NEUROSCIENCE RESEARCH NOTES

OPEN ACCESS | RESEARCH NOTES ISSN: 2576-828X

Drawing on paper versus drawing on a tablet: an EEG study

Abdelaziz Lamkaddem [1,2,*], Abdelkrim Janati Idrissi [1] and Zouhayr Souirti [1,3]

[1] Clinical Neurosciences Laboratory, Faculty of Medicine, and Pharmacy of Fez, Triq Sidi Hrazem, Sidi Mohamed Ben Abdellah University, Fez 30000, Morocco.
[2] Université Privée de Marrakech, P2009, Marrakech 40000.
[3] Neurology Department, Sleep Center. Hassan II University Hospital, Triq Sidi Hrazem, Fez 30000, Morocco.
***** Correspondence: lamkaddemabdelaziz@gmail.com; Tel.: +212 0604872888

Received: 10 June 2022; **Accepted:** 13 November 2022; **Published:** 11 February 2023
Edited by: King-Hwa Ling (Universiti Putra Malaysia, Malaysia)
Reviewed by: Indranath Chatterjee (Tongmyong University, South Korea);
Mayowa Adeniyi (Federal University of Health Science Otukpo, Nigeria);
M.S. Zobaer (The University of Texas Health Science Center, USA)
https://doi.org/10.31117/neuroscirn.v6i1.170

Abstract: Drawing is an activity that requires visual, emotional, and movement skills. This study compares, for the first time, children's brain activity during drawing on paper versus drawing on a tablet. First, we examined drawing activity in 26 right-handed children using the EEG combined with Event-Related Desynchronization (ERD) and Event-Related Synchronization (ERS) methods. Then, we asked participants to copy a house model where we used a Neurosoft EEG system to record the data and analyse it using the Brainstorm application. Both experimental conditions activate the brain's anterior and posterior cortices, but the activity in the anterior cortices was slightly higher during the drawing on paper than on the tablet. Conversely, compared to the paper condition, brain activity in the posterior cortices was slightly higher while drawing on the tablet.

Keywords: EEG; ERD/ERS; drawing; paper; tablet; cognitive task

1.0 INTRODUCTION

The tablet is convenient and straightforward for various tasks such as drawing and writing. It has become a popular tool nowadays, especially in light of the digital learning imposed by the Covid 19 pandemic. Drawing is a perceptual, mental, and movement task. It is also a dynamic ability depending on a planned effort to convey mental images the child creates when self-activating and adjusting his hands to the manipulated objects. Therefore, three dimensions determine children's drawing: representational, perceptive, and kinematic. During a drawing operation, the child holds the pen with three fingers and rotates his arm around the elbow, forearm, and hand, holding the pen around the wrist (Panesi & Morra, 2018; Meulenbroek et al., 2005). Whereas, while drawing with a finger on a screen (tablet), the painter uses effector mechanisms and biomechanical programs that differ from those used while drawing or writing with a pen on paper (Picard et al.,2014). Sommers and colleagues provided one of the most widely recognised cognitive theories of drawing, which said that drawing depends on visual perception and graphic production processes (Sommers, 1989; Guérin et al., 1999).

Furthermore, Roncato and the team considered also that externally cued drawing included four stages: examining the model, creating the drawing plan, executing the drawing plan, and comparing the drawing to the model (Roncato et al. 1987). An fMRI study showed that Internally-cued drawings activated fewer visual processing electrode sites than copying from a model (Ferber et al., 2007; Ogawa & Inui, 2009; Saggar et al., 2017). Copying from a model activated more visual processing electrode sites, such as the middle occipital gyrus, cuneus, and lingual gyrus. Drawing with the finger on the interface of the tactile tablet is still not understood because changing movement condition while children are learning may affect their subsequent performance (Longchamp et al., 2005). Drawing activates the brain areas parallel to the inferior premotor frontal, posterior inferior temporal, and parietal areas (Harrington et al., 2007). Makuuchi and colleagues studied the areas activated by drawing, including all occipital electrode sites (Makuuchi et al., 2003). The study aimed to clarify for the first time the potential impact of drawing with a pen on paper on brain activity versus drawing on a tablet using the Event-Related Desynchronisation / Event-Related Synchronisation technique (ERD/ERS). We hypothesised that the frontal electrode sites would be more active in drawing on paper with a pen, and the parieto-occipital electrode sites would be more active in drawing on the tablet surface with a finger.

2.0 MATERIALS AND METHODS

2.1 Participants and learning tasks

The clinical neuroscience laboratory recruited 26 right-handed children whose parent gave their formal consent, ten girls (14.3 ± 6.5 years old) and 16 boys (13 ± 8.4 years old). Their educational levels in primary public school were 4th, 5th, and 6th grades. Most have used the tablet for a moment or have a short experience. Then we asked them to draw a house by copying the model displayed on a blackboard. We performed this drawing task under two experimental conditions: a finger on the tablet surface without a pen versus a pen for drawing on a paper surface. The paper/tablet set up during the recording was on a table, and participants used felt pens for drawing on paper. The dimensions of the tablet used for the drawing were 21.5cm x 13.7cm.

2.2. Ethical Considerations

All the participants' parents were informed of the study's goals, we only invited those who signed and legalised the free consent with the appropriate authorities, and each participant was advised that he/she could leave the study at any time. Our purpose was to gather Data in an atmosphere of trust and respect for personal information privacy. The study was carried out following the recommendations of the ethics committee of the Sidi Mohamed ben Abdellah University of Fez.

2.3. Experimental protocol

We performed the recording using a *Neurosoft* EEG device (EEG and EP Digital Neurophysiological Software -Version 1.6.10.16.64 (bit) version 2017). First, we placed the 32 electrodes according to the 10/20 arrangement. Then, we asked the children to draw the house on paper with a pencil or index finger on the tablet. The EEG was continuously recorded throughout the drawing task.

2.4. Data pre-processing

The EEG data were processed using the Brainstorm software (Tadel et al., 2011). A given drawing trial, on average, was between 0 and 170.9s. The time window varied between -100 and 300ms. It was a long continuous recording broken into several segments automatically by Brainstorm to perform (ERS/ERD). This study used ERD/ERS analysis to evaluate lengthier brain activity in movement conditions according to surface topography (Pfurtscheller, 2001; Durka et al., 2001) using the Brainstorm interface (Brainstorm interface) (Tadel et al., 2011). The filters to eliminate low and high frequencies were between 1- 40 Hz. We eliminated eye movements, muscles, electrodes, heartbeats (1-7 Hz), and outside-world artefacts by using the Brainstorm interface. We recorded six trials for both experimental conditions for each child. Then we calculated the means of these trials from 145 files in the paper condition and 115 files in the tablet condition. We excluded the remaining 30 files because of the artefact signal of the recording channels. All participants completed all trials. Six trials for each participant were included in the total of trials.

2.5 ERS and ERD

The ERS/ERD signals were extracted by averaging the data from all trials. Then we performed the average of the events of all participants for both conditions. Finally, we calculated the baseline normalisation to determine the ERS/ERD and transformed the data into a Wavelet Morlet time / frequency map. The baseline was fixed between -100 and 0 ms. Event-Related desynchronisation (high activity) is a decrease in power relative to the EEG in a specific frequency wave according to the time of a cognitive or motor task (blue colour). On the other hand, Event-Related Synchronization (hypo-activity) is an increase in the power relative to the EEG in a specific frequency wave according to the time of a cognitive or movement task (red colour).

2.6 Statistical analysis

Data processing and signal analysis were performed using the Brainstorm interface (Matlab R 2018a). A non-parametric test with multiple comparison corrections was used to compute the p-values (α = 0.05) and compare files from the condition of tablet drawing with the finger (115 files) versus drawing with pencil on paper (145 files). Statistics comparing the two conditions (paper versus tablet) look like they included each trial as a separate participant.

3.0 RESULTS

Table 1 shows the mean amplitude/time in the drawing condition with a pen on paper and the finger on the tablet regarding baseline -100 and 0ms. The amplitude increased in the paper drawing condition, reflecting less intense brain activation (ERS). On the other hand, the amplitude decreased in the tablet drawing condition, reflecting high brain activation (ERD). The activity increased in the posterior area electrode site in both conditions. Nevertheless, it was higher in drawing on the tablet with finger condition **(Figure 1)**. An important ERD activity was registered in the drawing tablet condition in the prefrontal and frontal electrode sites (Fp1, Fp2, F7, F8) and an ERD in the parietal and occipital electrode sites in the tablet. In the tablet condition, desynchronised brain activity was recorded in the parietal and occipital electrode sites more than in temporal (T3, T4) and frontal-central (F4, C4) electrode sites **(Figure 2)**.

Table 1. The mean amplitude of the EEG signal according to the time regarding baseline –100 and 0ms.

Experimental conditions	Mean Ampli (Hz) (0 - 300ms)	Standard Deviation	*P*
Drawing on Paper	5,83.10 -9	1,99.10 -6	< 0.001
Drawing on Tablet	-8,72. 10 -9	1,96.10 -6	

4.0 DISCUSSION

We conducted this study to compare brain activity during drawing between two experimental conditions, pen drawing on paper versus index finger drawing on a tablet, using a modern EEG signal processing technique known as ERD/ERS analysis. Event-Related desynchronisation (high activity) is a decrease in power relative to the EEG in a specific frequency wave according to the time of a cognitive or motor task (blue colour). On the other hand, Event-Related Synchronization (hypo-activity) is an increase in the power relative to the EEG in a specific frequency wave according to the time of a cognitive or movement task (red colour).

After analysing the amplitude variations (ERD/ERS) across time, we noticed a difference in the regional brain activity between the two experimental conditions. Both experimental conditions activate the brain's anterior and posterior electrode sites. However, the activity in the anterior electrode sites was slightly higher during the drawing on paper than on the tablet. Compared to the paper condition, brain activity in the posterior electrode sites was slightly higher while drawing on the tablet. High-density electroencephalography studies revealed that the occipital and parietal areas were associated with low-frequency ERD activity in drawing tasks similar to our findings (Van der Weel et al., 2017; Ose Askvik et al.,2020). The superior parietal cortex was intensely involved in the drawing task and visuospatial coordination (Flores, 2002; Keisker et al.,2009).

Furthermore, the parietal cortices are strongly involved in body sensitivity and space perception. The premotor and motor cortices are involved in drawing through static and dynamic grip exerted by the pen on paper (Liao et al., 2014; Yuan & Brown, 2014). The lips, tongue, and fingers are the most sensitive body parts and have the most significant cerebral representation. Likewise, they have minor receptor fields and the most receptors quantity per skin unit. As a result, drawing with a finger on a tactile tablet stimulates somesthetic neurons, the visual-tactical bimodal neurons in the parietal area. However, Ino et al. (2003), reported that finger movements activate areas close to the sensory-motor cortex less intensely than the wrist and hand. The suitable parietal-occipital cortices are involved in complex visio-constructive tasks. Hand-eye coordination plays an essential role in feedback during drawing activities.

Studies with brain imaging or electroencephalography have proven that drawing activates the occipital cortices. Drawing encodes mental representations resulting from internal or external stimuli (McCrea, 2014). The information captured through visual perception is conveyed to the posterior occipital cortices. Likewise, copying from a model activated more visual processing cortices than internally-cued sketching (Ferber et al., 2007; Ogawa & Inui, 2009; Saggar et al., 2017). The activation of the parietal-occipital network reflects the role of visual perceptual components and visual-spatial working memory (Ferber et al., 2007; Yuan & Brown, 2014; Panes & Morra, 2021). In other studies, the right prefrontal areas have been mainly linked to creativity (Srinivasan, 2007). The posterior parietal cortex plays an essential role in the mental rotation skill, which works to assemble and compact all the figure elements (Hawes et al., 2019).

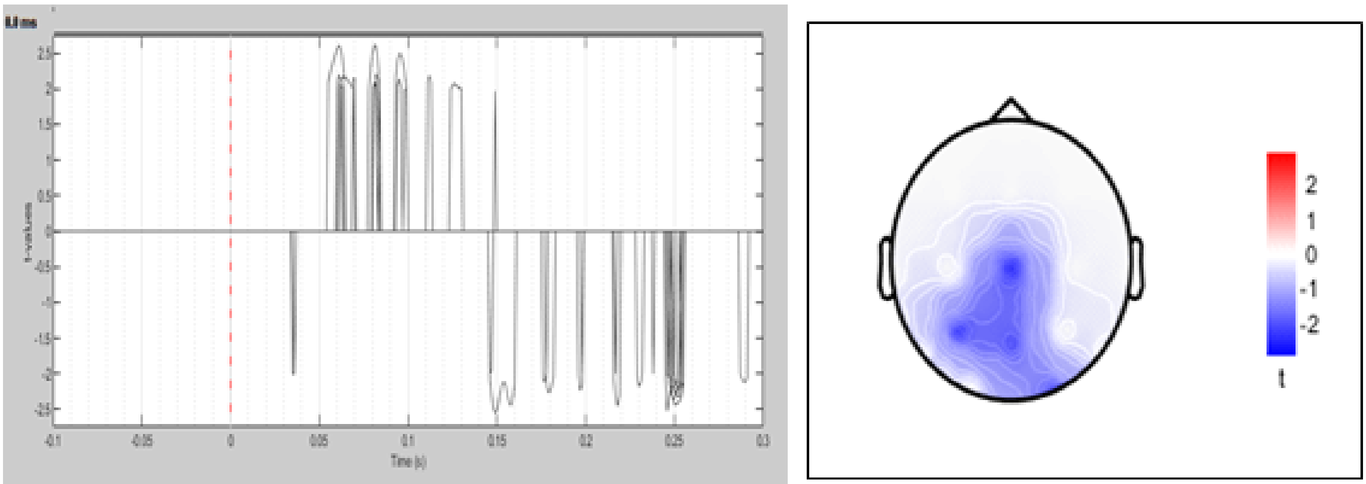

Figure 1. A head model for the unequal-sample Student-test showing a significant difference between the two conditions of finger drawing on tablet versus pen drawing on paper (p<0.001 (Bonferroni, Ntests=7619). There was an increase in the posterior area electrode site in both conditions, especially in drawing on the tablet with finger condition. A non-parametric test with multiple comparison corrections was used to compute the p-values (α = 0.05).

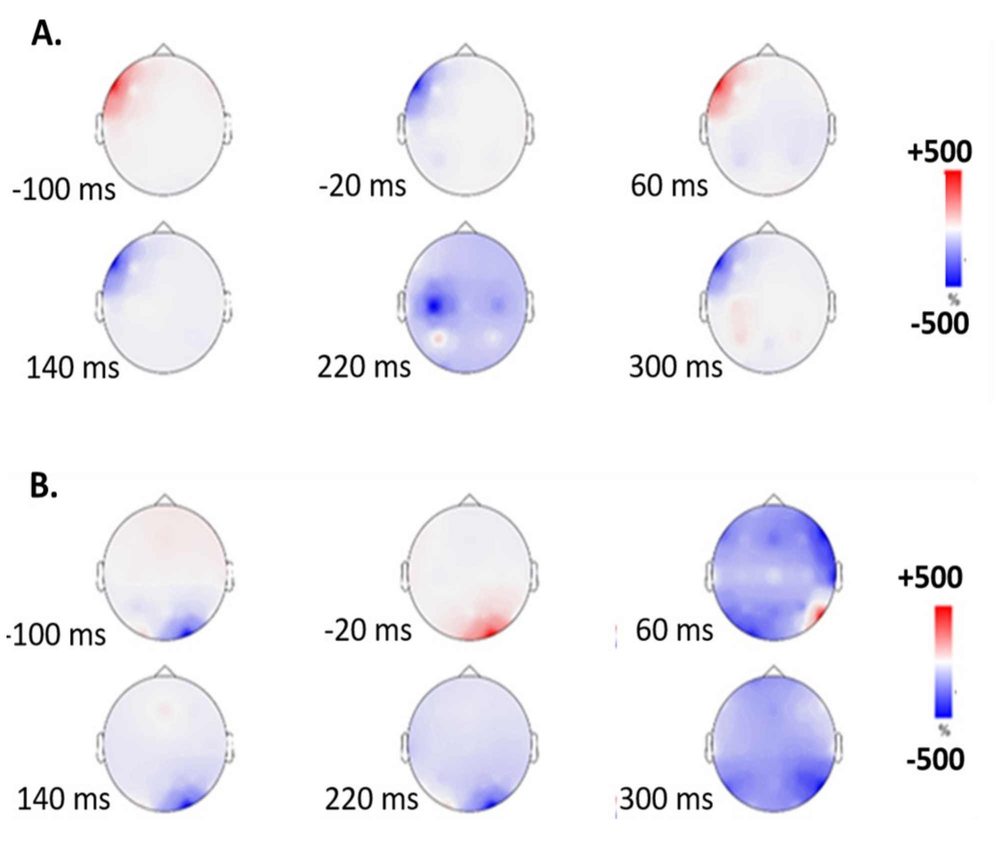

Figure 2. Brain activity in the drawing condition with Pen on Paper and with a finger on Tablet condition during the time windows (-100 ms), (-20 ms), (60 ms), (140 ms), (220 ms), (300 ms). (A) The ERD in the drawing condition on paper in the left frontal electrode sites in the time windows: (-20ms), (200ms), and (300ms). (B) The ERD activity of the drawing with the finger on the tablet in the left parietal-occipital electrode sites, repeated in the time windows: (-20ms), (60ms), and (220ms), and an extended ERD activity in the time windows (60ms) and (200ms).

We recognise some limitations in the results of our study. Our sample remains limited. All the participants had to perform the drawing activity on paper and tablet. We asked them to do these tasks to compensate for the limited number of participants. In addition, the number of electrodes used was also limited.

5.0 CONCLUSION

Drawing is a complex activity that incorporates visuo-constructive and sensory-motor processing networks. This study compares children's brain activity during drawing on paper versus drawing on a tablet for the first time. The brain's anterior and posterior cortices were activated in both experimental settings. However, activity in the anterior cortices was slightly higher while drawing on paper than drawing on a tablet with the index finger. Likewise, brain activity in the posterior cortices was slightly higher while drawing on the tablet. This study recommends using the EEG method to study drawing skills and encourage similar research on the tablet's utility in the classroom.

Acknowledgements: We thank Mme Meriem Elyoubi, Mss Nezha Malki, and Mohmed EL Bouzidi for their technical assistance.

Author Contributions: AL participated in the study concept and design, specifying the question and writing the manuscript. AJI participated in writing the manuscript. ZS participated in the study concept and design, specifying the question and writing the manuscript.

Conflicts of Interest: The authors declared no conflict of interest.

References

Durka, P. J., Ircha, D., Neuper, C., & Pfurtschellr, G. (2001). Time-frequency microstructure of event-related electro-encephalogram desynchronisation and synchronisation. *Medical & Biological Engineering & Computing, 39*, 315–321 https://doi.org/10.1007/BF02345286

Ferber, S., Mraz, R., Baker, N., & Graham, S. J. (2007). Shared and differential neural substrates of copying versus drawing: a functional magnetic resonance imaging study. *Neuroreport*, *18*(11),1089–1093. https://doi.org/10.1097/WNR.0b013e3281ac2143

Flores L. P. (2002). Occipital lobe morphological anatomy: anatomical and surgical aspects. *Arquivos de Neuro-psiquiatria*, *60*(3-A), 566–571. https://doi.org/10.1590/s0004-282x2002000400010

Guérin, F., Ska, B., & Belleville, S. (1999). Cognitive processing of drawing abilities. *Brain and Cognition*, *40*(3), 464–478. https://doi.org/10.1006/brcg.1999.1079-

Harrington, G. S., Farias, D., Davis, C. H., & Buonocore, M. H. (2007). Comparison of the neural basis for imagined writing and drawing. *Human Brain Mapping*, *28*(5), 450–459. https://doi.org/10.1002/hbm.20286

Hawes, Z., Sokolowski, H. M., Ononye, C. B., & Ansari, D. (2019). Neural underpinnings of numerical and spatial cognition: An fMRI meta-analysis of brain electrode sites associated with symbolic number, arithmetic, and mental rotation. *Neuroscience and Biobehavioral Reviews*, *103*, 316–336. https://doi.org/10.1016/j.neubiorev.2019.05.007

Ino, T., Asada, T., Ito, J., Kimura, T., & Fukuyama, H. (2003). Parieto-frontal networks for clock drawing revealed with fMRI. *Neuroscience Research*, 45(1), 71–77. https://doi.org/10.1016/s0168-0102(02)00194-3

Keisker, B., Hepp-Reymond, M. C., Blickenstorfer, A., Meyer, M., & Kollias, S. S. (2009). Differential force scaling of fine-graded power grip force in the sensorimotor network. *Human Brain Mapping*, *30*(8), 2453–2465. https://doi.org/10.1002/hbm.20676.

Liao, K., Xiao, R., Gonzalez, J., & Ding, L. (2014). Decoding Individual Finger Movements from One Hand Using Human EEG Signals. *PLOS ONE,* 9(1): e85192. https://doi.org/10.1371/journal.pone.0085192

Longcamp, M., Zerbato-Poudou, M. T., & Velay, J. L. (2005). The influence of writing practice on letter recognition in preschool children: a comparison between handwriting and typing. *Acta Psychologica*, 119(1), 67–79. https://doi.org/10.1016/j.actpsy.2004.10.019

Makuuchi, M., Kaminaga, T., & Sugishita, M. (2003). Both parietal electrode sites are involved in drawing: a functional MRI study and implications for constructional apraxia. *Brain research. Cognitive Brain Research*, *16*(3), 338–347. https://doi.org/10.1016/s0926-6410(02)00302-6

McCrea, S. (2014). A neuropsychological model of free-drawing from memory in constructional apraxia: a theoretical review. *American Journal of Psychiatry Neuroscience, 2*, 60–75. https://doi.org/10.11648/j.ajpn.20140205.11

Meulenbroek, R. G., Van Galen, G. P., Hulstijn, M., Hulstijn, W., & Bloemsaat, G. (2005). Muscular co-contraction covaries with task load to control the flow of motion in fine motor tasks. *Biological Psychology*, *68*(3), 331–352. https://doi.org/10.1016/j.biopsycho.2004.06.002

Ogawa, K., & Inui, T. (2009). The role of the posterior parietal cortex in drawing by copying. *Neuropsychologia*, *47*(4), 1013–1022. https://doi.org/10.1016/j.neuropsychologia.2008.10.022

Ose Askvik, E., van der Weel, F., & van der Meer, A. (2020). The Importance of Cursive Handwriting Over Typewriting for Learning in the Classroom: A High-Density EEG Study of 12-Year-Old Children and Young Adults. *Frontiers in Psychology*, *11*, 1810. https://doi.org/10.3389/fpsyg.2020.01810

Panesi, S., & Morra, S. (2018). Relationships between the early development of drawing and language: the role of executive functions and working memory. *The Open Psychology Journal*, *11*(1). DOI: 10.2174/1874350101811010015

Pfurtscheller, G. (2001). Functional brain imaging based on ERD/ERS. *Vision Research*, *41*(10-11), 1257–1260. https://doi.org/10.1016/s0042-6989(00)00235-2

Picard, D., Martin, P., & Tsao, R. (2014). iPads at school? A quantitative comparison of elementary schoolchildren's pen-on-paper versus finger-on-screen drawing skills. *Journal of Educational Computing Research*, *50*(2), 203-212.

Roncato, S., Sartori, G., Masterson, J., and Rumiati, R. (1987).Constructional apraxia: an information-processing analysis. *Cognitive Neuropsychology*, *4*, 113–129. https://doi.org/10.1080/02643298708252037

Saggar, M., Quintin, E. M., Bott, N. T., Kienitz, E., Chien, Y. H., Hong, D. W., Liu, N., Royalty, A., Hawthorne, G., & Reiss, A. L. (2017). Changes in brain activation associated with spontaneous improvization and figural creativity after design-thinking-based training: a longitudinal fMRI Study. *Cerebral Cortex*, *27*(7), 3542–3552. https://doi.org/10.1093/cercor/bhw171

Sommers, P. V. (1989). A system for drawing and drawing related neuropsychology. *Cognitive Neuropsychology*, *6*, 117–164. https://doi.org/10.1080/02643298908253416

Srinivasan N. (2007). Cognitive neuroscience of creativity: EEG based approaches. *Methods, 42*(1), 109–116. https://doi.org/10.1016/j.ymeth.2006.12.008

Tadel, F., Baillet, S., Mosher, J. C., Pantazis, D., & Leahy, R. M. (2011). Brainstorm: a user-friendly application for MEG/EEG analysis. *Computational Intelligence and Neuroscience*, *2011*, 879716. https://doi.org/10.1155/2011/879716

van der Meer, A. L. H. and van der Weel, F. R. (2017) Only Three fingers write, but the whole brain works: a high-density eeg study showing advantages of drawing over typing for learning. *Frontiers in Psychology*, *8*, 706. https://doi.org/10.3389/fpsyg.2017.00706

Yuan, Y., & Brown, S. (2014). The neural basis of mark-making: a functional MRI study of drawing. *PLOS One*, *9*(10), e108628. https://doi.org/10.1371/journal.pone.0108628