

Running Head: Neural Correlates of Belief Bias Inhibition

The neural correlates of belief-bias inhibition: the impact of logic training

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Abstract:

Dual-process theories propose two types of cognitive process -Type1 heuristic processing and Type2 analytic processing - that underlie belief biased reasoning. Previous studies have shown neural correlates of these types of processing, but the effect of logical training on neural activation in belief bias remains unclear. Functional Magnetic Resonance Imaging (fMRI) was used to investigate the brain activity associated with response change in a belief bias paradigm before and after logic training. Participants completed two sets of belief biased reasoning tasks. In the first set they were instructed to respond based on their empirical beliefs, and in the second - following logic training - they were instructed to respond logically. The comparison between conflict problems in the second scan versus in the first scan revealed differing activation for the left inferior frontal gyrus, left middle frontal gyrus, cerebellum, and precuneus. The scan was time locked to the presentation of the minor premise, and thus demonstrated effects of belief-logic conflict on neural activation earlier in the time course than has previously been shown in fMRI. These data, moreover, indicated that logical training results in changes in brain activity associated with cognitive control processing which is a form of Type2 processing. It is argued that this evidence favors a dual-process theory of belief-bias rather than a single process account.

Key words: Dual-process; Belief-bias; Logical training; Inhibition; Event-related fMRI

Introduction

When we discuss sports, politics or religion our beliefs have an influence on the arguments we are willing to accept. Beliefs (in this context our empirical knowledge about the world) have also been shown to have a profound effect on the inferences that people make in the lab (Evans, Barston & Pollard, 1983). In deductive reasoning (the process of inferring logically valid conclusions from premises), the belief-bias effect is that reasoners typically accept more believable conclusions than unbelievable conclusions, but also accept more logically valid conclusions than invalid. These factors interact such that performance on problems where belief and logic are consistent is superior to belief-neutral problems, however, participants have considerable difficulty where there is a belief-logic conflict **Error! Reference source not found.** Dual-process theories attempt to explain the observed phenomenon by proposing two types of cognitive process underlying belief-bias **Error! Reference source not found.** Type 1 processing, entails rapid belief-driven heuristics; whereas, Type 2 processing, entails slower analytic responding **Error! Reference source not found.** Where there is a belief-logic conflict these fast and slow processes compete, with slower responses correlating with increased logical responding **Error! Reference source not found.**

Dual-process theories such as these have been investigated through many behavioral studies, which have identified some basic principles of the two cognitive processes. For example, studies have demonstrated robust effects of response patterns, response times (increased response times to problems where logic and belief are in

conflict), and confidence ratings (feelings of 'rightness' predict rethinking times to reach logical conclusions) within the belief-bias paradigm **Error! Reference source not found.** which are well explained by dual-process accounts. Moreover, De Neys (2006b) demonstrated reductions in logical responding for conflict problems when participants were under a concurrent working memory load, while Evans and Curtis-Holmes (2005) demonstrated increased belief driven responses under a rapid response condition. There is also a wealth of individual differences data that indicate thinking dispositions and working memory are supportive of dual process accounts of many higher level cognitive tasks (e.g., Stanovich & West, 2000). Neuroscientific methods, such as fMRI, functional near infrared spectroscopy (fNIRS), repetitive transcranial magnetic stimulation (rTMS), and event-related potentials (ERPs) have made a valuable contribution to the area, demonstrating a range of findings consistent with the predictions of dual process theory **Error! Reference source not found..**

Using fMRI, researchers **Error! Reference source not found.** have found that the belief-bias effect is associated with increased activation of the right lateral prefrontal cortex (PFC). Tsujii and colleagues have also found the right lateral PFC was enhanced when participants gave logical responses to belief-logic conflict problems, thus corroborating fMRI studies with evidence from fNIRS and rTMS methodologies **Error! Reference source not found..** Although the right lateral PFC appears to be activated by belief-logic conflict, participants in these studies **Error! Reference source not found.** did not receive any formal training in logic - in fact, participants are usually selected on the basis of having had no training in formal logic.

Using positron emission tomography (PET) to compare brain activity in trials before and after logical training (i.e., training people to inhibit matching bias), Houde´ and colleagues **Error! Reference source not found.** found that the left-prefrontal network and right ventromedial prefrontal cortex were engaged when participants successfully overcome matching bias in the Wason Selection Task. However, previous studies have not yet demonstrated whether effects of logical training can induce a similar change in reasoning strategy and neural activity in the belief bias paradigm. According to the results of previous studies, the reasoning process can start as soon as the premises are presented **Error! Reference source not found.**, however, most fMRI studies have primarily focused on conclusion processing instead of on the processing of premises **Error! Reference source not found.** Therefore, it is important to examine the processing of the premises using fMRI to test for corroborating evidence of belief-logic conflict effects at this early stage in premise presentation.

To determine how brain functions change with logical training in belief-biased reasoning and to contribute to the discussion contrasting functional neuroanatomy and neuropsychology (Houdé, 2008; Goel, 2008), we conducted an fMRI study in which the participants were scanned both before and after logical training. In the first scan, participants were required to respond to the belief-biased items (both conflict problems and non-conflict problems) in accordance with their empirical beliefs, however, in the second scan participants were required to respond in accordance with logic. It was hypothesized that the logical training would exert greater influence on

the conflict problems, because the participants would need to inhibit their belief-driven responding and engage in analytic processing.

The present study aimed to determine (1) whether the pattern of brain activation associated with overcoming belief-bias through logical training is same as that of without logical training (Goel & Dolan, 2003), (2) whether Houdé et al.'s (2000) matching bias effect can be extended to a belief bias paradigm, and (3) whether these effects are observable earlier in the presentation of premises stimuli than has previously been shown in fMRI. Based on the previous studies **Error! Reference source not found.**, it was hypothesized that the processing of reasoning in the second scan versus in the first scan will activate regions in the right lateral PFC and the left-prefrontal network (i.e., left inferior frontal gyrus). The supposition is that this contrast would be related to belief-bias inhibition after logical training. Most importantly, the extent to which the cortical systems underlying belief bias are plastic with respect to logical training was examined.

Methods

Participants

Sixteen university students (eight men, aged 20–28 years; mean = 23.8 years; eight women, aged 20–26 years; mean = 23.0 years) from China were paid for their participation. They were selected on the basis of offering a belief-biased response to at least 70% of conditional reasoning problems where belief and logic conflicted (see Table 1) during a pre-test. All participants were right-handed, and with no reported neurological disorders, significant physical illness, head injury, or alcohol/drug abuse.

This study was approved by the local ethics committee of Shanghai Normal University, and all participants signed an informed consent form prior to their inclusion in the experiment.

Design and Stimuli

This study was organized into a 2*2 design. The first factor was the type of problem (see Table 1), consisting of 2 levels, conflict problems (in which the logical conclusion is inconsistent with one's beliefs) and non-conflict problems (in which the logical conclusion is consistent with one's beliefs). The second factor was logical training, consisting of 2 levels: naive participants prior to logical training and then post logic training. Specifically, participants were first required to perform the reasoning task without any logical training and were instructed to draw a conclusion based on their existing knowledge (or empirical beliefs) in the first scan, and were then asked to draw a conclusion based on logical rule after receiving a logical training in the second scan. Four conditions of stimuli were used in the experiment, namely belief-based instructions for non-conflict problems (BNC), belief-based instructions for conflict problems (BC), logic-based instructions for non-conflict problems (LNC), and logic-based instructions for conflict problems (LC). Each condition contained 120 items, encompassing 4 different conditional reasoning forms- Modus Tollens (MT), Denial of the Antecedent (DA), Modus Ponens (MP), and Affirmation of the Consequent (AC). Each form contained 30 items. The 240 items used during the first scan were the same as in the second scan.

INSERT TABLE 1 ABOUT HERE

Procedure

Items were presented in the following way (see Fig.1) during both scans: Each trial was initiated by a “+” in the center of screen for 0.5 s. The major premise (e.g., If a number can be divided by 2, then it is an even number) was then presented for 3.5 s. A blank screen was presented for a randomly varying duration of between 2 and 6 s, which was then followed by the minor premise (e.g., the number is not an even number), which was presented for 4s. During this time participants were required to draw a conclusion based on the premises. A blank screen was presented for a randomly varying duration of between 2 and 6 s, which was then followed by three possible options (see Table 1) to select from for 2 s. At this time, participants were asked to indicate which option was consistent with the conclusion they inferred (by pressing “1” if their own conclusion was consistent with the option 1, pressing “2” if they select the option 2, pressing “3” if they select the option 3). In order to familiarize the subjects with the procedure of this task, subjects were trained with 8 trials (2 trials for each reasoning forms) in the same procedure before the first scan. During the first scan, participants were instructed to draw a conclusion based on their empirical beliefs.

Participants then received several blocks of logical training. Each block contained 4 conditional reasoning forms (each form consisted of 5 items). The training procedure was the same as during scanning except that participants were given feedback (based on the logical rule) as to whether the response was right or wrong for each item. After each block, the experimenter provided the participants with the valid

responses for their erroneous responses. Furthermore, the experimenter explained why the answers were invalid and taught explained how to avoid the false conclusion. Participants whose accuracy rates in every conditional reasoning form were greater than 80% in a block were allowed to begin the second scan. All 16 participants met the criteria for continuing the test. The items used in training were differing from the test scan. During the second scan, participants were required to draw a logical conclusion based on logical rules.

INSERT FIGURE 1 ABOUT HERE

Imaging Data Acquisition

Imaging Data were collected by a 3 Tesla Siemens Magnetom Trio MRI scanner (Siemens Medical Systems, Erlangen, Germany). High-resolution T1-weighted anatomical images were acquired for each participant (voxel size= 1 mm×1 mm×1 mm). And Functional data were acquired using a T2-weighted gradient echo planar imaging (EPI) sequence (repetition time (TR) = 2,000 ms; echo time (TE) = 30 ms; matrix size: 64×64; field of view (FOV) = 220mm×220mm; flip angle = 90 degrees).

Imaging Data Analyses

Image preprocessing and statistical analysis were performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK, www.fil.ion.ucl.ac.uk/spm). There were five dummy scans removed from further analysis. Functional EPI images were slice-time corrected using sinc-interpolation and realigned to first volume to correct for head movement. The structural volume was coregistered to the mean functional

image and segmented into gray and white-matter probability maps. The segmented structural images were then spatially normalized to the MNI template and the derived normalization parameters were applied to the realigned functional data. Finally, functional images were spatially smoothed with an 8-mm full-width at half-maximum (FWHM) isotropic Gaussian kernel. Low-frequency drift in the BOLD signal was removed by a high-pass filter with a cutoff value of 128 s.

Individual analysis of imaging data was conducted using the general linear model implemented in SPM8. The model included task effects, a mean and linear drift for each of the 5 functional runs and 6 motion parameters. Task effects were comprised of BNC, BC, LNC, and LC. These were constructed by convolving condition-specific boxcar functions with a synthetic hemodynamic response function. In both scans, the BOLD responses of minor premise are of interest, however, these responses are based on differing instructions on how to respond. The major-premise, the conclusion, and the error trials were also included as non-interest regressors which were excluded from the analyses. The four parametric contrast images (BNC, BC, LNC, and LC), were calculated separately for each participant. They were submitted to a 2×2 analyses of variance (ANOVA) with the factors of problem type (belief-logic conflict problems versus non-conflict problems) and logical training (prior to logical training in the first scan and after logical training in the second scan) for all participants using a random effect model. All whole-brain univariate analyses were thresholded at $p < 0.001$ (uncorrected) with more than 50 extent voxels. Only clusters significant at $p < 0.05$ corrected using family-wise error (FWE) (Worsley, et

al., 1996) are reported unless otherwise specified.

Results

Behavioral data

Only items to which the participants responded based on the instructions were classified as accurate responses (i.e., belief-based responses in the first scan and logic based responses in the second scan). The accuracy rates and mean reaction times for the conclusion response during BNC, BC, LNC, and LC are shown in Table2.

It should be noted that the accuracy rates for conflict problems in the first scan (in which the belief-based responses classified as accurate responses) were 75%. Thus, if the logic based responses had been classified as accurate responses, the accuracy rates for conflict problems would have been below 25% in the first scan. In the second scan, in which the participants had received logical training, the accuracy rates of logically correct answers for conflict problems were 79%. From this perspective, the mean-accuracy rates based on the logical rules for the conflict problems increased significantly ($t(15) = 7.102, p < 0.0001$).

INSERT TABLE 2 ABOUT HERE

fMRI data

The ANOVA results showed that the main effect of logical training was associated with activation of the left inferior frontal gyrus, left middle frontal gyrus, cerebellum, and precuneus. Neither the main effect of the type of problem, nor the interaction between the type and the logical training were significant.

Through contrasting the LC and BC, the fMRI data showed that left inferior frontal gyrus (BA47), left inferior frontal gyrus (BA44/45), left middle frontal

gyrus(BA6), cerebellum, precuneus / posterior cingulate cortex (BA31) were activated (see Figure 2). These increased activations were consistent with the main effect of logical training. The opposite contrast (BC minus LC) showed no reliable difference in activation.

The comparison between conflict problems in the second scan versus in the first scan (i.e., LC versus BC) was the primary focus of the present study, nonetheless contrasts between non-conflict problems were examined. Direct comparison between LNC and BNC revealed a significant increase in neural activation in precuneus. The opposite contrast (BNC minus LNC) showed that anterior cingulate showed increased activation. Additionally, the contrast (BNC versus BC) and the contrast (LNC versus LC) showed no reliable difference in activation.

Masking

LC>BC: In order to rule out the possibility that the same areas are activated by BC, we conducted exclusive masking on the results from the BC condition to the LC>BC contrast. The pattern of results (mask threshold at $p<0.001$ uncorrected) remained consistent with that observed in the LC>BC contrast. Therefore, the observed activations of the left inferior frontal gyrus, left inferior frontal gyrus, left middle frontal gyrus, cerebellum, precuneus/posterior cingulate cortex are not observed during belief-based reasoning.

INSERT FIGURE 2 AND 3 ABOUT HERE

Discussion

This study investigated the neural basis of strategy change during belief-biased reasoning processes (e.g., conflict problems and non-conflict problems) using a logic

training manipulation. Participants whose dominant responses were based on their beliefs were trained to change their belief response into logical response in the two successive sessions.

The behavioral data showed that the accuracy rates of conflict problems based on the logical rules increased significantly (i.e., below 25% versus 79%) while there was no effect on non-conflict problems (i.e., they were equally solved before and after the training with 91% accuracy). These data demonstrate that the combination of the training manipulation and logic based instructions were successful in bringing participants' responses into alignment with the logical answers. These data are consistent with a change in reasoning strategy; however, there are alternative explanations that warrant further study. The increase in accuracy rates may be the result of a general practice effect, or some combination of the logic based instructions and logic training – future investigations should attempt to discount these alternative explanations. Nonetheless, the resultant differences in neural activation across the conflict problems are, therefore, the focal point of our discussion.

Functional MRI revealed that drawing a logical conclusion for the conflict problems in the second scan involved significantly greater activation in a left frontal network- including the left inferior frontal gyrus and left middle frontal gyrus, cerebellum, and precuneus/posterior cingulate cortex than drawing a conclusion based on their belief in the first scan. This result indicates that combination of logical training and logic instructions induced a change in responding, which produced changes in brain activity that were suggestive of qualitative differences between

belief-based processing and logic-based processing.

The data obtained by Houde´ and colleagues (2000) revealed activation in the left-prefrontal network, left posterior-cingulate, the right ventromedial prefrontal cortex, and right anterior cingulate. Consistent with Houde´ and colleagues' work, the present study also found that the left inferior frontal gyrus and left middle frontal gyrus were activated, however, the right prefrontal cortex was not activated in the present study. Two possible explanations for this discrepancy can be proposed. First, the findings of Houde´ and colleagues (2000) were reported in a block-design PET study that does not permit separate reading of the stimuli from the reasoning task **Error! Reference source not found.**, whereas the present study directly focused on the stage of the minor premise with event-related fMRI. A second explanation could be that differences were driven by the differing sources of bias. Houde´ et al. (2000) demonstrated training effects in the context of matching/perceptual bias whereas the reasoning items in the present study were belief-biased. Previous behavioral research has demonstrated differing patterns of correlations between response times and normative responding when comparing matching biased syllogisms and belief biased syllogisms (cf. Stuppel, Ball & Ellis, 2013 and Stuppel et al., 2011).

Neuroscientific studies of deductive reasoning have shown that explanatory inference is mediated by the inferior frontal cortex (or ventrolateral PFC) corresponding to Brodmann's Areas 44, 45, and 47 and more specifically by the left inferior frontal cortex (Barbey & Patterson, 2011; Goel et al., 2000; Goel & Dolan, 2004; Kroger et al., 2008; Monti et al., 2007; Noveck et al., 2004). In particular, the left

inferior frontal cortex is related to the process of detecting violations of norms and generating explanatory inferences about causality (Barbey & Patterson, 2011). For example, Berthoz et al (2002) provided evidence that the left inferior frontal cortex was recruited when participants detected violations of social norms and inhibited impulsive action (e.g., the decision to “spit out food made by the host”). Similarly, violations of empirical beliefs that conflict with the logical rule violate norms of basic empirical knowledge. Thus, the stronger activation in the left inferior frontal gyrus (BA44/45/47) for conflict problems in the second scan would support the hypothesized detection of the conflict between logic and belief, and inhibition of the belief-based process when participants were instructed to respond in accordance with logic. It has been consistently postulated that the left inferior frontal cortex has been shown to have a role in cognitive control **Error! Reference source not found.**, and in the enabling of the inhibition of responses and the resisting of temptation.

In contrast, evidence from fMRI, rTMS and fNIRS studies demonstrate that the inhibition of belief-bias is associated with increased activation of the right lateral PFC **Error! Reference source not found.** The first possible explanation for this discrepancy is that the previous studies **Error! Reference source not found.** directly compared conflict problems and non-conflict problems, while the present study, with the use of a logical training manipulation, compared conflict problems between two scans. It is proposed that participants need to devote cognitive effort to inhibit their existing beliefs in order to apply their newly developed logic-based strategy. In this process, participants may first recall the logical rules from the training phase and then

apply them to shift from a belief-driven reasoning strategy to a logical reasoning strategy. From this perspective, the observed increased activation in the left inferior frontal gyrus is explicitly sensitive to the logical rule that has been learnt in training, and the resulting of conflict detection.

A second possible explanation is that the activation of the right lateral PFC, shown in Goel and Dolan **Error! Reference source not found.**, might be involved the motor inhibition during the conclusion judgment stage, where participants indicate their response with a physical movement. In contrast, the left inferior frontal cortex in this study occurred during the presentation of the minor premise where no physical movement was required. Collectively, the findings of several studies support that the right lateral PFC is thought to play a critical role in motor inhibition **Error! Reference source not found.** This activation during the presentation of the minor premise is a notable contribution to the belief bias literature as it corroborates evidence from ERPs (Banks & Hope, 2014; Luo, et al., 2010; Luo, et al., 2008) indicating that belief-logic conflict may occur prior to the presentation of a conclusion with an alternative neuroscientific methodology.

Another of the activated areas in the left-prefrontal network was the left middle frontal gyrus (BA6). Kalbfleisch, Van Meter, & Zeffiro (2007) demonstrated that the left BA6 supports processing related to the difficulty or complexity of the task, moreover, Houde´ and colleagues **Error! Reference source not found.** argued that the left BA 6 is likely to be related to cognitive inhibition of matching bias. Thus, the stronger activation in the left BA6 for conflict problems in the second scan might be

involved in the cognitive effort devoted to inhibiting an alternative heuristic response - based on belief - to engage a logical strategy.

In addition to these differences in left frontal network activation, the conflict problems in the second scan relative to the first scan demonstrated contrasting activations in the cerebellum, and precuneus/posterior cingulate cortex (BA31). The cerebellum has previously been associated with the process of response reassignment **Error! Reference source not found.** in the second scan participants change from a belief-based response to a logic-based response, which is likely to be more analytic and more cognitively demanding **Error! Reference source not found..** Increased activation of the precuneus/posterior cingulate cortex (BA31) might be related to retrieving the inferential rules learnt during the training phase from memory **Error! Reference source not found..** Further support for this can be found in the contrast between belief instructions and logic instructions for non-conflict problems, which also revealed activation in the precuneus / posterior cingulate cortex (BA31) albeit with a relatively small effect. The recall of inferential rules would occur for both conflict and non-conflict problems and the post logic training activation of these areas are consistent with that explanation.

To summarize, this study investigated the neural correlates of reasoning response switching, contrasting belief-based responses with logic-based responses after logical training during belief biased reasoning. It was hypothesized that the logical training would specifically affect the conflict problems and changes in brain activity would be evidence of a training-induced change in reasoning strategy. The results showed that

the left inferior frontal gyrus (BA44/45/47), left middle frontal gyrus (BA6), cerebellum, and precuneus/posterior cingulate cortex (BA31) might be involved in cognitive inhibition of the belief-based process and switch to logic-based responding.

We are mindful that these comparisons with previous studies demonstrating common loci of activation across differing tasks are reverse inferences (e.g., Poldrack, 2006) and as such, are presented as tentative inductive conclusions; further research is required to replicate these patterns of activation using alternative belief bias materials and additional triangulating measures of behaviour. Further study also continues to be needed to assess precisely when and where the PFC is involved in problems where belief and logic conflict. Nonetheless, these data provide a useful contribution to the debate contrasting functional neuroanatomy and neuropsychology and the role of the PFC in conflict detection (Houdé, 2008; Goel, 2008).

This pattern of activation, nonetheless suggests that the combination of logical training, and the instruction to provide logical responses to a belief bias task, results in qualitatively different cognitive processes to those employed during belief-based responding rather than simply requiring an increased activation of a single process. As such, these data favor a dual process theory of belief bias (e.g., Stupple et al., 2011; Handley, Newstead & Trippas, 2011) rather than a single process account (e.g., Dube, Rotello & Heit, 2010).

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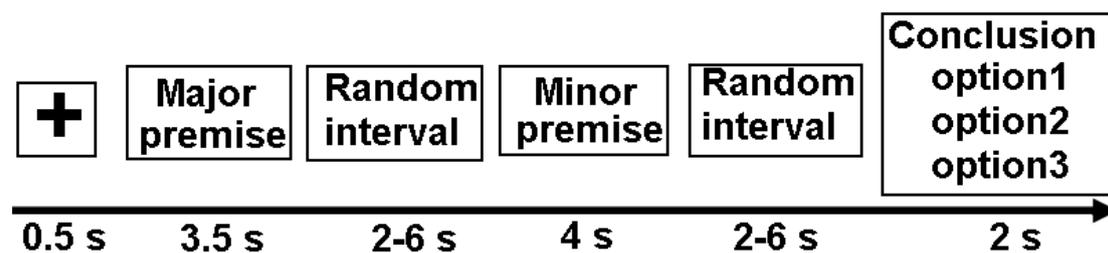


Figure 1 Timeline of stimuli Blood-oxygen-level dependence (BOLD) responses of **Minor premises** were the target events to which the conditions of fMRI data were locked.

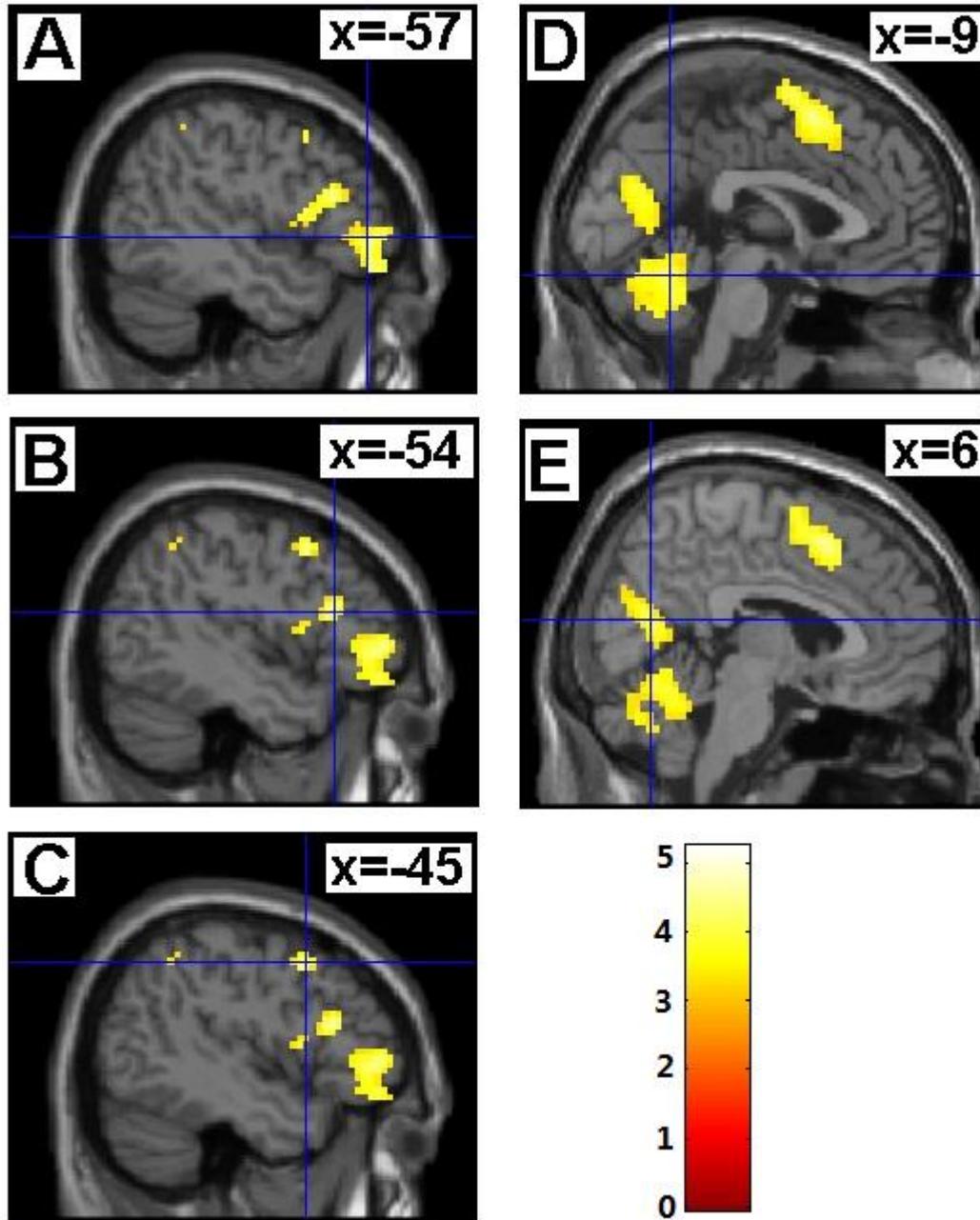


Figure 2 The neural activation (A: Inferior frontal gyrus (BA47), B: Inferior frontal gyrus (BA44/45), C: Middle frontal gyrus, D: Cerebellum, E: Precuneus) in the contrast of LC versus BC.

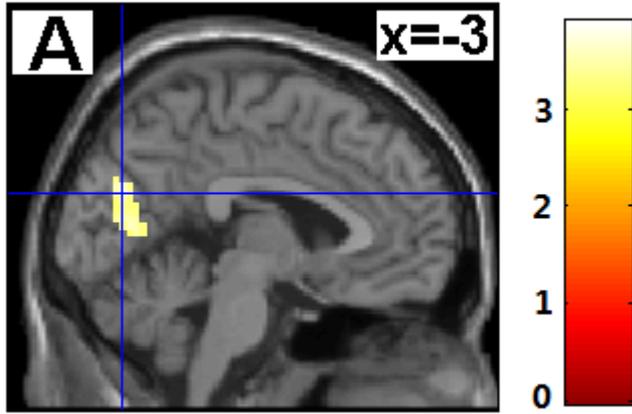


Figure 3 The neural activation (A: Precuneus) in the contrast of LNC versus BNC.

Table 1 Sample item of the study

Non-conflict problems	<p>Encompassing MT, DA, MP, and AC reasoning forms. Take MT form for example: Major premise: If a number can be divided by 2, then it is an even number Minor premise: The number is not an even number Option 1: The number can be divided by 2 Option 2: The number cannot be divided by 2 (Logic and Belief-based response) Option 3: Whether the number can or not be divided by 2 is uncertain</p> <p>Take MP form for example: Major premise: If one's answer is correct, then he will get score Minor premise: Somebody whose answer is correct Option 1: The person got score (Logic and Belief-based response) Option 2: The person did not get score Option 3: Whether the person got score or not is uncertain</p>
Conflict problems	<p>Encompassing MT, DA, MP, and AC reasoning forms. Take DA form for example: Major premise: If the ball is thrown into the basket, then the point will be scored Minor premise: The ball was not thrown Option 1: The point was scored Option 2: The point was not scored (Belief-based response) Option 3: Whether the point was scored or not is uncertain (Logic-based response)</p> <p>Take AC form for example: Major premise: If somebody did not pass the exam, then he should make-up Minor premise: Somebody was given a make-up examination Option 1: The person passed the exam(Belief-based response) Option 2: The person did not pass the exam Option 3: It is uncertain whether the person passed the exam or not (Logic-based response)</p>

Table2 Mean (SD) of Accuracy Rates and Reaction Times for BNC, BC, LNC, and

LC

	BNC	BC	LNC	LC
Accuracy Rates (%)	91(9)	75(27)	91(14)	79(24)
Reaction Times (ms)	808(177)	793(158)	761(173)	767(200)

Table 3 Coordinates of activation peaks

Regions activated	Hem	BA	X	Y	Z	Cluster p ^a	Cluster Size voxels(n)
LC – BC							
Inferior frontal gyrus	L	47	-57	30	-3	0.001	236
Inferior frontal gyrus	L	44/45	-54	15	12	0.020	128
Middle frontal gyrus	L	6	-45	12	48	0.000	494
Cerebellum	L		-9	-45	-27	0.000	585
Precuneus	R	31	6	-66	15	0.000	285
BC - LC							
No activation							
LNC - BNC							
Precuneus	L	31	-3	-75	24	0.004	226
BNC - LNC							
Anterior cingulate	R	32	3	54	9	0.000	884

^aThe resulting activations were computed by a voxel-wise intensity threshold of $p < 0.05$ using a correction of multiple comparisons via the family-wise error (FWE), and a cluster size of a minimum of fifty contiguous voxels.