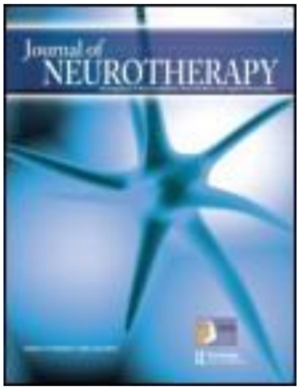

Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

# Practical Joking and Cingulate Cortex: A Standardized Low-Resolution Electromagnetic Tomography (sLORETA) Investigation of Practical Joking in the Cerebral Volume

Rex Cannon MA [a] , Joel Lubar PhD [b] , Jennifer G. Clements MS [a] , Ellen Harvey MA [a] & Debora Baldwin PhD [b]

[a] Experimental Psychology Program , University of Tennessee , Knoxville

[b] Psychology Department , University of Tennessee , Knoxville

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# Practical Joking and Cingulate Cortex: A Standardized Low-Resolution Electromagnetic Tomography (sLORETA) Investigation of Practical Joking in the Cerebral Volume

Rex Cannon, MA
Joel Lubar, PhD
Jennifer G. Clements, MS
Ellen Harvey, MA
Debora Baldwin, PhD

**ABSTRACT.** *Background*. This study investigated differences between brain regions during the evaluation of self-attitude toward practical joking and the evaluation of practical jokes utilizing standardized low-resolution electromagnetic tomography (sLORETA).

*Method*. Four male and 8 female nonclinical university students ($M$ age = 22.6 years) completed a Likert scale evaluating their perception of pranking behavior (LK) and rated pranks as good or bad (HE) while undergoing electroencephalographic (EEG) recording. The subjective scale and evaluation responses were recorded within the EEG record, extracted, and compared for significance.

*Results*. The sLORETA comparisons show significant differences between the judgments about practical jokes (LK) and the evaluation of practical jokes in written form (HE). The evaluation of practical joking appears to increase activation in the anterior and posterior cingulate gyrus. Both conditions show significant difference as compared to eyes-opened baseline.

*Conclusions*. The evaluative processes appear to involve posterior cingulate cortex, and decisions relating to self-attitudes toward practical joking may be more associated with the executive portions of anterior cingulate cortex. There is plausible long range communication between these regions during the process of evaluating self-attitudes toward practical jokes and making decisions about the "good or bad" qualities of practical jokes. Both conditions elicit activity in the left hemisphere; however, the LK condition shows maximum increase at BA 30, which implicates it in attentional, cognitive, and executive processes, including the reference to self. This posterior cingulate activation possibly integrates memory and evaluative processes related to the decision making element associated with the rating task.

Rex Cannon is Graduate Student, Experimental Psychology Program, University of Tennessee, Knoxville.
Joel Lubar is Professor Emeritus, Psychology Department, University of Tennessee, Knoxville.
Jennifer G. Clements is Graduate Student, Experimental Psychology Program, University of Tennessee, Knoxville.
Ellen Harvey is Graduate Student, Experimental Psychology Program, University of Tennessee, Knoxville.
Debora Baldwin is Associate Professor, Psychology Department, University of Tennessee, Knoxville.
Address correspondence to: Rex Cannon, MA, Developmental Cognitive Neuroscience Laboratory, Department of Psychology, University of Tennessee, Knoxville, TN 37996 (E-mail: rcannon2@utk.edu).

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**KEYWORDS.** Anterior cingulate, humor, neurophysiology, posterior cingulate, quantitative EEG, sLORETA

## *INTRODUCTION*

Humor is suggested to be an important, idiosyncratic facet of the human condition. Francois Truffaut (2005) suggests "when humor can be made to alternate with melancholy, one has a success, but when the same things are funny and melancholic at the same time, it's just wonderful." There are many defining characteristics of humanity; however, humor is one of the few phenomena that involve both the subjective and social selves. Comprehension of humor is suggested to involve equivalent faculties as social communication and social processing (Brown, Paul, Symington, & Dietrich, 2005). Functional magnetic resonance imaging (fMRI) investigations of brain regions implicated in humor have increased in the past few years, and many of these studies utilize methods in which the participants rate cartoons; television clips; or written words, jokes, and humorous stories. Much of the research report similar results, with increased activation of the left temporo-occipital junction, left inferior frontal gyrus, supplementary motor area (BA 6), and a subcortical network involving the ventral striatum, nucleus accumbens, and other hypothalamic and amygdaloid regions (Berns, 2004; Mobbs, Greicius, Abdel-Azim, Menon, & Reiss, 2003; Moran, Wig, Adams, Janata, & Kelley, 2003). Damage to the right frontal cortex (aphasics) negatively influences performance on nonverbal cartoon completion tasks as compared to left frontal damage; more specifically, the authors report a diminished capacity to establish clarity without impairment to the sensitivity and appreciation of the surprise element (Bihrle, Brownell, Powelson, & Gardner, 1986). Similarly, event-related brain potentials research reports that joke comprehension deficits are associated with damage to the anterior portion of the right frontal cortex (Coulson & Kutas, 2001). Social comprehension involves interconnected, bilateral networks, and persons with agenesis in the corpus callosum performed less efficiently than controls in evaluation of narrative joke forms, narrative memory, set-switching, and use of literal language (Brown et al., 2005). It is maintained that humor contains both cognitive and affective elements and that these processes elicit activity in the left hemisphere relating to clarity and integration of information, whereas the right hemisphere is reportedly active in the emotional aspects associated with the surprise element of humor (Moran et al., 2004).

A practical joke or prank is typically a situation set up to fabricate what the perpetrator imagines to be a humorous physical outcome at the expense of another person. Practical jokes are dissimilar from telling jokes or slapstick comedy in that these types of events produce the physical manifestation that the events are miscalculated, inept, or accidental. "Practical" refers to the fact that the joke consists of performing an action, rather than a play on words or a story, and this definition suggests that pranking behavior involves brain regions reported in research to be involved in numerous cognitive and affective processes, including but not limited to comprehension of the event and situation, social interpretation and perception, planning, forecasting results, language use and interpretation, social awareness and appropriateness, empathetic awareness, responsibility and cognitive competence to conceptualize abstract ideas, the appreciation of the humor in such external or internal events, motivation, memory, emotion, and reward processing (Bihrle et al., 1986; Bush, Luu, & Posner, 2000; Cabeza & Nyberg, 2000; Cannon, Lubar, Thornton, Wilson, & Congedo, 2004; Devinsky, Morrell, & Vogt, 1995; Farrant et al., 2005; Fazio et al., 1992; Feingold & Mazzella, 1991; Smith, Stephan, Rugg, & Doland, 2006). Moreover, it is posited that anterior cingulate cortex (AC) can be differentiated from posterior cingulate cortex on the basis of cytoarchitecture, patterns of projections, and differentiation of function. The AC is suggested to be instrumental in executive functions, whereas the posterior region is suggested to be implicated more in evaluative processes (Bush et al., 2000).

Although research involving humor has extended to identifying its potential to reduce the perception of pain, enhance affective states and possible advantageous effects on neuroendocrine and cardiac functioning (Gage, Akil, & Price, 2001) much of the available research has focused on written jokes, cartoons, or humorous stories but not on physical humor such as pranks. Thus, our study sought to establish if the subjective perception involved in the evaluation of pranks would activate the same regions as other types of humor and to examine the involvement of cingulate gyrus and prefrontal regions and possible neurophysiological differences between making decisions about the appropriateness of pranks and rating pranks as good or bad.

## METHOD

### Participants

This study was conducted with 12 participants, 4 male and 8 female nonclinical students with a mean age of 22.67 (range = 18–32, $SD = 3.7$). Eleven of the participants were right handed, and 1 was left handed. All participants read, agreed to, and signed an informed consent to protocol approved by the University of Tennessee Institutional Review Board. Participants received extra course credit for participating in this study. Exclusionary criteria for participation included previous head trauma, history of seizures, recent drug or alcohol use, and any previous psychiatric diagnosis.

### Procedures

Participants were prepared for EEG recording using a measure of the distance between the nasion and inion to determine the appropriate cap size for recording (Blom & Anneveldt, 1982). The ears and forehead were cleaned for recording with a mild abrasive gel to remove any oil and dirt from the skin. After fitting the caps (Electro-Cap International, Inc., Easton, OH), each electrode site was injected with electrogel and prepared so that impedances between individual electrodes and each ear were $< 6$ KΩ. The data were collected using the 19-leads standard international 10/20 system (FP1, FP2, F3, F4, Fz, F7, F8, C3, C4, Cz, T3, T4, T5, T6, P3 (T7), P4 (T8), Pz, O1, and O2) with a band pass set at 0.5–64.0 Hz at a rate of 256 samples per second. All recordings were carried out in a comfortably lit, sound attenuated room in the Neuropsychology and Brain Research Laboratory at the University of Tennessee, Knoxville. Lighting and temperature were held constant for the duration of the experiment. Each experimental session required 60 min to complete and consisted of three conditions; first, we obtained 3-min eyes-closed and eyes-opened baselines for comparison; second, the participants underwent EEG recording while completing eight questions containing a five-option Likert scale (LK condition) evaluating their perception of the appropriateness of pranking, from *strongly disagree* to *strongly agree;* then the participants rated eight examples of practical jokes as good or bad (HE condition; see Table 1), we allowed 1 min of resting between presentations. For all items the stimuli were presented using Microsoft PowerPoint software with time for each slide presentation at 8 sec. The participant responses for both conditions were marked within the EEG record. We compare both conditions to the eyes-opened baselines and then compare the two conditions. The data were collected and analyzed using the following frequency bands: delta (1.0–3.5 Hz), theta (3.5–7.5 Hz), alpha (7.5–12.50), beta 1 (12.50–22.00), beta 2 (22.00–32.00). Participants also provided a written record of the Likert scale and rating results as well as their thought processes during the evaluation condition.

### Data Preprocessing

All EEG data were processed with particular attention given to the frontal and

TABLE 1. Examples from Likert scale and pranks evaluated by participants as good or bad.

| |
|---|
| There are times when I like to pull pranks on other people. |
| • A. Strongly disagree |
| • B. Disagree |
| • C. Neutral |
| • D. Agree |
| • E. Strongly agree |
| I enjoy thinking up plans for pranks |
| • A. Strongly disagree |
| • B. Disagree |
| • C. Neutral |
| • D. Agree |
| • E. Strongly agree |
| Coat the receiver of someone's phone with shoe polish and then give them a call. Instant gratification. Make sure you match the colors of the polish and the phone. Small amounts of shaving cream work too. |
| Place clear cellophane over the toilet bowl but under the seat. Works best at parties where a large percentage of the people are drunk. |

temporal leads. We selected the 4 sec on both sides of the response markers giving consideration to all episodic eye blinks, eye movements, teeth clenching, jaw tension, body movements, and possible electrocardiogram (EKG) and removed them from the EEG stream. Fourier cross-spectral matrices were computed and averaged over 75% overlapping 4-sec artifact-free epochs, which resulted in one cross-spectral matrix for each participant and for each discrete frequency. We utilized routine procedures used with standardized low-resolution electromagnetic tomography (sLORETA) to reduce anatomical and localization errors due to interindividual differences in anatomy, head geometry, and electrode placement (Congedo, 2006; Congedo, Lubar, & Joffe, 2004; Petersson, Nichols, Poline, & Holmes, 1999).

### *Voxel by Voxel Comparisons*

To assess the electrophysiological differences between experimental conditions over the entire neo-cortex, we conducted all voxel-by-voxel $t$ tests setting the threshold to abs $(t) = 4.0$ utilizing a multiple hypothesis testing procedure for the within-subjects experimental design (NovatechEEG), which adopts multiple comparisons procedures based on the t-max test using the step-down version of the procedure with 5,000 random data permutations (Blair & Karniski, 1994; Holmes, Blair, Watson, & Ford, 1996, Westfall & Young, 1993). Current density for total relative power was extracted. The statistical analysis was conducted using the Multiple Hypothesis Testing (MhyT3!) software (Nova Tech EEG, Inc., Mesa, AZ). The statistical differences within conditions were corrected for all multiple comparisons using nonparametric analysis. All data were normalized, log transformed, and smoothed with a 21 mm moving average filter (MAF 3-D) before entering statistical analysis. The specific contrast between conditions was entered into one sample $t$ test corresponding to a corrected $p < .01$. All voxels were examined and statistical data were transformed into LORETA images. We compared both the LK and HE conditions to an eyes-opened baseline for total relative power and then compare only the LK and HE conditions for each of the aforementioned frequency domains.

### *Current Density Estimation*

sLORETA is a widespread linear, discrete, instantaneous, full-volume inverse solution for brain electromagnetic measurements (for reviews, see Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002a, 2002b). Whereas EEG is a measure of electric potential variations, sLORETA estimates the current density that results in the potential divergence on the scalp. Using realistic electrode coordinates (Towle et al., 1993) for a three-concentric-shell spherical head model coregistered on a standardized MRI atlas (Talairach, & Tournoux, 1988); for which anatomical labeling of the reconstructed neo-cortical volume is possible (Lancaster et al., 1997; Lancaster et al., 2000). We used the three-shell concentric spherical head model implementation made available from the Key Institute for Brain-Mind Research, Zurich, Switzerland. In this implementation, the current density is mapped for 2394 voxels of dimension $7 \times 7 \times 7$ mm covering the entire neocortex plus the AC and hippocampus.

## *RESULTS*

### *Condition–Baseline Comparisons*

Figure 1 shows the results for the LK condition compared to an eyes-opened baseline. The image from left to right shows horizontal slices of the brain ventral to superior with the z plane visible in the lower left corner of each window. The region of maximum increase for the LK comparison is identified at Talairach coordinates BA 30, posterior cingulate and parahippocampal gyrus. The maximum decrease is reported at Brodmann area 6 and Precentral gyrus. Figure 2 shows the results for the HE condition compared to eyes-opened baseline. The region of maximum increase is reported at BA 37 at parahippocampal gyrus and the region of maximum decrease is reported at BA 11 at middle frontal gyrus. The red in the image indicates regions of significant increase in current source density between conditions and the blue indicates regions of significant decrease in current source density between conditions.

### *Condition Voxel by Voxel Comparisons*

The data indicate that the evaluation of pranks activates numerous regions shown to be active in prior research involving humor processes (Berns, 2004; Mobbs et al., 2003; Moran et al., 2004). sLORETA restricts our discussion to gray matter;

FIGURE 1. The LK condition compared to an eyes-opened baseline.

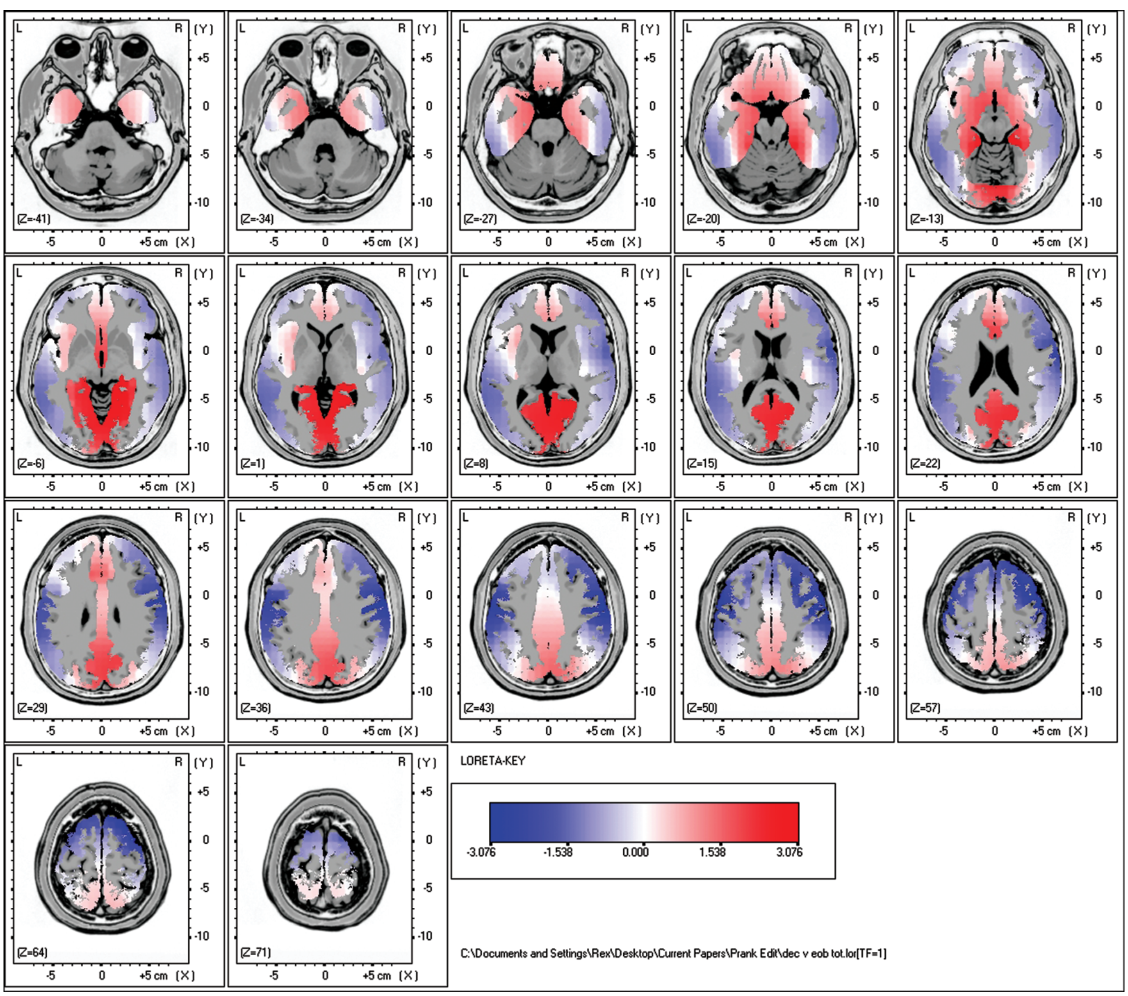
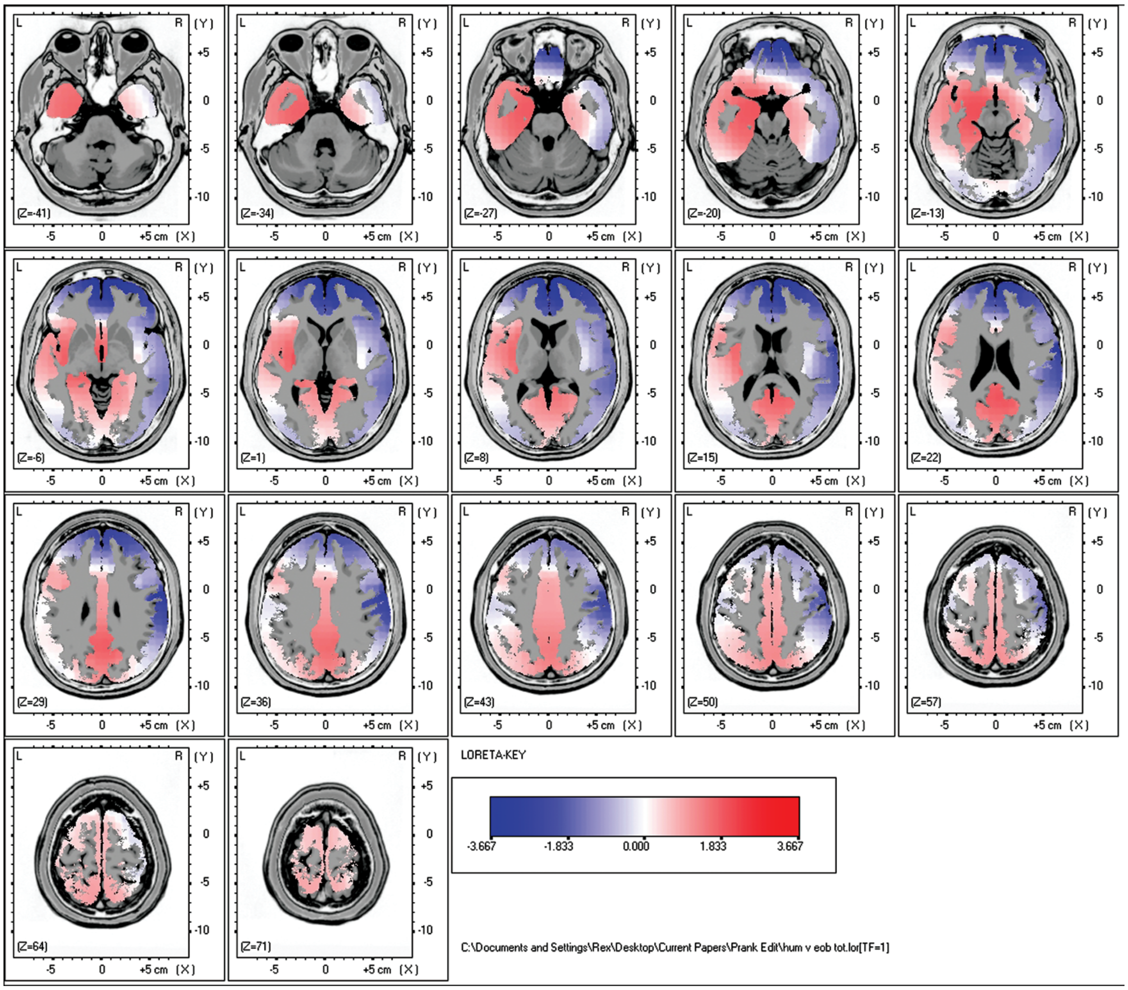


FIGURE 2. The HE condition compared to eyes-opened baseline.




however, we may infer to subcortical activation based on current knowledge of afferent and efferent connections between frontal and subcortical regions and current literature involving research on humor.

## DISCUSSION

Research involving humor and practical joking is in the most preliminary of phases, and in an unsophisticated sense, humor is proposed to consist of three focal brain components. The first component, cognition, aids in comprehension of the joke. The second component, movement, engages the facial muscles for a smile or laughter. The third component, emotion, produces the affective processes that compliment a jovial experience (Berns, 2004). Moran et al. (2004) reported changes in blood glucose metabolism using fMRI in many of the regions identified in this study during both the LK and HE conditions, especially in the temporal, parietal, and central regions of the cortex; however, one of the more difficult aspects comparing current source density derived from scalp generated EEG for particular frequency domains and other imaging methods such as fMRI or PET is that these type of studies provide information regarding the "where" of particular tasks and do not provide information as to the "what" of said tasks. In the following sections we attempt to integrate these two areas and discuss the results according to frequency domain and known regional function.

The cingulate cortex in general is suggested to have subdivisions involved in a variety of cognitive, emotional, motor, nociceptive, visceral, and visuospatial functions; the anterior portions are suggested to perform a primary role in executive processing, whereas the posterior regions are proposed to be more involved in evaluative processes. Moreover, it is accepted that the AC and lateral prefrontal cortices are involved in possible networks of attention (Cannon et al., 2007; Cannon et al., 2006) and working memory (Bush et al., 2000; Kondo et al., 2003). In the LK task as compared to baseline, the maximum current density increase for total relative power is shown at BA 30 at posterior cingulate. This region is suggested to be involved in evaluative processes (Bush et al., 2000) and attention (Overmeyer et al., 2001). The posterior cingulate and precuneus are implicated in consciousness, mental imagery, and self-reflection (Cavanna, 2007); similarly, the anterior cingulate is posited to be involved in consciousness, personality, and executive functions (Bush et al., 2000; Devinsky et al., 1995). The significant activations at anterior and posterior cingulate may represent important neural pathways facilitating interactions between anterior and posterior regions during the processing of attention, memory, self-reference, autobiographical information, and experiential knowledge (Magno & Allan, 2007).

The HE condition as compared to baseline for total relative power shows maximum increase at BA 37 at parahippocampal gyrus. This region is associated with visual processing, object recognition, and motion sensitivity (Dieterich, Bauermann, Best, Stoeter, & Schlindwein, 2007), linguistics, and spatial organization of text (Rektor, Rektorova, Mikl, Brazdil, & Krupa, 2006). The increase in this region is possibly related to encoding and retrieval processes involved in the reading, evaluation, and visual processing of information from the stimulus presentation facilitating the choice for each practical joke as good or bad. Alternatively, it may be directly related to the humor associated with the task and the processing of meaning and context. There are notable differences between the LK and HE as compared to baseline, especially in posterior central, prefrontal, and left temporal regions. Research indicates that the delta frequency is negatively correlated with both mild cognitive impairment and Alzheimer's disease (Babiloni et al., 2006) and is positively correlated with increased pain tolerance (Benedetti et al., 1999) and cognitive compensatory processes (Beste et al., 2007). The delta frequency is posited as instrumental in combination with the gamma frequency in reward motivation (Knyazev, Savostyanov, & Levin, 2005), the possible governing of cognitive processes (Basar et al., 2001), and visual encoding and retrieval processes (Osipova, Takashima et al., 2006; Osipova, Rantanen et al., 2006).

The theta frequency shows maximum increase at BA 10 in the superior frontal gyrus in the right prefrontal cortex. This region has been shown active during successful memory retrieval (Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996), acute skin and muscle pain (Svensson, Minoshima, Beydoun, Morrow, & Casey, 1997), decision-making processes (Rubinsztein et al., 2001) and reward processing (Rogers et al., 1999). Increases in theta amplitude are involved in memory processes (Burgess & Gruzelier, 2000; Canolty et al., 2006); contrarily, theta is also prominent in many dysfunctional contexts (Arns, Peters, Breteler, & Verhoeven, 2007; Chiaramonti et al., 1997), and thus the precise mechanism of theta in this analysis cannot be ascertained. However, of particular interest to this study are theta oscillations in both anterior and posterior regions that are demonstrated to be involved in memory, attention, and cognitive tasks (Klimesh, 1996; Klimesch, Doppelmayr, Russegger, Pachinger, & Schwaiger, 1998; Klimesh, Doppelmayr, Schimke, & Ripper, 1997; Klimesch, Schimke, & Schwaiger, 1994).

In the context of decision making it is reasonable to consider that prior knowledge and experience are of vital importance in the development of a decision and therefore regions in limbic and frontal areas would be expected to be active in frequencies involved in memory associated tasks. Although specific function is not indicated, the delta and theta frequencies show significant increase in both anterior and posterior cingulate regions shown in imaging studies to be active in a variety of tasks. Although the exact nature of the delta and theta frequencies in normal cognition remains unclear, further investigation of their contribution to cognition and executive processing may be of vital importance to understanding frequency specific patterns of activity in the brain.

The alpha frequency shows maximum increase in BA 8 at superior frontal gyrus in the left hemisphere. This region is anterior of the motor cortex and is shown active in fMRI experiments evaluating the management of uncertainty (Volz, Schubotz, & von Cramon, 2005) and is implicated in apathy associated with Alzheimer's disease (Apostolova et al. 2007), thus it may also be instrumental in the blending of cognitive, affect, and executive processes involved in the LK task. BA 8 and BA 9 are shown to be involved in the generation of melodies and sentences and may also be instrumental in the semantic processing and interpretation of visually presented stimuli (Brown, Martinez, & Parsons, 2006). The lower alpha frequency (7.5–10.0 Hz) is associated with attentional processes, whereas the higher alpha frequency (10–12 Hz) is more associated with working memory processes (Klimesh et al., 1998; Klimesh et al., 1997). The increase in alpha may be attributed to a blending of attention and working memory processes as the LK task required attention to details, response selection, and memory of terms and experiences for evaluative purposes. The region of significant decrease between conditions is estimated by sLORETA at the right hippocampus. This may reflect a more concentrated effort by central regions instrumental to this task rather than typical tasks involving novel information and learning (Shors & Matzel, 1997; Sinnamon, 2005; Yamaguchi, Aota, Naoyuki, Hiroaki, & Zhihua, 2004) that tend to illicit activity in this region; however, a plausible reason for this decrease as compared to the HE condition may provide insight into the hippocampal role in affective processing.

The beta 1 frequency shows maximum increase between conditions at BA 20 in the left hemisphere. This region is suggested to be involved in visual and auditory processing and recognition memory and to correlate with cognitive abilities (Johnson, Jung, Colom, & Haier, 2008). BA 20 is shown active during tasks involving auditory word processing (Zahn et al., 2000), sexual stimuli processing (Hagemann, 2002), normal sleep patterns (Mazza et al., 2006) and semantic memory (Mummery et al., 2000). The beta 2 frequency shows maximum increase at BA 40 in the right parietal region. This region is implicated in intelligence and memory (Colom, Jung, & Haier, 2007), attention (Cannon et al., 2007; Cannon et al., 2006), decision making (Deppe, Schwindt, Kugel, Plabmann, & Kenning, 2005), intention, and sensory processing (Fink et al., 1999). Similarly, the involvement of parietal regions is well known in cognition, memory, and executive functions (Fitzgibbon et al., 2008; Harris et al., 2000; Johannsen et al., 1997; Rosano et al., 2005). These higher frequencies in posterior parietal regions may be indicative of the need for faster processing in the evaluative regions for the facilitation of information to the anterior cingulate for a particular response selection.

The data illustrate the complexity and differences between evaluating the humor aspects of practical joking (HE) and self-reflective (LK) decision making relating to self-attitudes toward practical joking. The communication between anterior and posterior regions in lower frequencies is possibly attributed to neural circuitry relating to autobiographical memory, self-reflection and decision making processes because the regions showing increase in delta and theta in the medial and inferior frontal lobes are suggested to participate in prefrontal cortical networks that govern personal and social behavior, emotion, and executive decision-making processes (Bremner et al., 2003; Courchesne & Pierce, 2005); moreover, of particular interest are the increases in the higher frequencies specific to posterior regions involved in evaluation and procedural processing more so than anterior regions. This is an unexpected result as information suggests the frontal regions would be more active in higher frequencies during evaluative processes (Berns, 2004; Bihrle et al., 1986; Duncan & Owen, 2000). The data illustrate the complex relationship between anterior and posterior cingulate and the cortical intricacies of decision-making processes; moreover, as both conditions tend to activate regions in the left hemisphere this may add to the understanding of lateralization of affective processes. Humor is suggested to have beneficial effects on mood and health in general, and the data indicate that increased activity occurs in the left hemisphere, especially in the temporal and frontal regions during humor rating tasks, which is one possible reason for the positive influence of humor on both immune and central nervous system function and its projection as a central point in aspects of communication, interpersonal relationships, mood elevation, and coping with stress and trauma (Fry & Frese, 1992; McKeever & Dixon, 1981; Seifritz et al., 2003). Lubar, Congedo, and Askew (2003) reported excessive slow activity in the left prefrontal cortex of chronic depressives, which is a contrast to present findings; however, it is possible that both conditions initiate activity increase in the left dorsolateral prefrontal and temporo-parietal cortices. Similarly, our prior work explored anger memories in nonclinical participants and found activation in inferior and medial frontal cortices and limbic regions within the right hemisphere (Cannon et al., 2004). The rating of practical jokes as good or bad also produces increases in the medial right frontal regions as compared to evaluative processes; in effect this may offer insight into the clinical implications concerning differences between positive and negative emotional processing and right frontal involvement of social appropriateness and humor processing. More information is needed regarding the involvement of the left prefrontal cortex in emotion and its role in memory, rumination, pessimism, and negativism and the possibility of frequency specific functions.

Two limitations of neuroimaging based on inverse solutions as implemented in this research should be kept in mind. First, approximation of source generators are utilized based on electrical activity obtained from the scalp. Second, the spatial specificity of sLORETA with 19 electrodes utilizing 2,394 voxels is in the order of several centimeters cubed; therefore, the activity of brain regions close to the regions identified in this study could have influenced the results. The first limitation can be resolved by constructing realistic head models based on magnetic resonance imaging information. The second has been the object of a recent investigation (Congedo, 2006). One drawback to this study is a relatively small sample size; it would have been advantageous to include a coding mechanism for obtaining scores for the prank evaluation to be correlated with the identified regions in this study, and this is planned for future research. Further study of humor and the subcategories therein is necessary to begin to understand the complexities and wonders of this fundamental "human" process and the brain regions involved in deciding what is funny and appropriate.

## REFERENCES

Apostolova, L. G., Akopyan, G. G., Partiali, N., Steiner, C. A., Dutton, R. A., Hayashi, K. M., et al. (2007). Structural correlates of apathy in Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders*, *24*(2), 91–97.

Arns, M., Peters, S., Breteler, R., & Verhoeven, L. (2007). Different brain activation patterns in dyslexic children: Evidence from EEG power and coherence patterns for the double-deficit theory of dyslexia. *Journal of Integrative Neuroscience*, *6*(1), 175–190.

Babiloni, C., Frisoni, G., Steriade, M., Brescanin, L., Binetti, G., Del Percio, C., et al. (2006). Frontal white matter volume and delta EEG sources negatively correlate in awake subjects with mild cognitive impairment and Alzheimer's disease. *Clinical Neurophysiology*, *117*(5), 1113–1129.

Basar, E., Basar-Eroglu, C., Karakas, S., & Schurmann, M. (2001). Gamma, alpha, delta, and theta oscillations govern cognitive processes. *International Journal of Psychophysiology*, *39*(2–3), 241–248.

Benedetti, F., Vighetti, S., Ricco, C., Lagna, E., Bergamasco, B., Pinessi, L., et al. (1999). Pain threshold and tolerance in Alzheimer's disease. *Pain*, *80*(1–2), 377–382.

Berns, G. (2004). Something funny happened to reward. *TRENDS in Cognitive Sciences*, *8*(5), 193–194.

Beste, C., Saft, C., Yordanova, J., Andrich, J., Gold, R., Falkenstein, M., et al. (2007). Functional compensation or pathology in cortico-subcortical interactions in preclinical Huntington's disease? *Neuropsychologia*, *45*(13), 2922–2930.

Bihrle, A. M., Brownell, H. H., Powelson, J., & Gardner, H. (1986). Comprehension of humorous and nonhumorous materials by brain-damaged patients. *Brain and Cognition*, *5*, 399–411.

Blair, R. C., & Karniski, W. (1994). Distribution-free statistical analyses of surface and volumetric maps. In R. W. Thatcher, M. Hallett, E. R. John, & M. Huerta (Eds.), *Functional neuroimaging: Technical foundations* (pp. 114–118). San Diego, CA: Academic.

Blom, J. L., & Anneveldt, M. (1982). An electrode cap tested. *Electroencephalography and Clinical Neurophysiology*, *54*, 591–594.

Born, R., & Bradley, D. (2005). Structure and function of visual area MT. *Annual Review of Neuroscience, 28,* 157–189.

Bremner, J. D., Vythilingam, M., Vermetten, E., Southwick, S. M., McGlashan, T., Nazeer, A., Khan, S., Vaccarino, L. V., Soufer, R., Garg, P. K., Ng, C. K., Staib, L. H., Duncan, J. S., & Charney, D. S. (2003). MRI and PET study of deficits in hippocampal structure and function in women with childhood sexual abuse and posttraumatic stress disorder. *American Journal of Psychiatry, 160*(5), 924–932.

Brown, S., Martinez, M. J., & Parsons, L. M. (2006). Music and language side by side in the brain: a PET study of the generation of melodies and sentences. *The European Journal of Neuroscience*, *23*(10), 2791–2803.

Brown, W., Paul, L., Symington, M., & Dietrich, R. (2005). Comprehension of humor in primary agenesis of the corpus callosum. *Neuropsychologia*, *43*, 906–916.

Burgess, A. P., & Gruzelier, J. H. (2000). Short duration power changes in the EEG during recognition memory for words and faces. *Psychophysiology*, *37*(5), 596–606.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, *4*, 215–222.

Cabeza, R., & Nyberg, L. (2001). Imaging cognition II. *Journal of Cognitive Neuroscience 12*(1), 1–47.

Canolty, R. T., Edwards, E., Dalal, S. S., Soltani, M., Nagarajan, S. S., Kirsch, H. E., et al. (2006). High gamma power is phase-locked to theta oscillations in human neocortex. *Science*, *313*(5793), 1626–1628.

Cannon, R., Lubar, J., Congedo, M., Thornton, K., Hutchens, T., & Towler, K. (2007). The effects of Neurofeedback in the cognitive division of the anterior cingulate gyrus. *The International Journal of Neuroscience*, *117*(3), 337–357.

Cannon, R., Lubar, J., Gerke, A., Thornton, K., Hutchens, T., & McCammon, V. (2006). Topographical coherence and absolute power changes resulting from LORETA Neurofeedback in the anterior cingulate gyrus. *Journal of Neurotherapy*, *10*(1), 5–46.

Cannon, R., Lubar, J., Thornton, K., Wilson, S., & Congedo, M. (2004). Limbic beta activation and LORETA: Can hippocampal and related limbic activity be recorded and changes visualized in an affective memory condition? *Journal of Neurotherapy*, *8*(4), 5–24.

Cavanna, A. E. (2007). The precuneuos and consciousness. *CNS Spectrums*, *12*(7), 545–552.

Chiaramonti, R., Muscas, G. C., Paganini, M., Müller, T.J., Fallgatter, A. J., Versan, V., et al. (1997). Correlations of topographical EEG features with clinical severity in mild and moderate dementia of Alzheimer type. *Neuropsychobiology*, *36*(3), 153–158.

Colom, R., Jung, R. E., & Haier, R. J. (2007). General intelligence and memory span: Evidence for a common neuroanatomic framework. *Cognitive Neuropsychology*, *24*(8), 867–878.

Congedo, M. (2006). Subspace projection filters for real-time brain electromagnetic imaging. *IEEE Transactions on Biomedical Imaging*, *53*(8), 1624–1634.

Congedo, M., Lubar, J., & Joffe, D. (2004). Low-resolution electromagnetic tomography neurofeedback. *IEEE Trans. On Neuronal Systems and Rehabilitation Engineering*, *12*(4), 387–397.

Coulson, S., & Kutas, M. (2001). Getting it: Human event-related brain responses to jokes in good and poor comprehenders. *Neuroscience Letters*, *316*, 71–74.

Courchesne, E., & Pierce, K. (2005). Why the frontal cortex in autism might be talking only to itself: local over-connectivity but long-distance disconnection. *Current Opinion in Neurobiology*, *15*(2), 225–230.

Deppe, M., Schwindt, W., Kugel, H., Plabmann, H., & Kenning, P. (2005). Nonlinear responses within the medial prefrontal cortex reveal when specific implicit information influences economic decision making. *Journal of Neuroimaging*, *15*(2), 171–182.

Devinsky, O., Morrell, M., & Vogt, B. (1995). Review article: Contributions of anterior cingulate cortex to behaviour. *Brain*, *118*, 279–306.

Dieterich, M., Bauermann, T., Best, C., Stoeter, P., & Schlindwein, P. (2007). Evidence for cortical visual substitution of chronic bilateral vestibular failure (an fMRI study). *Brain*, *130*(Pt. 8), 2108–2116.

Duncan, J., & Owen, A. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences*, *23*(10), 475–483.

Farrant, A., Morris, R., Russell, T., Elwes, R., Akanuma, N., Alarćon, G., et al. (2005). Social cognition in frontal lobe epilepsy. *Epilepsy & Behavior*, *7*, 506–516.

Fazio, F., Perani, D., Gilardi, M. C., Colombo, F., Cappa, S. F., & Vallar, G. (1992). Metabolic impairment in human amnesia: A PET study of memory networks. *Journal of Cerebral Blood Flow and Metabolism*, *12*, 353–358.

Feingold, A., & Mazzella, R. (1991). Psychometric intelligence and verbal humor ability. *Personality and Individual Differences*, *12*(5), 427–435.

Fink, G. R., Marshall, J. C., Halligan, P. W., Firth, C. D., Driver, J., Frackowiak, R. S., et al. (1999). The neural consequences of conflict between intention and the senses. *Brain*, *122*(Pt. 3), 497–512.

Fitzgibbon, B. M., Fairhall, S. L., Kirk, I. J., Kalev-Zylinska, M., Pui, K., Dalbeth, N., et al. (2008). Functional MRI in NPSLE patients reveals increased parietal and frontal brain activation during a working memory task compared with controls. *Rheumatology*, *47*(1), 50–53.

Fry, L. J., & Frese, W. (1992). Bringing the convict back in: An ecological approach to inmate adaptions. *Journal of Criminal Justice*, *20*(4), 355–365.

Gage, F., Akil, H., & Price, D. (2001, December). *Human laughter and the brain*. Brain Briefings, Society for Neuroscience.

Hagemann, J. (2002). Effects of visual sexual stimuli and apomorphine SL on cerebral activity in men with erectile dysfunction. *European Urology*, *43*(4), 412–420.

Harris, I. M., Egan, G. F., Sonkkila, C., Tochon-Danguy, H. J., Paxinos, G., & Watson, J. D. (2000). Selective right parietal lobe activation during mental rotation: a parametric PET study. *Brain*, *123*(Pt. 1), 65–73.

Holmes, A. P., Blair, R. C., Watson, J. D. G., & Ford, I. (1996). Nonparametric analysis of statistic images from functional mapping experiments. *Journal of Cerebral Blood Flow and Metabolism*, *16*, 7–22.

Johannsen, P., Jakobsen, J., Bruhn, P., Hansen, S. B., Gee, A., Stoldkilde-Jorgensen, H., et al. (1997). Cortical sites of sustained and divided attention in normal elderly humans. *NeuroImage*, *6*(3), 145–155.

Johnson, W., Jung, R. E., Colom, R., & Haier, R. J. (2008). Cognitive abilities independent of IQ correlate with regional brain structure. *Intelligence*, *36*(1), 18.

Klimesch, W. (1996). Memory processes, brain oscillations and EEG synchronization. *International Journal of Psychophysiology*, *24*(1–2), 61–100.

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters*, *244*(2), 73–76.

Klimesch, W., Doppelmayr, M., Schimke, H., & Ripper, B. (1997). Theta synchronization and alpha desynchronization in a memory task. *Psychophysiology*, *34*(2), 169–176.

Klimesch, W., Schimke, H., & Schwaiger, J. (1994). Episodic and semantic memory: an analysis in the EEG theta and alpha band. *Electroencephalography and Clinical Neurophysiology*, *91*(6), 428–441.

Kondo, H., Morishita, M., Osaka, N., Osaka, N., Fukuyama, H., & Shibasaki, H. (2003). Functional roles of the cingulo-frontal network in performance on working memory. *NeuroImage*, *21*, 2–14.

Knyazev, G. G., Savostyanov, A. N., Levin, E. A. (2005). Uncertainty, anxiety, and brain oscillations. *Neuroscience Letters*, *387*(3), 121–125.

Kurova, N. S., & Cheremushkin, E. A. (2007). Spectral EEG characteristics during increases in the complexity of the context of cognitive activity. *Neuroscience and Behavioral Physiology*, *37*(4), 379–385.

Lancaster, J. L., Rainey, L. H., Summerlin, J. L., Freitas, C. S., Fox, P. T., Evans, A. C., et al. (1997). Automated labeling of the human brain: A preliminary report on the development and evaluation of a forward-transform method. *Human Brain Mapping*, *5*, 238–242.

Lancaster, J. L., Woldorff, M. G., Parsons, L. M., Liotti, M., Freitas, C. S., Rainey, L., et al. (2000). Automated talairach atlas labels for functional brain mapping. *Human Brain Mapping*, *10*, 120–131.

Levitin, D. J., & Menon, V. (2003). Musical structure is processed in language areas of the brain: A possible role for Brodmann Area 47 in temporal coherence. *NeuroImage*, *20*, 242–252.

Lubar, J. F., Congedo, M., & Askew, J. (2003). Low-resolution electromagnetic tomography (LORETA) of cerebral activity in chronic depressive disorder. *International Journal of Psychophysiology*, *49*, 175–185.

Magno, E., & Allan, K. (2007). Self-reference during explicit memory retrieval: an event-related potential analysis. *Psychological Science*, *18*(8), 672–677.

Mazza, S., Soucy, J. P., Gravel, P., Michaud, M., Postuma, R., Massicotte-Marquez, J., et al. (2006). Assessing whole brain perfusion changes in patients with REM sleep behavior disorder. *Neurology*, *67*(9), 1618–1622.

McKeever, W. F., & Dixon, M. S. (1981). Right-hemisphere superiority for discriminating memorized from nonmemorized faces: Affective imagery, sex, and perceived emotionality effects. *Brain and Language*, *12*(2), 246–260.

Mobbs, D., Greicius, M., Abdel-Azim, E., Menon, V., & Reiss, A. (2003). Humor modulates the mesolimbic reward centers. *Neuron*, *40*, 1041–1048.

Moran, J. M., Wig, G., Adams, R., Janata, P., & Kelley, W. (2004). Neural correlates of humor detection and appreciation. *NeuroImage*, *21*(3) 1055–1060.

Mummery, C. J., Patterson, K., Price, C. J., Ashburner, J., Frackowaik, R. S., & Hodges, M. D. (2000). A voxel-based morphometry study of semantic dementia: relationship between temporal lobe atrophy and semantic memory. *Annals of Neurology*, *47*(1), 36–45.

Naqvi, H. N., Rudrauf, D., Damasio, H., & Bechara, A. (2007). Damage to the insula disrupts addiction to cigarette smoking. *Science*, *315*(5811), 531–534.

Osipova, D., Rantanen, K., Ahveninen, J., Yillkoski, R., Happola, O., Standberg, T., et al. (2006). Source estimation of spontaneous MEG oscillations in mild cognitive impairment. *Neuroscience Letters*, *405*(1–2), 57–61.

Osipova, D., Takashima, A., Oostenveld, R., Fernandez, G., Maris, E., & Jensen, O. (2006). Theta and gamma oscillations predict encoding and retrieval of declarative memory. *The Journal of Neuroscience*, *26*(28), 7523–7531.

Overmeyer, S., Bullmore, E. T., Suckling, J., Simmons, A., Williams, S. C., Santosh, P. J., et al. (2001). Distributed grey and white matter deficits in hyperkinetic disorder: MRI evidence for anatomical abnormality in an attentional network. *Psychological Medicine*, *31*(8), 1425–1435.

Pascual-Marqui, R. D., Esslen, M., Kochi, K., & Lehmann, D. (2002a). Functional imaging with low-resolution brain electromagnetic tomography (LORETA): A review. *Methods and Findings in Experimental and Clinical Pharmacology*, *24C*, 91–95.

Pascual-Marqui, R. D., Esslen, M., Kochi, K., & Lehmann, D. (2002b). Functional imaging with low-resolution brain electromagnetic tomography (LORETA): Review, new comparisons, and new validation. *Methods and Findings in Experimental and Clinical Pharmacology*, *24*(Suppl. C), 91–95.

Petersson, K., Nichols, T., Poline, J., & Holmes, A. (1999). Statistical limitations in functional neuroimaging II. Signal detection and statistical inference. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *354*(1387), 1261–1281.

Rektor, I., Rektorova, I., Mikl, M., Brazdil, M., & Krupa, P. (2006). An event-related fMRI study of self-paced alphabetically ordered writing of single letters. *Experimental Brain Research. Experimentelle Hirnforschung. Experimentation Cerebrale*, *173*(1), 79–85.

Rogers, R. D., Owen, A. M., Middleton, H. C., Williams, E. J., Pickard, J. D., Sahakian, B. J., et al. (1999). Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *The Journal of Neuroscience*, *19*(20), 9029–9038.

Rosano, C., Aizenstein, H., Cochran, J., Saxton, J., DeKosky, S., Newman, A. B., et al. (2005). Functional neuroimaging indicators of successful executive control in the oldest old. *NeuroImage*, *28*(4), 881–889.

Rubinsztein, J. S., Fletcher, P. C., Rogers, R. D., Ho, L. W., Aigbirhio, F. I., Paykel, E. S., et al. (2001). Decision-making in mania: A PET study. *Brain*, *124*(Pt. 12), 2550–2563.

Rugg, M. D., Fletcher, P. C., Frith, C. D., Frackowiak, R. S., & Dolan, R. J. (1996). Differential activation of the prefrontal cortex in successful and unsuccessful memory retrieval. *Brain*, *119*(Pt. 6), 2073–2083.

Seifritz, E., Esposito, F., Neuhoff, J. G., Lüthi, A., Mustovic, H., Dammann, G., et al. (2003). Differential sex-independent amygdala response to infant crying and laughing in parents versus nonparents. *Biological Psychiatry*, *54*(12), 1367–1375.

Shors, T. J., & Matzel, L. D. (1997). Long-term potentiation: What's learning got to do with it? *The Behavioral and Brain Sciences*, *20*(4), 597–614.

Sinnamon, H. M. (2005). Hippocampal theta activity and behavioral sequences in a reward-directed approach locomotor task. *Hippocampus*, *15*(4), 518–534.

Smith, A. P., Stephan, K. E., Rugg, M. D., & Doland, R. J. (2006). Task and content modulate amygdala-hippocampal connectivity in emotional retrieval. *Neuron*, *49*, 631–638.

Svensson, P., Minoshima, S., Beydoun, A., Morrow, T. J., & Casey, K. L. (1997). Cerebral processing of acute skin and muscle pain in humans. *Journal of Neurophysiology*, *78*(1), 450–460.

Talairach, J., & Tournoux, P. (1988). *Co-planar stereoaxic atlas of the human brain*. New York: Theme Medical.

Towle, V. L., Bolaños, J., Suarez, D., Tan, K., Grzeszczuk, R., Levin, D. N., et al. (1993). The spatial location of EEG electrodes: Locating the best fitting sphere relative to cortical anatomy. *Electroencephalography and Clinical Neurophysiology*, *86*, 1–6.

Volz, K. G., Schubotz, R. I., & von Cramon, D. Y. (2005). Variants of uncertainty in decision-making and their neural correlates. *Brain Research Bulletin*, *67*(5), 403–412.

Westfall, P. H., & Young, S. S. (1993). *Resampling-based multiple testing. Examples and methods for p-values adjustment*. New York: Wiley & Sons.

Yamaguchi, Y., Aota, Y., Naoyuki, S., Hiroaki, W., & Zhihua, W. (2004). Synchronization of neural oscillations as a possible mechanism underlying episodic memory: A study of theta rhythm in the hippocampus. *Journal of Integrative Neuroscience*, *3*(2), 143–157.

Zahn, R., Huber, W., Drews, E., Erberich, S., Krings, Willmes, K., et al. (2000). Hemispheric lateralization at different levels of human auditory word processing: A functional magnetic resonance imaging study. *Neuroscience Letters*, *287*(3), 195–198.