1 Distinct Brain Mechanisms for Conflict Adaptation Within and Across Conflict Types

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Abstract

Cognitive conflict, like other cognitive processes, shows the characteristic of adaptation, i.e., conflict effects are attenuated when immediately following a conflicting event, a phenomenon known as the conflict adaptation effect (CAE). One important aspect of CAE is its sensitivity to the intertrial coherence of conflict type, i.e., behavioral CAE occurs only if consecutive trials are of the same conflict type. Although reliably observed behaviorally, the neural mechanisms underlying such a phenomenon remains elusive. With a paradigm combining the classic Simon task and Stroop task, this fMRI study examined neural correlates of conflict adaptation both within and across conflict types. The results revealed that when the conflict type repeated (but not when it alternated), the CAE-like neural activations were observed in dorsal anterior cingulate cortex, inferior frontal gyrus, superior parietal lobe, etc. (i.e., regions within typical task-positive networks). In contrast, when the conflict type alternated (but not when it repeated), we found CAE-like neural deactivations in a range of regions including bilateral superior and medial frontal gyri, bilateral angular cortex, bilateral temporal cortices, etc. (i.e., regions within the typical task-negative network). Moreover, this CAE-like neural deactivation predicts behavior performance. Network analyses suggested that these regions (for CAE-like neural activities within and across conflict type[s] respectively) can be clustered into two antagonistic networks. This evidence suggests that our adaptation to cognitive conflicts within a conflict type and across different types may rely on these two distinct neural mechanisms.

Key words: conflict adaptation effect, conflict type, fMRI, cognitive control, brain network

1. Introduction

Adaptation is an important property of many cognitive and neural processes which can occur at different cognitive levels when we are repetitively exposed to the same type of stimuli (Clifford & Palmer, 2018; Thompson & Burr, 2009; Zinke, Schweinberger, Kaufmann, & Kawahara, 2009). At higher levels of cognition, adaptation has been used as a research tool to probe the process of cognitive control, typically via adaptations in conflict processing. The conflict effect decreases after encountering an incongruent event relative to encountering a congruent event, a phenomenon known as the conflict adaptation effect (CAE) (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Gratton, Coles, & Donchin, 1992). Importantly, behavioral CAEs are highly sensitive to the coherence of the conflict type in adjacent trials, i.e., CAEs happen only when consecutive trials belong to the same conflict type (e.g., a Stroop type of conflict vs. a Simon type of conflict). Although this sensitivity of the CAE has been extensively reported and discussed at behavioral level (for a review, see Braem, Abrahamse, Duthoo, & Notebaert, 2014), the corresponding neural mechanisms are still unclear.

A behavioral CAE is commonly defined as the reaction time (RT) difference between the conflict effect after a congruent trial and the conflict effect after an incongruent trial, as described by the following equation:

$$CAE = (RT_{CI} - RT_{CC}) - (RT_{II} - RT_{IC}) \quad (1)$$

where C and I are the abbreviations of congruent and incongruent, respectively (Nieuwenhuis et al., 2006). To investigate sensitivity of the CAE to intertrial coherence on conflict type, the CAE-related brain activities in both within-type and across-type conditions need to be examined and compared (eight conditions). However, previous studies have examined brain areas showing a CAE-like neural activation mainly within the same conflict type (Carter et al., 2000; Chechko, Kellermann, Schneider, & Habel, 2014; Chun, Park, Kim, Kim, & Kim, 2017; Egner & Hirsch, 2005b), and the neural mechanisms understanding the loss of CAE in

75 across-type conditions have rarely been examined. Therefore, in this study, to explore
76 the full picture of the neural correlates of CAEs, especially the neural mechanisms
77 underlying sensitivity to conflict type, it was necessary to perform the analysis based
78 on its definition in both conflict type repetition and alternation conditions (see
79 Methods for details).

80 To date, there have been only a limited number of event-related potential
81 (ERP) studies and region of interest (ROI) studies attempting to reveal the
82 mechanisms underlying the conflict-type sensitivity. N2 and P3, two components
83 corresponding to the mental processing of conflict detection and attention allocation
84 (Clayson & Larson, 2011), were found to show a CAE only when the consecutive
85 conflict sequences were repeated (Q. Li et al., 2015; Z. Li et al., 2021). In addition, an
86 ROI-based functional magnetic resonance imaging (fMRI) study observed the conflict
87 type sensitivity functions that focused on the conflict detection region (i.e., anterior
88 cingulate cortex [ACC]) and executive control regions (i.e., premotor cortex and
89 dorsolateral prefrontal cortex [DLPFC]) (Kim, Chung, & Kim, 2010, 2012). These
90 studies together implied that the lack of behavioral CAEs in conflict-alternation
91 conditions might reflect the absence of conflict detection, attention allocation and
92 executive control mechanisms in alternating conflict type sequences. However, the
93 low spatial resolution of ERP technology (Q. Li et al., 2015; Z. Li et al., 2021) and the
94 ROI-based method (Kim et al., 2010, 2012) cannot describe the whole picture of
95 neural processing in CAEs sensitive to conflict types. It remains possible that other
96 CAE related brain areas reported in previous studies, such as the superior parietal lobe
97 (SPL) (Egner, Delano, & Hirsch, 2007) and inferior frontal gyrus (IFG) (Egner, 2011),
98 may also show conflict type sensitive CAE.

99 The current study aimed to elucidate the neural mechanisms of the sensitivity
100 of the CAE to conflict type with a whole-brain exploratory method. We adopted a
101 Stroop-color-Simon paradigm and collected fMRI data during the task performance.
102 This paradigm has been reported to be valid in producing robust behavioral and neural

103 conflict-type sensitive CAEs (Liu, Park, Gu, & Fan, 2010; K. Wang, Li, Zheng, Wang,
104 & Liu, 2014). We hypothesize that the conflict processing related brain areas, such as
105 the cingulo-opercular and frontoparietal regions, would show CAE-like neural
106 activities (mirroring behavioral CAEs) only in conflict type repetition but not in
107 conflict type alternation conditions. Additionally, we predict that the brain regions
108 showing conflict-type sensitive CAEs could predict the behavior.

109 **2. Methods**

110 **2.1. Participants**

111 Twenty right-handed volunteers (8 males and 12 females, average age:
112 21.7 ± 1.6 years) took part in the experiment. The sample size was decided based on
113 previous fMRI studies detecting similar CAE effects (Chun et al., 2017; Kim et al.,
114 2012; Purmann & Pollmann, 2015). All participants were healthy, with normal or
115 corrected-to-normal visual acuity and were free of psychiatric or neurological history.
116 Before the experiment, all participants signed an informed consent form that was
117 approved by the Institutional Review Board of the Institute of Psychology, Chinese
118 Academy of Sciences. All participants were compensated for their participation. One
119 participant was removed from the statistical analysis because of excessive head
120 motion (rotation > 2 degrees in two runs).

121 [Figure 1]

122 **2.2. Apparatus, Stimuli, and Procedure**

123 The paradigm was adopted from previous studies (Liu et al., 2010; K. Wang et
124 al., 2014) and modified for the fMRI experiment (see Figure 1). Stimulus presentation
125 was controlled by E-Prime 2.0 (Psychological Software Tools, Inc., Pittsburgh, PA,
126 USA). The stimulus was a center-displayed diamond (visual angle $4.9^\circ \times 4.9^\circ$) with
127 half (a triangle) painted either red or blue. The triangle pointed in one of four
128 directions (left, right, up, and down). A Chinese character indicating a color (i.e., “红”
129 meaning red, or “蓝” meaning blue) or having a neutral meaning (i.e., “杯” means a

130 cup, and “莫” means “do not”; these two words were selected because they had
131 similar font structure with “红” and “蓝”, respectively) displayed in black ink, was
132 overlaid in the center of the diamond. All stimuli were presented on a gray
133 background. Before scanning, the participants were trained to become familiar with
134 the task. The participants were allowed to enter the scanner to perform a formal test
135 when their training accuracy reached 90%. Color-response mapping was
136 counterbalanced across participants.

137 There were two types of conflicts during the test. In the Stroop conflict, the
138 word was either “red” or “blue”, and the color of the triangle was either red or blue.
139 Whether or not the character matched the color of the triangle formed the Stroop
140 congruent (StC) and Stroop incongruent (StI) conditions, respectively. In addition, the
141 triangle always pointed up or down to avoid a combination with a Simon conflict. In
142 the Simon conflict, the colored triangle pointed left or right. The consistency between
143 the orientation of the triangle and the response hand (left or right) determined the
144 Simon congruency, i.e., Simon congruent (SmC) or Simon incongruent (SmI). In
145 addition, the overlaying word was always color-irrelevant (e.g., “杯” meaning cup) to
146 avoid a combination with a Stroop conflict. The participants were instructed to make a
147 left or right key press based on the color of the stimulus (red or blue) while ignoring
148 other information and to respond as quickly and accurately as possible. From the
149 perspective of the participants, there were no differences between the Simon and
150 Stroop tasks. Therefore, there was no task switching between different conflicts.

151 The participants performed four test sessions. Each session consisted of 162
152 trials listed in a pseudorandom fashion, with equal numbers of StI, StC, SmI and SmC
153 trials intermixed randomly, and equal probability of each secondary trial sequence
154 (e.g., StC-SmI, SmC-StC). The pseudorandom lists were generated with the
155 AlphaSim function of AFNI software. Each trial lasted 2000 ms, with a prestimulus
156 fixation icon presented centrally for 100~300 ms, followed by a white diamond with a

character in the middle (700 ms); then, the task stimulus (a colored triangle) appeared 200 ms after the onset of the diamond and lasted for 500 ms, after which a poststimulus fixation icon was presented for the remainder of the trial. The participants were allowed a maximum of 1500 ms from the onset of the target display to respond. In addition, to better estimate the event-related fMRI signals, 55 blank trials with only the fixation icon, each lasting 2000 ms, were inserted into each session, dividing each long run into multiple mini-blocks. The number of fixation trials between mini-blocks followed the exponential distribution.

2.3. Behavioral Data Analysis

Data were analyzed with dependent variables of both reaction time (RT) and error rate (ER). To avoid misleading potential conflicting RT and ER results, we also calculated the linear integrated speed-accuracy score (LISAS), an index that has been proven to efficiently account for the variance in behavioral measures (Vandierendonck, 2017). The LISAS was calculated with the following equation:

$$\text{LISAS} = \text{RT} + \frac{SD_{RT}}{SD_{ER}} \times \text{ER}$$

The first trial of each mini-block (10.5%), error trials (3.7%), correct trials after an error trial (3.2%), and trials with RTs beyond 3 standard deviations (SDs) of the mean or shorter than 200 ms (0.4%) were excluded before analyzing the interaction between the previous congruency and the current congruency (i.e., the CAE). We conducted three-way repeated-measures analyses of variance (ANOVAs) of consecutive conflict type (2, repetition vs. alternation) $\times$ previous congruency (2, congruent vs. incongruent) $\times$ current congruency (2, congruent vs. incongruent) with RT, ER and LISAS, respectively. The interaction between conflict type alternation and the CAE was our major analysis of interest.

2.4. Image acquisition

Functional imaging was performed on a 3T Trio scanner (Siemens Medical Systems, Erlangen, Germany) using echoplanar imaging (EPI) sensitive to

183 blood-oxygen-level dependent (BOLD) contrast (in-plane resolution of $3.4 \times 3.4 \text{ mm}^2$,
 184 64×64 matrix, 32 slices with a thickness of 3 mm and an interslice skip of 0.99 mm,
 185 repetition time (TR) of 2000 ms, echo-time (TE) of 30 ms, and a flip angle of 90°). In
 186 addition, a sagittal T1-weighted anatomical image was acquired as a structural
 187 reference scan, with a total of 128 slices at a thickness of 1.33 mm with no gap and an
 188 in-plane resolution of $1.0 \times 1.0 \text{ mm}^2$.

189 **2.5. Image processing**

190 **2.5.1. Preprocessing.** The acquired images were processed using SPM12
 191 software (<http://www.fil.ion.ucl.ac.uk/spm/>). For each subject and for each functional
 192 run, the first five volumes were discarded. The remaining images were corrected for
 193 head movement between scans by an affine registration. In one of the twenty subjects,
 194 head movements of rotation within two of four functional runs exceeded 2 degrees
 195 and therefore was excluded from further analyses. The T1 image was segmented into
 196 gray matter, white matter, cerebrospinal fluid, skin, skull and air. The
 197 head-motion-corrected functional images were aligned to the T1-weighted anatomical
 198 image through rigid-body registration. Then, the EPI images were spatially
 199 normalized to standard Montreal Neurological Institute (MNI) space using the spatial
 200 normalization parameters that mapped the structural image to the MNI space template.
 201 Normalized data were smoothed using an 8 mm full-width at half-maximum (FWHM)
 202 Gaussian kernel.

203 **2.5.2. Whole-brain analysis.** For statistical analysis, fMRI data were analyzed
 204 using a two-level hierarchical general linear model (GLM). The first-level design
 205 matrix modeled fixed effects over the four sessions of smoothed data. Each session
 206 was modeled using eight event-related regressors, one for each of the conflict
 207 sequence conditions (repeated, altered, incongruent and congruent components
 208 represented by rep, alt, I and C, respectively, to define the conditions as repCC, repCI,
 209 repIC, repII, altCC, altCI, altIC, and altII). In addition, another regressor modeled
 210 errors/missed trials, and six regressors of no interest contained the realignment

parameters to correct for motion artifacts. The eight conditions and the error regressors were convolved with a canonical hemodynamic response function (HRF) in SPM. Low-frequency signal drifts were filtered using a cutoff period of 128 s. Linear t -contrasts for CAE (CI-CC vs. II-IC) as well as the reverse contrast in conflict type repetition and alternation were tested (Chun et al., 2017; Michels, 2016). We also examined the first-order contrasts (I vs C and its reverse contrast) on average for all conditions, as well as that for type repetition and alternation conditions separately (Table 2). In the second level, one-sample t -tests of the above contrasts were analyzed. We adopted the voxel-level threshold of $p < .005$ (one-tailed) and a minimum cluster of 300 voxels (2400 mm^3) to explore the whole-brain activities. The contrast images in volume were transferred into surface and visualized with Connectome Workbench software (Van Essen et al., 2013).

2.5.3. Post hoc ROI analysis of CAE-like neural activities. To further clarify the specific activation patterns in conflict-type repetition and alternation conditions, we performed an ROI analysis with the regions reported in the whole-brain analysis. We first tested whether each region showed a CAE activation in both conflict-type repetition and alternation conditions identified by equation (1) with one-sample t tests, and then extracted beta estimation values of each region (for the eight conditions) to illustrate the exact activation patterns.

To evaluate whether the neural activations of task-positive and task-negative networks could predict the corresponding behavioral performance, we took an overlap of the survival brain areas in conflict-type repetition condition and task-positive networks, including the frontoparietal network (FPN), the dorsal attention network (DAN) and the cingulo-opercular network (CON) as the task-positive areas; similarly, task negative areas were defined as the overlapping areas between the survival brain areas in conflict-type alternation condition and task-negative network (i.e., the DMN). Network atlas was adopted from Power et al. (2011).

238 **2.5.4. Connectivity analysis.** The Conn toolbox (Version 19.c,
239 Whitfield-Gabrieli & Nieto-Castanon, 2012) was used to compute the functional
240 connectivity of different brain areas activated in different conditions. The first peak
241 coordinates of task-positive and task-negative areas reported in the whole-brain
242 analysis (Table 1) were selected as ROIs. The weighted GLM method was used. By
243 convolving the HRF of the temporal BOLD signal, the ten events (eight task
244 conditions, one error/missing condition and one rest condition) regressors and their
245 first-order derivatives were included. In addition, six head motions as well as their
246 first-order derivatives, the white matter and the cerebrospinal fluid were regressed out.
247 The residuals were then used to calculate task-based functional connectivity. The
248 connectivity values of the eight conditions of interest (i.e., repII, repIC, repCI, repCC,
249 altII, altIC, altCI, and altCC) were averaged and then entered into second-level
250 analysis. Standard cluster-based parametric inferences were applied to examine the
251 clusters of functional network connectivity.

252 **3. Results**

253 **3.1. Behavioral Results**

254 For the RT, we observed a significant main effect of current congruency, $F(1,$
255 $18) = 153.37, p < .001, \eta_p^2 = .90$. Participants' responses were slower in incongruent
256 condition (445 ms) than in congruent condition (416 ms), indicating a conflict effect.
257 The main effect of previous congruency was also significant, $F(1,18) = 7.40, p = .014,$
258 $\eta_p^2 = .29$. Participants responded more slowly in post-incongruent conditions (432 ms)
259 than in post-congruent conditions (429 ms), indicating a post-conflict slowing effect
260 (Verguts, Notebaert, Kunde, & Wuhr, 2011). We also observed an interaction
261 between previous congruency and current congruency (i.e., CAE), $F(1,18) = 16.17, p$
262 $= .001, \eta_p^2 = .47$, suggesting that the conflict effect (incongruent vs. congruent) was
263 significantly smaller after incongruent trials (445 ms vs. 413 ms) than after congruent
264 trials (444 ms vs. 420 ms). Moreover, the interaction among consecutive conflict type,
265 previous congruency, and current congruency was significant, $F(1,18) = 12.15, p$

266 = .003, $\eta_p^2 = .40$. Simple effect analyses revealed that there was a significant CAE
 267 only in the conflict type repetition condition (16 ms), $F(1,18) = 26.19$, $p < .001$, but
 268 not in the conflict type alternation condition (0 ms), $F(1,18) < 0.01$, $p = .986$. No
 269 other main effects or interactions were observed (see Figure 2A).

270 For the ER, there was a significant main effect of current congruency (i.e.,
 271 conflict effect), $F(1, 18) = 27.06$, $p < .001$, $\eta_p^2 = .60$. Participants had a higher ER in
 272 incongruent conditions (4.2%) than in congruent conditions (1.6%). Importantly, the
 273 interaction among consecutive conflict type, previous congruency, and current
 274 congruency was significant, $F(1,18) = 4.96$, $p = .039$, $\eta_p^2 = .22$. Simple effect analyses
 275 revealed that there was a significant CAE only in the conflict type repetition condition
 276 (2.3%), $F(1,18) = 4.91$, $p = .040$, but not in the conflict type alternation condition
 277 (-1.3%), $F(1,18) = 2.65$, $p = .121$. No other significant main effects or interactions
 278 were found (see Figure 2B).

279 For the LISAS, there was a significant main effect of current congruency (i.e.,
 280 conflict effect), $F(1, 18) = 123.73$, $p < .001$, $\eta_p^2 = .87$. Participants responded more
 281 slowly in incongruent conditions (458 LISAS units) than in congruent conditions (421
 282 LISAS units). The interaction between previous congruency and current congruency
 283 (i.e., CAE) was significant, $F(1,18) = 13.76$, $p = .002$, $\eta_p^2 = .43$, suggesting that the
 284 conflict effect (incongruent vs. congruent) was smaller after incongruent trials (459
 285 LISAS units vs. 417 LISAS units) than after congruent trials (457 LISAS units vs.
 286 425 LISAS units). Moreover, the interaction among consecutive conflict type,
 287 previous congruency, and current congruency conditions was significant, $F(1,18)$
 288 $= 20.56$, $p < .001$, $\eta_p^2 = .53$. Simple effect analyses revealed that there was a
 289 significant CAE only in the conflict type repetition condition (24 LISAS units),
 290 $F(1,18) = 26.10$, $p < .001$, but not in the conflict type alternation condition (-3 LISAS
 291 units), $F(1,18) < 1$. No other main effects or interactions were observed (see Figure
 292 2C).

293 [Figure 2]

294 3.2. FMRI Results

295 **3.2.1. Brain activation correlates of CAEs: when conflict type repeats vs.**
 296 **when it changes.** When the previous trial was of the same conflict type, the CAE (i.e.,
 297 greater conflict effect [activation in incongruent condition minus activation in
 298 congruent condition] after a congruent trial than the conflict effect after a conflict trial)
 299 is reflected in the activation of the bilateral inferior occipital cortices (IOC), bilateral
 300 SPL, ACC, IFG, and middle temporal motion complex (MT+) (Table 1). In contrast,
 301 when the conflict type changes between consecutive trials, the conflict effect
 302 (incongruent activation minus congruent activation) after a previous congruent trial
 303 was found to be greater than that after a previous conflict trial in the bilateral superior
 304 frontal gyri (SFG), left pre-central gyrus (preCG), bilateral angular gyri (AG) and
 305 bilateral lateral temporal cortex (LTC), also showing CAE-like activities.

306 [Table 1]

307 [Figure 3]

308 **3.2.2 Brain activation correlates of conflict effects.** The average conflict
 309 effect was associated with brain areas commonly reported in conflict tasks, such as
 310 supplementary motor area, inferior parietal lobe, and so on. We also observed
 311 deactivation of superior/medial frontal regions. Further analyses showed that the
 312 activations were driven by the conflict type repetition condition, and the deactivations
 313 were driven by type alternation condition (see Table 2).

314 [Table 2]

315 **3.2.3. Post hoc ROI analysis of CAE-like neural activities.**

316 One-sample t test of the CAEs revealed clear dissociations between the
 317 conflict type repetition and alternation conditions (Figure 4 and 5, bar plots). On the
 318 one hand, those brain areas showing CAE-like neural activities in conflict type
 319 repetition condition were entirely inactive in conflict type alternation condition
 320 ($ps > .110$). On the other hand, those brain areas showing CAE-like neural activities

in conflict type alternation condition were either inactive (for the bilateral SFG, left preCG, left AG and bilateral LTC, $ps > .090$) or deactivated (for the right AG, $p = .032$) in the conflict type repetition condition. In addition, we extracted the activations for each of the eight basic conditions (e.g., repIC, Figures 4 and 5, line graphs). We found that the areas activated in the conflict type repetition condition were positively activated, and the areas activated in the conflict type alternation condition were negatively activated in most cases.

[Figure 4]

[Figure 5]

3.2.4. Verifying the involvement of task-positive/task-negative networks. In

view of the above results, we investigated whether the areas showing CAE-like neural activities in the conflict type alternation condition matched the task-negative network, and the areas showing CAE-like neural activities in the conflict type repetition condition matched the task-positive networks. We applied two different methods to clarify this issue. First, the masks of task-positive and task-negative networks from Power et al.'s (2011) parcellation (see the grey areas in Figure 3A and 3B) were used to examine whether the activated areas were contained by the task-positive/negative networks. We computed the percentage of voxels inside the suspected networks, with the regions reported in Table 1, except the bilateral IOC and left preCG. For instance, we suspected that the brain areas of the ACC, IFG, MT+ and bilateral SPL activated in the conflict type repetition conditions were inside the task-positive networks. The number of voxels overlapping with the task-positive networks was 1773, and the total number of activated areas was 2755. Therefore, the brain area percentage within task-positive networks for the conflict type repetition condition was 64.4%. Similarly, the brain area percentage within the DMN for the conflict type alternation condition was 74.0% (3599/4862).

To examine whether the task-positive and task-negative brain areas functioned as networks, we computed the functional connectivity between these ROIs.

Connectivity analysis revealed two closely connected clusters (see Figure 6). One cluster constituted the brain areas activated in the conflict type alternation condition, namely, the bilateral AG, bilateral SFG and bilateral LTC, with 15 (i.e., a full connection, $C_6^5 = 15$) significant ROI-to-ROI connections, $F(2,17) = 234.90$, $p\text{-FDR} = .000$. The other cluster constituted the brain areas activated in the conflict type alternation condition, namely, the ACC, MT+, IFG, and bilateral SPL, with eight significant ROI-to-ROI connections (the two nonsignificant connections were IFG-MT+ and ACC-MT+), $F(2,17) = 100.38$, $p\text{-FDR} = .000$. These two clusters were significantly anti-correlated, with 29 ROI-to-ROI connections (with an exception only between r-SFG and IFG), $F(2, 17) = 85.43$, $p\text{-FDR} = .000$.

[Figure 6]

3.2.5. Correlations between brain activities and behaviors. Correlation analyses were conducted to examine whether task-positive and task-negative areas modulated the CAE size. The activated regions within task-positive and task-negative networks (by excluding the voxels outside the corresponding networks) were selected as two whole ROIs. The CAE-like neural activities of the task-positive and task-negative ROIs were calculated similarly to the behavioral CAEs (i.e., the LISAS results). We found a significant negative correlation between the task-negative ROI (de)activation and the behavioral performance in the conflict type alternation condition, $r = -0.43$, $p = .034$ (see Figure 7B). However, no correlation was observed between the average activation of task-positive areas and CAEs in the conflict type repetition condition, $r = 0.25$, $p = .15$ (see Figure 7A).

[Figure 7]

4. Discussion

With the Stroop-color-Simon paradigm which discreetly combines the two distinct types of conflict, the present study aimed to examine the neural mechanisms underlying the sensitivity of the CAE to the coherence of conflict types. We demonstrated that with an adequate analytic strategy, CAE-like neural activities can

377 be observed both within a conflict type and between distinct conflict types.
 378 Specifically, when the conflict type repeated (but not when it alternated), CAE-like
 379 neural activities were manifested as an activation pattern in regions within
 380 task-positive networks (i.e., the dACC, IFG, SPL and MT+). Whereas when the
 381 conflict type alternated (but not when it repeated), CAE-like neural activities were
 382 associated with a deactivation pattern in regions within task-negative networks (i.e.,
 383 the SFG, AG and LTC). The CAE-like neural activities of task-negative networks
 384 could also predict the behavioral cross-type CAEs. Network analyses suggest that the
 385 two groups of brain regions showed synchronous activity within their respective
 386 group, on the other hand regions showed antagonistic activity between the two groups.
 387 To our knowledge, this is the first report on the task-negative network correlates of
 388 the sensitivity of CAEs in relation to conflict types. These findings extended our
 389 understanding of the conflict type sensitive CAE processing.

390 **4.1. CAE-like neural activities in DMN Regions When Conflict Type Alternates**

391 One novel finding of this study is that when conflict-type alternates, our neural
 392 adaptation to conflicts is related to deactivation of regions within the task-negative
 393 network, i.e., after a conflict trial of another type, these regions tend to be more
 394 de-activated in the current incongruent condition than they do in the current congruent
 395 condition.

396 The DMN was originally characterized as a network of regions consistently
 397 being deactivated in non-self-referential, goal-directed tasks, though later it was better
 398 known as a network that becomes active during conscious rest (Raichle, 2015).
 399 Meanwhile, many DMN regions can be activated by tasks involving certain implicit
 400 processes, such as introspection, and was considered to be the source of
 401 “mind-wandering” (Andrews-Hanna, 2012). Therefore, the deactivation of the DMN
 402 is regarded as a way to reduce internal distraction, which may act as a resource
 403 compensation mechanism in demanding tasks (Anticevic et al., 2012; Rajan et al.,
 404 2019). Considering these facts, the CAE pattern we observed that after a conflict trial

of another type, DMN regions tend to deactivate further for the current conflict event, may reflects the way how our brain reacts to successive control demand of another cognitive type. As shown by the correlation results, when the control demand was larger, as indexed by the lower behavioral cross-type CAE, a stronger CAE-like neural activity in DMN (corresponding to the larger deactivation of DMN in post-incongruent condition) was observed. Therefore, the DMN might have been reactively involved in the resource compensation when conflict type alternated.

Our network analysis further suggests that activity within these DMN regions tend to be synchronous and are antagonistic to activity of the task positive network (3.2.4). It seems that the adaptive reaction of our neural system to alternating conflict events is primarily manifested as the deactivation in DMN region rather than reconfiguration in task positive regions.

4.2. CAE-like activities in Task-positive Regions When Conflict Type Repeats

When a conflict type repeats, the same conflict resolution mechanism is supposed to be involved. Therefore, participants needed to in real time mobilize the conflict-processing mechanism that resides in task-positive regions, causing activation in these regions which were captured by fMRI signals (M. M. Botvinick, Braver, Barch, Carter, & Cohen, 2001; Kerns et al., 2004).

The task-positive regions (i.e., dACC, IFG, SPL, MT+) we observed well replicated previous studies (Egner, 2011; Egner et al., 2007; Egner & Hirsch, 2005a; Kerns, 2006; Kerns et al., 2004; Sheth et al., 2012). The dACC is believed to play a key role in conflict detection during dynamic conflict adjustment (M. Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; M. M. Botvinick et al., 2001); the right IFG is believed to act as the source of on-line cognitive control in dynamically resolving conflicts (Egner, 2011); and the SPL and MT+ are believed to bias attention resources towards task-relevant stimuli (Egner et al., 2007; Egner & Hirsch, 2005a; Purmann & Pollmann, 2015). Moreover, we found strong intrinsic connectivity between the dACC, IFG, SPL and MT+ areas, indicating that the CAE was probably attributable

to a broader conception of task-positive networks, which had been largely concealed in previous studies. This idea is consistent with a recent finding that conflict resolution involves widely distributed brain areas (Q. Li et al., 2017).

Akin to the behavioral performance, these task-positive areas showed a conflict-type sensitive feature, that is, the CAE-like neural activities were not found in these areas. These results nicely replicated previous ERP studies (Q. Li et al., 2015; Z. Li et al., 2021) that found CAE sensitivity on the conflict related N2 and P3 components, but we localized the source of domain-specific CAE with a higher spatial resolution. The inactivation of the task-positive areas in the conflict type alternation condition may provide a direct explanation for the loss of the CAE when conflict type alternated. In comparison with the previous perspectives that the dissociated cognitive control mechanisms underlying Stroop and Simon conflicts prevented the CAE from occurring (Egner, 2008; Egner et al., 2007; Egner & Hirsch, 2005b; Kim et al., 2012), we shed light on the dynamic mechanisms underlying the loss of cross-conflict CAEs.

4.3. Other Findings

In addition to the task-positive areas, we also observed similar conflict type sensitive activities in the visual area (i.e., IOG). This may help to resolve discrepancies regarding how cognitive control modulates sensory inputs in conflict processing. Generally speaking, conflict resolution can be achieved by either facilitating task-relevant stimuli or suppressing task-irrelevant stimuli (Z. Li, Goschl, & Yang, 2020). With a face-name Stroop task, a previous study found that the fusiform face area showed a CAE-like neural activity (similar to the results of the IOG in the conflict type repetition condition in our study) when the face was task-relevant, but not when the face was task-irrelevant (Egner & Hirsch, 2005a). Egner and Hirsch (2005a) thus proposed that the conflict resolution was achieved by facilitating task-relevant information. However, this explanation was challenged by the findings of several behavioral studies (Lee & Cho, 2013; Yang et al., 2017); these

researchers observed a loss of cross-conflict CAEs when task-relevant information was kept constant while task-irrelevant information changed, which was unexpected since the repetition of task-relevant information should have produced the CAE. However, our results implied that the repetition of task-relevant information may not produce the CAE when the conflict type alternated, because the task-relevant facilitation control mechanism that supports a CAE was absent, as shown by the inactivation of task-positive and visual areas. We thus propose that the facilitation of task-relevant information does underlie the conflict processing when the conflict type repeats, but it is turned down when the conflict type alternated.

We also observed that the preCG was deactivated in the conflict type alternation condition. The preCG area is generally believed to be related to motion function. A previous study found that higher activation of the preCG contributed to a faster response (P. Wang, Fuentes, Vivas, & Chen, 2013). Moreover, decreased activity in the preCG has been related to impairments in motor preparation and execution (Spinelli et al., 2011). Therefore, the deactivation of the preCG in the post-incongruent condition in our study is probably related to post-conflict slowing, as shown in the RT results. Such a finding was consistent with a previous ERP study that localized the source of RT slowing to the precentral area (Chang, Ide, Li, Chen, & Li, 2017). Post-conflict slowing possibly reflects a speed-accuracy tradeoff to make the future response less error-prone (Weissman, 2020), and the preCG might play a key role in achieving this process.

4.4. Limitations

There is a notable limitation in our study. Previous studies have suggested that the CAE could be attributed to both an adjustment in top-down control and bottom-up associative learning such as feature binding (for a review, see Duthoo et al., 2014). A common practice to examine the pure cognitive control mechanisms underlying the CAE is to remove the bottom-up learning trials (e.g., Yang et al., 2017), which accounted for approximately half of the total trials in our design. To obtain greater

detecting power, we did not remove these bottom-up learning trials. The basic behavioral results should not have been influenced, because there is evidence that whether the bottom-up factors were removed or not did not affect the sensitivity of the CAE to conflict type (Weissman, 2020). Although it is possible that the brain (de)activations reported in our study also reflected the processing of bottom-up learning, the observation of within-conflict CAE activations mainly in task-positive networks implied a dominant contribution of cognitive control (instead of learning). Therefore, we mainly discussed the results from the top-down control perspective. To better examine the pure cognitive control mechanisms, future studies could be designed by increasing the stimulus-response sets (Braem et al., 2014; Braem et al., 2019; Duthoo et al., 2014).

4.5. Conclusion

Our study found that there are different brain areas involved in the within-conflict and cross-conflict CAE. On the one hand, when conflict type repeated (rather than when it alternated), the activation of task-positive areas, such as the dACC, IFG, SPL and MT+, contributed to the within-conflict CAE. On the other hand, when the conflict type alternated (rather than when it repeated), the deactivation of task-negative areas, such as the SFG, AG and LTC, contributed to the absence of the cross-conflict CAE. These two anticorrelated networks collectively modulated the conflict type sensitive CAE.

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670 Tables

671 Table 1. Brain activations for CAE effects in conflict type repetition and alternation conditions.

Region	L/R	MNI coordinate			Volume (No. of voxels)	MaxZ	BA
		x	y	z			
<i>(CI-CC) > (II-IC), conflict type repetition</i>							
inferior occipital cortex	L	-18	-96	-2	4517	5.98	18
fusiform gyrus	L	-28	-66	-22		3.92	19
fusiform gyrus	L	-48	-36	-14		3.59	37
inferior occipital cortex	R	38	-74	-4	2478	4.58	18
fusiform gyrus	R	38	-44	-10		4.49	19
superior parietal lobe	R	20	-50	50	867	4.45	7
superior parietal lobe	L	-26	-64	40	628	3.72	7
dorsal anterior cingulate cortex	R	12	20	48	555	4.00	32
inferior frontal gyrus	R	46	10	18	382	4.43	9
middle temporal motion complex	L	-40	-52	0	323	3.67	19
<i>(II-IC) > (CI-CC), conflict type repetition</i>							
None							
<i>(CI-CC) > (II-IC), conflict type alternation</i>							
superior frontal gyrus	L	-12	42	44	2630	4.33	9
superior frontal gyrus	L	-42	18	46		3.95	8
rostral anterior cingulate cortex	R	14	44	4		3.66	32
superior frontal gyrus	R	16	30	54	717	4.31	8
middle frontal gyrus	R	46	14	46		2.71	8
precentral gyrus	L	-22	-18	62	668	4.19	4
angular gyrus	L	-44	-70	12	523	3.61	39
lateral temporal cortex	L	-60	6	-16	344	3.90	21
angular gyrus	R	52	-62	28	344	3.12	39
lateral temporal cortex	R	56	-14	-22	304	3.62	21
<i>(II-IC) > (CI-CC), conflict type alternation</i>							
None							

672

673 Table 2. Brain activations for the first-order contrast analysis

Region		L/R	MNI coordinate (mm)			Volume (No. of voxels)	Max Z	BA
			x	y	z			
<i>I > C on average</i>								
supplementary motor area		R	10	-4	66	5117	5.22	6
middle frontal gyrus		L	-26	-4	60		4.86	6
precentral gyrus		L	-44	-2	34		4.15	6
inferior parietal lobule		L	-30	-52	36	4269	4.94	40
superior parietal lobule		R	28	-54	44		4.30	7
precuneus		L	-10	-76	48		3.40	7
fusiform gyrus		L	-38	-42	-24	3183	4.55	37
inferior occipital gyrus		L	-32	-78	-8		4.29	19
lingual gyrus		L	-16	-104	-22		3.47	17
culmen		R	44	-46	-30	2090	4.27	37
middle occipital gyrus		R	24	-90	0		4.15	19
middle occipital gyrus		R	56	-76	-16		3.36	19
inferior frontal gyrus		L	-44	-2	34	730	4.15	6
insula		R	32	20	4	406	4.84	13
<i>I < C on average</i>								
superior frontal gyrus		L	-16	44	26	1878	4.34	10
superior medial gyrus		R	14	48	26		4.29	9
medial frontal gyrus		L	-14	46	-6		3.80	32
<i>I > C in the conflict type repetition condition</i>								
supplementary motor area		R	12	-6	72	8699	5.53	6
inferior frontal gyrus		L	-30	28	-2		5.50	47
middle frontal gyrus		L	-30	-4	44		4.87	6
precuneus		L	-24	-56	38	6768	4.93	7
precuneus		R	6	-64	60		4.76	7
postcentral gyrus		R	46	-30	38		4.60	2
middle occipital gyrus		L	-28	-80	0	4164	4.78	18
culmen		L	-42	-50	-28		4.16	37
lingual gyrus		L	-16	-102	-22		3.64	17
inferior temporal gyrus		R	38	-74	-4	3211	4.63	19
culmen		R	46	-48	-30		4.39	37
declive		L/R	0	-88	-28		3.25	-
inferior frontal gyrus		R	44	18	4	890	3.23	45
<i>I < C in the conflict type repetition condition</i>								
None								

I > C in the conflict type alternation condition

superior frontal gyrus	L	-14	-10	72	431	4.19	6
------------------------	---	-----	-----	----	-----	------	---

I < C in the conflict type alternation condition

medial frontal gyrus	L	-18	36	26	1133	3.69	9
superior frontal gyrus	R	20	44	54		3.60	8
anterior cingulate gyrus	R	8	38	12		3.40	32
cuneus	L	-12	-96	28	456	4.03	19

674

675 **Figures**

676
677 *Figure 1.* Experimental design and procedures. Participants were asked to respond to the color of the triangle and
678 ignore any other information.

679

680
681 *Figure 2.* Behavioral CAE as measured by RT, ER and LISAS. When adjacent trials are of the same conflict type,
682 CAE can be observed, i.e., an incongruent previous trial leads to a smaller conflict effect than a congruent previous
683 trial does. In contrast, when adjacent trials are of the different conflict types, no CAE is observed. Error bars
684 indicate standard errors. Con = congruent; InC = incongruent; Rep = repetition of conflict type; Alt = alternation of
685 conflict type; RT = reaction time; ER = error rate; LISAS = linear integrated speed-accuracy score.

Figure 3. Brain correlates of the CAE for conflict-type repetition and alternation conditions respectively. Significant regions for the CAE contrast, (CI-CC)-(II-IC), are shown in A and B. The dark gray areas indicate the task-positive networks (including the dorsal attentional network, frontoparietal network and cingulo-opercular network) in (A) and task-negative network (i.e., the DMN) in (B). The templates of networks were adopted from the atlas of Power et al. (2011). Abbreviations. IOC = inferior occipital cortex; FG = fusiform gyrus; SPL = superior parietal lobe; ACC = anterior cingulate cortex, IFG = inferior frontal gyrus, MT+ = middle temporal motion complex; SFG = superior frontal gyrus; preCG = precentral gyrus; AG = angular gyrus; LTC = lateral temporal cortex; L = left; R = right.

Figure 4. The activation of each ROI activated in conflict type repetition condition. The line graphs show the beta values as a function of congruent and incongruent conditions for both current and previous trials and their relationship (type repetition or alternation). The points above the dash lines denote positive activations. The bar plots show the CAE-like neural activities calculated by beta contrasts of (CI-CC) - (II-IC). Error bars stand for standard error. *** denotes $p < .001$; ** denotes $p < .01$; * denotes $p < .05$. Abbreviations. Con = congruent; InC = incongruent; Rep = repetition; Alt = alternation.

703

704

705 *Figure 5.* The (de)activation of for each ROI activated in conflict type alternation condition. The line graphs show
 706 the beta values as a function of congruent and incongruent conditions for both current and previous trials and their
 707 relationship (type repetition or alternation). The points below the dash lines denote negative activations (i.e.,
 708 deactivations). The bar plots show the CAE-like neural activities calculated by beta contrasts of (CI-CC) - (II-IC).
 709 Error bars stand for standard error. *** denotes $p < .001$; ** denotes $p < .01$; * denotes $p < .05$. Abbreviations. Con
 710 = congruent; InC = incongruent; Rep = repetition; Alt = alternation.

711

712

713 *Figure 6.* Functional connectivity of the task-positive and task-negative brain areas activated during the conflict
 714 type repetition and alternation conditions. The color denotes the t-value for each connectivity.

715

716

717 *Figure 7. Scatter plot of the relationships between fMRI-level and behavioral-level CAE in the conflict-type*

718 *repetition condition (A) and the conflict-type alternation condition (B).*

Simon

Stroop

Congruent

Incongruent

500-700ms

200ms

500ms

600-800ms

A **B** **C**

A **B**

A **B**