Commentary on "Neural correlates of mirth and laughter: a direct electrical cortical stimulation study" by Yamao and colleagues.

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In their recent paper, Yamao and colleagues (Yamao et al., in press) report two cases of mirth during direct electrical stimulation of the basal temporal cortical surface of the left hemisphere of the brain, in patients with temporal lobe epilepsy. Here, one patient with an intact hippocampus reported mirth and exhibited laughter during stimulation, while a second patient with hippocampal sclerosis reported mirth in the absence of laughter (with the latter emerging at a delay, and only with longer and more intense stimulation). The authors argue that this is a demonstration for the dissociation of the motoric and emotional aspects of mirth, where mesial temporal lobe pathology in one patient prevented the engagement of motoric responses appropriate to the emotional experience. Moreover, the authors claim a neural commonality between language processing and mirth because the sites at which stimulation led to mirth more often also showed impairments in language task performance (compared with "no-mirth" sites).

There are several aspects of these findings that should be treated with caution. First, even though there is a precedent for temporal lobe involvement in humour processing and mirthful experiences, the current study reports only two patients and there is very little behavioural detail upon which to interpret the quality of the experience reported by these individuals. In the case of Patient 1, the EMG data show that stimulation at the key site for mirth first produced contralateral contractions of the upper lip, which then led to a bilateral smile, laughter and reported feelings of mirth. According to the facial feedback hypothesis, this finding could be interpreted as suggestive of a motor priming of an emotional experience rather than direct stimulation of the emotional state – studies using botolinum toxin (Botox) to weaken frowning movements have shown consequent impairments in behavioural and neural responses to negative emotional stimuli (Havas, Glenberg, Gutowski, Lucarelli & Davidson, 2008; Hennenlotter et al., 2009), while a study asking participants to hold a pen in the teeth (and thus forcing the mouth into a smiling position) demonstrated enhanced positive evaluations of humorous stimuli (Strack, Martin & Stepper, 1988). Another interpretation of Patient 1's experience could be a post-hoc evaluation of an unusual somatosensation generated by the contralateral lip movement, rather than a primary feeling of mirth at stimulation. Similarly, Patient 2 reported her feelings of mirth in association with hearing a particular familiar melody, which thus suggests that the experience was triggered by some sort of hallucinatory auditory sensation and not primarily by emotion itself.

Some authors such as Borchers and colleagues (Borchers, Himmelbach, Logothetis & Karnath 2012) have argued that the complexity of the summed local and remote effects of electrical cortical stimulation, coupled with a history of variable behavioural outcomes of the technique, places strong limitations on the interpretability of findings. They state that electrical stimulation "is not the gold standard with respect to causality between neuronal activity on the one hand and behaviour on the other" (p. 69). Other authors have defended these criticisms; Desmurget and colleagues (2013) offer detailed and convincing counter-arguments to claims of a lack of specificity, and highlight in particular the evidence that perioperative functional DES in brain surgery patients is highly effective in preventing post-operative behavioural disruption to specific functions (e.g. spoken language). However, they do suggest that it is important to combine DES with observations from other types of data, such as lesion and neuroimaging evidence, stating that “it should be clear that DES outcomes cannot be unambiguously interpreted in isolation” (p. 447). In the present study, given the small number of cases and the rather underspecified behavioural data (see below for more detailed discussion of this point), the reader must make quite large assumptions to accept that the effects of stimulation are directly and specifically engaging the emotional pathway to laughter production, and not, for example, more remote regions generating movement (Patient 1) or auditory hallucinations (Patient 2). The interpretation that the presence of hippocampal sclerosis in one patient offers evidence for a clear dissociation of emotional and motoric responses to mirth should be taken as speculative until this can be demonstrated in more individuals.

A major point of difficulty with this study is the inference made by the authors regarding shared neural substrates for language and mirth, where they point out that the electrodes producing mirthful experience also showed impairments on performance of language tasks. As the authors have chosen to report their language task findings elsewhere, we have very little detail to aid our understanding of the nature of the language processing deficits and how performance of these tasks might have practically interacted with the behavioural effects of mirth. However, a rather straightforward alternative hypothesis is that the effects of contralateral mouth movement (Patient 1) and auditory sensation (Patient 2) were simply effective distractors from the language tasks, where impaired task performance was more likely due to the effects of divided attention than reflective of some underlying computational commonalities between mirth and linguistic perception.

When asking a participant to report on their subjective emotional state, the experimenter must assume this response as the ground truth of that person's experience. In the current experiment, it is very difficult to say whether the onset of mirth is simultaneous with the stimulation itself or rather emerges from some later evaluation of other consequences of the stimulation. One possible avenue for further exploration of these responses could be to explore the perceptual characteristics of the facial and vocal expressions produced during early stimulation. An authentic, Duchenne smile should feature contraction of both the zygomatic major muscles of the mouth and the orbicularis oculi muscles around the eyes (Ekman, Friesen & Davidson, 1990) – approaches such as the Facial Affect Coding System (FACS) can be used to track even small movements of individual muscles in order to interpret the participant's state (Ekman, Friesen & Hager, 2002). In this study, this could be done with the initial contralateral raising of the lips in order to assess whether the movement (and any accompanying contraction elsewhere on the face) is characteristic of a natural smile or perhaps no more than an unusual somatosensory experience eliciting a later mirthful feeling in the patient. From studies of emotional expression in the voice, there is evidence for acoustic differences between authentic and posed expressions of laughter, which can be readily detected by listeners in classifying the underlying emotional state of the laughing individual and in making perceptual evaluations of qualities such as arousal and valence of the heard expressions (Bryant and Aktipis, 2014; McGettigan et al., 2013; Scott, Lavan, Chen & McGettigan, 2014). Thus, in a general sense, there are methods that could be brought to bear on the questions of 1) whether the elicited expressions are representative of particular emotional categories and 2) in the case of Patient 1, the extent to which one can infer engagement of voluntary or involuntary systems (or, to use the authors' terms, volitional and emotional) for laughter production.

In sum, Yamao and colleagues have presented two thought-provoking case studies of mirth during direct cortical stimulation of the left basal temporal lobe. They suggest that they have shown evidence for differential engagement of volitional and emotional pathways for laughter production following mirthful experience – I argue that the reported behavioural and EMG data are insufficient to support this claim, especially given potential limitations in interpreting the neural effects of stimulation from such a small patient sample. However, this work draws attention to important challenges in the study of the neural systems controlling emotional expressions, particularly in the interpretation of subjectively reported experiences. Future work should endeavor to offer more detailed characterizations of the timing and perceptual quality of facial and vocal expressions, in order to gain insights into the engagement (or not) of authentic emotional experiences by cortical stimulation.

References

Borchers, S., Himmelbach, M., Logothetis, N., Karnath, H. (2012) Direct electrical stimulation of human cortex — the gold standard for mapping brain functions? *Nature Reviews Neuroscience 13*, 63-70.

Bryant, G. A., & Aktipis, C. A. (2014). The animal nature of spontaneous human laughter. *Evolution and Human Behavior 35*, 327-335.

Desmurget, M., Song, Z., Mottolese, C., Sirigu, A. (2013) Re-establishing the merits of electrical brain stimulation. *Trends in Cognitive Sciences 17*, 442-449.

Ekman, P., Friesen, W.V., Davidson, R.J. (1990) The Duchenne Smile – Emotional expression and brain physiology II. *Journal of Personality and Social Psychology 58*, 342-353.

Ekman, P., Friesen, W. V., & Hager, J. C. (Eds.). (2002). Facial Action Coding System [E-book]. Salt Lake City, UT: Research Nexus.

Havas, D.A., Glenberg, A.M., Gutowski, K.A., Lucarelli, M.J., Davidson, R.J. (2008) Cosmetic Use of Botulinum Toxin Affects Processing of Emotional Language. *Psychological Science 21*, 895-900.

Hennenlotter A., Dresel C., Castrop F., Ceballos-Baumann A.O., Wohlschläger A.M., Haslinger B. (2009) The link between facial feedback and neural activity within central circuitries of emotion -- new insights from botulinum toxin-induced denervation of frown muscles. *Cerebral Cortex 19*, 537-542.

McGettigan, C., Walsh, E., Jessop, R., Agnew, Z.K., Sauter, D.A., Warren, J.E., Scott, S.K. (2013) Individual Differences in Laughter Perception Reveal Roles for Mentalizing and Sensorimotor Systems in the Evaluation of Emotional Authenticity. *Cerebral Cortex* doi:10.1093/cercor/bht227

Scott, S.K., Lavan, N., Chen, S., McGettigan, C. (2014) The Social Life of Laughter. *Trends in Cognitive Sciences* doi:10.1093/cercor/bht227

Strack, F., Martin, L.L., Stepper, S. (1988) Inhibiting and Facilitating Conditions of the Human Smile: A Nonobtrusive Test of the Facial Feedback Hypothesis. *Journal of Personality and Social Psychology 54*, 768–777

Yamao, Y., Matsumoto, R., Kunieda, T., Shibata, S., Shimotake, A., Kikuchi, T., Satow, T., Mikuni, N., Fukuyama, H., Ikeda, A., Miyamoto, S. (in press) Neural correlates of mirth and laughter: a direct electrical cortical stimulation study. *Cortex*