

Increasing cognitive control abilities inhibit creative responses, but not if they are too “far” away: A tDCS study

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Introduction

The role of cognitive control in creativity is still debated. On the one hand, *lower* cognitive control can facilitate generation of more novel ideas. On the other, *higher* cognitive control can facilitate the evaluation of these ideas, thus leading to creative ideas that are both novel and appropriate. Studies applying brain stimulation techniques on the prefrontal cortex have demonstrated how inhibiting cognitive control mechanisms can enhance the generation of creative responses. In the current study, we demonstrate for the first time how increasing cognitive control mechanisms via brain stimulation can inhibit such generative processes. Furthermore, we show how this enhanced inhibition is limited in its effect on responses, contingent upon their “semantic distance”.

tDCS



Fig. 1. tDCS illustration

Stimulation

- Cathodal, anodal, and sham (N = 15 each)
- F7, contra. Mastoid
- 1.5 mA for 17min
- Stimulation began 3 min prior to 1st trial

Uncommon Sentence Completion Task

- Participants are presented with sentences missing a final word and are asked to generate uncommon endings to complete them:
 - A good way to exercise is to ride a _____
 - For Christmas dinner, the family ate a _____
- Participants are presented with 120 sentences, varying in sentence length (4-12 words) and cloze probability (70%-90%)

Measures

- Voice onset RT
- Semantic distance (Latent Semantic Analysis inverse score)
- Phonemic Fluency (FAS)
- Reading Span
- Amazon Mechanical Turk ratings of responses (Novelty, Appropriateness, Creativity)

Amazon Mechanical Turk Creativity Ratings

Novelty

The property of originality or newness of the response in relation to completing the sentence. Furthermore, a novel response can be completely unrelated to the end of the sentence

Parameter	Estimate	Std. Error	P-value
(Intercept)	2.78	0.21	< .001
SL	0.04	0.01	< .001
FAS	0.01	0.00	.02
SD	1.44	0.01	< .001
RT	-0.11	0.01	< .001
Anodal	-0.27	0.09	.004
Cathodal	0.00	0.09	.99

Table 1. Fixed effects estimates of variables in the model significantly predicting Novelty, Appropriateness, and Creativity

Appropriateness

The inherent explanatory ease of the responses to complete the sentence. Whether the response is comprehensible, understandable, and accessible in relation to the sentence that it completes

Parameter	Estimate	Std. Error	P-value
(Intercept)	4.93	0.31	< .001
SL	-0.01	0.01	.15
FAS	-0.01	0.01	.02
SD	-1.62	0.17	< .001
RT	0.12	0.02	< .001
Anodal	0.80	0.21	< .001
Cathodal	0.22	0.21	.28
Anodal x SD	-0.64	0.22	.04
Cathodal x SD	-0.35	0.22	.11

Creativity

Can add up to more than the sum of its parts (novelty and appropriateness), and represents how much the response is clever, or non obvious, in completing the sentence

Parameter	Estimate	Std. Error	P-value
(Intercept)	3.02	0.16	< .001
WL	-0.05	0.01	< .001
Cloze	0.56	0.14	< .001
FAS	0.00	0.00	.03
SD	1.57	0.04	< .001
RT	-0.08	0.01	< .001

Fig. 2. Fixed effects analysis of the effect of stimulation on Novelty, Appropriateness, and Creativity. Error bars show 95% confidence interval

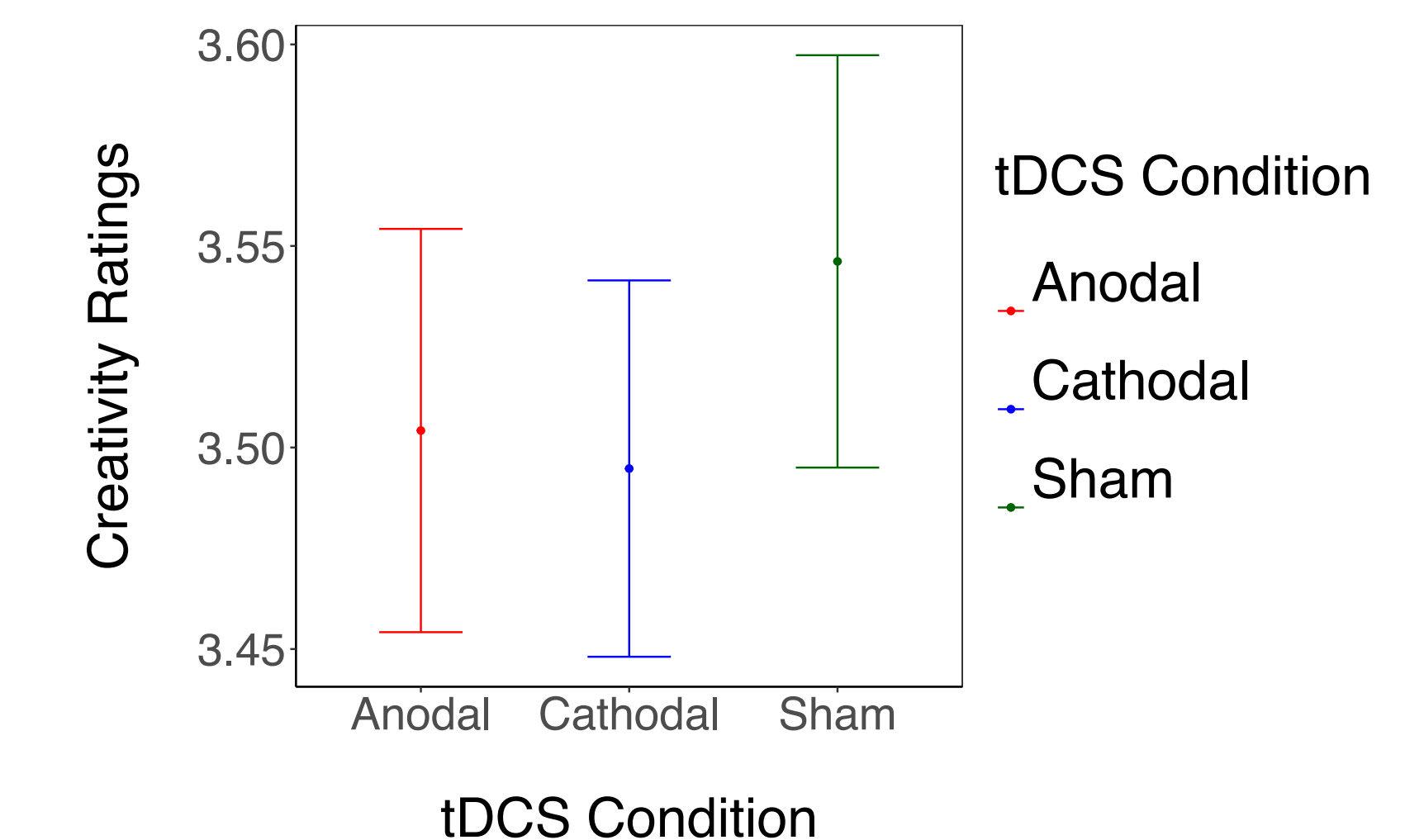
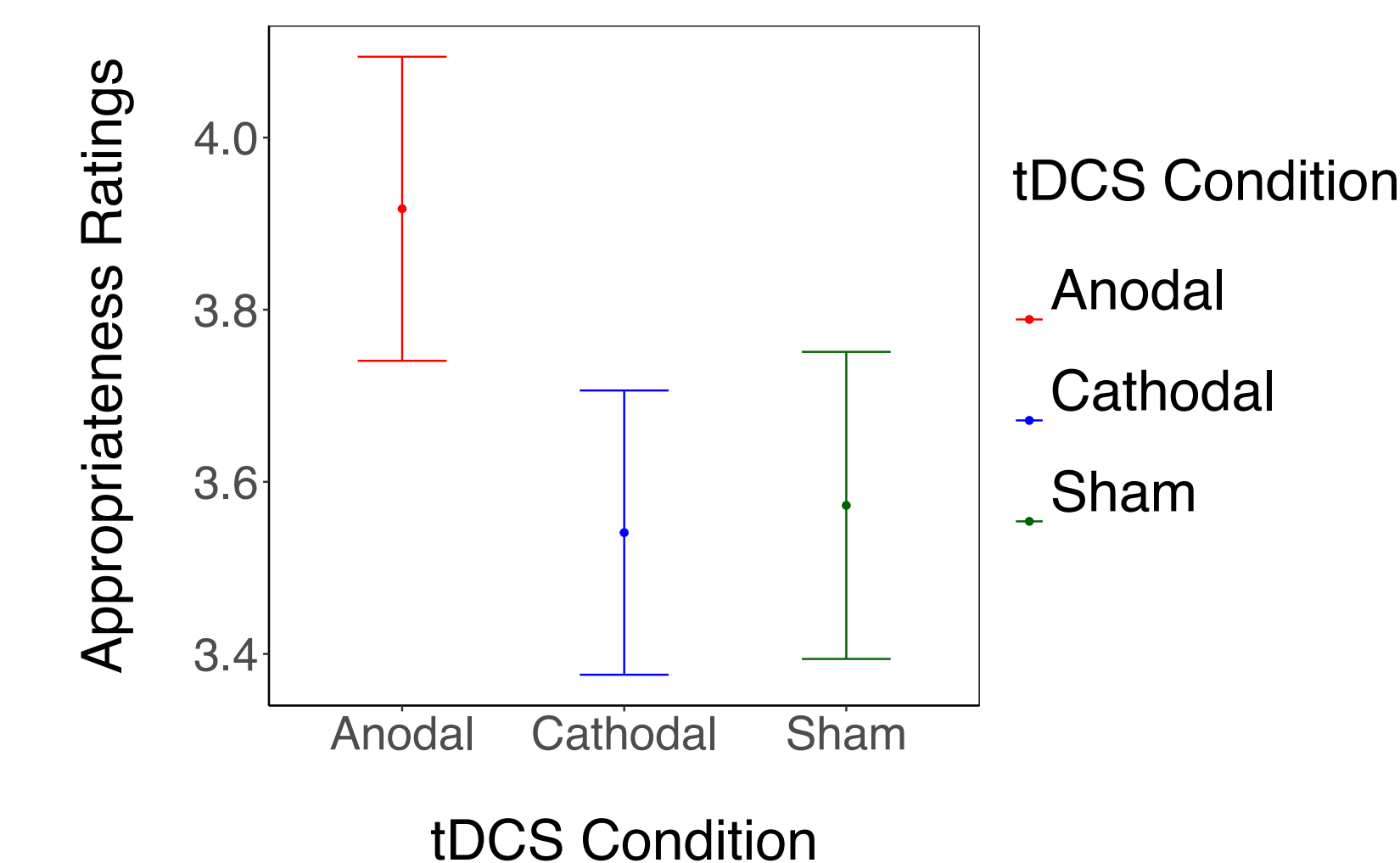
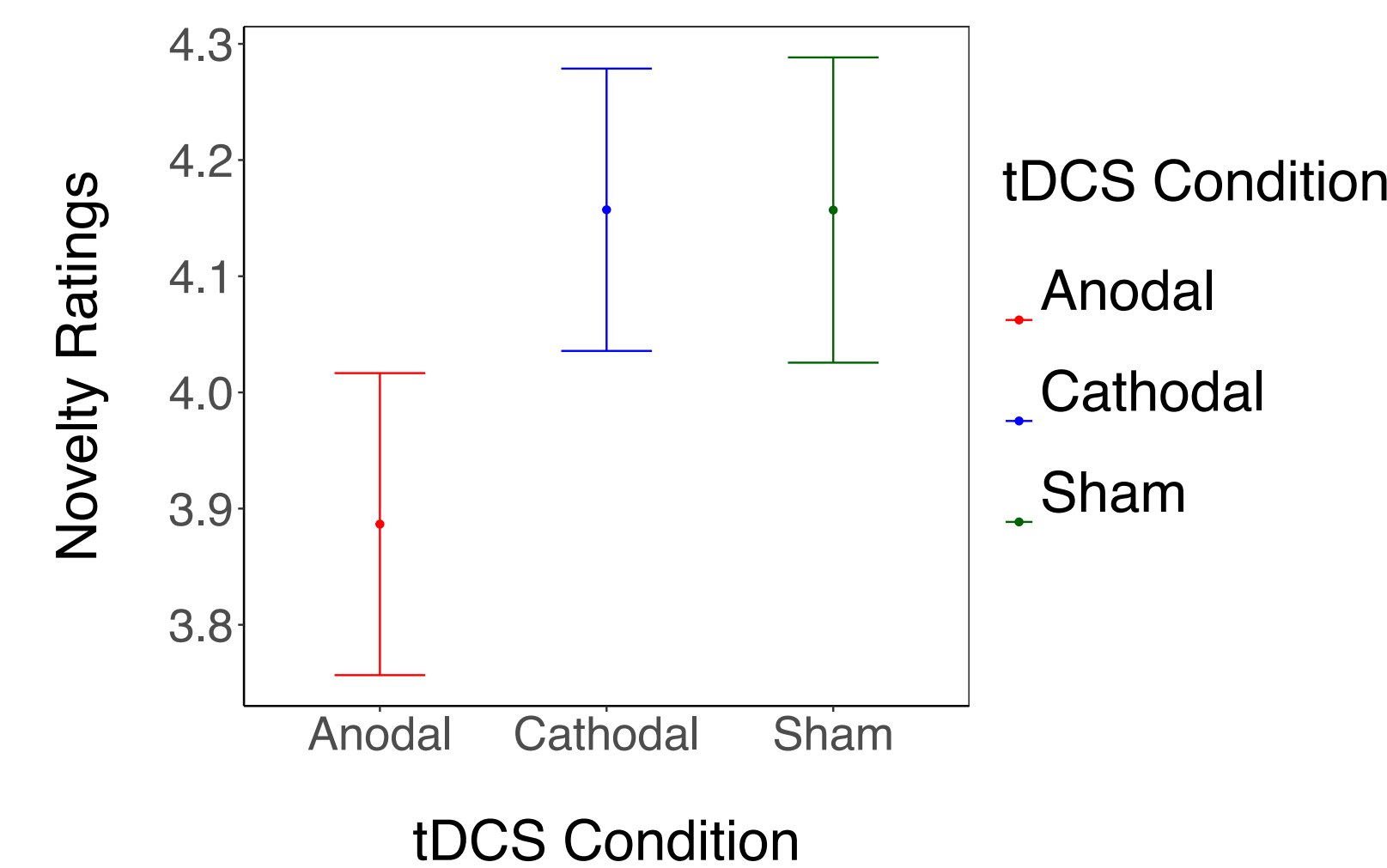
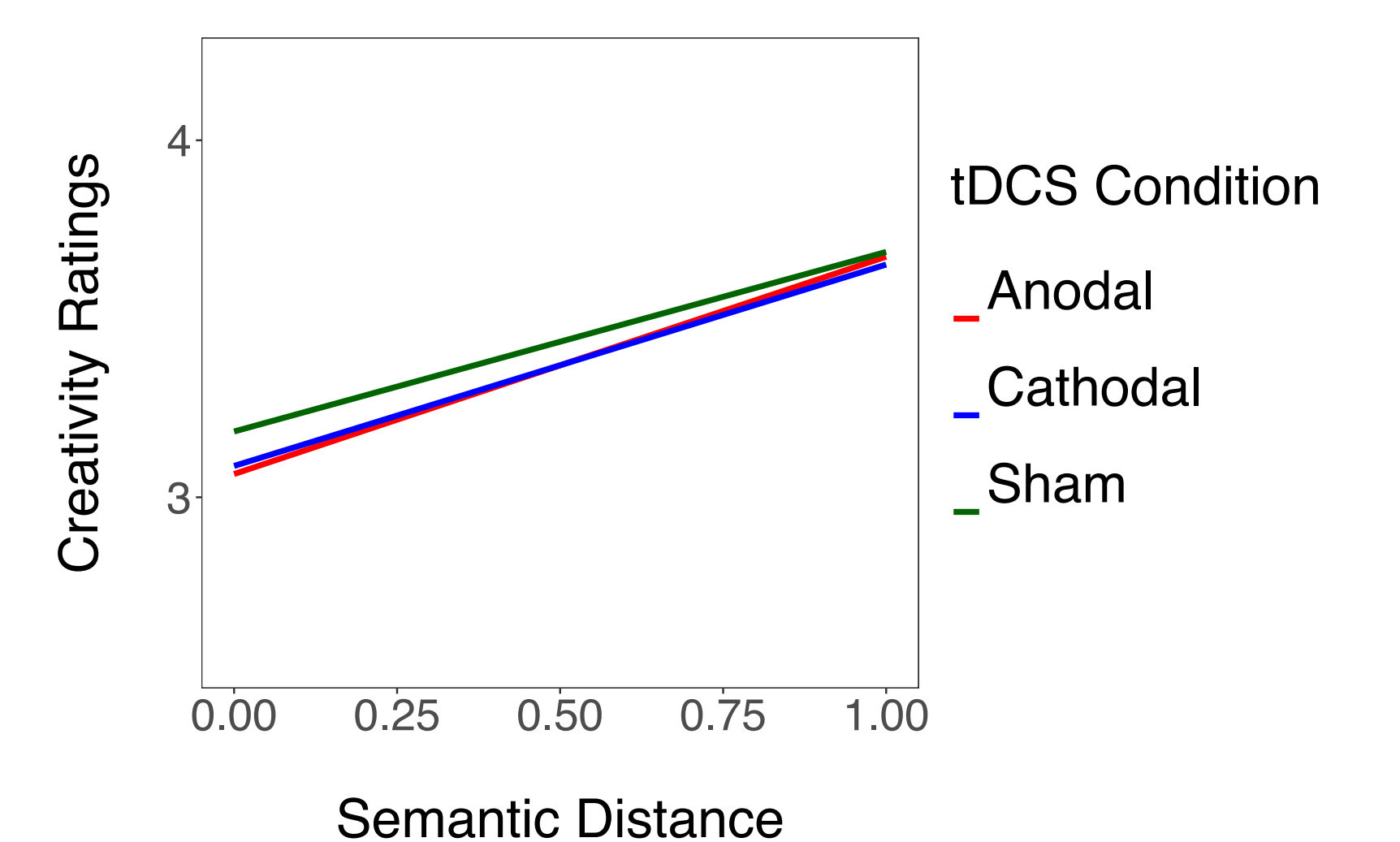
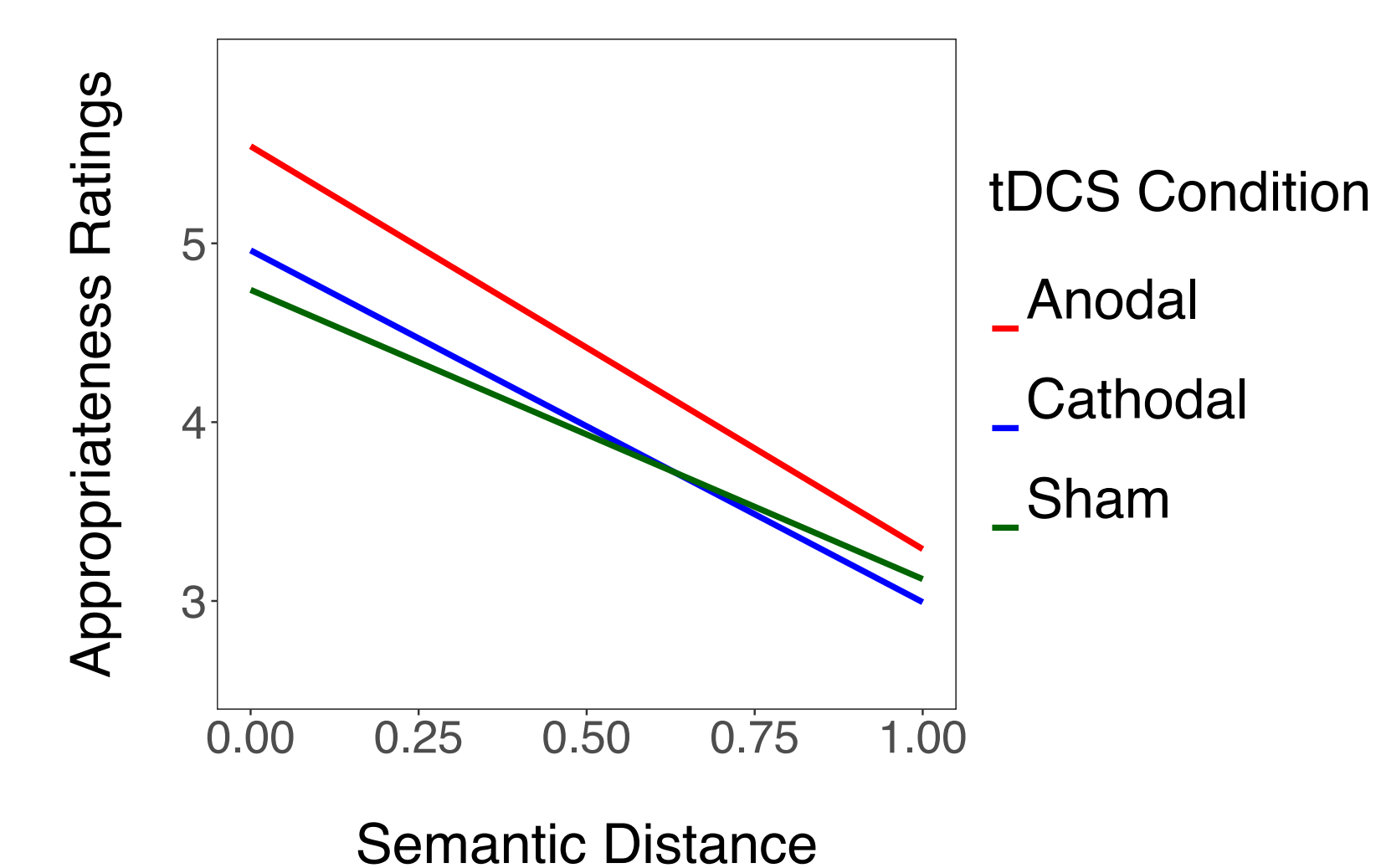
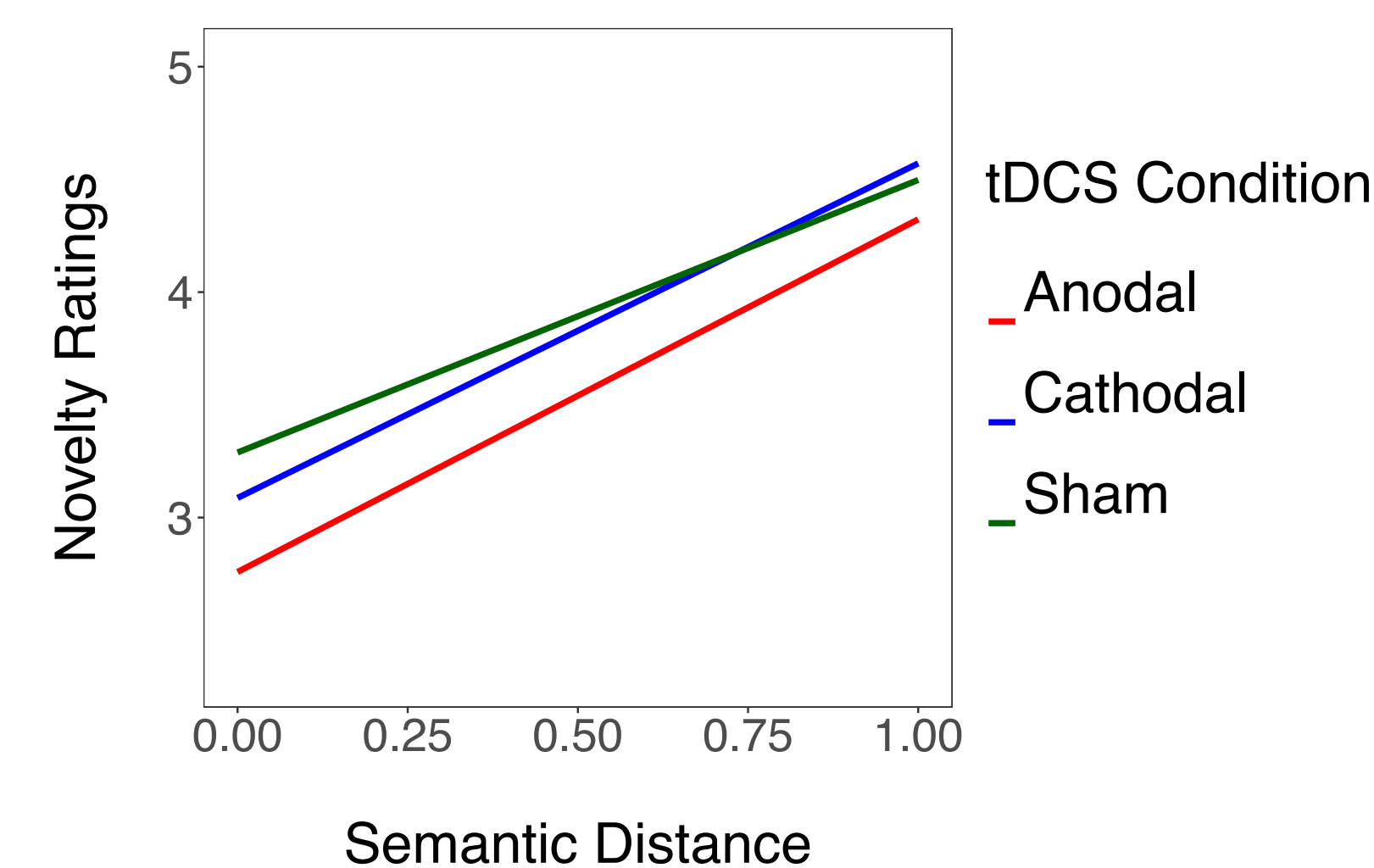


Fig. 3. Slope analysis of the interaction between tDCS stimulation and semantic distance on Novelty, Appropriateness, and Creativity



Linear Mixed Effect Models

- Regression model selection analysis to predict Novelty, Appropriateness, and Creativity (**Table 1**)
- Fixed effect parameter estimate analysis on the effect of stimulation (**Fig. 2**)
- Slope estimate analysis on the interaction between stimulation condition and semantic distance (**Fig. 3**)

Conclusions

- Anodal stimulation produced significant differences in the types of responses participants generated to the uncommon sentence completion task.
- Furthermore, semantic distance significantly increased the novelty of a response and decreased its appropriateness.
- Such responses were subjectively rated by an independent group of judges to be more appropriate and less novel.
- Semantic distance significantly interacted with tDCS stimulation for appropriateness ratings, and approached significance for novelty ratings.

