Cognitive-Motor Dissociation Following Pediatric Brain Injury: What About the Children?

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ABSTRACT

Objective: Following severe brain injury, up to 16% of adults showing no clinical signs of cognitive function nonetheless have preserved cognitive capacities detectable via neuroimaging and neurophysiology; this has been designated cognitive-motor dissociation (CMD). Pediatric medicine lacks both practice guidelines for identifying covert cognition, and epidemiologic data regarding CMD prevalence.

Methods: We applied a diverse battery of neuroimaging and neurophysiological tests to evaluate two adolescents (aged 15 and 18) who had shown no clinical evidence of preserved cognitive function following brain injury at age 9 and 13 respectively. Clinical evaluations were consistent with minimally conscious state (minus) and vegetative state, respectively.

Results: Both subjects’ EEG, and one subject’s fMRI, provided evidence that they could understand commands and make consistent voluntary decisions to follow them. Both subjects’ EEG demonstrated larger-than-expected responses to auditory stimuli, and intact semantic processing of words in context.

Interpretation: These converging lines of evidence lead us to conclude that both subjects had preserved cognitive function dissociated from their motor output. Throughout the 5+ years since injury, communication attempts and therapy had remained uninformed by such objective evidence of their cognitive abilities. Proper diagnosis of CMD is an ethical imperative. Children with covert cognition reflect a vulnerable and isolated population; the methods outlined here provide a first step in identifying such persons to advance efforts to alleviate their condition.
Introduction

Severe brain injuries are a leading cause of death and disability among children and adolescents. In those who survive, emergence from coma typically results in a disorder of consciousness (DoC).\(^1\) This includes periods with signs of arousal but no clear evidence of awareness of self or environment (vegetative state, sometimes known as unresponsive wakefulness syndrome: VS/UWS) and periods with inconsistent evidence of awareness (minimally conscious state, MCS).\(^1\) In adults who are in coma, VS/UWS or MCS, a lack of observable motor behavior may obscure the presence of high-level cognitive function as revealed by functional neuroimaging and neurophysiological assessments.\(^1\) In the chronic phase, such studies have reported that 40-75\% of participants with no detectable signs of awareness at the bedside retain high-level cognitive functions.\(^1\) The condition of such patients has been called cognitive motor dissociation (CMD).\(^2\) Adults with CMD demonstrate significantly better prognosis when identified during early intensive care.\(^3\)

These findings are highly significant both clinically and normatively. In the early stages following injury, accurate diagnoses of preserved or emerging cognitive function can influence decisions about withdrawal of care, the provision of appropriate interventions and access to rehabilitation.\(^1,3\) In the long term, it is especially important to diagnose residual cognitive function so that families can make informed decisions about augmentative communication strategies, and about the appropriate educational and social environments to mitigate the person’s isolation.
However, precise diagnosis of emerging cognitive function in DoC is both difficult and error-prone\(^4\) and, to date, wholly unaddressed in pediatrics. Current cognitive measures rely on co-emergence of motor function—for example, motor control is necessary to demonstrate command-following.\(^5\) This reliance on overt behavior can obscure the presence of residual cognition. In adult DoC, the use of neuroimaging and neurophysiology to inform diagnosis, when available, is now a practice guideline and has been adopted by AAN, ACRM and NIDILRR\(^4\) and the EAN.\(^6\) In pediatric DoC, by contrast, only very few attempts\(^7\)–\(^11\) have been made to apply objective assessments of functional brain activity, and they have provided only circumstantial evidence of covert consciousness as they have not examined brain responses in command-following or language comprehension paradigms. As a result, there is insufficient evidence to develop similar guidelines for pediatric brain injury.

To address this gap, we conducted a systematic, comprehensive, multimodal assessment of cognitive function in two adolescents living with chronic DoC following severe brain injuries. We employed a battery of behavioral, neurophysiological and neuroimaging assessments to diagnose and quantitatively characterize multiple aspects of cognitive function. We expect these tests to be re-deployable in a wider range of cases.

**Methods**

**Participants:**
Two male adolescent subjects, initially referred to an adult DoC research program,\(^12\) participated in this study. They were part of a larger companion study (under review\(^13\)) in which they are labeled as participants C and E. Here they are labeled as Subjects 1 and 2 (S1 and S2). The companion study reports\(^13\) on two EEG tests: event-related potentials in the oddball paradigm (ERP, see below), and EEG correlates of motor-command following (MCF-EEG, see below) taken in 8 participants in DoC and 36 participants in other cognitive
In the current study we focus on only 2 of the DoC participants by providing a comprehensive profile that includes fMRI motor command-following (MCF-fMRI), EEG correlates of semantic comprehension (N400), FDG-PET, structural MRI imaging and clinical histories along with the previously reported ERP and MCF-EEG findings. Our criterion for selecting two DoC subjects for deeper study was that they had positive MCF-EEG despite being unresponsive at the bedside. One additional DoC subject matched these criteria but could not be studied in greater depth, as they were in the acute phase following injury with medical complications that prevented neuroimaging studies. All procedures were approved by the institutional review boards (IRBs) of Weill Cornell Medicine and Blythedale Children’s Hospital. Parental consents were obtained as per IRB protocols.

S1: The subject was 9 years old when he experienced a traumatic brain injury complicated by hypoxemia and associated cardiac arrest. He was a restrained passenger in a motor vehicle collision and was intubated at the scene with a Glasgow Coma Scale (GCS) of 4. Detailed clinical histories are provided in the Supplementary Material. S1 was 15 and 16 years old during the two separate series of testing and imaging for the current study.

S2: The subject was 13 years old when he experienced anoxic brain injury secondary to cardiac arrest. CPR was initiated immediately, and he was intubated in the field and provided four separate shocks with an automated external defibrillator for ventricular fibrillation. During hospital stay he was noted to have supraventricular tachycardia and an accessory pathway was ablated. Detailed clinical histories are provided in the Supplementary Material. He was 18 years old when he completed the testing and imaging for the current study.

Procedures:

To assess neurophysiological and neuroimaging evidence of command-following we employed a motor imagery task, similar to previous studies in adults\(^{14}\) and pediatrics,\(^{13}\) using
EEG. We also employed both a motor imagery and a spatial navigation task in fMRI, as has been done before in adults.\textsuperscript{15} To assess processing of auditory stimuli, we measured auditory evoked potentials (AEP) and P300 event-related potentials during an “oddball” stimulus paradigm.\textsuperscript{13} To assess semantic comprehension, we measured N400 event-related potentials elicited by recordings of previously-published spoken sentences,\textsuperscript{16} as previously applied to healthy populations (age 16 to 32) and brain-injured populations.

**PET, MRI, fMRI & EEG data acquisition**

MRI & fMRI data from both pediatric subjects were collected with a Siemens MAGNETOM Prisma 3.0 T Scanner at New York-Presbyterian (NYP) Hospital/Weill Cornell Medical Center between October 2019 and March 2020. Each scan included a sagittal 3D T1 MPRAGE acquisition, as well sagittal 3D T2 FLAIR with fat saturation, with respective axial and coronal reformats, with a resolution of 0.8 mm x 0.8 mm x 0.8 mm. A functional MRI was obtained with a multiband gradient-echo EPI sequence with TR=2000ms, TE=30ms, and 32 slices of 3.74mm x 3.74mm x 4mm voxels acquired in interleaved increasing order. PET data was acquired using a 64-slice Biograph mCT PET/CT scanner (Siemens Healthineers, Erlangen, Germany). [18F] FDG PET/CT was obtained with pediatric protocol according to published recommendations, including weight-based FDG dosing and low dose CT following the ALARA principle.\textsuperscript{17} In S1, two MRI/fMRI sessions were conducted 15 months apart and a single PET scan was obtained at the later time point. In S2, there was a single time point during which MRI, fMRI and PET scans were all collected.

Electroencephalographic data were recorded from 128-channel HydroCel Geodesic Sensor Net (GSN) (EGI, Eugene, OR, United States).\textsuperscript{18} In S1, a gel-based cap was used and in S2, a sponge-based cap was used. The impedance of all electrodes was < 75 kΩ at the beginning of the recording. The signals were recorded at 1000 Hz with a high-pass filter at 1Hz to remove DC drift. Speakers (Micro innovations 2-piece speaker system) were located at 45° (left/right
of the midline) at a distance of 57cm to the ears. Each speech stimulus was normalized to have equal perceived loudness at a volume of ~ 70 dB hearing level. Stimulus presentation was conducted using the BCI2000 software. Data were acquired with BCI2000, integrated via the Lab Recorder software (Lab Streaming Layer package) which is a system for unified, time-synchronized measuring. All EEG data reported are from the second visit of S1 and the single visit of S2.

**Stimuli and Tasks**

**Motor command following (EEG)**

Similar to previous studies in adults and pediatrics, In the motor imagery task, subjects alternately heard the commands “Keep opening and closing your right/left hand,” and “stop and relax” (interleaved 8 trials of left hand; 8 trials of right hand; 16 trials of rest). Each trial consisted of pre-recorded commands in a female voice; commands lasted approximately 2s, providing subjects with 13s to perform the mental imagery task (trials were delivered 15s apart). In S1 there were a total of 3 sessions over 3 days and in S2 there were 4 sessions over 4 days.

**Motor and non-motor command following (fMRI)**

We used experimental designs similar to previous fMRI studies used to detect command following in DOC subjects, notably motor imagery and spatial navigation. For the spatial navigation task, the subject was asked to imagine walking around the rooms of their house. For the motor imagery task, the patient was asked to move their (his or her) left arm. The patient was asked to perform alternating sessions of repeated rest-imagery cycles. A period of rest or imagery lasted 16 seconds each, with the rest-imagery cycle repeated 8 times. In S1, a single session of each task was conducted, at each of two time-points, 15 months apart. For S2, two sessions were acquired for each task during the same scan.
Auditory oddball: This EEG paradigm, frequently used in both adults\textsuperscript{20} and pediatrics,\textsuperscript{13} consists of frequent standard tones with randomly interspersed but infrequent deviant tones and other auditory stimuli. It requires no participation from the subject beyond passive listening. While both sounds trigger event-related potentials (ERPs), the ERPs time-locked to standards and those time-locked to oddballs exhibit robustly detectable differences. 1) In-house version: Stimuli were square-wave beeps of 340 ms duration with a fundamental frequency of either 400 Hz (standard) or 575 Hz (deviant), as well as a variety of “novel” deviant sounds designed to elicit an enhanced P3a component.\textsuperscript{20} Each recording session comprised 410 stimuli (270 standard beeps, 80 deviant beeps, 60 novel deviant sounds) presented in random order in a 1-second repeating rhythm.

Semantic processing (EEG event-related potentials)
Previously published sentences\textsuperscript{16}, composed of 6-8 words were used.\textsuperscript{21} This stimulus which consists of 320 congruent trials (e.g., “Apples and cherries are a type of fruit.”) and 320 incongruent trials (e.g., “A wild pig is called a shirt.”) has previously been applied to healthy populations (age 16 to 32)\textsuperscript{22} and brain injured populations.\textsuperscript{23} The inter-stimulus interval between the sentences was 3.5-4.5 s. All stimuli were spoken by a young female English native speaker. All sounds had a sampling rate of 44.1 kHz, a resolution of 32 bits and were presented at a sound level of \~70dB. In S1 there were a total of 5 sessions over 4 days and in S2 there were 3 sessions over 3 days.

Data Analysis

EEG data preprocessing and event related potential (ERP) analyses

EEG data processing was as described in a previous study\textsuperscript{13} and are included in the supplementary material.

Analysis of semantic event related potentials
For the semantic processing ERP analysis, data were segmented into 1000ms epochs time-locked to the onset of the auditory target word (200ms pre-stimulus and 800ms post-stimulus). Mean amplitudes were calculated for each stimulus type for each individual at Cz electrode site. We calculated the t test statistics between the congruent and the incongruent condition at each timepoint.

**Spectral analysis of motor-command-following EEG**

Analysis of command-following EEG data is as described in a previous study and are included in the supplementary material.

**fMRI analyses**

The fMRI data were pre-processed using the CONN toolbox. Functional preprocessing included realignment, slice-timing correction, segmentation and intensity normalization, and 6mm FWHM smoothing. BOLD data were high-pass filtered using a cutoff of 128 seconds to remove slow signal fluctuations. The analysis was performed with SPM12 (Wellcome Trust Center for Neuroimaging, London, UK) using a general linear model (GLM) with a canonical hemodynamic response function (HRF) to assess task vs rest activations. In order to identify auditory responses to the verbal commands, a new condition block design was created with an impulse of 0 length at the beginning of each verbal command (both ‘start’ and ‘stop’ commands) and convolved with a HRF. For each scan, contrasts between periods of active imagery with periods of rest were calculated, with 8 periods of imagery and rest for S1 and S2. The GLM & contrasts were performed twice for S2, separately for each session and with sessions concatenated. Contrasts were performed across all voxels in the brain. Thresholder statistical t-value maps were plotted. All p-values reported are uncorrected.
Data availability:

Data and stimuli from this study are available from the corresponding author upon reasonable request.

Results

Behavioral Assessment:

S1 was assessed at two time points 15 months apart using the standardized neurobehavioral assessment Coma Recovery Scale - Revised (CRS-R); the first assessment was 5 years after injury. He demonstrated a consistent startle to visual threat but no evidence of an ability to fixate on objects or track them visually through space. He likewise consistently responded to sounds in his environment with generalized facial and limb movements, and in addition, he showed evidence of orienting toward the sound. He consistently demonstrated spontaneous vocalizations but there was no evidence of verbal communication or comprehension through command-following. His exam was inconsistent across time points: his response to the presentation of pain (nail bed pressure) ranged from localized movement of a non-stimulated limb toward the painful stimulus during the first assessment (suggesting emergence to MCS)—to unspecific movement in multiple limbs in the second assessment (more characteristic of VS/UWS). The CRS-R total score at visit 1 was 10 and at visit 2 was 7.

S2’s arousal and responsiveness were assessed using the CRS-R during his single assessment for this study, almost five years post injury. His clinical presentation was consistent with VS/UWS as he demonstrated sustained wakefulness with startle to sound, abnormal posturing to pain, and spontaneous vocalizations. He did not respond to any visual stimuli or demonstrate any evidence of verbal comprehension, functional object use, or communication. The CRS-R total score was 6.
**Structural and metabolic markers of brain injury:**

MRI and FDG PET/CT imaging revealed changes in brain structure and cerebral metabolism consistent with severe traumatic (S1) and hypoxic-ischemic (S2) brain injuries (Figure 1). In S1, MRI demonstrated moderate frontal predominant parenchymal volume loss with corresponding PET findings of disproportionately decreased FDG avidity in the bilateral frontal cortex. In S2, MRI demonstrated marked generalized parenchymal volume loss with superimposed disproportionate volume loss in the left frontal, temporal and parietal operculum; PET additionally demonstrated a disproportionate decrease in FDG avidity in the bilateral parietal precuneus, left greater than right lateral parietal convexity, and bilateral calcarine cortex.

[INSERT FIGURE 1 HERE]

**EEG correlates of motor command following:**

During attempted hand movement to command, contralateral desynchronization of EEG sensory-motor rhythms was seen in both subjects, manifested as a reduction in bandpower in the alpha frequency band (Figure 2). In S1, positive responses were seen to attempted movement of the left hand (permutation test: \( p = 0.04 \)) but not right \( (p = 0.67) \); in S2, positive responses were seen to attempted movement of both hands \( (p = 0.01 \) left; \( p = 0.03 \) right).

[INSERT FIGURE 2 HERE]

**fMRI correlates of motor and non-motor command following:**

We further evaluated motor and non-motor command-following abilities using fMRI (Figure 2). In S1, a differential response (command vs. rest) was observed in bilateral Brodmann Area 6 \( (p < 0.005, \) uncorrected); imagined spatial navigation elicited significant activation at the occipito-parietal junction \( (p<0.001, \) uncorrected). In S2, no significant responses were observed to either command type.
EEG correlates of auditory stimulus processing:

In Figure 3, we compare the responses to the “oddball” paradigm in both subjects against 11 other pediatric subjects with brain injuries. We note that, in comparison to subjects in disorder of consciousness (DoC) who had no evidence of motor command-following, both S1 and S2 had larger auditory evoked potentials (AEP) to the frequent standard stimuli, as well as larger P300 responses in the difference wave between standard and rarer deviant stimuli. Their magnitudes are comparable to those of a group of children who had emerged from DoC and were categorized as being in a confusional state (CS)—see Kim et al. (2022) for details, including results on a broader spectrum of cognitive recovery states.

[INSERT FIGURE 3 HERE]

EEG correlates of semantic processing:

Both subjects exhibited a normal N400 event-related potential (Figure 4). This negative deflection at 400ms latency is specific to words that are semantically incongruent with the preceding sentence context, as compared with congruent words.

[INSERT FIGURE 4 HERE]

Discussion

The current findings provide convergent evidence for cognitive-motor dissociation (CMD) in two adolescents who had remained in disorders of consciousness (DoC) over several years. The results illustrate that CMD arises in pediatric patients with severe brain injuries, and raise many troubling questions in light of the very limited existing published literature on pediatric DoC.
As shown by our neurophysiological and neuroimaging assessments of motor command-following, both subjects could understand commands sufficiently to follow them accurately without physical cues, make a voluntary decision to follow them, and remain focused on the task instructions (positive fMRI results in S1, positive EEG in both subjects). Such evidence of command-following, derived from EEG or fMRI as proxies for absent behavioral responses, has been the distinguishing feature of CMD. To the best of our knowledge, there are no reports of such motor-command-following results in pediatric brain injury, with the exception of our report on the current subjects as part of a larger sample (in which one further subject in DoC also showed positive EEG results in motor command-following). It is important to note that false negative command-following results are common both in fMRI and, independently, in EEG. This is even true in uninjured subjects, but especially so in people with brain injury due to the greater fluctuations in arousal. The positive predictive value of these tests far outweighs their negative predictive value—therefore, we ascribe no particular interpretation to S2’s negative fMRI results.

The problem of false-negative command-following results motivates additional tests that could contribute to a CMD diagnosis via assessment of independent aspects of cognition. Furthermore, tests that characterize residual and recovered cognitive abilities quantitatively and in greater detail, beyond mere detection of the presence or absence of covert cognition, are needed to facilitate appropriate communication with people in CMD. For these reasons, we augment the command-following findings by reporting EEG-based assessments of auditory and rudimentary attentional processing using an “oddball” paradigm, and of language processing using spoken sentence stimuli. The auditory oddball test is described in more detail, and validated in a larger sample across the full spectrum of cognitive recovery following brain injury, in a companion study. In this larger cohort of patient subjects, the P300 measure is more consistently related with positive EEG correlates of motor command-following (including the two subjects in the current study) compared to AEP measures.
Evidence of language processing was provided by EEG measurements that demonstrated intact processing of word meaning (typical N400 event-related potentials in response to semantically incongruent words at the end of a sentence). Throughout the years in which these two subjects had remained in DoC, attempts at communication and therapy had remained uninformed by any such objective evidence of their auditory processing and language comprehension. This vividly highlights the crucial gap in current clinical practice.

Each of the tests has previously been shown to be informative in DoC research studies on adults. Functional MRI or EEG correlates of attempted movement to command have been used to detect awareness and motor planning in the absence of overt, purposeful movements.\textsuperscript{14,28} Task-based brain signal analytics can reveal CMD in 15–20\% of patients judged unresponsive on clinical examination.\textsuperscript{1} Variation in the amplitude of the auditory evoked potential (AEP) has been linked to arousal and selective attention,\textsuperscript{29} allowing identification of residual consciousness in severely brain-injured adults.\textsuperscript{30} Absent, reduced-amplitude or longer-latency AEPs are associated with poorer outcomes following adult TBI.\textsuperscript{31} In the oddball difference wave, two components (the N2\textsuperscript{32} and P3\textsuperscript{20}) are considered to be dependent on attention to target discrimination\textsuperscript{20} and information processing. In adults, the P3 has been employed to improve diagnosis and prognostication in severe brain injury.\textsuperscript{31,33} The N400 has been shown to be preserved (albeit at reduced amplitude) in the group mean data from adults in VS/UWS and MCS. This has previously been presented as unreliable on an individual-patient basis in DoC\textsuperscript{34} due to its low negative predictive value. However, when present, it is predictive of positive outcomes.\textsuperscript{23,34}

While accurate diagnosis of pediatric CMD is clearly important, the life of such children is not improved by its identification alone—without providing specific targets for improving rehabilitation or communication strategies.\textsuperscript{35} The ultimate goal, in the absence of further motor recovery, is to restore meaningful communication with family and caregivers, allowing
re-integration into the community.\textsuperscript{36} This is both clinically significant and a mandate of the Americans with Disabilities Act.\textsuperscript{37} Moving both clinical care and research in the direction of this goal, unfortunately, remains a challenge even for adults with CMD. In adults, attempts have been made using motor imagery in fMRI\textsuperscript{38} and EEG\textsuperscript{39} to build a brain-computer interface (BCI) allowing two-way communication. Apart from isolated reports, very little progress has been made—importantly, CMD patients demonstrate difficulties converting command-following responses into communication signals. Similar BCI methods have had some limited success in patients with locked-in syndrome; however, unlike the special case of locked-in syndrome, CMD is more generally characterized by concomitant injuries across a broad range of cerebral functions.\textsuperscript{12} Therefore, significant challenges remain to be surmounted in both adult and pediatric CMD, among which accurate diagnosis is just the first step. With our results, we demonstrate possible active BCI channels—motor imagery and spatial imagery. Establishing a range of options, as we have shown, may be a necessary first step in achieving individualized communication solutions for this heterogeneous and underserved population.

Future work will also need to address four challenges. First, we require deeper knowledge of the effects of trauma on the developing brain. For example, as described elsewhere,\textsuperscript{13} we noted that S1’s auditory evoked potential had a longer latency more characteristic of his age at injury (9 years) than at testing (15 years). It is unclear whether this reflects “stunting” of brain development. Second, rigorous validation studies are required to determine the reliability of additional assessments (beyond motor command-following) in identifying CMD—this might include, for example, passive language paradigms that have previously been used in pediatric DoC studies.\textsuperscript{7–11,13} Third, the current research and clinical infrastructure needs to expand to allow neuroimaging and neurophysiological studies for pediatric subjects with brain injury. Finally, we require a better understanding of which of the wide range of possible injury and disease mechanisms allow for, or preclude, CMD.\textsuperscript{2} We
have incomplete knowledge even concerning the ways in which different injury and disease mechanisms might impact the various tests (such as command-following) that we use to infer CMD. This limitation significantly impacts the immediate generalizability of the present findings and of similar results in pediatrics and adults alike.

In summary, the accurate diagnosis of CMD is challenging, and the condition is unrecognized in children. Our study, the first of its kind in pediatrics, demonstrates proof of principle for identifying CMD in children and adolescents, and lays out a hierarchical toolset for individualized assessments. As these and similar results emerge, they should shape the way new patients are assessed, and chronic patients re-assessed. Even as the implications for treatment remain to be finalized, the immediate impact of such assessments will be to guide the way in which clinicians and caregivers talk to people in disorders of consciousness. This toolset should be expanded still further, validated, and adapted to ensure applicability in younger children. The ultimate goal should be to produce a reliable clinical algorithm for detecting covert consciousness in people of all ages. Concerted efforts to translate these research tools into practicable bedside assessments constitute a clinical and ethical imperative and should be a focus of future work. Emerging technologies can be envisioned that may help remedy these conditions and affirm the rights of the child to autonomy and self-determination. Seen from this perspective, the present findings set a major challenge to improve the standard of care for children and adolescents with severe brain injuries to bring the international evidence base and practice recommendations in line with those emerging for adults.4

Supplement -- http://links.lww.com/CPJ/A333

References


Figure legends

**Figure 1: Structural and metabolic integrity:** Left panels A–F: 16-year-old male S1 (TBI at age 9). Right panels G–L: 18-year-old male S2 (anoxic brain injury at age 13) Panels A, C and E for S1 and Panels G, I and K for S2 show axial, coronal, and sagittal fused PET/CT windowed at 0–9 SUV for S1 and 0–13 SUV for S2; Panels B, D, and F for S1 and Panels H, J, and L for S2 show the corresponding T1 MPRAGE MRI.
**Figure 2. Command-following using EEG and fMRI:** EEG scalp topographies of spectral power differences during attempted hand movement in the alpha (8 - 12Hz) frequency band. EEG results are show from S1’s session 3 (panels A, B, C, D) and S2’s session 2 (F, G, H, I): colored scalp maps display average difference in log spectral power between attempted movement and baseline at rest. Grayscale maps represent the p-value of a two-group test performed separately at each electrode position. “Overall” p-value is from a one-sided permutation test of a statistic reflecting contralateral desynchronization (reduction in EEG spectral power) and ipsilateral synchronization (increase in power). Panels (E) and (J) show bilateral fMRI responses in BA6 to the command “Move your left arm” (highlighting activation in the right hemisphere in the leftmost panel) for the second of S1’s two sessions and S2’s single session, respectively: colors indicate significant t-statistics.
Figure 3: EEG correlates of auditory stimulus processing. The log noise-corrected magnitudes of the auditory evoked potential (AEP, panel A) and P300 event-related potential (panel B) are shown for S1 and S2 in comparison with 11 other pediatric subjects with brain injury. Subjects are split into four groups according to whether they were in a disorder of consciousness (DoC) or had emerged from DoC into confusional state (CS), and whether they had positive or negative EEG findings in motor-command-following (MCF-EEG + or − ).
Figure 4: Time-locked EEG correlates of semantic processing: from a single representative session with S1 (panel A) and another with S2 (panel B), event-related potentials from electrode position Cz are shown time-locked to the onset of the last word in a sentence, which is either semantically congruent (blue) or incongruent (orange) with the preceding sentence context. Time points at which there was a statistically significant difference (p<0.05) between conditions are indicated with a black line and asterisks.