

## Case Report

## Knitting induced fronto-central theta rhythm

Jake H. McKay, William O. Tatum \*

Department of Neurology, Mayo Clinic, Jacksonville, FL, United States of America

## ARTICLE INFO

## Article history:

Received 5 June 2019

Accepted 30 August 2019

Available online 31 October 2019

## ABSTRACT

Fronto-central theta rhythms on EEG have been associated with cognitive tasks requiring attention and concentration, such as mental arithmetic or geometric construction. With the advent of video monitoring, there have been reports of new, task-specific, fronto-central theta rhythms reported with active texting or playing videogames on mobile phones. Concentration or attention combined with manual dexterous acts is challenging to simulate in an artificial and non-spontaneous environment, such as an epilepsy monitoring unit. We report a case of a fronto-central theta rhythm during active knitting using a needle and yarn with only passive concentration to highlight involvement of a corticomotor component underlying the neural networks involved in the efferent expression of scalp EEG to differentiate it from similar rhythms.

© 2019 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Fronto-central theta rhythms have been shown to be associated with cognitive tasks requiring concentration or attention, such as arithmetic, geometric construction, series reasoning, and even meditation [1–3]. With the advent of video-EEG monitoring, there have been increasing numbers of reports of new, task-specific, fronto-central theta rhythms reported with texting or playing videogames on mobile phones [4,5]. It was proposed that the frontocentral theta associated with texting rhythm (TR) was the scalp EEG equivalent of neural coding seen during nonauditory communication or task-specific cognitive processing [4,6]. However, it is difficult to simulate combinations of influence involving unprovoked concentration during bimanual tasks in a non-spontaneous environment. We report a similar case of a patient with fronto-central theta rhythm present exclusively with the use of the bilateral fingers and hands when actively knitting using a knitting needle and yarn with only passive mental concentration, supporting the contribution of a cerebral motor task generator to task-associated frontocentral theta rhythm that is independent of an electronic stimulus.

## 2. Case description

A 53-year-old right-handed female with a history of unspecified abuse and a hobby of knitting with yarn and wool was admitted to epilepsy monitoring unit for differential diagnosis. She learned to knit in the 4th grade and had been knitting regularly for the past 5 years.

Her vital signs and neurologic examination were normal. A cell phone video of the patient's characteristic spell was reviewed at bedside, with semiology of a blank stare with blinking of the eyes and sporadic, non-rhythmic, flexion–extension movements isolated to her 5th digit in the left hand. She was able to state “okay” when asked “how are you doing” by her husband. She reports she was unable to speak, but she could hear and understand during the event.

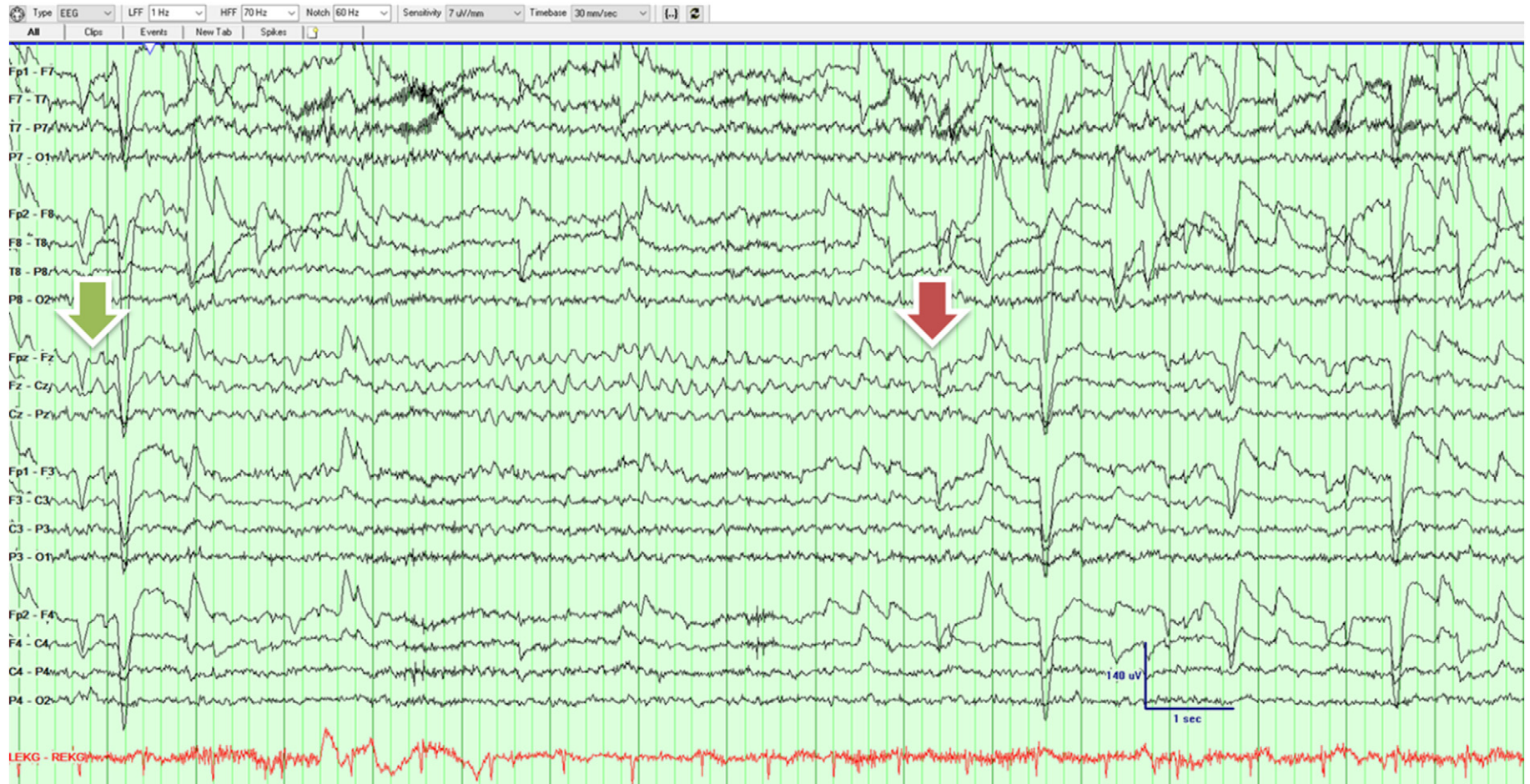
The patient underwent 48 h of continuous video-EEG monitoring without interictal epileptiform discharges or events captured. During the course of the second day of EMU monitoring, she frequently knitted with fluid bimanual movements involving the thumbs and digits using a needle and yarn to pass the time, often while watching TV or speaking with her husband. A reproducible fronto-central theta rhythm was identified throughout day 2 of monitoring with a task-specific and time-associated fronto-central 5–6 Hz theta rhythm during active knitting (Fig. 1). She noted that due to her long history of knitting, she reported that she did not feel the task required significant mental concentration.

She was clinically diagnosed with psychogenic, nonepileptic attacks supported by two cell phone videos with paroxysmal, start and stop semiology and 48 h of normal interictal EEG during video-EEG monitoring. Despite the diagnosis, the patient has continued monthly spells over the past 5 months but experienced a significant reduction in duration and frequency with cognitive behavioral therapy.

## 3. Discussion

We report a reproducible task-associated fronto-central theta rhythm on EEG during active knitting in a patient [1,2]. The electrographic appearance associated with knitting was spatially and temporally similar to that seen in the texting rhythm, but different in terms of being time

\* Corresponding author at: Mayo Clinic Department of Neurology, 4500 San Pablo Rd., Jacksonville, FL 32224, United States of America.  
E-mail address: [Tatum.William@mayo.edu](mailto:Tatum.William@mayo.edu) (W.O. Tatum).



**Fig. 1.** EEG demonstrating a monomorphic fronto-central theta rhythm generated during periods of active knitting. The green and red arrows indicate the beginning and end of the pattern on the tracing, respectively.

and task associated instead of a paroxysmal time-synched monomorphic theta rhythm identified during texting or gaming [4]. The TR described by Tatum and colleagues is distinct from other central theta rhythms (i.e., spontaneous Ciganek rhythm and normal fronto-central theta activated by concentration alone) due to its monomorphic morphology, discrete fronto-central location, and paroxysmal time-synched association with a task involving a personal electronic device [5]. We expand the tasks known to generate fronto-central theta beyond electronic devices to include a motor task involving knitting albeit with less abrupt onset and offset [6].

The fronto-central theta rhythm generators involved with knitting may overlap with the TR, given their similar electrographic appearance while performing tasks of interest involving motor movements of the bilateral fingers and hands [4]. However, knitting involves complex pattern recognition and visuospatial processing that is unique from TR [7]. Yoon and colleagues recently reported that increased occipital-cerebellar gray matter identified with source-based morphometry was significantly correlated with improved speed on the trailmaking test-A, which requires visuospatial search and processing speed similar to knitting [8]. Previous MEG/EEG study of calculation induced fronto-central theta rhythms by Ishii and colleagues demonstrated a generator in the dorsal anterior cingulate and adjacent medial prefrontal cortex [2]. We speculate that the fronto-central theta rhythm involved with knitting has a primary generator involving prefrontal cortex concentration processing and motor planning in the supplementary motor area (part of the medial prefrontal cortex), with network connectivity to the primary motor cortex. Furthermore, there is likely variable input from parieto-occipital-cerebellar cortex directed visuospatial processing and the parietal somatosensory cortex [7]. Prior scalp EEG source localization of 4 patients with TR was also notable for mesial frontal lobe predominance [9]. The similarity in the electrographic appearance of the knitting rhythm to the TR and other frontocentral theta rhythms probably resides in the limited resolution of scalp EEG to reflect intracranial network connections originating at different, yet overlapping, generators, demonstrating the relatively restricted repertoire of extracerebral EEG biorhythms. Our patient reported that she did not experience substantial mental concentration when knitting. However, a controlled study involving passive finger and/or thumb tapping bilaterally simulating texting on a blank screen without cognitive involvement was insufficient to generate the same theta rhythm, supporting a spectrum of cognitive-motor relationship [6].

Similar to other forms of fronto-central theta, the significance of the knitting rhythm lies in recognizing it as a benign rhythm in order to prevent misidentification as ictal or representing encephalopathy. In addition, as interest in brain computer interfaces continues to grow, increased recognition of the corresponding generators of EEG patterns may play a central role in the functioning of new interfaces, as the EEG can be utilized as a biomarker [10].

#### 4. Conclusions

Task-specific and time-associated fronto-central theta rhythm on scalp EEG was identified in a patient during spontaneous knitting. The

similarity of the EEG patterns to those produced with electronic devices further implicates cognitive motor localization required for complex bimanual motor tasks and suggests the effect of a corticomotor cerebral generator involved in concentration, motor planning, and the initiation of movement on the efferent expression of fronto-central theta identified with scalp EEG.

#### Ethical publication statement

Institutional review board approval was not required as this manuscript is a case report and no experimental intervention was undertaken. All presented data and figures have been reviewed to ensure patient anonymity.

#### Prior presentations

None.

#### Declaration of competing interest

None of the authors have any conflicts of interest to disclose.

#### Acknowledgments

We thank Dr. Anthony Ritaccio for his contribution in assisting with obtaining data used for this manuscript.

#### References

- [1] Ishihara T, Yoshii N. Multivariate analytic study of EEG and mental activity in juvenile delinquents. *Electroencephalogr Clin Neurophysiol* 1972. [https://doi.org/10.1016/0013-4694\(72\)90026-0](https://doi.org/10.1016/0013-4694(72)90026-0).
- [2] Ishii R, Canuet L, Ishihara T, Aoki Y, Ikeda S, Hata M, et al. Frontal midline theta rhythm and gamma power changes during focused attention on mental calculation: an MEG beamformer analysis. *Front Hum Neurosci* 2014. <https://doi.org/10.3389/fnhum.2014.00406>.
- [3] Jirakittayakorn N, Wongsawat Y. Brain responses to a 6-Hz binaural beat: effects on general theta rhythm and frontal midline theta activity. *Front Neurosci* 2017. <https://doi.org/10.3389/fnins.2017.00365>.
- [4] Tatum WO, DiCiaccio B, Kipta JA, Yelvington KH, Stein MA. The texting rhythm: a novel EEG waveform using smartphones. *J Clin Neurophysiol* 2016. <https://doi.org/10.1097/WNP.0000000000000250>.
- [5] Sener U, McKay JH, Feyissa AM, Tatum WO. Videogame-induced theta rhythm. *J Clin Neurophysiol* 2019. <https://doi.org/10.1097/wnp.0000000000000575>.
- [6] Tatum WO, DiCiaccio B, Yelvington KH. Cortical processing during smartphone text messaging. *Epilepsy Behav* 2016. <https://doi.org/10.1016/j.yebeh.2016.03.018>.
- [7] Baxendale S. Ability to knit may be impaired following right temporal lobe resection for drug-resistant epilepsy. *Epilepsy Behav Case Reports* 2019. <https://doi.org/10.1016/j.ebcr.2018.10.001>.
- [8] Yoon YB, Shin WG, Lee TY, Hur JW, Cho KIK, Sohn WS, et al. Brain structural networks associated with intelligence and visuomotor ability. *Sci Rep* 2017. <https://doi.org/10.1038/s41598-017-02304-z>.
- [9] Tatum W, Yelvington K, Rodin E. In reply to "texting rhythm with temporal predominance". *J Clin Neurophysiol* 2016. <https://doi.org/10.1097/WNP.0000000000000354>.
- [10] Wolpaw JR, Birbaumer N, McFarland DJ, Pfurtscheller G, Vaughan TM. Brain-computer interfaces for communication and control. *Clin Neurophysiol* 2002. [https://doi.org/10.1016/S1388-2457\(02\)00057-3](https://doi.org/10.1016/S1388-2457(02)00057-3).