

Posthypnotic suggestion removes Stroop conflict but does not affect error monitoring

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Abstract

Neuroimaging data consistently implicate the anterior cingulate cortex (ACC) within a network involving conflict. Researchers debate whether the same underlying computation by the ACC is involved both in error detection and conflict monitoring. Since our recent fMRI data showed that ACC activity related to conflict could be reduced by hypnotic suggestion, we examined the error-related negativity (ERN), an electrophysiological index of response monitoring elicited by error and localized to the ACC, both in the presence and absence of conflict. We hypothesized that despite reports of reduced ACC activations following conflict removal, the midfrontal ERN would be maintained. We show unaltered ERN amplitude regardless of conflict and conclude that the ACC effectively monitored responses despite reduced activity levels following the reduction of conflict suggesting that the mechanisms of error detection do not rest upon prior conflict.

Background

Proficient readers required to name the ink color of a displayed word are usually slower and less accurate identifying the ink color of an incompatible color word (e.g., responding "blue" to the word "RED" displayed in blue ink) than identifying the ink color of a neutral or congruent item (e.g., responding "red" to the word "LOT" or the word "RED" inked in red). When highly-suggestible subjects are given a hypnotic suggestion to view words as nonsense the interference in reaction time found for the incongruent trials disappears¹⁻³ and anterior cingulate activity is greatly reduced⁴. In the current study we ask if this reduction in ACC activity influences the amplitude of the ERN.

Hypotheses

Given that it is possible to experimentally reduce Stroop conflict¹⁻⁴, if the ERN is even partly invoked by conflict we would expect it to be reduced following conflict removal or reduction, compared to typical conflict.

Methods

Participants

Behavioral and event-related potentials (ERP) data were collected from 12 highly-suggestible participants, both naturally vigilant and under posthypnotic suggestion. All subjects were right-handed, presented normal color vision, and demonstrated high English proficiency and no Chinese proficiency. Participants were individually screened for suggestibility in a hypnotic context using both a standard group test (Harvard-A) and an individual test (SHSS-C). Hypnotizability scores were 10 or above (out of 12).

ERP Data Acquisition

ERPs were sampled at 250 Hz with 128-electrode dense-array geodesic sensor net referenced to the vertex. With the exception of voltages exceeding $\pm 100 \mu V$, transients exceeding $\pm 50 \mu V$, and electro-oculogram activity exceeding $\pm 70 \mu V$ trials were averaged in a response-locked fashion, digitally transformed to an average reference, band-pass filtered (0.5-20 Hz), and corrected for baseline over a 200 msec window before response onset. For each subject and condition, amplitude minimum was determined within a predetermined latency window of 0-100 msec. Differences between conditions were validated by computing pairwise t-test comparisons with a criterion where the dependent variables were calculated by averaging peak amplitudes and latencies recorded over a midfrontal site (electrode #6). Procedure

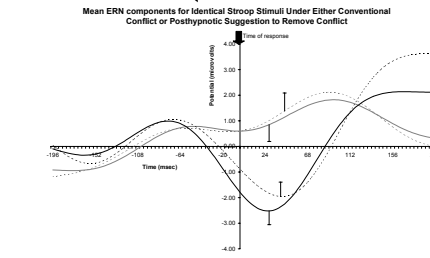
Participants were randomly assigned to an administration order of the two experimental conditions (i.e., either Suggestion or NoSuggestion). Half the subjects first ran the Stroop task following a standard hypnotic induction with an embedded posthypnotic suggestion and then when naturally alert. The remaining participants experienced these two conditions in the reverse order. In the identity of errors, all subjects were urged to only attend to the ink color and to identify it quickly even at the cost of a few mistakes.

To impede reading of the stimuli, a specific posthypnotic suggestion instructed subjects to construe the subjects to view the Stroop words as nonsense strings (e.g., written in Chinese). See top right corner for the exact wording of the suggestion.

When not under the posthypnotic suggestion condition, subjects were instructed to fixate on a central cross and respond (i.e., depress a key) conventionally.

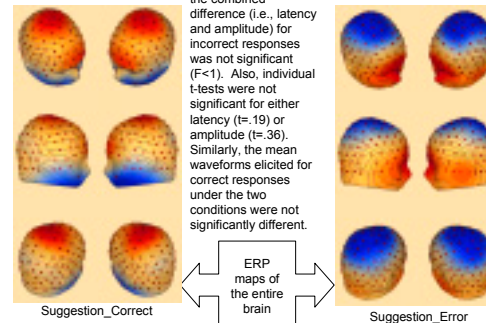
Error-related Negativity

Brain waves comprising the ERN were grand-averaged across all participants from the individual response-locked average waves elicited by each participant across all experimental conditions. Waveforms elicited by incorrect responses without suggestion peaked at a negative potential of $1.96 \mu V$ some 40 msec after the response whereas incorrect responses under suggestion reached a $-2.52 \mu V$ nadir 28 msec following response.



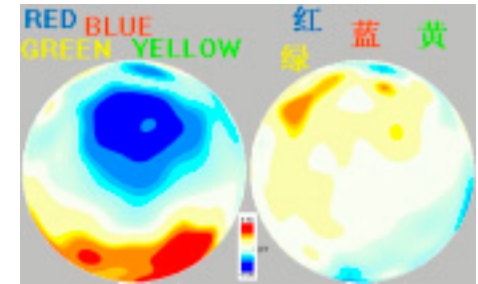
	Suggestion		NoSuggestion	
	Correct	Incorrect	Correct	Incorrect
Congruent	1041	111	1090	62
Neutral	1042	110	1058	94
Incongruent	1041	111	1071	81
$F(3, 11)$	3124	332	3219	237

A statistical F-test of the combined difference (i.e., latency and amplitude) for incorrect responses was not significant ($F < 1$). Also, individual t-tests were not significant for either latency ($t = 19$) or amplitude ($t = 36$). Similarly, the mean waveforms elicited for correct responses under the two conditions were not significantly different.



The Posthypnotic Suggestion

"Very soon you will be playing the computer game. When I clap my hands, meaningless symbols will appear in the middle of the screen. They will feel like Chinese characters, and you will not attempt to attribute any meaning to them. This gibberish will be printed in one of four ink colors: red, blue, green or yellow. Although you will only be able to attend to the symbols' ink color, you will look straight at the scrambled signs and crisply see all of them. Your job is to quickly and accurately depress the key that corresponds to the ink color shown. You will find that you can play this game easily and effortlessly."



Target-locked ERPs showing mean response of 12 highly-hypnotizable subjects 123 msec following onset of incongruent Stroop words. Left and right panels show NoSuggestion and Suggestion, respectively. The posthypnotic suggestion seems to alter early visual processing (i.e., P1 and N1).

Conclusions

Our behavioral results reaffirm earlier reports showing that a specific posthypnotic suggestion to construe Stroop words as nonsense strings eliminated the Stroop conflict compared to a no-suggestion condition¹⁻³. Although fMRI results showed that such suggestion-induced conflict removal involved a significant reduction in ACC activity⁴, our ERP data showed that the ERN, an index of performance monitoring localized to the ACC, remained unchanged regardless of suggestion. These data reveal that responding to identical input stimuli, subjects were able to maintain comparable executive monitoring of conflict, as indexed by the ERN, independent of conflict resolution. Thus, whereas ACC activity may be reduced following the elimination of conflict, by the time a response is produced (i.e., at least 400 msec following stimulus presentation) the ACC is capable of effective performance monitoring.

References

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The Stroop Conditions

Congruent:

RED, YELLOW, GREEN, BLUE

Neutral:

LOT, FLOWER, KNIFE, SHIP

Incongruent:

RED, YELLOW, GREEN, BLUE

In responding to the ink color of an incompatible (incongruent) color word, participants are usually much slower and less accurate than in identifying the ink color of a control (neutral) item. This is called the Stroop Interference Effect and is one of the most robust and well-studied phenomena in attentional research.

Behavioral Results

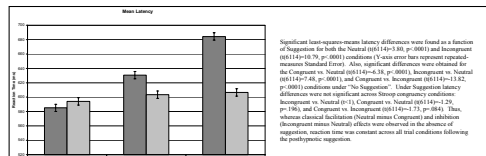


Table 1: Mean behavioral Stroop data for twelve highly suggestible individuals. Reaction time (RT in msec) and accuracy (ACC in %) alongside their Standard Deviations (SD) are shown as a function of the posthypnotic suggestion.

	Suggestion		NoSuggestion		Suggestion		NoSuggestion	
	RT	SD	RT	SD	ACC	SD	ACC	SD
Congruent	594	136.2	585	139.9	90.4	29.5	94.6	22.6
Neutral	603	145.5	631	165.1	90.4	29.5	93.0	25.6
Incongruent	607	154.7	684	218.6	90.5	29.4	91.8	27.4