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Cognitive functioning in people with epilepsy plus severe learning disabilities: a systematic analysis of predictors of daytime arousal and attention

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In spite of the high prevalence of epilepsy and the importance of preserving cognitive function in people with learning disabilities, this population has received relatively little research attention. This study sets out systematically to investigate possible predictive factors of inter-ictal states of arousal and attention. The daytime function of 28 people with epilepsy and severe learning disabilities was assessed by performance on a two-choice reaction time vigilance task, behavioural analysis of time-sampled video recordings taken in naturalistic settings, and carer ratings on visual analogue scales. This methodology yielded eight discrete functional measures, from which two further index measures were derived after principal components analysis. A range of clinical and psychosocial assessments was completed and subjects had 36 hour ambulatory EEG and sleep EEG monitoring. Regression models identified significant predictors of cognitive function from a range of potential explanatory variables i.e. demographic, clinical, pharmacological, background EEG rhythms and sleep parameters. Results indicated that greater severity of learning disability, longer bedtime periods, poor sleep efficiency, frequent seizures and antiepileptic drug polytherapy were significant predictor variables. Explained variance (adjusted R^2) was greater than 50% for six of 10 outcome variables (range up to 85%). Furthermore, significant regression equations ($P < 0.05$) were obtained for all but one variable. Thus, these results appear reasonably robust. Results support an interactional model of daytime arousal and attention in people with epilepsy plus severe learning disabilities. Inter-ictal cognitive function appears to be mediated by a combination of organic, circadian (sleep wake), clinical and pharmacological factors.

Key words: epilepsy; learning disability; cognitive function.

INTRODUCTION

The prevalence of epilepsy in learning disabilities varies from 20–50%, relating directly to the severity of the underlying brain damage in the population studied[1–5]. This compares with a general population prevalence of 0.5–1%[6,7]. People with learning disabilities often present with multiple seizure types and epilepsy typically comprises just one aspect of a complex clinical picture. Other comorbidity can be wide-ranging (e.g. cerebral palsy, sensory handicap, poor physical health, mobility and communication problems, mental health problems). Furthermore, seizures often prove refractory to antiepileptic drug (AED) treatment[8]. The introduction of the 'new' AEDs, the wider recognition of the 'epilepsy plus' population and the extension of outcome assessment, beyond seizure counting, to quality of life measurement, have all contributed to an increased research interest in this population in recent years[7,9]. This is particularly welcome because one of the greatest clinical challenges is associated with improving efficacy, both of treatments and services, for people with learning disabilities.

The evaluation of cognitive functioning has long been recognized as important in the study of epilepsy, and in trials of AEDs[10–12]. Post-ictal effects can be measured in terms of psychomotor slowing, confusion,

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impairment of consciousness, and even sleep. Similarly, side-effects of AEDs may involve lethargy and drowsiness. In the majority of people with epilepsy, the resumption of 'normal' functioning can be measured and population norms are available for a range of performance tests[11]. However, in people with severe learning disabilities, baselines and deviations from baseline are difficult to establish reliably and few tests have standardization samples with which to compare assessment data[13,14]. Furthermore, collateral problems such as vision and hearing deficits, communication difficulties, behaviour problems and stereotyped mannerisms may lead to considerable measurement error[15]. These issues are compounded in group studies which generally comprise heterogeneous samples, making it difficult to determine sources of significant effects accurately.

In spite of these logistical problems, daytime impairments experienced by people with learning disabilities are of considerable importance, particularly because they are intrinsically less able to counteract or compensate for them. Furthermore, the minimization of such impairment is likely to contribute significantly to quality of life. The individual's state of arousal, selective attention and readiness to respond are precursors not only to information-processing, learning and memory, but also to social participation and social inclusion[16]. Therefore, identifying factors which are predictive of good/poor daytime function, using methods which are valid for this population, appears to be a priority. It seems likely that a multifactorial model should be investigated recognizing the potential influence of the degree of brain damage, nature and quality of sleep, type of epilepsy, frequency of seizures, number of AEDs and other clinical and demographic variables.

This study sets out to provide an objective analysis of possible predictors of daytime arousal and attention in people with epilepsy who also have severe learning disabilities. In particular, the research aim is to investigate the *relative* influence of such factors upon daytime alertness. The design is, therefore, primarily correlational involving both bivariate and multivariate (regression, principal components) models. The study utilizes intensive observational methods, continuous EEG monitoring and the objective assessment of vigilance. Rating scales and seizure diaries, completed by carers, are also included to represent the type of data generally available to practitioners in clinical settings.

MATERIALS AND METHODS

Subjects

Twenty-eight adults (mean age: 31 years; range: 16–51) with epilepsy plus severe/profound intellectual disability participated in the study. Degree of disability was confirmed by assessment of functional ability and developmental level. Subjects had a clinical history of epilepsy and a current seizure problem (75% at least weekly) and the majority (61%) had multiple seizure types. Of those with single seizures, nine presented with tonic–clonic and two with complex partial attacks. Seventy-nine per cent were on polytherapy, with two AEDs being the most common regime. Information on AEDs prescribed is provided in Table 1. It should be noted that the study was conducted prior to the general availability of the 'new' AEDs. Exclusion criteria included poor or deteriorating physical health, evidence of current mental illness based upon structured assessment[17] and severe sensory handicap. All subjects required 24 hour supervision and care. Inspection of Table 1 reveals a significantly disabled population, the majority being male, with many having severe refractory epilepsy.

Measures

Psychosocial functioning

Structured assessments were undertaken to assess psychosocial behaviour and functional dependence. It was felt that such factors may be predictive of daytime arousal and attention and should be considered in the prediction analyses. The Vineland Adaptive Behaviour Scales[18], PIP Developmental Charts[19], Aberrant Behavior Checklist[20] and the Psychosocial Behaviour Scale[21], therefore, were completed during interviews with principal carers. Summary descriptive data are presented in Table 1 and reveal a range of behavioural problems associated with generally high dependency. The sample appears typical of the population of people with severe/profound intellectual disability.

EEG assessment

Comprehensive EEG assessment was conducted in two stages. Firstly, each subject had a 'standard' EEG assessment in a hospital department using a Walter–Graphtex system with surface electrode placement in a standard montage. Four weeks later a 36 hour EEG was conducted in the home environment using the Oxford Medilog 9000-II ambulatory system. This allowed people to participate in ordinary activities and to sleep in their own beds. Signal verification was by means of a PC laptop interface (Medilog Mentor Signal Quality Monitor). Thirteen electrodes were attached and fixed with collodion in a standard montage. The Medilog recorded data on audiocassette via a waist-mounted recorder. Tapes were replayed via the Medilog 9200 Monitoring Replay System and analysed in terms of dominant background rhythms, evidence of spike/wave

Table 1: Demographic, clinical and psychosocial information on the sample ($n = 28$).

Sex	20 male	8 female
Age	Mean = 31.0 yr	range: 16–51 yr; SD 9.88
Residence	12 family home 3 community staffed house 13 health care residence	
Degree of intellectual disability (from Vineland Adaptive Behaviour Scales and PIP Developmental Charts)	13 severe	15 profound
Seizure frequency	7 at least one per day 14 at least one per week 4 at least one per month 3 at least one per 3 months	
Antiepileptic drugs (AEDs)	6 one AED prescribed 14 two AEDs prescribed 8 three or more AEDs prescribed	22 on sodium valproate 20 on carbamazepine 10 on phenytoin 4 on vigabatrin 2 on lamotrigine 2 on primidone (12 on rectal diazepam as required)
Seizure types	11 with one seizure type 9 with two seizure types 5 with three seizure types 3 with four seizure types	
Behaviour	Aberrant Behavior Checklist Psychosocial Behaviour Scale	Mean = 26.57 (range: 7–91; SD 18.91) Mean = 15.54 (range: 4–33; SD 8.28)

activity and standardized criteria for the description and manual staging of sleep[22]. Detailed information on the sleep characteristics of the sample is reported elsewhere[23].

Diary measures

Carers completed seizure diaries for each observed seizure. Code letters were assigned to individualized behavioural descriptions of each seizure type and recorded against date/time/place in a pocket-sized diary kept with the subject at all times (see Espie and Paul (1997)[16]). Carers were also trained in the use of sleep diaries to record subjective estimates of sleep pattern. These were completed retrospectively for each night soon after rising and comprised information on various parameters of subjects' sleep patterns[23].

Measures of arousal and attention

There is no single criterion measure of arousal state. Therefore, three methodologies were used during a period of intensive observation coinciding with ambulatory EEG assessment.

Vigilance assessment. Due to the severe intellectual limitations of the subjects a simple two-choice reaction time device was purpose made. The display comprised red and white lights positioned 10 cm apart with corresponding large coloured buttons, 4.5 cm in diameter, 5 cm below each light. The subject's task was to switch off the light by pressing the appropriate coloured button. Illumination of lights followed a pre-set, variable interval schedule. A series of practice and familiarization trials was provided for each subject through teaching the psychomotor task as a game where the subject received positive feedback (verbal praise) for successfully extinguishing the light. After training, a separate series of 15 experimental trials was conducted to provide data for the investigation. The following scoring procedure was adopted:

VIGPOS: when the subject responded correctly, extinguishing the light within 15 s
VIGERR: when the subject responded incorrectly, pressing the wrong button within 15 s
VIGNIL: when the subject pressed neither button within 15 s

False positives, i.e. responses made prior to a light coming on, were not recorded.

Behaviour state assessment. A Panasonic NV-SIB palmcorder was used to film 1 minute samples each 30 minutes during one daytime period (10 a.m.–3 p.m.). This procedure generated 8–10 samples per subject. Data collection aimed to be unobtrusive, and was conducted in each individual's natural environment, e.g. a unit in an adult training centre, the lounge at home. Video samples were subsequently rated in terms of the most frequently occurring behaviour state. This was a retrospective form of analysis compared with Guess *et al.* (1993) where dominant state was rated during a brief break between samples of 10-s duration[24]. Video recording, however, has the advantage of providing a

verifiable record, independent of idiosyncratic interpretation and memory. Also, our 60-s samples provided important contextual information to aid coding of behaviour state.

Classification of behaviour state. Behaviour state was coded according to Guess *et al*'s criteria although, consistent with the experience of others[25], inter-rater agreement was not uniformly strong. Discrepancies were examined and adjustments made to certain criteria (e.g. in relation to activities such as eating, watching television). Our aim was to eliminate error conservatively by means of *not* crediting a more optimal state unless firm evidence was available. Inter-rater reliability was initially calculated based upon the published criteria[24]. Three subjects were selected at random for whom 149 samples of 1 minute duration were available. Independent classification to dominant state code by two trained research workers yielded 103 agreements and 46 disagreements (69% concordance). After refining the classification criteria a further three subjects were selected and the procedure replicated. Of 156 samples, 129 were identically classified with 27 in disagreement; a concordance of 83%.

Thus, inter-rater agreement improved substantially and revised criteria were adopted for the following behaviour states: Asleep–Inactive (S_1), Asleep–Active (S_2), Drowsy (DR), Daze (DA), Awake–Inactive–Alert (A_1), Awake–Active–Alert (A_2), Awake–Active/Self-stimulatory (A_2S), Crying Agitated (CA), and Seizure (S).

Staff ratings. In addition to vigilance measurement and behaviour state assessment, which attempt to quantify arousal objectively, it was important to gather global, subjective information. It is primarily such impressions which determine care practices. The principal daytime carer of each client, therefore, completed a simple Visual Analogue Scale by placing a cross on a 10-cm line with poles labelled as 'not at all' and 'extremely'. The two measures reported here are for 'concentrating well' (VASconc) and 'tiredness' (VAStired). Data presented represent the mean of 5 days ratings from the intensive period of study. The 'lethargy' subscale of the Aberrant Behavior Checklist was also used as a subjective rating of arousal.

RESULTS

It is of interest to investigate not only discrete variables from each measurement methodology but also their inter-relationships and possible common (derived) factors. Results are presented in four sections. First, descriptive analysis of the specific measures; second, regression analyses (i.e. predictors) of each measure; third, correlational analyses considering inter-relationships between measures; and finally, principal components analysis and regression analysis for derived factors.

Descriptive analyses — patterns of arousal and attention

Vigilance data were available for 25 of the 28 subjects. Seven subjects scored between 13 and 15 for VIGPOS; nine scored 13 to 15 for VIGNIL; and the remaining nine obtained a spread of scores across VIGPOS, VIGNIL and VIGERR. The sample, therefore, conforms to three distinct subgroups representing correct responding, nonresponding and mixed responding (28%, 36% and 36%, respectively).

Behaviour state data were available for all subjects. The median number of 1 minute time samples available per subject was 10 (range: 8–10). Average distribution of time spent per behaviour state provided an accurate summary for the whole sample. These relative proportions were A_1 (32%), A_2 (29%), A_2S (16%), DR (7%), DA (7%), S_1 (6%), S_2 (2%) and CA (1%). Thus, subjects spent 61% (range: 20–100%) of observed time in the optimal awake states of A_1 and A_2.

Visual analogue data were available on VASconc ($n = 27$) with a mean of 3.22 (range: 0.2–7.4; SD 2.33) and VAStired ($n = 26$) with a mean of 3.16 (range: 0–8.13; SD 2.19). Ratings for lethargy (AB-Cleth) were available for all subjects with a mean of 8.43 (range: 0–25; SD 6.49). As a group, therefore, the subjects were rated as not concentrating well, rather lethargic, but were not particularly regarded as evidencing daytime tiredness.

Regression analyses — the prediction of arousal and attention

A series of multiple regression analyses was conducted, by means of the BREG (best subsets regression) procedure on MINITAB, to investigate variation in scores for each criterion measure. This produces the best regression model to explain the maximum amount of variance (adjusted R^2). It permits consideration of whether or not the addition of a variable improves prediction and permits the determination of the importance of added variables in the overall regression equation.

Demographic and other variables from the wide range of assessments on intellectual/functional status, psychosocial behaviour, epilepsy and sleep were included in the analyses. In particular, seizure type, seizure frequency, drug regime and dominant EEG

Table 2: Regression analyses for eight discrete outcome measures of arousal and attention and two derived index variables.

Outcome variable	F ratio	P	R^2	Adj. R^2	Explanatory variables (P)
VIGPOS	9.01	0.001	46.2	41.1	older (0.033) later bedtime (0.073)
VIGERR	10.09	0.012	77.1	69.4	less efficient sleep (0.011) more AEDs (0.051)
VIGNIL	9.92	<0.001	67.6	60.8	younger (0.017) greater intellectual disability (0.020) more delta in EEG (0.046) more seizures (0.060)
A_1	5.84	0.008	60.9	51.8	earlier bedtime (0.017) fewer REM episodes (0.036) more AEDs (0.096)
A_2	17.93	0.002	90.0	85.0	less intellectual disability (0.003) shorter sleep period time (0.009) fewer seizures (0.038)
VASconc	7.51	0.003	40.6	35.2	older (0.011) higher sleep efficiency (0.030)
VAStired	5.83	(0.090)	88.6	73.4	greater sleep latency (0.036) greater sleep time (0.043) greater time in bed (0.045) lower sleep efficiency (0.047)
ABCleth	6.28	0.007	35.3	29.7	earlier bedtime (0.010)
'Alert/engaged'	18.58	<0.001	66.2	62.6	later bedtime (0.004) less intellectual disability (0.021)
'Lethargic/tired'	5.32	0.014	33.6	27.3	earlier bedtime (0.071) gender (female > male) (0.090)

background rhythm were entered in relation to epilepsy. Sleep characteristics were regarded as possible predictors of daytime function because a previous analysis had suggested that people with severe intellectual disability have abnormal sleep patterns, spend lengthy periods of time in bed, and their actual sleep is *less* than their carers report[23]. Table 2 presents the best subsets regression solution for each criterion variable.

Prediction of vigilance

VIGPOS was predicted by age (being older) and (later) bedtime; together accounting for 41% of variance. Incorrect responses on the same task (VIGERR) were also associated with a combination of two variables, i.e. EEG-defined sleep efficiency (poorer efficiency) and taking (more) AEDs. These variables accounted for 69% of variance. For VIGNIL, four variables (age (being younger), intellectual disability (greater), EEG delta activity (more) and seizure frequency (greater)) accounted for 61% of variance.

Prediction of behaviour state

Prediction analysis for behaviour state variables revealed that for A_1, 52% of variance was accounted for by three variables, i.e. bedtime (earlier), REM sleep episodes (fewer) and AEDs (more). Eighty-five percent of variance in the optimal A_2 state was predicted by a combination of three variables. These were (less) intellectual disability, (shorter) EEG-defined sleep periods and (fewer) seizures. No significant predictors emerged for A_2S, DA, or DR, probably due to the limited range and frequency of presentation of these states.

Prediction of rating scale scores

VASconc was predicted by (older) age, and (higher) sleep efficiency. These variables accounted for 35% of variance. VAStired had four predictor variables accounting for 73% of variance. These were all sleep EEG measures, i.e. (greater) sleep latency, (longer) sleep period time and time spent in bed, and (lower) sleep efficiency. For ABCleth, 30% of variance was explained by (earlier) bedtime.

Correlational analyses — the inter-relationship between measures of arousal and attention

Table 3 presents a correlation matrix of the vigilance, behaviour state and VAS scores. Observed interrelationships are generally in expected directions but are modest in magnitude. For example, the behaviour state A_2 is positively correlated with correct vigilance responses (VIGPOS) and subjective ratings of 'concentration' (VASconc), and inversely with nonresponding (VIGNIL) and DR and DA states. Interestingly, behaviour states A_1 and A_2 are significantly inversely correlated. DR is positively correlated with nonresponsiveness on the vigilance task (VIGNIL) and with ratings of ABCleth. The strongest correlation, an inverse one between VIGPOS and VIGNIL ($r = -0.933$), is not surprising as the response set of correct, incorrect

Table 3: Correlation matrix for vigilance (VIGPOS, VIGERR, VIGNIL), behaviour state (A_1, A_2, A_2S, DR, DA) and subjective rating scores (VASconc, VAStired, ABCleth).

	VIGPOS	VIGERR	VIGNIL	A_1	A_2	A_2S	DR	DA	VAS conc	VAS tired
VIGERR	0.213									
VIGNIL	−0.933**	−0.550**								
A_1	−0.072	−0.338	0.186							
A_2	0.453*	0.237	−0.475**	−0.517**						
A_2S	0.006	−0.003	−0.004	−0.073	−0.517**					
DR	−0.493**	−0.347	0.549**	0.051	−0.417*	−0.282				
DA	−0.118	0.131	0.052	0.046	−0.431*	−0.278	0.301			
VASconc	0.562**	0.326	−0.594**	−0.245	0.346	0.231	−0.357	−0.211		
VAStired	−0.200	−0.141	0.222	0.042	−0.215	−0.335	0.373	0.365	−0.017	
ABCleth	−0.523**	−0.402*	0.595**	0.159	−0.443*	−0.044	0.598**	0.152	−0.370	0.370

*$P < 0.05$; **$P < 0.01$.

and nonresponse can be defined by determining only two of the three variables. In general, however, correlations which are significant fall below 0.6. This suggests that there is a degree of independence between the measures, and justifies the seperate analyses of measures in the preceding section.

Principal components analysis

The correlation matrix (Table 3) also suggests a degree of common factor variance. A preliminary Principal Components Analysis (PCA) yielded a three-factor solution, explaining 72.9% of variance, with variables loading *within* their respective methodological groups (Factor 1, reaction time measures; Factor 2, behaviour state measures; Factor 3, subjective ratings). However, this simply confirms the strengths of the arithmetic inter-dependence of the reaction time dataset and the behaviour state datasets. Therefore, a further PCA was conducted in an attempt to construct a *between* methodologies model of arousal and attention. The variables with the highest positive loadings for Factors 1 and 2 (above), i.e. VIGPOS (0.852) and A_2 (0.767), respectively, were selected for entry along with the subjective ratings (because these were not arithmetically interdependent).

The results of this PCA are presented in Table 4. Two factors were extracted having eigenvalues greater than 1 and explaining greater than 10% of variance[26]. Together these accounted for 72% of total variance. Factor I, labelled 'alert/engaged', comprises measures of arousal and attention from all three methodologies (VIGPOS, A_2, ANAconc), and Factor II ('lethargic/tired') comprises two subjective ratings (ABCleth, ANAtired). This is a relatively pure factorial solution with strong and positive factor loadings, although ABCleth does also load inversely on Factor I.

These factors were then used to derive new scores representing commonalities between measures. This was achieved by computing index scores, representing equal weightings of the original items, standardized into 1–100 scales for 'alert/engaged' and 'lethargic/tired', respectively. Correlation between these new measures was calculated at $r = -0.381$ ($P = 0.08$; two-tailed) indicating only a modest relationship, and supporting the view that these are somewhat independent constructs relevant to the measurement of attentional state. Regression analyses were then conducted on these variables, the results of which are reported in Table 2.

For the variable 'alert/engaged', 63% of variance was explained by a combination of (later) bedtime and (less) intellectual disability. By comparison, lethargy/tiredness did not yield a strong regression equation. Only 27% of variance was explained with (earlier) bedtime and gender (females more lethargic) demonstrating near significant effects.

DISCUSSION

The results of this study lend support to a multifactorial model of daytime attention and arousal state. Although to some degree dependent upon the particular measure, some consistency, nevertheless, emerged indicating that greater intellectual disability, longer night-time sleep periods, poor quality sleep, AED polytherapy, and more frequent seizures contribute significantly to poorer daytime function. Explained variance (as measured by adjusted R^2) was greater than 50% for six of the 10 outcome variables, and fell below 30% for only two variables. Furthermore, statistically significant regression equations ($P < 0.05$) were obtained for all but one variable. Thus, the results appear reasonably robust. For example, 85% of variance in the optimal awake state (A_2) was explained by a highly significant regression equation ($F = 17.93$, $P = 0.002$) with degree of intellectual disability ($P = 0.003$), time spent in bed ($P = 0.009$), and seizure frequency ($P = 0.038$) all contributing as predictor variables (Table 2).

Table 4: Principal Components Analysis of measures of arousal and attention with derived factors and factor loadings ($n = 28$).

Factor	Factor name	Eigenvalue	% Total variance	Cumulative %	% Explained variance
I	'alert/engaged'	2.495	49.9	49.9	69.5
II	'lethargic/tired'	1.095	21.9	71.8	31.5

	Factor I	Factor II
VIGPOS	0.830	−0.251
A_2	0.719	−0.138
VASconc	0.811	0.122
VAStired	0.028	0.935
ABCleth	−0.592	0.634

Severity of learning disability, sleep characteristics and age were generally stronger predictors of cognitive function than were epilepsy-related variables (e.g. seizure frequency, AEDs, delta rhythm in EEG) although the latter did add significant explanatory power to the solution. It is not surprising that greater learning disability predicts poorer attentional skill, however, the consistency with which greater time spent in bed was associated with poorer daytime performance is interesting (VIGERR, A_1, VAStired, ABCleth, 'lethargic/tired'). This suggests that circadian rhythms, which regulate the sleep to wakefulness continuum, may be poorly adjusted in these people. There is long-standing evidence of a similar phenomenon in elderly and demenTing individuals[27]. Putting people to bed early also may be a coping strategy for carers of these relatively passive but dependent people. In this respect it is important to note that duration and quality of sleep are not synonymous. Indeed, the implication of our results is that a shorter sleep period is associated with better daytime performance (VIGPOS, A_2, VASconc, 'alert/engaged'). Also, older subjects tended to have better daytime function than younger subjects. This may reflect a bias in our sample, however, it should be noted that our subjects were predominantly young adults (mean age of 31 years). Therefore, the effect of age may simply represent some aspect of delayed developmental progression.

AED polytherapy was found to be modestly predictive of attentional errors (VIGERR) and a predominance of the less actively 'engaged' state of arousal (A_1). Increased background delta may be indicative of AED-related toxicity and this was predictive of greater nonresponsiveness on the vigilance task (VIGNIL), as was greater seizure frequency. Fewer seizures were predictive of good quality arousal (A_2) as previously mentioned. It is very important to note that this study did not measure seizure-related effects upon attention and arousal either during a seizure or in the post-ictal recovery period. Clearly, the predictive effects of seizures *per se* at these times would have had very marked effects upon cognitive function, through impairment of consciousness. Rather, this study does provide a valid comparison of the predictive value of the variables under investigation during inter-ictal phases, i.e. their 'normal' functioning periods; and also the times at which most patients are seen by physicians.

The observed inter-correlations (Table 3) across the measurement methodologies (vigilance, behaviour state, ratings) yield some convergent validation of the assessment procedures used in this study. This is also supported by Principal Components Analysis where a factorially 'pure' solution was obtained accounting for a high proportion of variance (72%). Factor I comprised strong loadings from each of these three methodologies (0.830, 0.719, 0.811, respectively; Table 4). This in itself is an important contribution to the literature as recent consensus is that there is a lack of validated procedure for the appraisal of cognitive skills/deficits in this population[14]. Although behaviour state observation is time-consuming, video telemmetry material might be suitable for behaviour state coding and these will be available for some patients. Similarly, the simple vigilance task may be readily incorporated into assessment practice, perhaps being undertaken by a neurophysiology technician. Carer ratings also appear to be useful, particularly in the identification of negative symptoms (i.e. 'lethargy/tiredness'; Factor II).

Our results suggest that the daytime cognitive performance of people with epilepsy and severe learning disabilities may be best understood within an interactional model comprising pathological (brain damage, seizure sensitivity), chronobiological (circadian (sleep–wake) rhythm), neurochemical (drug effects/side-effects/tolerance) and biobehavioural (seizure frequency, sensory stimulation/habituation) factors. It is proposed that this model be used in clinical hypothesis testing where there is concern regarding an individual's cognitive performance. Of course, the elements are not mutually exclusive, and they highlight the importance of avoiding simplistic explanations of the complex phenomenon of attention. Although this research has gone beyond the mere exploration of correlates, towards identification of explanatory variables, nevertheless, the results should be regarded as preliminary and requiring replication. Furthermore, it cannot be assumed at this point that interventions based upon the model (e.g. reducing time

spent in bed, increasing sensory stimulation, changing to AED monotherapy) would result in improved arousal and attention. These are empirical questions which also merit systematic study. Finally, the methods for assessing arousal and attention developed as part of this research would benefit from further field testing, particularly in clinical settings, to investigate their practical usefulness.

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