



## **Transverse temporal gyrus radio**

Skip Nav Destination PDF Split View Section content Figures & map; tables Video Audio Supplemental Data To explain speech-evoking response patterns within auditory responsive cortex of the posterolateral superior temporal (PLST) gyrus, time-frequency analyses of event-related band power in the high gamma-frequency range (75–175 Hz) were performed on the electrocorticizers recorded of high-density subdural grid electrodes in 8 patients undergoing evaluation for medically intractable epilepsy. Stimuli were 6 stop consonant-vowel (CV) syllables that ranged in their consonant place of articulation (POA) and voice start-up time (VOT). Initial supplementation was maximal across multiple centimetres of PLST, bothered about 400 ms, and was often followed by oppression and a local outward expansion of activation. Maximal gamma power overlapped either the Nα or Pβ deflections of the average evoked potential (AEP). Correlations were observed between the relative range of gamma tape responses evoked by uneducated stop CV syllables (/da/, /ka////) and their corresponding pronounced stopping CV syllables (/ba/,/ga/,/da/), as well as by the STEM of the stimuli. VOT is also represented in the temporary patterns of the AEP. These findings, obtained in the passive wacky state, suggest that PLST discriminates acoustic features associated with POA and STEM and serves as a measure on which task-related speech processing. Studies of a possible hierarchy of cyphrotonic fields involved in speech perception are generally modeled after the organization of auditory fields observed in nonhuma primates (Cheai and Bacet 2000, 2005; Hacket 2000, 2006), and various exhibition selectivity toward a sound source in space (Rauschecker and Tian 2000; Z000; Bact 2000; Hacket 2000, 2007, 2008). This organisation envisages a hierarchical scheme of interconnected nuclear, belt fields usplay tonotopian organizations that parallel to those of adjacent core fi

homologies between auditory cortical fields in the monkey and those in humans (Galaburda and 1980; Rivier in Clarke 1997; Hackett 2003, 2007, 2008; Et al. 2002; Sweet et al. 2005; Fullerton and Pandya 2007; Hackett 2007). Previous human intracranial studies of our laboratory and others have identified an acoustically responsive area on posterastrale superior temporal gyrus (STG) that we refer to as the posterolateral superior temporal auditory field, or PLST (Howard et al. 2000). Field PLST responds to both simple and complex sounds, including speech, with robust average evoked potential (AEPs), the latter further modulated by audiovisual interactions (Celesia 1976, Crone et al. 2003; Reale et al. 2007; Besle et al. 2008; Chang et al. 2008; Chang et al. 2010). Functional neuroimaging studies have shown activation of a region of the STG that overlaps with electrophysiologically identified PLST. As found in electrophysiological studies of PLST, functional magnetic resonance imaging (fMRI) results show activity that arises here is evocated by language-related stimuli, as well as by a wide range of speech and nonspeech sounds (Binder et al. 2000; Hall et al. 2002; Scott and Johnsrude 2003; Hart et al. 2004; Uppenkamp et al. 2006). As a rule, however, more complex sounds, such as FM or amplitude-modulated (AM) tones, syllables, or words produce greater activation of this area than simpler sounds such as noise bars or pure colors, Results from imaging studies led investigators to conclude that this region on the STG represents an intermediate stage in the neural networks that sustain speech perception (Scott and Johnsrude 2003); Liebenthal et al. 2005; Uppenkamp et al. 2006; Poeppel et al. 2008). If this turns out to be the case, then it is not at all clear whether this area should be considered an auditory belt or parabelt field in the current hierarchical model and whether it should be considered an area that later originated in human evolution (Hackett 2003, 2007). Regardless of any homology PLST can share with nonhuman primates, its functional organization remains poorly understood. Based on maps of SEA's obtained through click stimulation, it was earlier suggested that PLST may not be functionally homodeous (Howard et al. 2000). Neuroimaging studies have not yet identified functional organizational patterns in this area, possibly due to limits of spatial resolution imposed by this methodology. This paper addresses guestions related to the role of PLST in processing fundamental features of speech sounds, using simple consonant vowel (CV) syllables presented in a passive listening paradigm. In these experiments, we recorded time-frequency analysis of event-related band power (ERBP) in the electrocortic cost gram (ECoG) directly from the cortex, which is identifying induced changes in the which, unlike the AEP, is not phase-closed to the stimulus. Using this approach, it has been shown to elicke sound prominent prominently in the high gamma frequency range (>75 Hz) of the ECoG recorded in both Heschl's gyrus (HG, Bruges et al. 2009; Nourski et al. 2009 general, activity in the gamma frequency tape showed important functions in sensory perception reflected (Herrmann et al. 2007; Jensen et al. 2007). Moreover, augmented strength in the gamma frequency range correlates both with fMRI results and with neuronal firing patterns (Mukamel et al. 2005; Niessing et al. 2005; Ray, Crone, et al. 2008; Privman et al. 2007). Finally, gamma enlargement recorded near lamina 1 showed that a sensitive and reliable index of the A1 tonotopic organization as defined by multiunit activity recorded in lower lamina 3 in the wacky monkey be (Steinschneider et al. 2008). The latter finding suggests that organizational patterns of gamma activation recorded above the pyal surface in the human brain may also be a meaningful reflection of unit activity organization located in the subyar cortical depths. Taken together, the above considerations suggest that time-frequency analysis of the ECoG may provide valuable insights into the organization of PLST, since it relates to speech perception. The objectives of this paper are to 1) define the temporary and spatial dynamics of syllable-evoking activity against spatial resolutions higher than those previously used in similar studies (eq. Crone et al. 2001; Edwards et al. 2009, 2010) in order to better understand basic characteristics of PLST that promote the neural representation of 2 of the most fundamental phonetic parameters of speech; stops consonant place of articulation (POA) and voice start-up time (VOT). Results from this study will therefore help explain the neural network of language using ERBP (see Canolty et al. 2007; Edwards et al. 2010). More subjects (4 women) between the ages of 20 and 56 vears participated in this study. Each patient was evaluated for potential surgical disorder of medically intractable epilepsy. All research protocols were approved by the University of Iowa Human Subjects Review Board prior to their initiation, and all patients gave informed consent before their participation. Subjects can revoke consent at any time during the research procedures without interrupting their medical evaluation. Research surveys did not disrupt the concurrent acquisition of clinically required data, and the patients did not incur any additional risks through their study participation. Subjects remained on a flucturing regimen of anticonvulsant drugs after the of their neurologist. Each subjects, including L145, which had a moderate sensorineural hearing deficiency at frequencies of & gt;3 kHz. However, all subjects, including L145, exhibited normal speech discrimination counts. Additional subject demographics are presented in Table 1. Clinical evaluations indicated that neither HG nor PLST seizure of foci was in any patient. Hemisphere of Survey and Subject ID Age and Sex Handedness Wada (language domination) Verbal IO Full scale IQ R139 53 F Left Right 76 77 R142 33 F Right Left 80 82 L145 56 F Right Left 91 95 L146 29 F Right Left 89 247 29 M Left 105 100 R149 22 M Left Bilateral 82 75 R175 20 M Right Left Unavailable 111 L178 47 M Right left 103 96 Stimuli Six stop CV lettering was presented (/ba/, /ga/, /pa/, /ta/, and /ka/). These syllables were previously used, so facilitate comparisons of evoke neural activity in auditory-responsive areas on the lateral temporary lobe with those in HG (Steinschneider et al. 1999) and monkey primary auditory cortex (A1) (Steinschneider et al. 1995, Steinschneider and Fishman 2010). Syllables were built on the parallel branch of a KLSYN88a speech synthesizer (Klatt DH and Klatt LC 1990), contained 4 formators (F1 to F4), and were 175 ms expensive (Fig. 1). Fundamental frequency began at 120 Hz, falling linearly to 80 Hz. Steady-state formant frequencies were 700, 1200, 2500, and 3600 Hz. Commencement frequencies for F2 and F3 of /ba/were 800 and 2000 Hz/ga/ga Formant transitions for F2 and F3 were 40 ms expensive. All syllables had the same F1, which had a start-up frequency of 200 Hz and a 30 ms form overpass, and F4, which did not contain a formant transition. So, /ga/have the same F2 as /da/and same F3 as/ba/. A 5-me period of friction thrilling F2-F4 preceded the commencement of voting. Amplitude of frication was increased by 18 dB at the start of F2 for /ba/ (800 Hz) and /ga/ (1600 Hz) and F3 for /da/ (3000 Hz). Spectral structure was such that /ba/en/da/did diffuse onset spectra max at either low or high frequencies, while/ga/had a more compact onset spectrum maximal at intermediate values. These patterns were suggested to be important for discrimination from stopping consonants ranging in their POA (b/vs. /vs. /vs. /g/) (Stevens and Blumstein 1978). The uneducated CV syllables (/dad/, /ta/, and /ka/) were identical to their pronounced counterparts (/ba/, /da/, and /ga/) except for an increase in the TUNING from 5 to 40 ms. For the uneducated CV syllables, the next 35 ms contained aspirational noise. Syllables were accurately identified during informal presentations to various members of the laboratories at Albert Einstein College of Medicine and University of Iowa and are available on request. Open in new tabDownload slideSinthic syllables listed in the present Amplitudes of the higher shapers are emphasised in the figure. On average, the steady-state portions of F1 were 8.5 dB harder than F2, with further waste of 3.4 and 4.8 dB between higher shapers. See text for additional details, Survey methods Clinically targeted arrays of platinum-iridium disc electrode contacts embedded in a silicon membrane are implanted on the pyal surface to place over the temporary lobe (Howard et al. 2000; Reale et al. 2007). Electrode contacts were 1.6 mm in diameter and had an inter-contact spacing of 5 mm. The grid arrays are centered across more posterior temporary regions and coverage typically included the better, middle, and portions of the inferior temporary gyri, with additional expansion being variably included segments of parietal, central, and frontal brain areas. Lattice arrays contain 96 (12 × 8) electrodes in 7 subjects and 64 (8 × 8) in another. Additional subdural arrays and depth electrodes were also implanted as clinical needs dictated. Depth electrodes are also implanted in the ipsilateral HG of the 4 subjects with the right hemisphere arrays. These hybrid depth electrodes (Howard et al. 1996) had 4 platinum perimeter macrocontacts, 0.5 mm long and spaced 10 mm apart, with closer spaced microcontaxes between them. Recordings from the depth electrodes are beyond the scope of this paper. Pre- and postimplantation MRI scans were performed in all subjects (Siemens TIM Trio 3 T with 12 channel head array coil). Structural MRI volumes were created from T1weighted images (coronal scans, 256 × 256 matrix with 1-mm cutting thickness, 0.78 × 0.78 × 1.0 mm in-aircraft resolution with 2 image set average) using Analyze software (version 9, Analy Directze). High resolution intraoperative photos were used to identify grid contact locations relative to coarse anatomical landmarks on the hemispheric surface. Electrode contact positions were then manually depicted at corresponding cortical locations have been identified on the postimplantation MRI and pictured on the preoperative image set using a manual anatomical template that matches technique (Bruges et al. 2008, 2009). Experimental recording sessions begin a few days after surgical implantation. Data acquisition was carried out in electrophysiological survey suites in the University of Iowa General Clinical Research Center. Subjects were awake, sitting either comfortable in their hospital bed or in a nearby chair. However, their attention statements are not strictly controlled during this survey paradigm. Thus, sounds have been presented with the subjects awake, but not actively paying attention to the stimuli, and intermittent covered attention cannot be excluded. The ECoG was simultaneously obtained from all electrodes against sampling rate of 2034.5 Hz and and a band pass of 1.6–1000 Hz using a TDT RX5 or RZ2 processor (Tucker-Davis Technologies). The survey reference was a platinum disc electrode contact of an additional lattice array located on the underview of the ipsilateral anterior temporary lobe or in contacts were relatively inactive relative to the arrays encountering the lateral temporary lobe. Syllables were rendered binaural by calibrated insert headphones (ER4B; Excertive Research), which is integrated into tailored earforms. Healthy intensity levels were selected individually by each subject to allow for comfortable listening and easy discrimination of the syllables. These intensities were ~50 dB above hearing thresholds. All 6 syllables were presented with equal probability in random order in the same survey blocks with an interstimulus-onset interval of 2 s in 6 subjects. In subjects L178 and R175 the voices (/ba/, /ga/, and /da/) and unfactureed (/dad/, /ka/, /ta/) CV syllables were presented in consecutive survey blocks. Typically, each stimulus was offered 50 times. Data analysis ECoG data was analyzed in the time domain by calculating the ERBP. ERBP analysis of individual stimulus trials in the survey blocks was carried out within the range of 10-250 Hz in 5 Hz inkrements using a wavelet transformation based on complex Morlet wavelets (Oya et al. 2002). The wavelet constant ratio is defined as 2πf0σ = 9, where f0 is the center frequency of the wavelet and σ is its standard deviation in frequency. ERBP was calculated on a trial-to-trial basis as a ratio relative to median baseline strength within the same 5 Hz frequency band measured between 100 and 200 ms before stimulus onset. Edge effects (contribution of energy from artifacts caused by the window of recording epochs to the poststimulus onset interval used to estimate baseline power) were inept for the range of center frequencies corresponding to high gamma frequency bands. Individual trials with waveform peaks/troughs greater than 2.5 standard deviations from the average of the 50 stimulus presentations have been rejected from analysis to reduce pollution through electric artifacts, epileptic spikes or paroxysmal high amplitude slow-wave activity. The lead author examined the results of the rejection calculations to further reduce the possibility that abnormal activity polluted the surveys and to ensure that this rejection value did not lead to the discarding of high amplitude signals that are time-lock for stimulus presentations. Average ERBP is calculated in 200 ms non-overlapping containers starting at stimulus onset and expanding 1 s, and 50 ms non-overlapping containers start at stimulus onset and the expansion 300 ms. Both time scales are thought to be important for analyzing (eg. Boemio et al. 2005; Poeppel et al. 2008). The rationale for using 200 ms containers is also based on 1) examining gamma activity at a time frame that would provide a broad overview of syllable-evoking activity and be more compatible with the temporary resolution of fMRI, 2) examining gamma activity in a time frame a response latency on PLST > 25 ms). The rationale for investigating gamma activity at the higher temporary resolution of 50 ms containers is also based on 1) preliminary analysis showing that no significant activity occurred within the first 50 ms after stimulus onset, and thus the first time bin effectively isolated this latency of response period, and 2) this window of integration is relevant to the distinction of activity based on consonant POA as defined by multi-activity in the monkey and AS's in the human (Obleser et al. 2006; Tavabi et al. 2007; Steinschneider and Fishman 2010; see also Chang et al. 2010 that used a 40 ms window). Average ERBP was first calculated for the 5 Hz wide frequency bands. After that, changes were averaged together to produce 3 bands: 75–90, 95–115 and 125–175 Hz. The purpose of binding the 5 Hz frequency bands in larger tyres (e.g. 75–90 Hz) was to reduce the overdescription that the highest frequencies (e.g. 125-175 Hz) would have than the 5 Hz bands simply concocted. The strength in each of these 3 bands at each electrode contact in the grid arrays is calculated in each of the time containers and averaged together for each stimulus and for each topic. The resulting values were then analyzed to determine whether they differed significantly from baseline using t-tests corrected for various comparisons by the false discovery method of Benjamini and Hochberg (1995) (see also Boatman-Reich et al. 2010). Following this analysis, the responses to all syllables are on average together to calculate an average syllable-evoked response to each electrode contact. All non-essential changes have been treated as zeros in the below average across all syllables. Lower gamma frequencies (30–70 Hz) were excluded from reducing contributions from faster frequency components in the AEP. Furthermore, a comparison analysis that included 30-45 and 50-70 Hz tyres was carried out in the same manner to determine whether the inclusion of only high gamma activity led to more robust response changes. A paed-down t-test comparing the 30-175 Hz Series (5 bands) versus the 75-175 Hz Series (3 bands) revealed the restrictive 75-175 Hz Series evoked greater reactions when he examined ERBP within the first investigation. 2007. ms timekeeper(t727 = 10.86, P&It; 0.0001). Additional methodological details will be presented in the Results where appropriate to reduce redundancy. Results Syllables Elicit Large Amplitude Responses from Places on PLST Large amplitude AEPs and ERBP were recorded from several electrode contacts located on PLST of both hemispheres and in all subjects (for one data set, see Supplemental Figs. 1). These responses are exonerated by the AEPs and ERBP of an electrode contact located on PLST in subject L146 in response to the stimulus/dad/(Fig. 2A). The AEP shown in Figure 2B is characterised by a polyphasic waveform with an initial positive deflection with a peak around 50 ms (Pα), a large negative deflection around 160 ms (Nα) followed by a large positive wave with peak latency around 235 ms (see Howard et al. 2000). ERBP derived from the same ECoG activity represented in the AEP is shown in Figure 2C. Pronounced power increases spanning range are evoked. Maximal force is centered in the high gamma bands and extends upwards to analyze the highest frequencies. Opens in new tabDownload slideExample from AEP and ERBP logged from a site on PLST in topic L146 in response to the syllable/pa/. (A) Electrode grille on top of image of the left hemisphere. The electrode contact from which the sample data is logged is shown in red. (B) AEP evokes by /dad/. The initial positive wave peaks at 50 ms and is followed by large negative and positive deflections that peak at 167 and 235 ms. (C) ERBP evoke by/dad/, respectively. Maximal power increases are centered in the high gamma bands. Distribution of initial activation Too much temporary cortex Significant gamma activation within the first 200 ms after stimulus onset extends together much of PLST. Data from each of the 8 subjects are shown in Figures 3 and 4 for left and right hemisphere grids, respectively. Color coding is based on the ratio of average ERBP for all 6 syllables within the first 200 ms after stimulus onset compared to baseline, expressed in dB. Filled circles represented survey sites where increases in gamma activity were significantly larger than baseline for at least one syllable. Color represents the scope of the power change. Larger filled circles indicate that significant differences occurred for all 6 syllables; smaller-filled circles indicate that significant differences occurred for less than 6. Open circles depict websites at which gamma activity failed to achieve meaning thresholds. Dysfunctional electrode contacts are designated by an x on the grid. Sites showing greater increases in strength, and those exhibiting significant increases to all 6 syllables, are largely limited to posterior STG, while lower amplitude increases and sites where not all significant increases are not evoked, often observed across adjacent cortices Open in new tabDownload sliderBP at high gamma frequencies evoked by the average response to the 6 syllables in the 4 subjects with left hemisphere electrode grilles. Responses are measured from 0 to 200 ms after stimulus onset and represent the relationship between the ERBP during this period and baseline. Larger colored circles represent electrode sites where all 6 syllables evoke responses significantly larger than baseline. Smaller colored circles represent websites where at least one syllable has elicated a significantly larger than baseline. response. Dysfunctional electrodes are marked with an x. The largest increases in ERBP are limited to circular regions of PLST. Electrode spacing is 5 mm. SF indicates the Sylvian fissures. Open in new tabDownload slider PDP at high gamma frequencies evoked by the average response to the 6 syllables in the 4 subjects with real hemisphere electrode grids. Conventions for the illustration are the same as for Figure 3. Temporary Dynamics of Gamma Activity Many electrode sites display high-amplitude gamma activity during the first 200 ms after syllable onset continue to do so during the 200- to 400-ms time interval. This pattern may have been extended further for sounds longer than the 175 ms syllables, but this speculation will require future scrutiny using sounds of varying duration. After the initial period of activation, most sites that maximal gamma activity show a made-out decision of activity that often falls below prestimulus baseline levels, usually starting in the 400-600 ms time interval. While the specific time values of increases and decreases in ERBP have flucilated across subjects, this basic pattern has been observed for all subjects. The change from supplementation to suppression of the gamma activity is illustrated in Figure 5, which depicts the overall grid patterns of high gamma power on average across all 6 syllables of 0 to 600 ms for subjects L145 (A-C) and R142 (D-F). For both subjects, power increases that are maximal in the first 200 ms are reduced over time. On many websites, power in the 400- to 600-ms time interval falls significantly below baseline levels. This effect was most pronounced on the 2 sites in each subject that had maximum excitement during the first 200 ms (arrows). Open in new tabDownload slideTemporal patterns of gamma activity of 0 to 600 ms respectively for subjects L145 (A-C) and R142 (D-F) are shown in the left and right columns. Electrode contacts showing maximal activity significantly below baseline levels by the 400- to 600-ms time interval (arrows). Examined at 50-ms intervals, average ERBP is generally maximally between 100 and 200 ms. Maximal power changes take place between 100 and 150 ms in 2 subjects, and 200 250 ms in 1 subject. Compared to the temporary profile of AEP, this ERBP maxima overlaps either the last half of the large initial negative deflection (Na) or the front half of the following positivity (PB). These patterns are illustrated in Figure 6. Open in new tabDownload slideTemporal dynamics of ERBP plotted at 50-ms intervals (0-300 ms) posted on the APUs with the largest initial negative component (NB) recorded from each topic. AEP amplitudes are indicated on the left y ace, while the right y-ace image the ERBP averages across all grid electrode sites and all 6 syllables. Vertical dotted lines demarcaated the six 50-ms intervals. Large AEP components are marked in the upper left-hand chart according to previously used conventions (Howard et al., 2000). See text for details. Figure 6 depicts the AEP on average across all syllables from -100 to 500 ms poststimulus commencement for each subject. The SEPs selected for illustration represent the waveform for each subject exhibiting the largest initial negative deflection (Na). The AEP for subject R142 also displays short-story deflects evoked by the offset of the stimuli. Plotted with the AEPs are the average ERBS across the entire grids in 50-ms intervals of 0 to 300 ms (filled circles). This time intervals are characterized by the vertical dotted lines in the figure Almost without exception, there are no significant force changes evoked by the syllables within the first 50 ms after stimulus onset. Maximal ERBP always overlaps with either the fall phase of Na or the rising phase of PB. There is also a trend for the peak latency of the ERBP to parallel the abandonment of the AEP. Therefore, the 2 subjects (R142, R149) with the shortest abandonment spicies in the ERBP also have one of the shortest Nephonic deflections of all the subjects. In contrast, the subject (L178) with the longest abandonment peak in the ERBP has the longest abandonment Na deflection for all the subjects. Intermediate relationships are observed for the other 5 subjects. Spatial Dynamics of Gamma activity The time-floor gamma activation along PLST is not uniform, as there is an outward expansion of gamma enlargement from areas of initial activation to areas both anterior and posterior along the gyrus. Commonly, regions of maximal activation begin shortly after stimulus onset are replaced later in time by maximal activity is illustrated in Figures 7 and 8. Figure 7 depicts the course of activity in 50-ms intervals for 2 subjects. For L145, initial activation begins in central regions of PLST (A) and over time spreads in both anterior and posterior directions showing strong initial activation include those that arrows. Over time, there is a sequential spatial redistribution of ERBP so that at the 250- to 300-ms interval, those locations that display initial power increases show noticeably degraded power, while surrounding areas contain significant increases in strength. For R175, strong initial activation includes a website located across more posterior portions of PLST (D). Over several hundred milliseconds, this activation lapses to a point where no syllable eludes significant increases in ERBP. Instead, areas anterior together PLST become the main sources of local activation. Additional patterns of spatial dynamics of activity within PLST are shown in Supplementary Figure 2. Open in new tabDownload slideSpatial dynamics of ERBP plotted at 50-ms interval in the 3 periods, noted in the digit for subjects L145 (left column). For L145, there is a spatial movement of maximal activity from the center of PLST to regions more anterior and posterior along the gyrus (arrows). For R175, the electrode site shows maximal activity during the 50- to 100-ms time interval no longer shows significant activity at 250–300 ms (arrow), as opposed to surrounding sites more anterior and posterior next to PLST. Open in new tabDownload slideSpatial dynamics of ERBP plotted at a high temporary resolution for subjects L145, L178, and R175. Selected electrode grids. Power wave shapes for these electrodes are shown in the middle and right columns. Waveforms represent the average (± error) for the ERBP evoked by all 6 syllables. See text for details. These dynamic changes are further illustrated against finer temporary resolution for selected electrode channels (Fig. 8). The left-hand column (A-C) depicts electrode grids listing PLST from 3 subjects, with selected sites identified by color-coded letters. On the right are ERBP waveforms derived from activity on these sites on average across all 6 syllables. For L145 (A) activation was initially maximized on websites c and d, while those electrodes spanning 5 mm increments have anterior (b and a) and posterior (e and f) along the grid of c and d progressively longer startup lettenches and more pronounced activity at later periods. Similar patterns are seen for L178 (B). Here, websites d (anterior) and f (posterior) have nearly identical start-up letches and time courses and each represents the 2 sites with the largest early activation in the 50- to 100-ms time interval. Sites along PLST lake anterior to have later start-ups, even if on-site activity is b larger than that on-site d. Later responses are observed at electrodes e (more anterior) and g (more posterior) relative to f, even if weather site e with a later startup has greater ERBP increases. Comparable spatial patterns are observed for topic (C). Representation of Consonant POA To this point, focus is on common patterns of gamma activity on average across responses to all 6 CV syllables. This analysis, analysis, investigates whether speech-evoked activity is systematically modulated by the phonetic parameters of the consonants. To further investigate this problem, we analyzed whether the relative extent of ERBP systematically flucilated as a function of the POA of the CV syllables. Analyses were conducted separately for the time intervals of 50–100, 100–150 and 150–200 ms. The interval of 0-50 ms was excluded based on minimal high gamma responses to PLST during this time (Fig. 6). Later intervals were ruled out because it was reasoned that POA differences should occur early in the responses and later activity would likely reflect the general vowel shared by all syllables (Steinschneider and Fishman 2010). Electrode sites are included in the analyses if they contain significant reactions to at least 4 of the speech sounds in the specified time intervals. This criterion has reduced the inclusion of false positive data (eq. only one stimulus evoked a significant response), limited, but did not exclude inclusion from websites not located on PLST (Supplemental Figs. 3). ensuring that at least one significant response from both the voices (/b/, / g/, / d / ) and unfacacted (/p/, /k/, /t/) consonants were included. The analysis began by ranking on each brain website, studying the extent of ERBP evoked by the 3 pronounced CV syllables (/ba/, /ga/, and /da/). The resulting rank order is a reflection of the selectivity of a given brain site to acoustic features associated with POA; the 3 stimuli with a common VOICE. The created rank order pattern was then used to elicit the relative amplitudes of the gamma responses by their corresponding unfurling resume syllables predicted (/dad/, /ka/, and/ta/). If only one pronounced CV syllable evoked a significant response, the predicted position on that site was performed using the 3 unfurling resume syllables and then compared to the responses evoked by the pronounced CV syllables. It was reasoned that if the range of gamma tape responses ranged as a function of POA, independent of VOT, then the POA-based rank ordered answers should be the comparable for the pronounced and unchetched stimulus sets. Cumulative statistical analyses (Friedman test) of the resulting rank orders were carried out across all survey sites that reached the above inclusion criterion. A significant correlation was found between the POA-based rankings of the responses to predicted and observed CV syllables that are limited to the 100- to 150-ms time interval (N=174, degrees of freedom = 2, Friedman statistics = 16.64, P = 0.0002). Results are shown in Figure 9. Post hoc tests (Dunn multiple comparison test) revealed that rank 3 was larger than both ranks 2 and 1 (P&It; 0.01). In contrast, the same test for the 50–100 ms (N = 72, Friedman statistics = 0.27) and 150–200 ms (N= 209, Friedman statistics = 2.42) time intervals did not yield significant For the 100- to 150-ms time interval, correct predictions for the greatest responses occurred on 44% of the brain sites examined (76/174, random ratio 33%, unilateral Fisher's Exact Test P = 0.03). The most accurate predictions occurred when /ba/ or /dad/gave the biggest response (28/52, 54%). Predictions were correct when /da/ or /ta/ evoked the largest response to 42% of the brain sites examined (30/72), while the least accurate predictions occurred when /ga/or /ka/ the largest response (18/50, 36%). evoked. The latter result is likely based on the acoustic ambiguity of the synthetically constructed/ga/en/ka/, which common second former transitions with /ba/and/dad/shared. Open in new tabDownload slideRank sequence of gamma activity between 100 and 150 ms poststimulus commencement for the votes (VOT = 5 ms; /ba/. /ga/. and /da/) CV syllables partially predict the ranking of gamma activity in the same time interval for the unfurled resumes that have the same POA (VOT = 40 ms; /dad /. /ka/en/ta/). Rankings are on the 174 sites that contain at least 4 significant responses to the syllables, and thus guarantee that at least one significant response will occur for the pronounced and uneducated syllables. A significant correlation between the POA-based rankings of the responses to the pronounced and unhumid resume syllables has been observed, thus indicating that PLST has an organization that respects, to some extent, the POA of stopping consonants. See text for details. Significant correlations were also observed when comparisons between differences in responses evoked by /ba/en/da/(/ba/-da/) correlated with those simultaneously obtained between /dad/en/(dad/-/-ta/; Pearson correlation coefficient r = 0.1795, P &It; 0.02). These syllables have the most spectral clear POA profiles used in this study, with /ba/and/dad/dominated by lower frequencies at stimulus onset while/da/en/dominated by higher frequencies. In addition, differences between responses evoke by /ga/en/da/correlated with those simultaneously obtained between /ka/en/ta/ (Pearson correlation coefficient r = 0.1572, P&It; 0.04). The correlation between responses evoked by /ba/en/ga/with those obtained for/dad/and/ka/was not significant. Collectively, these findings show that the relative extent of gamma-band reactions within PLST are modulated as a function of acoustic stimulus functions associated with stopconsonant POA in the time interval of 100-150 ms after stimulus onset. However, because these analyses are on pooled data the results cannot be used to identify possible topographic patterns of PLST from which survey Acquired. Further work is clearly needed to identify whether topographic patterns exist within PLST, to compare reactions between dominant and non-predominant hemispheres, and to related speech-evoked activity with those obtained from simpler stimuli (e.g., pure, AM and FM-tone). Representation of VOT Previous studies have shown that VOT is partially represented by temporary patterns of activity within posteramedial HG, a region corresponding to core auditor's cortex (Steinschneider et al. 1999). Syllables with short VOTs evoke AEPs with a distinctive triphasic morphology, while syllables with long VOT additional components contain timelocked to tune out onset. Furthermore, this change in response morphology based on syllable VOT is more prominently observed in more anterolateral portions of the posteromedial HG (Steinschneider et al. 1999, 2005). Similar patterns in the AEP recorded of HG have been observed in the current study. but a full description of this data is beyond the scope of this paper. Shown, however, representative EPe was obtained from PLST in 2 subjects (R139, R149) on average about reactions to pronounced (blue) and unfacted (red) syllables (Fig. 10). AEP morphology is modulated by the VOT of the syllables. There are prominent shifts in the latencies of all, but the initial peaks in the waveforms (evoked by stimulus onset) evoke by the uneducated CV syllables. These shifts are always to later timepoints and approach the 40 ms VOT of these syllables. New waveform deflects are introduced that approach the extended STEM value. These VOT-modulated profile types are observed to a different extent in all 6 subjects, although there has been a tendency for recordings of the right hemisphere to demonstrate the effect to a greater extent than from the left. Additional subjects will be required to further characterize this observation. In new tabDownload slideSEPs recorded from PLST, opens by syllable STEM modified. AEPs evoke by the average reactions to the pronounced CV syllables (/ba/, da/, and /ga/) are shown in blue, while the superimposed AEPs evoke by the average responses to the uneducated resume syllables (/dad/, /ta/, and /ka/) are shown in red. Anatomical places where AEPs were recorded for subject R139 and R149 are shown on the right side of each AEP make up 40 µV deflection (negative up-going). See text for details. In addition to a temporary representation of VOT in PLST, there are also reliable differences in the range of ERBP that are evoked by pronounced versus unfacted resumes. These findings are shown in Figure 11, which depicts the difference in amplitude of gamma activity from 100 to 150 ms / ba / and /pa / (same POA) different VOT) compared to differences for /da/en/ta/ (filled black circles, solid black regression line) and /ga/en/ka/(open grey grey line) at all lattice electrode sites that had significant reactions to at least 4 of the 6 syllables. These sites are the same as those used for the analysis of POA previously described. For both VOT-based comparisons, there is a statistically significant relationship between the gamma responses evoked by the pronounced versus unfurling resume syllables. Pearson correlation coefficients compare (/ba/ - / pa/) with (/da/ - / ta/) and (/ga/ - / ka/) are both 0.79 (P&It; 0.0001). Linear regression lines also differ significantly from zero for the 2 comparisons (F1,172 = 294.3, P &It; 0.0001, respectively). Correlations identified in the 100- to 150-ms time interval continued in the 150- to 200-ms time interval. Pearson correlation coefficients that compare (/ba/ - / pa/) with (/da/ - / ta/) and (/ga/ - / ka/) are 0.68 and 0.69 (P &It; 0.0001) respectively. In contrast, correlations in the 50- to 100-ms time interval were not statistically significant. Open in new tabDownload slideRelifiable differences in the range of gamma tape responses evoked by being pronounced versus unfacted resumes are observed on PLST. The difference in amplitude of gamma activity from 100 to 150 ms for /ba/en/pa/ (same POA, different STEM) are plotted against the differences for /da/en/(filled black circles, solid regression line) and /ga/en/ka/(open grey square, shattered regression line) at all 174 lattice electrode sites that showed at least 4 significant responses to the syllables (same as for Fig. 9). For both VOT-based comparisons, there is a statistically significant relationship between the gamma responses evoked by the pronounced versus unfurling resume syllables. See text for details. The absence of a correlation for VOT in the 50- to 100-ms interval does not mean that this stimulus parameter did not modulate speech-evoke gamma activity during this period, as many electrode sites failed to achieve the measure for inclusion in the analysis (i.e. significant reactions of less than 4 CVs). When comparing the summarized amplitudes of gamma activity across all grid electrode sites for each topic between the 3 unfactured syllables and normalizing the responses to a percentage of the total force across all syllables in this period, there was a 2-feed increase in strength for pronounced versus the uneducated syllables (0.67 vs. 0.33, appropriate t-test t7 = 7.301, P = 0.0002). This ratio decreased during the 100- to 150-ms interval to 0.56 for the pronounced syllables and 0.44 for the uneducated syllables (pampered t-test t7 = 7.301, P = 0.0002). 1.312, P = 0.23) and leveled during the 150- to 200-ms fall (0.50). Booking Summary of This study identifies 4 characteristics of changes in high gamma frequency strength evoked by CV syllables as recorded from subdural lattice electrodes placed across auditory area PLST. 1) Initial activation in gamma frequency range is maximal across several centimetres of field PLST. Power is generally maximal between 100 and 200 ms after stimulus onset and overlaps the last half of the Na and leads half the PB deflections of the AEP. Gamma activation lasts ~400 ms and is often followed by suppression below baseline levels. 2) There is an outward expansion in both anterior and posterior directions within PLST from a region of initial activation along HG on the lateral STG. 3) Correlations exist between the relative sizes of gamma tape responses evoked by unfacted stopping CV syllables and their corresponding stopping CV syllables. 4) VOT has both a temporary and an amplitude representation in PLST, as observed in differences in AEP waveforms and relative sizes of gamma tape responses. The latter findings suggest that PLST responses are modulated by acoustic speech features associated with the phonetic features of POA and VOT. Distribution and timing of initial activation Too much lateral cortex Numerous studies have shown that speech soundly evokes short-latency high-frequency gamma reactions from the posterior region of the STG (e.g., Crone et al. 2001, 2006; Canolty et al. 2007; Edwards et al. 2009, 2010). The spatial resolution of the lattice electrodes used in the current study may provide a more detailed estimate of this activation. While partially dependent on grid placement, maximal arousal, as defined by significant responses to all 6 syllables throughout most of the sounds' duration, ranges from 2.5 to 4.5 cm along PLST, and less arousal can occur across the entire width of the grid (5.5 cm). Maximal excitement tends to embrace the contents of PLST, indicating the relative specification of the response. Because noticeably different patterns can occur between adjacent sites (e.g. in amplitude, time course, and stimulus sensitivity), a spatial resolution for high gamma ERBP of about 0.5 cm (spacing of electrodes) can be estimated. Maximal activation occurs between 100 and 200 ms after stimulus onset, with responses significantly greater than baseline starting at about 50 ms. Concordant values were previously reported (Crone et al. 2001; Edwards et al. 2005, 2010; Canolty et al. 2007). While the extended duration of gamma enlargement (~400 me) was also reported (Crone et al. 2001; Edwards et al. 2005, 2010; Towle et al. 2008), these studies did not observe gamma suppression after arousal. The reason for the difference may reflect the passive paradigm used in the current study. In primate models of gamma activity in the auditory and visual cortices, gamma activation is associated with increases in single and multiunit unit fire (Friedman-Hill et al. 2000; Frien et al. 2002; Steinschneider et al. 2008). Therefore, it's reasonable to adopt taking suppression of gamma activity tends to be associated with, at the very least, a relative net absence of increased neuronal firings if not outright inhibition. Thus, current findings suggest that after PLST is activated for several hundred milliseconds, it is followed by a relative suppression of activity in the passive waking state. As a rule, maximal gamma enlargement overlaps the latter half of the Nα and front half of the Pβ components of the AEP (Crone et al. 2001; Edwards et al. 2005). However, both of these studies concluded that the dominant generators of the AEP recorded from PLST were from tangible sources located on HG and the better temporal aircraft, based on the inversion of AEP components among the Sylvian fissures. Smaller contributions from local radially oriented sources on the lateral surface were also suggested as generators of the AEPs imultaneously with gamma activity from PLST. While a detailed discussion of the AEPs recorded of PLST is beyond the scope of this paper, polarity of the peaks in the AEP recorded under the Sylvian fissures and to lie pIST (e.g. ~100 to 150 ms for the large amplitude Na component, see Figs 6 and 10) is not reversed in polarity from those recorded from the dorsolateral scalp and therefore are not consistent with a dipole source located on the supratemporal aircraft (Scherg et al. 1989; Liégeois-Chauvel et al. 1994; Yvert et al. 2005). Instead, these responses are likely dominated by locally produced field potential and are consistent with lateral generators described as the T complex (e.g. Celesia 1976; Näätänen and Picton 1987; Knight et al. 1988; Cacace et al. 1990). The usefulness of a unified gamma measure (i.e. average ERBP change from baseline on the ECoG frequencies of 75–175 Hz) for the examination of auditory cortical processing is emphasised by the specificity of the response that occurs within the first 200 ms after stimulus startup. Maximal activity is limited to a limited region of several centimeters centered within PLST. At the moment, it is unclear, belt and parabelt regions of auditory cortex defined in the old world monkey and that in humans (Cheese and Hackett 2000: Rauschecker and Tian 2000: Hackett et al. 2001: Hackett 2003, 2007). The presence of 1) very short-release activation of PLST through electrical stimulation of posteromedial HG, 2) short-latency major amplitude AEPs (Howard et al. 2000: Bruges et al. 2003: Reale et al. 2007; Sinai et al. 2009; Chang et al. 2010), 3) short-latency gamma activity (Crone et al. 2001; Edwards et al. 2008; Sinai et 2009) evokes through both speech- and nonspeech sounds in this region, and 4) syllable-evoked activity that seems to reflect stimulus acoustics (e.g., stimulus VOT VOT In the AEP) instead of higher order speech-related functions strongly suggest that this auditory area is located early in the putative human auditory cortex hierarchical processing stream. Although PLST has been placed several centimetres away from core cortect of medial HG, some of these properties look characteristic of belt cortect, at least as physiologically defined in the monkey model. In a previously reported fMRI study, investigators observed patterns of auditory evoking responses to speech and nonspeech stimuli within PLST that led them to conclude that it was an intermediate area that was likely functioned as a belt region of auditory cortex (Uppenkamp et al. 2006). Additional research is clearly needed to clarify this issue. Despite its proposed intermediate role, PLST appears to be crucial to speech perception. There is a high specificity between electrode sites on PLST that elicits large amplitude gamma responses through syllables or words and disruption of speech perception through electrical stimulation, with anterior language regions (eq. Broca's area, Matsumoto et al. 2004). Stimulation of websites on PLST that have had functional connections to anterior language areas can also deliver speech arrests. Finally, the potential importance of PLST for speech perception is extruded by its response sensitivity to syllables ranging in consonant POA and VOT. The presence of high-frequency gaming mounts should not be interpreted as a demonstration that all the tyres are generated by similar physiological processes. Multiple generators have been proposed for induced gamma activity not incorporated directly into the high-frequency phase-closed components of the AEP. These include local circuit interactions between and between pyramidic cells and inhibitory interneurons, all mediated through both synoptic activity and electrical coupling (e.g. Metherate and Cruikshank 1999; LeBeau et al. 2003; Cunningham et al. 2004; Traub et al. 2005; Fries et al. 2007). Therefore, our measure of gamma responses should be considered not an index of one specific neuronal process, but as a reliable and sensitive indicator of local cortical activity. Finally, subjects in these and all studies that involve placement of intracranial electrodes have brain dysfunction. Some

patients with temporary lobe epilepsy have language dysfunction, and there is evidence of reorganization of the neural networks that subdivide speech perception in this environment (eq. Boatman and Miglioretti 2005; Thivard et al. 2007; Powell et al. 2007). Thus, caution should be exercised when extrapolating findings to subjects without Dysfunction. In general, intracranial studies examine auditory and language functions incorporating data from a number of subjects and from non-optimal electrode placements determined exclusively on clinical soils. Atypical results of even a single subject can therefore skew statistical analyses and data interpretation. Given this scenario, it is beneficial for each new study to replicate and expand past observations. Replication provides reassurance that experimental findings are reliable indices of normal cortical function. The concrete between these and previous studies on the fundamental observations of timing and spatial distribution of gamma activity that enthrals the lateral STG indicates their reliability despite variations in subjects, research paradigms and methods of ECoG analysis and supports the validity of the additional results that make up the rest of this report. Outward extension of activation along PLST Timing of gamma activity is not uniform next to the PLST. Gamma supplementation takes place first in a circular region of PLST and is followed by supplementation at both adjacent sites on PLST and in both anterior and posterior directions along the STG. While successive activation of gamma activation has been shown during active word processing of PLST to regions outside the STG (Canolty et al 2000; Edwards et al, 2010), these earlier and less pronounced dynamics were not previously reported. It is tempting to suggest that this progression of activation over time represents the initial stages of an outward expansion of intracortic sound processing along the temporary lobe in adjacent auditory cortical fields that can be observed even in the passive waking state. Similar long-range anterior and posterior extensions have been observed in functional neuroimaging studies that explore cortical activation as the intelligentness of speech improves (e.g., etc. Scott et al. 2006). The currently described outward expansion of activation is credible based on anatomically defined cortical connections between adjacent auditory fields in the primacy (e.g. Cheese and Hackett 2000, Jones 2003). However, this activation pattern may also partially represent parallel inputs from subcortical areas or other non-simplified cortical areas (e.g., auditory core). In support of the latter proposal, data combination fMRI, Granger causality mapping, and anatomical pathway analysis using diffusion tensor probabilistic mapping showed 2 pathways that built on from primary auditory cortex to both more anterior and posterior regions on the STG (Upadhyay et al. 2008). Further research incorporates several methodologies, including channel detection using electrical stimulation (eg. Bruges et al. 2003; Matsumoto et al. 2004; Greenlee et al. 2007) will likely be required to resolve this issue. of Consonant POA Gamma responses are modulated by consonant POA. There is a statistically significant relationship in the from gamma enlargement 100-150 ms after stimulus onset between responses evoked by pronounced CV syllables (/ba/, /da/, and/ga/) and their unfactured counterparts (/dad/, /ta/, and /ka/), as a function of POA. So one can predict, for example, that if the response to a given electrode site to the pronounced bilabial stop CV syllable/ba/is greater if/ga/or/da/, then a similar relationship will hold when examining the relative amplitudes of responses to the unfuncted stops (that is, /dad/will elicit the greatest response). Furthermore, correlations exist between the relative differences in amplitudes for /ba/versus/da/and their unfuncted counterparts/pa/en/ta/in the same timeframe. An additional correlation between the relative differences in amplitudes for /ga/versus/da/ and their unfactured counterparts/ka/en/ta/ was observed. These findings complement the first intracranial electrophysiological demonstration of an organization of human auditory cortex modulated by the phonetic parameter of stopconsonant POA (Chang et al. 2010). In that study, the authors identified distinct patterns of SEPs recorded across the posterior lateral surface of the STG in passive listening subjects showing the phonetic differences between the pronounced CV syllables/ba/, /ga/, and /da/. Here we show supplemental ERBP data demonstrating correlations with respect to POA despite variation in the voice parameter of the stopconsonants. Modulation of gamma activity in the 100- to 150-ms period is consistent with both the work of Chang et al. (2010) and previous non-invasive studies investigating the representation of POA in auditory cortex. Chang et al. (2010) found that the 110- to 150-ms period in the AEP allowed the most accurate discrimination among stopping consonants. Numerous studies support the importance of early neural activity within a few hundred milliseconds bilaterally localized to HG, the planum temporal and PLST for extracting phonetic information from acoustic properties (for reviews, see Obleser and Eisner 2008; Poeppel et al. 2008). Different dipole source localizations for the center of gravity of activity for the magnetic evoke responses P50m and N100m are present for syllables ranging in their consonant POA (Obleser et al. 2007). While magnetic reactions are relatively insensitive to ginal crested patterns of activity and will therefore be relatively unreliable in detecting changes in neural activity on PLST, their timing suggests that information related to consonant POA should be available in the PLST by a rate code of neural activity. Temporarily discrete rate codes for neural activity are evoked by syllable onset of discriminatory responses evoked by stopping consonants ranging in their POA in A1 from wacky monkeys and dipped rats (Steinschneider et al. 1995; Engineer et al. 2008: Steinschneider and Fishman 2010). These discriminations are based on the differential spectral content of the syllables at the beginning and the underlying tonoopic organization. The basis of this relationship is parsimonic with the hypothesis that within the first 20 ms of consonant onset (release) the short-term spectrum is a major determinant of the perception of stop consonant POA (Stevens and Blumstein 1978; Blumstein and Stevens 1979, 1980; Chang and Blumstein 1981). Overall, this scheme is consistent with findings that vocalizations are represented, at least in A1, by the spectrotemporal discharge pattern of spatially distributed neuron populations determined by the field's tonotopic organization (e.g., tonotopic organization). Wang et al. 1995). While it is attractive to suggest that the selectivity of gamma enlargement in PLST to syllables ranging in their consonant POA is based on some underlying spectral organization, other explanations are possible. This includes a phonetically-based organization (eg. Chang et al. 2010) or one determined by complex acoustic features such as sensitivity to FM that track formantoorgange. However, auditory cortex on HG is organized tonotically (Howard et al. 1996; Formisano et al. 2003; Bitterman et al. 2008), and it would be reasonable to suggest that information transfer from human core auditory regions is modulated by this organization. This idea is supported by the tonotopic organizations of belt regions observed in monkeys (Morel et al. 1993; Kosaki et al. 1997; Rauschecker and Tian 2000, 2004). Further support is provided by fMRI evidence that this region distinguishes syllables ranging along consonant POA based on the spectral content provided at consonant onset (Obleser et al. 2007). It is clear that detailed investigations of underlying organizational schemes based on acoustic or higher order characteristics and their possible relationships with speech-specific activity are required in the PLST (e.g., see Liebenthal et al. 2005). Finally, it is of note that differentiation of gamma activity respectfully consonant POA has been obtained using a simple position metric based on activity from websites where at least 4 of the 6 syllables evoke responses significantly larger than baseline (see also Steinschneider and Fishman 2010 for a similar approach in monkey A1). It is likely that incorporating additional sites into the analysis or examining response patterns generated across the entire electroderode grids may have improved response differentiation. The latter paradigm is successful by Chang et al. (2010) and in an fMRI study that used more-variable pattern analysis to classify, and later predicted, answers specifically for or speaker identity (Formisano et al. 2008). Interestingly, the authors determined that spectral qualities of the first 2 formators were pivotal to vowel diversitation, while the fundamental frequency of the speech sounds was important in classifying speakers. These findings further highlight the need to examine PLST for underlying organizations based on spectral, AM and FM sensibilities. Furthermore, response differences occurred despite the use of highly stylized, and minimalist syllables whose spectral content and VOT were highly overlapping. All syllables shared the same first and again formataries, /ga/en/ka/have the same second formant transitions as /da/en/ta/and shared the same third formant transitions as/ba/en/dad, and VOTs were constantly held at either 5 or 40 ms instead of modulated according to consonant POA. It is likely that more realistic syllables with additional differences in their spectral and temporary characteristics will have improved response diversitation among the sounds. Representation of the VOT speech parameter has been widely studied in A1 of animal models, intracranial surveys in HG, and human noninvasive surveys (eg. Eggermont 1995; Schreiner 1998; Simos et al. 1998; Liégeois-Chauvel et al. 1999; Steinschneider et al. 1999, 2003, 2005; Sharma and Dorman 2000; Eggermont and Ponton 2002; Trébuchon-Da Fonseca et al. 2005; Engineer et al. 2008). Animal and human intracranial studies in HG have clearly shown that when the VOT differs sufficiently from 0 me, there are 2 temporarily discrete responses time-closed for consonant release and voice onset. More detailed analysis of SEPs recorded from the posterior-medial half of HG shows that there is not a single temporary pattern for short and lengthy VOTs (Steinschneider et al. 1999, 2005). Instead, there's a flucturing pattern with more posterior-medial sites require a shorter VOT to exhibit the same temporary response. It has been suggested that this variation is based on the interaction between the spectrotemporal characteristics of the syllables and the proposed tonoopic gradient in HG and that the average pattern on auditory core will better approach the perceptual boundary (Steinschneider et al. 2005). Electrodes on PLST display single-on and double-on patterns similar to those seen in HG, indicating that VOT can be represented by a temporary code in this auditory area. It remains for further investigation of whether this temporary code can predict perceptual boundaries and whether it merely represents the temporary envelope of the sounds. In a similar vein, it also remains for further investigation of whether this pattern is more prominent over-dominant (e.g. (e.g. Et al. 1999; Trébuchon-Da Fonseca et al. 2005). Although survey sites illustrated in Figure 10 were in the right hemisphere for both subjects, subject R139 was the right hemisphere dominant and subject R149 had bilateral language representation (Table 1). While temporary representations are available at the level of PLST to distinguish pronounced from unfactured stop consonants, evidence in accordance with a rate code has also been observed. When, for example, the gamma response in the intervals from 100 to 150 and 150 to 200 ms was greater for /ba/than/dad/, a similar relationship was seen for the reaction differences between /da/en/en/ga/en/ka/. Thus, there seems to be parallel representation, manifested in gamma response amplitude, of both the POA and VOT speech parameters. Again, while it's tempting to speculate that these representations are based on phonetic categories, explanations based on more fundamental sound features are possible. For the VOT parameter, it can be based on differential sensitivity of the survey sites to spectrate content. The uneducated stop consonants contain a greater proportion of higher frequencies embedded in the aspirational noise, which is reduced in the syllables with a STEM of 5 ms. Similar observations were seen in monkey A1 at higher-best frequency sites (Steinschneider et al. 2003). Additional Considerations Results were obtained under passive listening conditions. Attention to sound liquidates scalp-recorded AEPs in the early stages of auditory cortical processing, as evidenced by response improvements starting at the level of mid late latency components and expanding to the later N1 and P2 waves (Woldorff and Hillvard 1991: Woldorff et al. 1993: Woods et al. 1994; Neelon et al. 2006; Sabri et al. 2006). Gamma enlargement is selectively improved in the auditory and somatosensory cortices when subjects perform simple discriminatory tasks (Ray, Niebur, et al. 2008). Future studies will therefore be expected to determine the extent to which speech-evoked ERBP changes reflecting stimulusPOA and VOT are modulated when subjects perform language-related tasks. Funding National Institutes of Health: National Institute of Deafness and other Communication Disorders (R-01-DC04290 to M.H., R-01-DC00657 to M.S.); General Clinical Research Centers Program (MO1-RR-59 to M.H.); Hoover Fund; Carver Trust. The authors thank Dr Richard A. 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