This paper has been published under Creative Common Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) allowing to download articles and share them with others as long as they credit the authors and the publisher, but without permission to change them in any way or use them commercially.

ORIGINAL ARTICLE

doi: http://doi.org/10.31577/ansr.2026.68.2.4

Effects of right anterior temporal intermittent theta-burst stimulation on verbal and nonverbal insight problem solving

Filip Jendrol [1], Marián Špajdel [1], Peter Teličák [1]

[1] Department of Psychology, Faculty of Philosophy and Arts, University of Trnava, Slovakia,

Correspondence to: Filip Jendrol, Department of Psychology, Faculty of Philosophy and Arts, University of Trnava, Hornopotočná 23, 918 43 Trnava, Slovak Republic.
e-mail: filip.jendrol@truni.sk

Submitted: 2026-08-06 Accepted: 2026-09-30 Published online: 2026-11-11

Key words: **Transcranial Magnetic Stimulation; Problem Solving; Creativity; Temporal Lobe; Functional Laterality; Dichotic Listening Tests**

Act Nerv Super Rediviva 2026; **68**(2): 75–80 **PII:** 68022604
© 2026 Act Nerv Super Rediviva

Abstract

OBJECTIVES: This study examined whether repetitive transcranial magnetic stimulation (rTMS) over the right anterior temporal lobe (rATL) facilitates insight problem solving. We also explored whether speech lateralization moderates stimulation effects.
METHODS: 41 participants were randomly assigned to either experimental (n = 20) or control (n = 21) group. Participants in the experimental group received active rTMS consisting of 600-pulse intermittent theta-burst stimulation over the rATL, whereas participants in the control group received sham stimulation over the same area. Immediately afterward, all participants completed the Remote Associates Test (RAT) and the language-independent RAT (LI-RAT), with proportions of correct solutions and self-reported Aha! experiences recorded. Speech lateralization was assessed using dichotic listening tasks with syllables and words.
RESULTS: rTMS over rATL did not significantly affect solution accuracy or the proportion of Aha! experiences on either the verbal RAT or non-verbal LI-RAT. Neither syllable nor word laterality indexes significantly moderated rTMS effects.
CONCLUSION: Our results using rTMS failed to support previous findings with other stimulation techniques suggesting a central role of the rATL in insight. Further research should clarify how stimulation target, stimulation technique, task characteristics, and individual differences influence neuromodulation effects on insight.

Introduction

Insight is a nonlinear process of cognitive restructuring in which a solution suddenly emerges through the formation of a novel association between previously unrelated concepts. It is typically accompanied by the affective "Aha!" experience and contrasts with analytical problem-solving, which unfolds through a deliberate, linear sequence of steps (Danek 2024). As a vital component of creative cognition, insight has been the focus of extensive research into its mechanisms and neural substrates over the past two decades (Chesebrough *et al.* 2024). Early neuroimaging studies (Jung-Beeman *et al.* 2004; Subramaniam *et al.* 2009) suggested that it depends more on the right (RH) than the left (LH) hemisphere, especially the right anterior temporal lobe (rATL). This has been interpreted within the context of hemispheric specialization, where the LH specializes in fine semantic coding, while the RH specializes in coarse semantic coding (for reviews, see

Kounios & Beeman 2014; Salvi 2024). Later reviews (Sprugnoli *et al.* 2017) and a meta-analysis (Shen *et al.* 2018) revealed a more distributed network spanning both hemispheres, including the left inferior frontal gyrus, left amygdala, right medial frontal gyrus, and right hippocampus. However, neuroimaging findings remain correlational. Causal evidence can be obtained using non-invasive brain stimulation (NiBS) techniques – such as tDCS, tACS, and tRNS (Cortes *et al.* 2023) – which have become increasingly common in insight research. Most studies target either the left dorsolateral prefrontal cortex (lDLPFC) for its role in cognitive control (Cerruti & Schlaug 2009) or the rATL for its role in coarse semantic coding (Salvi *et al.* 2020).

For the lDLPFC, anodal tRNS (Peňa *et al.* 2021) and tDCS (Cerruti & Schlaug 2009; Metuki *et al.* 2012; Zmigrod *et al.* 2015) seem to improve Remote Associates Test (RAT) performance, though null (Li *et al.* 2023; Xiang *et al.* 2021) and marginal effects (Peňa *et al.* 2022) have also been reported. In contrast, performance on visual insight tasks appears unaffected by anodal lDLPFC stimulation (Bartel *et al.* 2020) and may instead benefit from cathodal stimulation of this brain region (Liu *et al.* 2025; Luft *et al.* 2017; Peňa *et al.* 2021).

For the rATL, anodal tDCS has been shown to enhance performance on visual insight problems such as matchstick arithmetic (Chi & Snyder 2011) and the 9-dot problem (Chi & Snyder 2012). However, Aihara *et al.* (2017) did not replicate these effects using a more robust design. More recently, Sprugnoli *et al.* (2021) improved accuracy on the RAT but not on rebus puzzles using tRNS. A common limitation of many studies is their reliance on task success as the sole indicator of insight, despite evidence that "insight problems" can also be solved analytically. Reporting whether participants actually experienced an Aha! moment is therefore critical (Webb *et al.* 2016). Two NiBS studies specifically measured Aha! experiences. Santarnecchi *et al.* (2019) applied gamma-frequency tACS to the rATL and found improved RAT performance and a marginal increase in Aha! moments, but no effects on rebuses. Similarly, Salvi *et al.* (2020) demonstrated that HD-tDCS over the rATL enhances RAT performance and that these improvements were directly associated with a higher proportion of Aha! solutions, on a large sample.

Despite growing interest in NiBS-based insight research, few studies have examined individual differences that might moderate the effects of stimulation. Xiang *et al.* (2021) evaluated anxiety as a moderator but found no influence on tDCS effects. Santarnecchi *et al.* (2019) reported that responsiveness to rATL tACS correlated with functional connectivity between the temporal lobes, as measured by resting-state fMRI. We propose that speech lateralization, as assessed via dichotic listening (Špajdel 2020), may represent another moderator. Although hemispheric differences have long inspired research on insight (e.g., Chi & Snyder 2012, 2011; Salvi *et al.* 2020), the coarse- versus fine-semantic-coding model reflects an average population-level pattern (Kounios & Beeman 2014). This raises the question of whether individual variation in speech lateralization could moderate the effects of rATL stimulation. On average, literal language is processed predominantly by the LH, whereas the RH shows greater involvement in processing figurative language, which relies on access to multiple, less salient associations (Faust & Mashal 2007; Jung-Beeman 2005; Voyer *et al.* 2008). Accordingly, rATL stimulation could have different effects in individuals with atypical speech lateralization. Moreover, laterality index derived from dichotic listening negatively correlates with corpus callosum size (Westerhausen & Hugdahl 2008), suggesting that it may also reflect interhemispheric connectivity, which Santarnecchi *et al.* (2019) identified as relevant to the effects of rATL stimulation.

In summary, insight problem-solving appears to be influenced by stimulation of regions in both hemispheres. Studies targeting the rATL tend to yield more consistent results than those targeting the lDLPFC. However, outcomes may vary by task type, with the RAT producing more reliable effects. Only a limited number of studies have investigated how NiBS influences Aha! moments, and individual differences in responsiveness to NiBS remain largely underexplored. The present study investigates the effects of rATL stimulation on insight problem-solving using TMS, which provides superior spatial specificity compared to tDCS and can directly activate neuronal groups (Cortes *et al.* 2023). We employ two types of insight problems (verbal and non-verbal) to assess the domain specificity of the rATL stimulation effect. We also explore whether speech lateralization moderates the effects of rATL stimulation. Based on prior research, we hypothesize that rATL TMS will enhance performance on the verbal insight task and increase the frequency of Aha! moments. We do not formulate hypotheses about performance on visual insight task due to inconsistent prior findings. The moderating role of speech lateralization likewise remains an exploratory part of the study, given the limited previous research.

Methods

Participants and procedure

Participants were recruited through convenience sampling from psychology students at Trnava University. Exclusion criteria were epilepsy or a history of epileptic seizures, metal implants in the skull, psychiatric medication use, and pregnancy. Before participation, all participants provided written informed consent, were informed about the potential risks of rTMS, and completed a questionnaire assessing rTMS-related risk factors (Rossi *et al.* 2009). The study received ethical approval from the Ethics Committee of the Faculty of Arts at Trnava University (Approval No. 3/2026).

Copyright © 2026 Activitas Nervosa Superior Rediviva ISSN 1337-933X

The sample originally included 42 participants, but one female participant was excluded before rTMS because she became pregnant. The final sample comprised 41 participants: 20 in the experimental group (5 men, 15 women; M_{age} = 32.45, SD_{age} = 10.10) and 21 in the control group (6 men, 15 women; M_{age} = 30.71, SD_{age} = 8.55).

The study was conducted across two sessions. During the first session, participants completed a dichotic listening task. During the second session, participants were randomly assigned to either the experimental or control group. Participants in the experimental group received rTMS over the rATL, whereas participants in the control group received sham rTMS over the same area. Immediately after rTMS, participants completed insight problem-solving tasks.

Transcranial magnetic stimulation

Repetitive transcranial magnetic stimulation (rTMS) was delivered over the right anterior temporal lobe using a DuoMAG XT stimulator (Deymed Diagnostic, Czech Republic) equipped with a 70-mm actively cooled butterfly coil (DuoMAG 70BF-Cool). The stimulation site was localized at the midpoint between the FT8 and FT10 electrode positions according to the international 10–10 EEG system. This scalp-based location was selected as an approximation of the anterior temporal cortex, approximately corresponding to Brodmann area 38. Stimulation was administered using the conventional 600-pulse intermittent theta-burst stimulation (iTBS600) protocol, consisting of three-pulse bursts delivered at 50 Hz and repeated at 5 Hz. Each 2-s stimulation train comprised 10 bursts and was followed by an 8-s inter-train interval, yielding a total of 20 trains, 600 pulses, and an overall stimulation duration of approximately 190 s. Stimulation intensity was set at 80% of each participant's active motor threshold. Sham stimulation had the same parameters; however, the stimulation coil was tilted at 90° to the scalp. No serious adverse events occurred. Mild transient discomfort was reported by 1 participant in the sham condition.

Insight problem solving

Insight problem-solving was assessed using two sets of problems. Both were presented using PsyToolkit (Stoet 2010, 2017) on a computer screen. The two tasks were administered in separate blocks in randomized order; however, the order of problems within each block was fixed. Participants were instructed to find a solution within 20 seconds and to click a button beneath the problem as soon as they had one. After clicking, they reported the solution verbally to the experimenter and then reported whether an Aha! moment occurred by choosing either *Yes* or *No*. Prior to each block, participants were familiarized with the task instructions and with the definition of an Aha! moment, adapted from Laukkonen and Tangen (2018). They also completed one practice problem for each task type without time constraints.

The verbal task comprised 20 items from the Slovak version of the Remote Associates Test (RAT; Marko *et al.* 2019), a lexical–semantic task in which participants are presented with three cue words (e.g., *Same, Tennis, Head*) and must generate a solution associated with all of them (*Match*). The nonverbal task comprised 20 items from the language-independent RAT (LI-RAT; Becker & Cabeza 2023), a visual–semantic task in which participants are shown two pictures (e.g., *Corset, Stopwatch*) and must identify an object that is visually similar to the first picture and conceptually related to the second (*Hourglass*). For both tasks, problem-solving ability scores were calculated as the percentage of items correctly solved. Insight scores were calculated as the percentage of correctly solved problems accompanied by an Aha! moment out of all correct solutions.

Speech lateralization

For the purposes of the present study, two verbal dichotic listening tasks – one using consonant-vowel (CV) syllables and the other using Slovak consonant-vowel-consonant (CVC) words – were developed. The auditory stimuli were presented from a personal computer through Sennheiser supra-aural headphones with a total harmonic distortion of <0.7% at a sound-pressure level of 75 dB. Each dichotic listening task consisted of 30 items. The first 15 items were presented in the original left–right channel configuration. In the second half of the task, items 16–30 repeated the same stimulus pairs, but the stimuli originally presented to the left ear were presented to the right ear, and vice versa. Thus, the ear of presentation was counterbalanced across the two halves of the task, and each stimulus pair was presented once in each channel configuration. The order of the two dichotic listening tasks was randomized across participants. A free-recall paradigm was used, whereby participants were instructed to report orally all stimuli they had perceived, irrespective of the ear of presentation. Responses were recorded by the experimenters.

Two laterality indexes (LI) were calculated: one for syllables and one for words. For each stimulus type, LI was calculated using the following formula: LI = (R – L)/(R + L), where R and L represent the numbers of single correct responses reported from the right and left ear, respectively. LI values range from −1 (lateralization toward the right hemisphere) to +1 (lateralization toward the left hemisphere).

Results

Table 1 Statistical analyses were conducted using R software, with the *readxl, psych*, and *BayesFactor* packages. Frequentist statistics were supplemented with Bayesian methods, as they are more robust to small sample sizes and allow evaluation of evidence in favor of the null hypothesis. For frequentist analyses, the

Tab. 1. Differences in insight problem solving between groups

Variable	Control group		Experimental group		Statistics			
	M	SD	M	SD	t	df	*p*	BF_{10}
LI-RAT (solution)	42.86	16.63	49.50	15.30	-1.33	38.96	0.191	0.62
RAT (solution)	45.00	17.82	45.25	22.15	-0.04	36.47	0.969	0.31
LI-RAT (insight)	61.54	32.93	67.36	26.55	-0.62	37.99	0.536	0.36
RAT (insight)	58.44	33.54	72.40	28.92	-1.43	38.63	0.161	0.68

level of statistical significance was set at $p < 0.05$. For Bayesian analyses, we relied on default priors. We used commonly applied criteria to interpret BF_{10} values (Kass & Raftery 1995), according to which BF_{10} values greater than 3 indicate moderate support for the alternative hypothesis. In contrast, values below 1/3 indicate moderate support for the null hypothesis.

Testing the effect of rTMS on insight problem solving

The effect of rTMS over the rATL on insight problem-solving was examined by comparing performance levels and the frequency of Aha! experiences between the control and the experimental group, using Welch's t-tests. The groups did not differ significantly in the percentage of correctly solved items or in the percentage of Aha! experiences for either the verbal or non-verbal task. Bayesian analyses generally provided inconclusive evidence, except for RAT performance, for which moderate evidence favored the null hypothesis. Results are presented in Table 1.

Testing the moderating effect of speech lateralization

In the next part of the analysis, we tested whether speech lateralization moderated the effect of rTMS over the rATL on insight problem solving using moderated regression analyses. In all analyses, group assignment was included as the independent variable (control vs. experimental), while the moderators were the laterality indexes for syllables and words. Neither the laterality index for syllables nor the laterality index for words moderated the effect of rTMS on the percentage of correctly solved items or the percentage of Aha! experiences for either the verbal or non-verbal task. Bayesian analyses yielded inconclusive evidence, with Bayes factors indicating no clear support for either the alternative or the null hypotheses. The results are presented in Table 2.

Discussion

In this study, we tested whether rTMS over rATL facilitates insight problem-solving across different task types and explored the role of speech lateralization as a potential moderator of these effects.

Effect of rTMS on insight problem solving

The results showed that rTMS over the rATL did not significantly affect insight problem solving, whether assessed by solution accuracy or by the occurrence of Aha! experiences, in either the verbal RAT or the non-verbal LI-RAT. Regarding LI-RAT, to our knowledge, no previous study has used this task specifically, but NiBS studies employing other non-verbal tasks have yielded mixed findings (Aihara *et al.* 2017; Chi & Snyder 2012, 2011; Santarnecchi *et al.* 2019; Sprugnoli *et al.* 2021). The explanation proposed by Santarnecchi *et al.* (2019) for

Tab. 2. Results of analyses testing the moderating effect of speech lateralization

Dependent variable	Moderator	b (interaction)	SE	t	*p*	BF_{10}	R^2
LI-RAT (solution)	LI (syllables)	1.70	30.86	0.06	0.956	0.443	0.044
RAT (solution)	LI (syllables)	-56.58	36.43	-1.55	0.129	1.031	0.114
LI- RAT (insight)	LI (syllables)	-2.34	57.89	-0.04	0.968	0.435	0.010
RAT (insight)	LI (syllables)	-65.62	58.72	-1.12	0.271	0.700	0.106
LI-RAT (solution)	LI (words)	17.74	13.27	1.34	0.190	0.865	0.095
RAT (solution)	LI (words)	-1.04	16.76	-0.06	0.951	0.413	0.040
LI- RAT (insight)	LI (words)	12.04	25.49	0.47	0.640	0.492	0.017
RAT (insight)	LI (words)	20.76	26.53	0.78	0.439	0.540	0.066

Note. b = regression coefficient of the Group × Moderator interaction term; SE = standard error; R^2 = model coefficient of determination.

Copyright © 2026 Activitas Nervosa Superior Rediviva ISSN 1337-933X

the absence of an effect on rebus solving may also apply to the LI-RAT: both tasks require integrating visual and semantic information, so performance may depend on a broader temporal–parietal–occipital network, making modulation of the rATL alone insufficient. However, Bayesian analyses supported neither the alternative nor the null hypothesis, so the present data do not provide conclusive evidence for the absence of an effect.

Bayesian analysis supported the null hypothesis regarding RAT performance, in contrast to previous studies that reported improvements following tACS (Santarnecchi *et al.* 2019), HD-tDCS (Salvi *et al.* 2020), and tRNS (Sprugnoli *et al.* 2021); however, Aihara *et al.* (2017) failed to improve RAT performance using tDCS. This discrepancy may reflect differences in the stimulation method, experimental design, or targeted brain region. Stimulation sites within the rATL have varied across studies, including T8 (Salvi *et al.* 2020; Santarnecchi *et al.* 2019; Sprugnoli *et al.* 2021), 1.5 cm anterior to T8 (Aihara *et al.* 2017), the midpoint between T8 and FT8 (Chi & Snyder 2011, 2012), and the midpoint between FT8 and FT10 targeted in the present study, following the international 10–10 EEG system. It is therefore possible that the more posterior sites used in studies reporting improved RAT performance were better suited to modulating processes relevant to task performance than the more anterior target used here. Moreover, previously used techniques, including tDCS, HD-tDCS, tACS, and tRNS, generally produce less focal stimulation than rTMS (Cortes *et al.* 2023). Their broader spatial effects may therefore have increased the likelihood of modulating regions relevant to task performance, although alongside other areas. Future research could compare different NiBS techniques within a single study, thereby helping to disentangle the effects of stimulation modality from those of target location and other methodological differences.

An alternative possibility concerns differences between RAT variants. Previous studies (Salvi *et al.* 2020; Santarnecchi *et al.* 2019; Sprugnoli *et al.* 2021) used the compound RAT, in which the solution must form a compound with each cue, whereas our study used the classic RAT, where cue–solution relations may involve compounding, synonymy, or broader semantic links (Bowden & Jung-Beeman 2003). Although the tasks are highly similar, these differences could affect how candidate solutions are retrieved, evaluated, and semantically integrated. However, to our knowledge, the two variants have not been directly compared with respect to the cognitive processes involved in solving them. Future research could therefore examine which cognitive processes mediate the effects of NiBS on insight problem solving and how these processes vary across tasks with different properties.

Moderating effect of speech lateralization

In the second part of the study, we examined whether individual differences in speech lateralization moderate the effect of rTMS over the rATL on insight problem solving. Neither laterality index significantly moderated the effect of rTMS on insight, operationalized as the percentage of correctly solved items or the percentage of Aha! experiences, in either task type. However, the Bayesian analyses yielded inconclusive evidence. Moreover, the lack of a significant overall effect of rTMS on insight problem solving further limits the interpretation of individual differences in this effect.

The present findings therefore do not allow firm conclusions regarding the relationship between speech lateralization and the processes targeted by rATL stimulation. Nevertheless, they point to several issues that may be considered in future research. Speech lateralization may not closely correspond to hemispheric specialization for coarse versus fine semantic coding, which underpins accounts linking the rATL to insight (Kounios & Beeman 2014). Alternatively, the modality used to assess language lateralization may be important. Previous research has found only a weak association between laterality indices for speech comprehension, measured using dichotic stimulation, and reading, measured using the visual half-field technique (Graves 1983; Weinstein & Graves 2002). Because the RAT was presented in written form, an index of reading lateralization may be more appropriate for assessing language-processing lateralization in this context.

Limitations

Our findings are limited by the small sample size. Although samples of this magnitude are not uncommon in NiBS research due to the practical demands of these protocols (Chi & Snyder 2011, 2012; Zmigrod *et al.* 2015), the sample size may have reduced statistical power and constrained the generalizability of the results. Replication in a larger sample is therefore warranted. In addition, neuronavigation-guided rTMS was not used. Although EEG system-based scalp localization provides reasonably reliable coil positioning (Herwig *et al.* 2003) and remains common in cognitive research, it does not account for individual variability in brain anatomy. Neuronavigation could therefore improve the precision of stimulation targeting.

Conclusions

The present study found no significant effect of rTMS over the rATL on verbal or non-verbal insight problem solving, whether assessed by solution accuracy or Aha! experiences. For RAT performance, Bayesian analysis supported the null hypothesis, whereas evidence for the remaining outcomes was inconclusive. Speech lateralization did not moderate the effect of rTMS on insight in either task type. Future research should more directly examine the role of stimulation target, stimulation technique, task characteristics, and potential moderators of NiBS effects.

Acknowledgments

We would like to thank Alexandra Lacková for her contribution to the collection of dichotic listening data for this research.

REFERENCES

1 Aihara T, Ogawa T, Shimokawa T, Yamashita O (2017). Anodal transcranial direct current stimulation of the right anterior temporal lobe did not significantly affect verbal insight. *PLoS One.* **12**(9): e0184749.
2 Bartel G, Marko M, Rameses I, Lamm C, Riečanský I (2020). Left Prefrontal Cortex Supports the Recognition of Meaningful Patterns in Ambiguous Stimuli. *Front Neurosci.* **14**: 152.
3 Becker M & Cabeza R (2023). Assessing creativity independently of language: A language-independent remote associate task (LI-RAT). *Behav Res Methods.* **55**(1): 85–102.
4 Bowden EM & Jung-Beeman M (2003). Normative data for 144 compound remote associate problems. *Behav Res Methods Instrum Comput.* **35**(4): 634–639.
5 Cerruti C & Schlaug G (2009). Anodal Transcranial Direct Current Stimulation of the Prefrontal Cortex Enhances Complex Verbal Associative Thought. *J Cogn Neurosci.* **21**(10): 1980–1987.
6 Chesebrough C, Salvi C, Beeman M, Oh Y, Kounios J (2024). Waves of insight: A historical overview of the neuroscience of insight. In: Salvi C, Wiley J, Smith SM, editors. The emergence of insight. Cambridge: Cambridge University Press, ISBN 9781009244251, p. 223–250.
7 Chi RP & Snyder AW (2011). Facilitate Insight by Non-Invasive Brain Stimulation. *PLoS One.* **6**(2): e16655.
8 Chi RP & Snyder AW (2012). Brain stimulation enables the solution of an inherently difficult problem. *Neurosci Lett.* **515**(2): 121–4.
9 Cortes RA, Holzman DD, Green AE (2023). Neuromodulation to Enhance Creative Cognition: A Review of New and Emerging Approaches. *J Cogn Enhanc.* **7**(1): 1–18.
10 Danek AH (2024). The phenomenology of insight: The Aha! experience. In: Ball LJ & Tourangeau FW, editors. The Routledge international handbook of creative cognition. NY: Routledge, ISBN 9780367503468, p. 308–331.
11 Faust M & Mashal N (2007). The role of the right cerebral hemisphere in processing novel metaphoric expressions taken from poetry: A divided visual field study. *Neuropsychologia.* **45**(4): 860–870.
12 Graves R (1983). Mouth asymmetry, dichotic ear advantage and tachistoscopic visual field advantage as measures of language lateralization. *Neuropsychologia.* **21**(6): 641–649.
13 Herwig U, Satrapi P, Schönfeldt-Lecuona C (2003). Using the international 10-20 EEG system for positioning of transcranial magnetic stimulation. *Brain Topogr.* **16**(2): 95–99.
14 Jung-Beeman M (2005). Bilateral brain processes for comprehending natural language. *Trends Cogn Sci.* **9**(11): 512–518.
15 Jung-Beeman M, Bowden EM, Haberman J, Frymiare JL, Arambel-Liu S, Greenblatt R, et al. (2004). Neural Activity When People Solve Verbal Problems with Insight. *PLoS Biol.* **2**(4): e97.
16 Kass RE, Raftery AE (1995). Bayes Factors. *J Am Stat Assoc.* **90**(430): 773–795.
17 Kounios J & Beeman M (2014). The cognitive neuroscience of insight. *Annu Rev Psychol.* **65**: 71–93.
18 Laukkonen RE & Tangen JM (2018). How to Detect Insight Moments in Problem Solving Experiments. *Front Psychol.* **9**: 282.
19 Li Y, Beaty RE, Luchini S, Dai DY, Xiang S, Qi S, et al. (2023). Accelerating Creativity: Effects of Transcranial Direct Current Stimulation on the Temporal Dynamics of Divergent Thinking. *Creat Res J.* **35**(2): 169–188.
20 Liu G, Ga R, Wang C, Hu H, Liang Z, Yu Q, et al. (2025). Cathodal stimulation on left dorsolateral prefrontal cortex facilitates restructuring process underlying insight problem solving. *Creat Res J.* 1–12.
21 Luft CDB, Zioga I, Banissy MJ, Bhattacharya J (2017). Relaxing learned constraints through cathodal tDCS on the left dorsolateral prefrontal cortex. *Sci Rep.* **7**(1): 2916.
22 Marko M, Michalko D, Riečanský I (2019). Remote associates test: An empirical proof of concept. *Behav Res Methods.* **51**(6): 2700–2711.
23 Metuki N, Sela T, Lavidor M (2012). Enhancing cognitive control components of insight problems solving by anodal tDCS of the left dorsolateral prefrontal cortex. *Brain Stimul.* **5**(2): 110–115.
24 Peña J, Sampedro A, Balboa-Bandeira Y, Ibarretxe-Bilbao N, Zubiaurre-Elorza L, García-Guerrero MA, et al. (2022). Comparing transcranial direct current stimulation and transcranial random noise stimulation over left dorsolateral prefrontal cortex and left inferior frontal gyrus: Effects on divergent and convergent thinking. *Front Hum Neurosci.* **16**: 997445.
25 Peña J, Sampedro A, Gómez-Gastiasoro A, Ibarretxe-Bilbao N, Zubiaurre-Elorza L, Aguiar C, et al. (2021). The Effect of Changing the Balance Between Right and Left Dorsolateral Prefrontal Cortex on Different Creativity Tasks: A Transcranial Random Noise Stimulation Study. *J Creat Behav.* **55**(4): 899–915.
26 Rossi S, Hallett M, Rossini PM, Pascual-Leone A, Safety of TMS Consensus Group (2009). Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. *Clin Neurophysiol.* **120**(12): 2008–2039.
27 Salvi C (2024). Markers of insight. In: Ball LJ & Tourangeau FW, editors. The Routledge international handbook of creative cognition. NY: Routledge, ISBN 9780367503468, p. 475–490.
28 Salvi C, Beeman M, Bikson M, McKinley R, Grafman J (2020). TDCS to the right anterior temporal lobe facilitates insight problem-solving. *Sci Rep.* **10**(1): 946.
29 Santarnecchi, E, Sprugnoli G, Bricolo E, Costantini G, Liew SL, Musaeus CS, et al. (2019). Gamma tACS over the temporal lobe increases the occurrence of Eureka! Moments. *Sci Rep.* **9**(1): 5778.
30 Shen W, Tong Y, Li F, Yuan Y, Hommel B, Liu C, et al. (2018). Tracking the neurodynamics of insight: A meta-analysis of neuroimaging studies. *Biol Psychol.* **138**: 189–198.
31 Špajdel M (2020). Dichotická stimulácia v psychologickej diagnostike. Trnava: Filozofická fakulta Trnavskej univerzity v Trnave, ISBN 9788056802687.
32 Sprugnoli G, Rossi S, Emmendorfer A, Rossi A, Liew S, Tatti E, et al. (2017). Neural correlates of Eureka moment. *Intelligence.* **62**: 99–118.
33 Sprugnoli G, Rossi S, Liew SL, Bricolo E, Costantini G, Salvi C, et al. (2021). Enhancement of semantic integration reasoning by tRNS. *Cogn Affect Behav Neurosci.* **21**(4): 736–746.
34 Stoet G (2010). PsyToolkit: A software package for programming psychological experiments using Linux. *Behav Res Methods.* **42**(4): 1096–1104.
35 Stoet G (2017). PsyToolkit: A Novel Web-Based Method for Running Online Questionnaires and Reaction-Time Experiments. *Teach Psychol.* **44**(1): 24–31.
36 Subramaniam K, Kounios J, Parrish TB, Jung-Beeman M (2009). A brain mechanism for facilitation of insight by positive affect. *J Cogn Neurosci.* **21**(3): 415–432.
37 Voyer D, Bowes A, Techentin C (2008). On the perception of sarcasm in dichotic listening. *Neuropsychology.* **22**(3): 390–399.
38 Webb ME, Little DR, Cropper SJ (2016). Insight Is Not in the Problem: Investigating Insight in Problem Solving across Task Types. *Front Psychol.* **7**: 1424.
39 Weinstein S, Graves RE (2002). Are Creativity and Schizotypy Products of a Right Hemisphere Bias? *Brain Cogn.* **49**(1): 138–151.
40 Westerhausen R & Hugdahl K (2008). The corpus callosum in dichotic listening studies of hemispheric asymmetry: A review of clinical and experimental evidence. *Neurosci Biobehav Rev.* **32**(5): 1044–1054.
41 Xiang S, Qi S, Li Y, Wang L, Dai DY, Hu W (2021). Trait anxiety moderates the effects of tDCS over the dorsolateral prefrontal cortex (DLPFC) on creativity. *Pers Individ Dif.* **177**: 110804.
42 Zmigrod S, Colzato LS, Hommel B (2015). Stimulating Creativity: Modulation of Convergent and Divergent Thinking by Transcranial Direct Current Stimulation (tDCS). *Creat Res J.* **27**(4): 353–360.

Copyright © 2026 Activitas Nervosa Superior Rediviva ISSN 1337-933X