was replicated in a forensic case. The additional history of snoring and mild breathing disorder validated in the PSG may be a contributing cause of his low SWA, high CAP rate, and arousal into non-conscious acts when sleep deprived and over-caffeinated.

Figure 4—Absolute slow wave activity across four NREM cycles for controls, sleepwalkers and CD

The data for Controls and Sleepwalkers are taken from Gaudreau et al. Dynamics of slow-wave activity during NREM sleep of sleepwalkers and control subjects. *Sleep* 2000;23:755-60.

These data constituted the basis for the opinion that the defendant was likely in a non-rational state due to SW at the time of the events charged, even though the PSG was conducted eight months after the event. Those who have warned sleep medicine clinicians not to testify in forensic cases, stating this would be tantamount to practicing “junk science,” may not have been aware of the research establishing the reliability of the sleeping brain wave profile using spectral analysis. The application of relevant science, including spectral analysis scoring of PSG, should become integrated into the guidelines recommended for those serving as sleep experts. An unfortunate aim of the critical literature has been to discourage research given the description of these efforts as “attempts to ‘stimulate’ sleepwalking in the laboratory (by sleep deprivation, medication administration, or alcohol ingestion) are completely worthless and totally inappropriate.”²⁴ There is, for example, a strong need for research involving larger samples to clarify disparate findings between studies with small samples.^{21,36,37}

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ACKNOWLEDGMENTS

The authors thank Babak Mokhlesi, M.D., for his additional literature search, Eric Frenette, M.D., for providing an independent scoring of the SWA in the PSG of CD, and Jacques Montplaisir, M.D., for permission to reprint Figure 1 from Gaudreau et al. Dynamics of slow-wave activity during NREM sleep of sleepwalkers and control subjects. *Sleep* 2000;23:755-60.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication February, 2013

Submitted in final revised form April, 2013

Accepted for publication April, 2013

Address correspondence to: Rosalind Cartwright, 680 N. Lake Shore Dr., Chicago, IL 60611; Tel: (312) 642-1065; Fax: (312) 642-1371; E-mail: drdrcartwright@gmail.com

DISCLOSURE STATEMENT

This was not an industry supported study. The authors have indicated no financial conflicts of interest. The senior author acted for the defense pro bono.