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Brief Communication

Initial Comparison of Routine Electroencephalography and Event-Related Potentials in Patients with Cognitive Complaints

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ABSTRACT: Routine electroencephalograms (EEGs) assess brain function, but can be time-consuming, resource-intensive and setting-restrictive. Brain vital signs (BVS) evaluation, derived from EEG-based event-related potentials (ERPs), offers a rapid, standardized evaluation of cognitive function. In this study, 20 outpatients with cognitive complaints underwent both routine EEGs and BVS evaluation. While only 4 participants showed abnormal EEG results, 11 had at least one of the six BVS out-of-range, suggesting increased sensitivity to cognitive impairment. This commentary discusses the feasibility and potential value of standardized BVS evaluation as a simple objective method for cognitive function evaluation.

RÉSUMÉ: Comparaison initiale entre l'électroencéphalographie de routine et les potentiels évoqués chez des patients présentant des plaintes cognitives. Les électroencéphalogrammes (EEG) de routine évaluent les fonctions cérébrales, mais peuvent aussi nécessiter du temps, être coûteux en ressources et s'avérer restrictifs en termes de réglages. L'évaluation des signes vitaux cérébraux (SVC), dérivée des potentiels évoqués (PE) basés sur les EEG, offre une évaluation rapide et standardisée des fonctions cognitives. Dans cette étude, 20 patients ambulatoires ayant fait part de plaintes cognitives ont subi à la fois des EEG de routine et une évaluation de leurs SVC. Alors que seuls 4 d'entre eux ont présenté des résultats anormaux dans le cadre d'EEG, 11 ont donné à voir au moins un des six SVC dont les valeurs étaient hors-limites, ce qui suggère une sensibilité accrue aux troubles cognitifs. Ce commentaire entend donc examiner la faisabilité et la valeur potentielle de l'évaluation standardisée des SVC en tant que méthode simple et objective d'évaluation des fonctions cognitives.

Keywords: Brain vital signs; clinical feasibility; cognitive complaints; electroencephalogram; event-related potentials

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Cognitive screening tools administered after patient complaints are prone to underdiagnosis,[1] revealing a need for improvement. Routine electroencephalograms (EEGs) are a widely used clinical tool for assessing neurophysiological function. However, routine EEG typically involves 20–60 minutes of recording[2] with "activating methods," such as photic stimulation and hyperventilation (to elicit epileptiform activity).[3] In addition to the recording time, EEG requires highly specialized personnel for electrode application, artifact mitigation, and data recording and handling.[4] While routine EEG is a useful, high-density technique to analyze brain electrophysiology, it can be time-consuming and resource-intensive.

The brain vital signs (BVS) framework[5] offers a more rapid, accessible alternative. Introduced in a 2016 publication,[5] the last nine years of research focused on this framework as physiological proof of a living body, similar to blood pressure. It uses portable EEG technology to automatically extract well-established event-related potentials (ERPs) – N100, P300 and N400 – as objective indicators of cognitive processing (see Supplementary Materials). While evaluating BVS across diverse pathologies from concussions to dementia[6] has provided clinical validation, its use in a hospital-based electrodiagnostic clinical setting with comparison to routine EEG is novel. This comparison is important for positioning standardized, automated ERP evaluation as a complementary cognitive assessment to resource-intensive evaluations like routine EEG.

This observational pilot study assessed the feasibility of employing the BVS framework in a hospital setting alongside routine EEG. An exploratory analysis compared abnormalities in BVS results to routine EEG. The hypothesis was that, due to the functional aspect of ERPs compared to the clinical-standard

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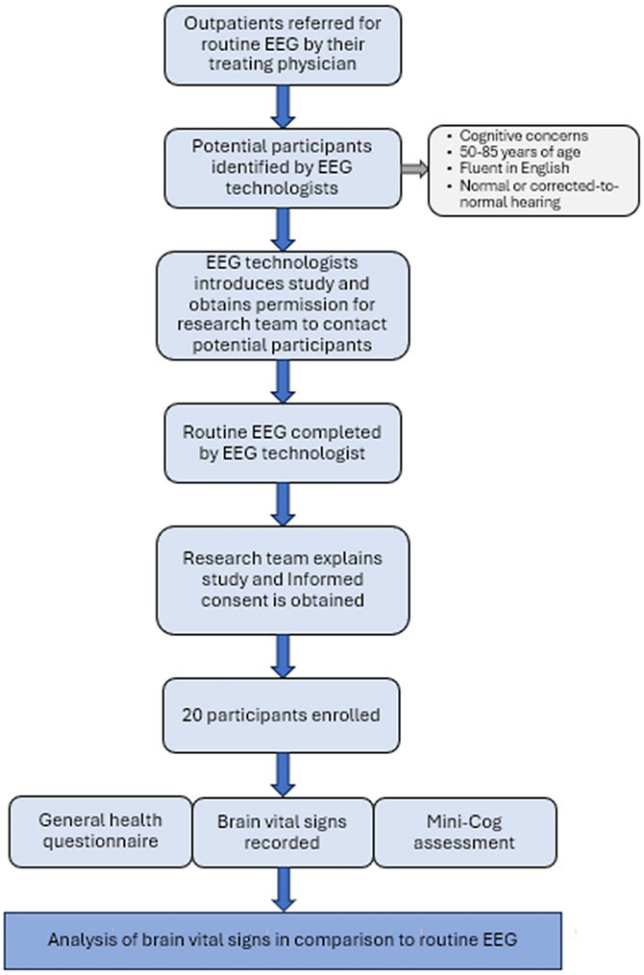

Figure 1. Flowchart of study enrollment process and data collection. *EEG = electroencephalogram.*

resting-state EEG, the BVS framework would detect more abnormalities than the routine EEG in clinical patients experiencing subjective cognitive complaints.

In the current study, 20 outpatients at the Royal Columbian Hospital of Fraser Health in New Westminster, British Columbia, were referred to a routine EEG for cognitive concerns. Participants were recruited for the study only when they were already prescribed to have a routine EEG by their treating physician (Figure 1). The participants were between 50 and 85 years of age, fluent in English and had normal or corrected-to-normal hearing.

The BVS framework[5] (employed with the NeuroCatch® Platform - Version 1.1) uses EEG to rapidly extract the N100, P300 and N400 ERPs. They were stimulated using a 6-minute standardized auditory sequence consisting of tones and spoken word pairs. An oddball paradigm with frequent standard tones and infrequent oddball tones elicited the N100 and P300 components, while semantically matched or mismatched word-pairs (e.g., match: bread-butter; mismatch: bread-window) elicited the N400. Participants passively listened and decided if the word pairs matched or mismatched. EEG data were recorded at 500 Hz and processed to generate individual BVS metrics (details in Supplementary Data). ERP peaks were automatically identified[5] and manually verified by an expert. One participant's BVS data were corrupted, leaving a sample size of 19 for analysis. Each participant underwent repeated BVS scans; the first scan was used for all participants.

To contextualize results, a comparison group of 181 individuals (mean age = 40 years; range = 8–84 years; 91 females) from NeuroCatch reference data was included. Comparison thresholds were defined as group median ± 3 interquartile range (IQR) values, providing a broad comparison range to better highlight outliers.

Participants also completed a general health questionnaire and Mini-Cog assessment at data collection. Clinical EEG reports of each participant were retrieved and included a normal or abnormal categorization by a neurologist. Clinical information (e.g., referral letters, consultations and clinic notes) was retrieved from Meditech system within 6 months of the BVS scan for 16 of the 19 participants; three lacked data on problems and medications.

Participant characteristics by overall sample, BVS results and routine EEG groupings are shown in Table 1. From the sample (n = 19; 50 to 76 years of age (mean age [standard deviation] - 65.3 [7.7] years), 11 (57.9%) showed at least one BVS abnormality, whereas 4 (21.1%) had abnormal routine EEGs (Table 1). Of those with abnormal routine EEGs, only two also showed BVS abnormalities. BVS abnormalities included the latency (response time) and amplitude (response strength/synchrony) for the N100, P300 and N400 components. Most out-of-range BVS values reflected slower latencies and reduced amplitudes, except for one case showing an elevated P300 amplitude relative to the reference range.

The mean amplitude and latencies of ERPs between participants grouped by routine EEG results and BVS results were compared (Table 2). For those who had abnormal routine EEGs, the mean latency of the P300 and N400 ERPs was slower than those who had normal routine EEGs (309.00 and 513.50 vs. 285.87 and 474.57, respectively; Table 2). Those who had normal routine EEGs had lower mean amplitudes for all three ERPs compared to those who had abnormal routine EEGs. In contrast, those who had abnormal BVS results had lower mean amplitudes for all three ERPs compared to those who had normal BVS results. The mean latency for the P300 ERP was also slower for those who had abnormal BVS results. The amplitude and latency for each of the three ERPs are shown in Figure 2 as a radar plot between routine EEG groupings and BVS groupings. Figure 3 shows the normal and abnormal EEG grouped average waveforms, including the latency and amplitude (Table 2), of all three ERP components.

Both the clinically standard EEG and the BVS platform identified participants with abnormal brain function. The trend in Table 1 shows that neurological problems are better captured by BVS scans, while other comorbidities are associated with clinical EEG assessments. BVS identified an abnormality in 60% of patients with cognitive complaints, 37% more than clinical routine EEG. The difference in BVS and routine EEG abnormalities in these results suggests the complementary value of the BVS framework in addition to the routine EEG. The wide comparison range used (median ± 3 IQR values) encompasses the majority of the reference data to better highlight large outliers. These results suggested the increased sensitivity of the framework to detect abnormalities that may go unnoticed by routine EEG. Not only was the BVS sensitive, but the technology was also fast and convenient: it effectively reduced the assessment time by 70% from the standard care clinical EEG, and the assessment can come to the patients' bedside (instead of being limited to hospitals or clinic settings). Once proven effective, these features can benefit the clinical uptake of the technology.

The N400 component detected the most BVS abnormalities in seven participants. The N400 ERP is associated with higher-level cognitive processing[7] and is sensitive to cognitive issues.[6] Specifically, Ighalo et al employed the BVS framework in care home residents. While all measures seemed abnormal, the N400

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Table 1. Characteristics of all participants and by clinical EEG grouping and BVS grouping

		Clinical EEG Group		BVS Group	
Variable	**Overall**	**Abnormal**	**Normal**	**Abnormal**	**Normal**
Sample size (*n*)	19	4	15	11	8
Age (mean ± sd)	65.3 ± 7.7	69.8 ± 4.7	64.1 ± 8.0	65.8 ± 7.2	64.5 ± 8.7
Sex (female, %)	42.1	25.0	46.7	36.4	50.0
Education (mean ± sd)	14.8 ± 1.9	16.0 ± 1.6	14.5 ± 1.9	14.7 ± 2.0	14.9 ± 2.0
Mini-Cog (mean ± sd)	4.5 ± 1.0	4.5 ± 1.0	4.5 ± 1.1	4.3 ± 1.3	4.8 ± 0.5
TGA (%)	36.8	25.0	40.0	45.5	25.0
Stroke/TIA (%)	31.3	25.0	33.3	30.0	33.3
Other neurological problems (%)	43.8	25.0	50.0	50.0	33.3
Heart diseases (%)	25.0	50.0	16.7	30.0	16.7
TBI (%)	12.5	0.0	16.7	20.0	0.0
Abnormal lipid levels (%)	37.5	50.0	33.3	30.0	50.0
OSA (%)	25.0	50.0	16.7	20.0	33.3
Diabetes (%)	25.0	75.0	8.3	20.0	33.3
Hypertension (%)	43.8	50.0	41.7	50.0	33.3
Self-rated health status poor (%)	0.0	0.0	0.0	0.0	0.0
Fine (%)	57.9	50.0	53.3	45.5	62.5
Good (%)	31.6	50.0	26.7	36.4	25.0
Excellent (%)	15.8	0.0	20.0	18.2	12.5
Number of medications (mean ± sd)	3.4 ± 3.1	6.3 ± 4.0	2.5 ± 2.1	3.8 ± 3.4	2.8 ± 2.6
Number of problems (mean ± sd)	4.7 ± 3.0	7.5 ± 4.1	3.8 ± 1.9	4.6 ± 3.3	4.8 ± 2.6

BVS = brain vital signs; EEG = electroencephalogram; Mini-Cog = quick screening for early dementia detection; TGA = transient global amnesia; TIA = transient ischemic attack; TBI = traumatic brain injury; OSA = obstructive sleep apnea; n = number of participants; sd = standard deviation; % = percentage of participants.

Table 2. Mean amplitude and latencies of BVS ERPs between routine EEG result groupings and BVS result groupings

	BVS Event-related potential (ERP)	**N100**		**P300**		**N400**	
Measure	**By Clinical EEG Group**	***n***	**mean ± sd**	***n***	**mean ± sd**	***n***	**mean ± sd**
Amplitude(μV)	**Abnormal**	4	−4.67 ± 2.91	4	5.14 ± 2.36	4	−2.35 ± 1.43
	Normal	15	−3.68 ± 1.87	15	4.77 ± 2.87	14	−1.21 ± 1.10
Latency (ms)	**Abnormal**	4	99.50 ± 1.91	4	309.00 ± 41.46	4	513.50 ± 50.32
	Normal	15	102.27 ± 9.62	15	285.87 ± 76.55	14	474.57 ± 56.73
	By BVS Group						
Amplitude(μV)	**Abnormal**	11	−3.40 ± 2.46	11	4.71 ± 3.17	10	−0.98 ± 1.44
	Normal	8	−4.56 ± 1.25	8	5.02 ± 2.12	8	−2.06 ± 0.56
Latency (ms)	**Abnormal**	11	100.36 ± 9.58	11	302.36 ± 87.95	10	480.20 ± 57.45
	Normal	8	103.50 ± 7.23	8	274.75 ± 33.79	8	487.00 ± 58.86

BVS = brain vital signs; ERPs = event-related potentials; EEG = electroencephalogram; n = number of participants; sd = standard deviation; μV = microvolts; ms = milliseconds. (One participant did not have an N400 response, potentially due to a lack of attention or a lack of being able to semantically separate incongruent word pairs).

followed the patterns of age and mini-mental state examination results.[6] In line with the current study, these findings indicated that objective neurophysiological measures of impairment are detectable and may relate to a pattern of cognitive function. In the current study, the BVS framework detected more abnormalities and could potentially help in addressing patients' cognitive concerns alongside the traditional routine EEG in clinical settings.

ERPs have been shown to be sensitive to cognitive changes and give insight into future developments of cognitive impairments. One study conducted by Gironell et al.[8] found that patients who had significantly slower P300 ERP latencies throughout a two-year period had a higher probability of being diagnosed with Alzheimer's disease. Another study showed how certain ERPs can differentiate patients with progression in cognitive impairments.[9] This highlights

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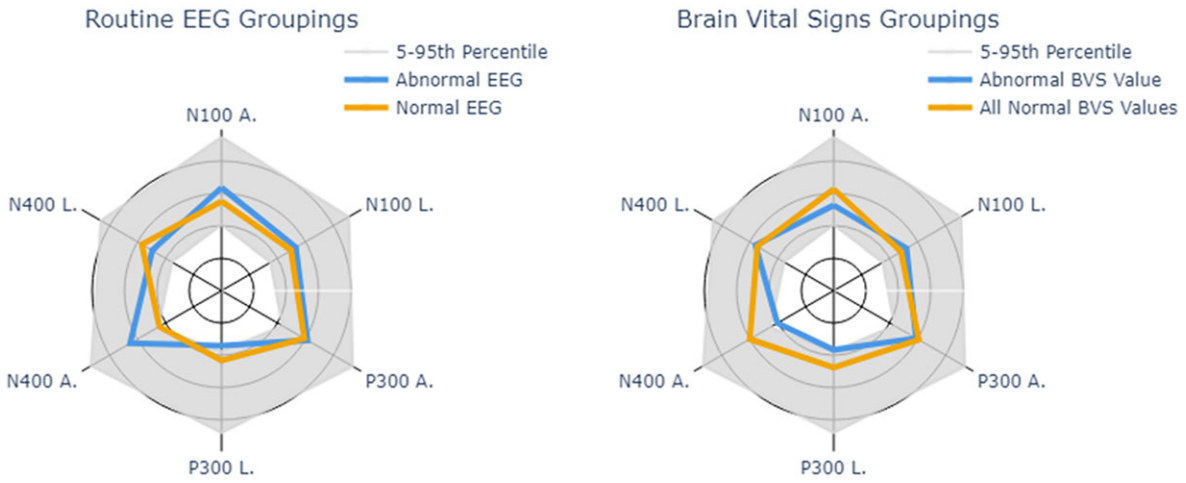

Figure 2. Brain vital signs radar plots by routine EEG grouping and brain vital signs grouping. *Note: EEG = electroencephalogram; BVS = brain vital signs; A = Amplitude; L = Latency; Gray shaded area indicates the 5th to 95th percentile for all reference data scans.*

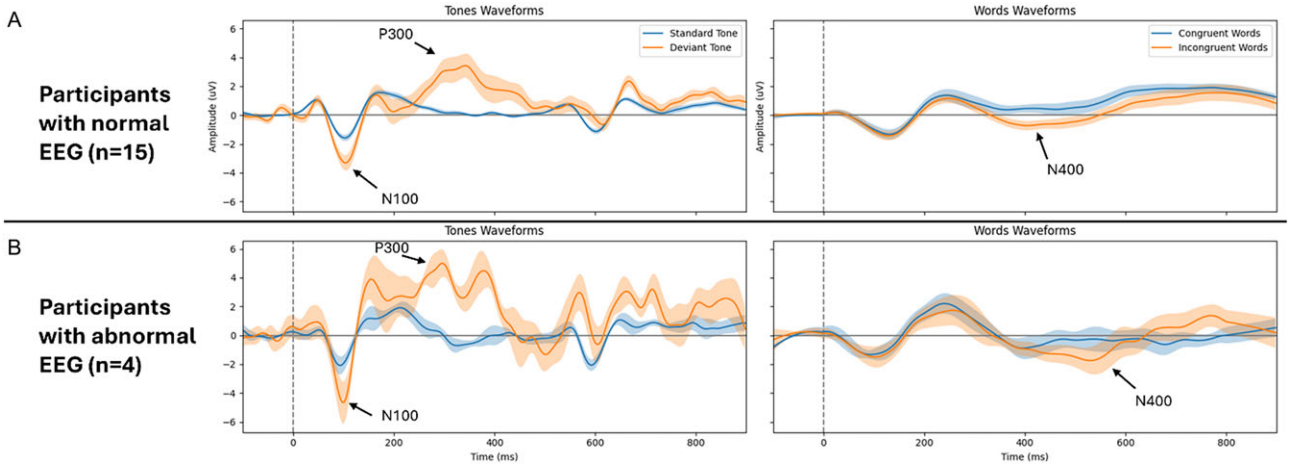

Figure 3. Average waveforms elicited by tones and word pairs in participants with a normal (A) and abnormal (B) EEG. General location of N100, P300, and N400 components is noted. 90% confidence interval shading included. *Note: EEG = electroencephalogram.*

the significant impact that introducing ERP measurements in clinical settings could have, in addition to routine EEGs, in early detection of cognitive impairments.

Interpretations of EEG results can vary between professionals.[10] Perhaps rapid, automated ERPs, employed by the BVS framework, could improve the reliability and consistency of EEG interpretations. The present study showed the ability of ERPs to detect additional abnormalities compared to routine EEGs, which could assist professionals in analyzing routine EEG data and confirming the presence or absence of cognitive impairments. In addition to the initial detection of impairments, ERPs can assist in monitoring and tracking the improvements to cognition.

Our results must be interpreted with caution. We had a relatively small sample, limiting the statistical power to always detect a difference when such a trend was seen. Also, the participants were from a single clinic with imbalanced normal or abnormal EEG presentation, limiting the generalizability of the finding. Future research with increased sample size is needed to explore more equally distributed EEG-labeled samples. Additional investigations are also needed to understand the effectiveness and efficiency of using both methods to assess cognition, along with more in-depth neuropsychological investigations.

Despite the limitations, this study represents the initial effort to directly compare BVS-extracted values of ERPs and the standard-care EEG in clinical patient participants, providing insights into developing/examining novel technologies for improving the diagnosis and care of people with subjective cognitive complaints. In conclusion, this study shows the complimentary value of the BVS framework as a fast and convenient portable method of brain function assessment in addition to routine EEG.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/cjn.2025.10362.

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Author contributions. GM, XS and RCND contributed to project study design and manuscript editing. XS also contributed to result interpretation, data analysis

and presentation review and consultation, supervision, and research funding acquisition. EDK contributed to data collection, data processing, statistical analysis, figure creation and manuscript drafting. KH contributed to data collection, figure creation and manuscript drafting. MG contributed to data collection and manuscript editing. TOF contributed to manuscript drafting and editing.

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Competing interests. RCND is the co-founder of HealthTech Connex Inc., and the NeuroCatch Platform with financial and/or business interests that may be affected by the research reported in this paper. EDK and TOF are employed by NeuroCatch Inc., which may be affected by the research reported in this paper. KH, MG and XS have no disclosures with the present study.

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