doi: 10.13241/j.cnki.pmb.2015.01.028

High and Low Conflict Decision-making Differently Impair the Subsequent Performance of Executive Control as Assessed by the Multi-Source Interference Task*

WANG Yan[1], *DU Xiao*[2], *TANG Yi-yuan*[2△]

(1 Interdisciplinary Center for Social and Behavioral Studies, Dongbei University of Finance and Economics, Dalian, Liaoning, 116025, China; 2 Institute of Neuroinformatics, Dalian University of Technology, Dalian, Liaoning, 116024, China)

ABSTRACT Objective: The present study mainly focused on the effect of prior decision-making task difficulty on subsequent executive control. **Methods:** Forty healthy subjects were randomly assigned to either high-conflict moral-personal dilemmas group or low-conflict non-moral scenarios group. The performance differences of the Multi-Source Interference Task (MSIT) following different decision-making tasks were investigated. **Results:** Results showed a worse performance in the subsequent MSIT for participants making moral-personal judgments than those making non-moral ones. Moreover, a relatively larger difference was found in the most effort-demanding condition of the MSIT, and a considerably worse performance was made by participants making moral judgments than non-moral ones. **Conclusions:** The difficulty of prior decision-making task would greatly influence the subsequent performance of executive control.

Key words: Moral decision-making; Executive control; Multi-Source Interference Task

Chinese library classification (CLC): B842 Document code: A

Article ID: 1673-6273(2015)01-114-06

Introduction

Decision-making is the core activity in human social life. Human decision-making, especially moral decision-making has long been a topic of philosophical debate. In recent years, a moral judgment task involving classic moral dilemmas, demonstrated that both "cognitive" and emotional processes play crucial and sometimes mutually competitive roles [1]. Compared to non-moral scenarios, moral-personal dilemmas often involve serious bodily harm or death to another person or people, which would evoke strong social emotional responses [2]. Koenigs and his colleagues suggested that there was no significant difference between patients with damage to the ventromedial prefrontal cortex (VMPFC) and normal participants when they were doing low-conflict non-moral scenarios task, but in high-conflict moral-personal scenarios, VMPFC patients made a greater proportion of 'appropriate' judgments relative to normal people[3].

An example of moral-personal dilemma question is: is it acceptable to smother the baby in order to save the lives of the other people who are hiding? When considering such moral-personal dilemmas, brain regions linked to emotion such as medial frontal gyrus, the amygdala would exhibit increased activity. However, in non-moral scenarios (for instance, is it appropriate for you to take the train instead of the bus in order to ensure you are not late for your meeting?), areas involved in reasoning and working memory (e.g., dorsolateral prefrontal cortex and inferior parietal) are more strongly activated [4]. In the high-conflict moral decision-making process, making utilitarian choices emerge from cognitive control mechanisms based on the dorsolateral prefrontal cortex (DLPFC), whereas non-utilitarian choices arouse from emotional responses relying on the medial prefrontal cortex (MPFC)[5]. Thus, it is generally accepted that moral-personal dilemmas evoke the competition between an automatic "hot" emotional response and a "cold" cognitive control[1,6].

Effortful decision-making is costly and requires self-control[7]. Drawing on a series of studies, Vohs and her colleagues argued that making choices were linked to reduced self-control, for instance, reduced persistence in the face of failure, less physical stamina and more procrastination [8,9]. Some studies indicated that many of the self's activities rely on a common resource, akin to energy or strength, which is limited and easily to be depleted [10-12]. When the resource was depleted by an initial act, subsequent unrelated act might be impaired[13]. For example, performing one act of self regulation might impair performance on a subsequent, seemingly unrelated act of self-control [11]. Other studies also showed that depletion of the self's resources might lead to overrating by dieters [14], intellectual underachievement [15] and impulsive overspending[16]. Vohs and his colleagues suggested that making choices and exerting self-control drew on a common and limited resource, and doing decision-making tasks would deplete the re-

*Foundation items: National Natural Science Foundation of China (60971096); 973 Program(2012CB518200)

Author introduction: WANG Yan(1983-), female, PHD, Mainly engaged in cognitive neuroscience

△Corresponding author: TANG Yi-yuan, E-mail: yy2100@126.com

(Received: 2014-07-05 Accepted: 2014-07-29)

source used for self-control and active responding[9].

Executive control is also costly. Prior efforts at executive control would reduce executive resources and temporally undermine subsequent efforts at executive control [17]. Executive control is the core of executive function, and executive function is a term for processes responsible for higher-level action control [18]. Del Missier and his colleagues have shown that decision-making and executive function are closely linked and the successful application of decision rules requires the capacity of executive function[19], therefore it is reasonable that decision-making might consume the resource for executive control and might have some impacts on subsequent executive control.

Studies mentioned above have mainly investigated the relation between decision-making and its subsequent self-control performance. However, little is known about the executive control performance differences following different high/low conflict decision-making tasks. The present study intends to find out if different degrees of the difficulty (or conflict) in decision-making tasks (high-conflict moral-personal task vs. low-conflict non-moral task) would affect the following executive control by applying the Multi-Source Interference Task (MSIT)[20,21], in which Stroop interference [22-24], Simon interference [25] and Flanker interference [26,27] are combined together to improve the difficulty of cognitive interference [28,29]. And we expect a worse performance of the MSIT after decision-making of moral-personal dilemmas than non-moral ones.

1 Methods

1.1 Participants

Forty right-handed students (26 male, mean age 24.7 years, range 22-28 years) from Dalian University of Technology volunteered to participate in this study for pay. All participants have no history of neurological or psychiatric illness and have normal or corrected-to-normal vision. No participant was aware of the purpose of this study until debriefing.

1.2 Stimuli and Procedure

Participants were randomly assigned to either high-conflict moral-personal dilemmas group or low-conflict non-moral scenarios group. Each group had 20 participants and the gender and age of the two groups were matching. All subjects were tested individually. The experimental materials for the decision-making tasks were based on the prior studies [1,30]. Each participant should finish 20 high-conflict moral-personal dilemmas or 20 low-conflict non-moral ones. Each dilemma was presented on the computer monitor as text through a series of three screens, the first two describing a scenario and the last posing a question about the appropriateness of an action one might perform in that scenario. Participants were allowed to read at their own pace, pressing a button to advance from the current screen to the next screen. After reading the question on the third screen, participants responded by pressing one of two buttons ("appropriate" or "inappropriate"). And then, a white screen appeared for 1s, followed by the next dilemma. Participants of either group completed two practice dilemmas and could ask any questions before beginning the experimental trials.

After finishing the decision-making task, all participants completed the Profile of Mood States (POMS)[31], in which six scales: anger-hostility (A), depression-dejection (D), fatigue-inertia (F), tension-anxiety (T), vigor-activity (V) and confusion-bewilderment (C) were used to evaluate their mood states.

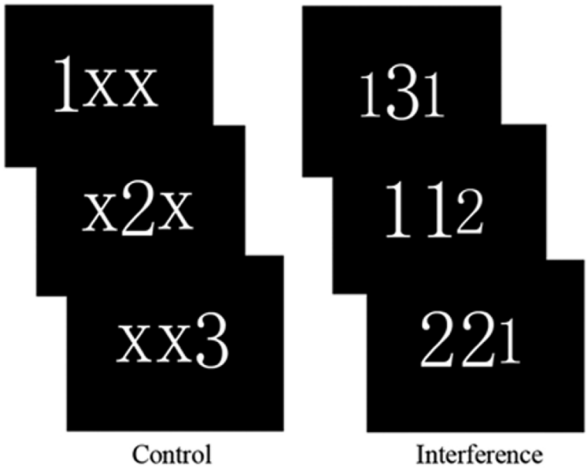

Fig. 1 The MSIT trial examples

Subsequently, participants of both group completed the MSIT [20]. As Fig. 1 indicated, there were two types of stimuli, control ones and interference ones. During 'control' trials, the distractors were always the letter 'x', target numbers were always large and placed congruently with their position on the button-press (e.g. the number '1' would appear in the first [leftmost] position). During 'interference' trials, the distractors were other numbers (1, 2 or 3), target numbers could be large or small and they were never placed congruently with their position on the button-press[20,21].

All participants were given a button-press and instructed that the keypad buttons represented one, two, and three from left to right. They were told to use the index, middle and ring fingers of the right hand to respond. They were also instructed that sets of three numbers (1 and/or 2 and/or 3) and/or letters (x) would appear in the center of the screen at most 1750ms, and that one number would always be different from the other two (matching distractor) numbers or letters. Participants were asked to report, via but ton-press, what the identity of the number different from the other two items was. After a response, the next trial followed. The experiment consisted of the practice and experimental sessions. The practice session had 30 trials (three control trials repeated twice with 24 interference trials). The experimental session has three blocks with 192× 3 = 576 stimuli, and participants can take a rest in between. Each block has 192 stimuli in two kinds. The stimuli

are pseudorandom presented and the experiment lasts about 20 minutes. For all trials, participants were instructed to answer as quickly as possible but to make sure that they gave the right answer. After completing the MSIT, participants were debriefed and thanked.

2 Results

For participants of low-conflict non-moral scenarios group and high-conflict moral-personal dilemmas group, independent-samples t-test revealed that there was no significant difference between the two groups for both gender and age. In the decision-making task, although longer time was taken by the moral-personal dilemmas, independent-samples t-test showed no significant difference in time for the two groups finishing the whole tasks (P>0.05).

Mood states of participants were assessed using POMS after finishing decision-making tasks. Independent-samples t-test showed that none of the six scales of POMS showed significant differences between the two groups (P>0.05). It seemed that there was no significant difference in mood states after finishing low-conflict non-moral or high-conflict moral-personal dilemmas.

For the MSIT results, the negative correlation between accuracy rate and reaction time (RT) was significant, r = -0.492, P<0.001, thus there was not a speed accurate trade off. As Table 1 indicated, participants of both groups made more errors in the interference condition than in the control condition, and the response for the interference condition was also slower. That was to say, the performance of the control condition was obviously better than that of the interference condition. Comparing the performance of two groups finishing different decision-making tasks, we found that participants of high-conflict moral-personal dilemmas group behaved worse than those of low-conflict non-moral scenarios group as indicated by longer RT and more errors.

Table 1 Mean accuracy rate (%) and RT (ms) for the two groups

Type	Position	Reaction time(ms)		Accuracy rate(%)	
		Non-Moral	Moral	Non-Moral	Moral
Control	Position 1	655.77± 65.15	670.43± 76.61	99.55± 1.23	98.80± 1.40
	Position 2	679.74± 76.02	705.06± 94.19	99.15± 1.57	98.10± 2.34
	Position 3	694.92± 73.80	705.84± 78.34	98.90± 1.62	98.35± 1.73
Interference	Position 1	844.63± 95.25	885.68± 88.25	94.90± 4.75	93.75± 4.68
	Position 2	820.32± 98.09	854.08± 101.67	95.70± 3.79	90.50± 6.92
	Position 3	840.40± 80.68	863.82± 96.97	97.35± 2.23	94.30± 4.52

Independent-samples t-test was carried out for RT and accurate data separately. As to the accuracy rate under the overall experimental trials, control trials and interference trials, the non-moral scenarios group performed better than the moral-personal dilemmas group, t (38) = 2.433, P=0.020, d=0.77. Separate analysis demonstrated that the accuracy rate of moral-personal dilemmas group was obviously smaller than that of non-moral scenarios group for the interference trials, t (38) = 2.651, P=0.012, d=0.84, and there was not any significant difference between the two groups for the control trials. More importantly, as to the response target in the second position of the interference trials (interference merged), the differences were considerably larger, and non-moral scenarios group performed significantly better than moral-personal dilemmas group, t (38) = 2.947, P=0.006, d=0.93 (Fig. 2). The RT performance of the two groups did not make any outstanding difference.

Further analyses were conducted for the accuracy rate. Repeated measures analysis of variance (RMANOVA) revealed a significant effect of target type, F (1, 38) = 90.334, P<0.001, η p2 =0.704, smaller accuracy rate was found for interference than control trials. More importantly, the target type by group interaction turned out to be significant, F (1,38) = 6.466, P=0.015, η p2 =0.145, post-hoc analyses revealed that the differences between the two groups were more significant for the interference trials, better performance were found for the non-moral scenarios group than the moral-personal dilemmas group. In addition, the effect of target position was significant, F (2, 76) = 6.275, P=0.007, η p2=0.142, the second position was more difficult than the other two positions. The interaction between target position and participants group was also significant, F (2, 76) = 3.941, P=0.037, η p2 =0.094, post-hoc analyses showed that non-moral scenarios group performed significantly better than moral-personal dilemmas

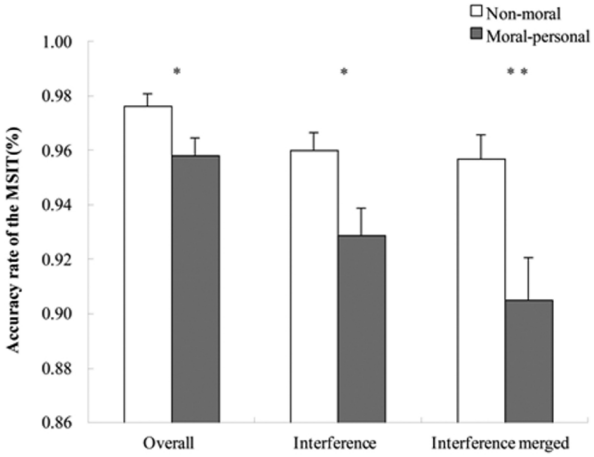

Fig. 2 Accuracy rate of the MSIT for the two groups. *P<0.05, **P<0.01.

group when the target was in the second position. As to the interaction between target type and target position, it was also significant, F(2, 76) = 5.459, P=0.010, η p2 =0.126. It indicated that the target in the second position of the interference trials assumed the most difficult condition for both groups (Fig. 3). As far as the target size, it didn't make any significant differences between the two groups.

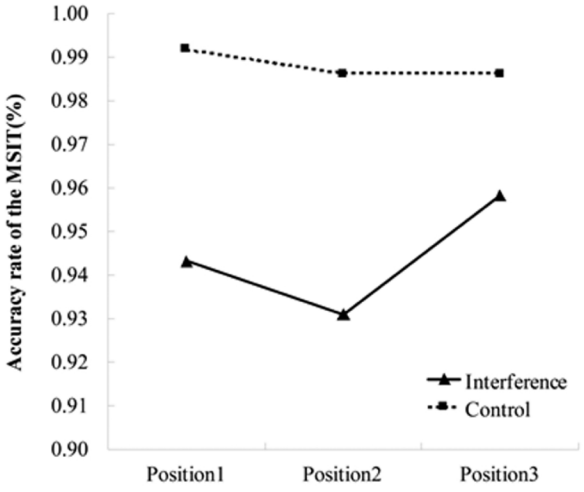

Fig. 3 Accuracy rate of the MSIT for the three target positions

3 Discussion

In the present study, the differences of the MSIT performance after high-conflict moral decision-making task and low-conflict non-moral one were investigated. Results showed that although making a series of decisions of the same quantities, participants finishing high-conflict moral-personal dilemmas behaved worse in the subsequent MSIT task relative to those facing to low-conflict non-moral ones. Further analysis revealed that the two groups did not show any significant difference in relatively simple control trials, but in the interference trials of more conflicts, the accuracy rate of the non-moral scenarios group was much better than the moral-personal dilemmas group; most interesting was that in the most difficult condition of the task (Flanker, Simon and Stroop conflicts all existed), the performance of the non-moral scenarios group was extremely better than the moral-personal dilemmas group.

For the results of POMS after accomplishing the decision-making tasks, the two groups reported similar mood states without significant difference. Therefore, the effects of decision-making were not due to change of mood states [9]. In addition, the time for the two groups spending on the whole decision-making tasks didn't show any significant difference.

It seems that the differences of the decision-making tasks make the different results of the subsequent executive control. Compared to the low-conflict non-moral scenarios, more emotion is involved in the high-conflict moral-personal dilemmas, which might generate a stronger affective response [1]. During the judgment of "appropriate" or "inappropriate" for an act in moral-personal dilemmas, the competition between emotion and cognition might arise [5], usually participants need override one response and substitute it with another one, and the interruption and initiation functions might need energy. Relative to the non-moral ones, the moral-per sonal dilemmas are difficult and expending efforts. Schmeichel (2007)[17] has demonstrated that task difficulty determines the magnitude of subsequent decrements in executive capacity, and the harder the more impairing. It is reasonable to think that some choices are more deleting than others[9]. Therefore, relative to low-conflict non-moral ones, high-conflict moral-personal dilemmas might consume more resources and lead to worse performance in the subsequent task.

Making decisions drains self-regulatory resource [9,32], and self-regulation has been defined as any attempt to override or alter one's thought [33], which might share a high degree of conceptual overlap of executive control. Thus decision-making might consume the same resource for both executive control and self-regulation. Pocheptsova et al (2009)[34] also suggested some choices occurring after careful deliberation were monitored by more effortful processing, also called the executive control. As executive control processes depend on a limited and depletable resource, completing any difficult or effortful task, even it does not require executive control, would deplete capacity and undermine later efforts at ex ecutive control [17]. Therefore, we can infer that the prior deci sion-making task will reduce the resource for executive control and impair the subsequent performance of executive control task.

Tasks measuring inhibitory control are powerful tools for studying execution function [35,36]. The MSIT has been proven to be an effective task to study normal human cognition and psychiatric pathophysiology [20,21]. In the present MSIT results, it was much more difficult to do the interference trials than the control trials, and target in the second position of the interference trials was the most difficult condition. This is because when the target number is in the middle, the numbers flanked on both sides reflecting Flanker interference[36]; target number per se is in interference with its position, reflecting Stroop interference[24]; the position of target number is interference with the correct response side, the spatial incompatibility reflecting Simon interference [35]. In other words, this condition involves Stroop, Simon and Flanker conflicts. Accordingly, results indicated that the accuracy rate of the experiment for this condition was lowest. It seemed that more difficult the task was, the more significant differences there would be between the two groups accordingly with better performance for low-conflict non-moral scenarios group than high-conflict moral-personal dilemmas one. Tasks requiring more self-control were more affected by depletion than tasks requiring less self-control [12], thus difficult trials might be easily affected by the deple tion of the re-

sources. Finishing the prior decision making task consumed a limited resource for executive control, and the wastage was not same due to different degrees of difficulty (or conflict) for the two decision-making tasks, resulting in the differences between the two groups in the subsequent task. Therefore, the more difficult one that need more resources might be more likely to be impaired by absence of the resource, which leads to considerably worse performance following moral-personal dilemmas than non-moral ones in the interference merged condition of the MSIT.

4 Conclusion

The focus of the present research is on comparing the execute control differences following two different decision tasks: high-conflict personal moral decision-making task vs. low-conflict non-moral one. Results showed a relatively larger difference following two decision-making tasks in the most effort-demanding condition of the MSIT, people who made moral decisions behaved worse in subsequent executive control than those faced non-moral ones, which might due to high-conflict moral decision-making process consuming more resource for executive function. To our knowledge, these findings are the first to demonstrate that distinct high/low conflict decision-making tasks would induce different subsequent performances of executive control, which could help to better understand the moral/non-moral distinction in decision-making.

References

[1] Greene JD, Nystrom LE, Engell AD, et al. The neural bases of cognitive conflict and control in moral judgment [J]. Neuron, 2004, 44(2): 389-400

[2] Sarlo M, Lotto L, Manfrinati A, et al. Temporal dynamics of cognitive-emotional interplay in moral decision-making [J]. J Cogn Neurosci, 2012, 24(4): 1018-1029

[3] Koenigs M, Young L, Adolphs R, et al. Damage to the prefrontal cortex increases utilitarian moral judgements [J]. Nature, 2007, 446(7138): 908-911

[4] Greene JD, Sommerville RB, Nystrom LE, et al. An fMRI investigation of emotional engagement in moral judgment [J]. Science, 2001, 293(5537): 2105-2108

[5] Moll J, de Oliveira-Souza R. Moral judgments, emotions and the utilitarian brain [J]. Trends Cogn Sci, 2007, 11(8): 319-321

[6] Moore AB, Clark BA, Kane MJ. Who shalt not kill? Individual differences in working memory capacity, executive control, and moral judgment [J]. Psychol Sci, 2008, 19(6): 549-557

[7] Hare TA, Camerer CF, Rangel A. Self-control in decision-making involves modulation of the vmPFC valuation system [J]. Science, 2009, 324(5927): 646-648

[8] Vohs KD. Self-regulatory resources power the reflective system: Evidence from five domains [J]. J Consum Psychol, 2006, 16 (3): 217-223

[9] Vohs KD, Baumeister RF, Schmeichel BJ, et al. Making choices impairs subsequent self-control: a limited-resource account of decision making, self-regulation, and active initiative [J]. J Pers Soc Psychol, 2008, 94(5): 883-898

[10] Baumeister RF. Yielding to temptation: Self-control failure, impulsive purchasing, and consumer behavior [J]. J Consum Psychol, 2002, 28(4):670-676

[11] Baumeister RF, Bratslavsky E, Muraven M, et al. Ego depletion: is the active self a limited resource? [J]. J Pers Soc Psychol, 1998, 74(5): 1252-1265

[12] Muraven M, Baumeister RF. Self-regulation and depletion of limited resources: Does self-control resemble a muscle? [J]. Psychol Bull, 2000, 126(2): 247-259

[13] Muraven M, Tice DM, Baumeister RF. Self-control as limited resource: regulatory depletion patterns [J]. J Pers Soc Psychol, 1998, 74 (3): 774-789

[14] Vohs KD, Heatherton TF. Self-regulatory failure: a resource-depletion approach [J]. Psychol Sci, 2000, 11(3): 249-254

[15] Schmeichel BJ, Vohs KD, Baumeister RF. Intellectual performance and ego depletion: role of the self in logical reasoning and other information processing [J]. J Pers Soc Psychol, 2003, 85(1): 33-46

[16] Vohs KD, Faber RJ. Spent Resources: Self-Regulatory Resource Availability Affects Impulse Buying [J]. J Consum Psychol, 2007, 33 (4): 537-547

[17] Schmeichel BJ. Attention control, memory updating, and e motion regulation temporarily reduce the capacity for executive control [J]. J Exp Psychol Gen, 2007, 136(2): 241-255

[18] Perner J, Lang B. Development of theory of mind and executive control [J]. Trends Cogn Sci, 1999, 3(9): 337-344

[19] Del Missier F, Mäntylä T, Bruine de Bruin W. Executive functions in decision making: An individual differences approach [J]. Thinking & Reasoning, 2010, 16(2): 69-97

[20] Bush G, Shin LM, Holmes J, et al. The Multi-Source Interference Task: validation study with fMRI in individual subjects [J]. Mol Psychiatry, 2003, 8(1): 60-70

[21] Bush G, Shin LM. The Multi-Source Interference Task: an fMRI task that reliably activates the cingulo-frontal-parietal cognitive/attention network [J]. Nat Protoc, 2006, 1(1): 308-313

[22] Stroop JR. Studies of interference in serial verbal reactions [J]. J Exp Psychol Gen, 1992, 121(1): 15-23

[23] Liu X, Banich MT, Jacobson BL, et al. Common and distinct neural substrates of attentional control in an integrated Simon and spatial Stroop task as assessed by event-related fMRI [J]. Neuroimage, 2004, 22(3): 1097-1106

[24] Luo C, Lupiá ñez J, Fu X, et al. Spatial Stroop and spatial orienting: the role of onset versus offset cues [J]. Psychol Res, 2010, 74 (3): 277-290

[25] Simon JR, Berbaum K. Effect of conflicting cues on information processing: the 'Stroop effect' vs. the 'Simon effect' [J]. Acta Psychol, 1990, 73(2): 159-170

[26] Eriksen BA, Eriksen CW. Effects of noise letters upon the identification of a target letter in a nonsearch task [J]. Perception, & Psychophysics, 1974, 16(1): 143-149

[27] Fan J, McCandliss BD, Fossella J, et al. The activation of attentional networks [J]. Neuroimage, 2005, 26(2): 471-479

[28] Duncan J. EPS Mid-Career Award 2004: brain mechanisms of attention [J]. Q J Exp Psychol, 2006, 59(1): 2-27

[29] MacDonald SW, Karlsson S, Rieckmann A, et al. Aging-related increases in behavioral variability: relations to losses of dopamine D1 receptors [J]. J Neurosci, 2012, 32(24): 8186-8191

[30] Young L, Koenigs M. Investigating emotion in moral cognition: a review of evidence from functional neuroimaging and neuropsychology [J]. Br Med Bull, 2007, 84(1): 69-79

[31] Shacham S. A shortened version of the Profile of Mood States [J]. J Pers Assess, 1983, 47(3): 305-306

[32] Evans AM, Dillon KD, Goldin G, et al. Trust and self-control: The moderating role of the default [J]. Judgm Decis Mak, 2011, 6(7): 697-705

[33] Metcalfe J, Mischel W. A hot/cool-system analysis of delay of gratification: dynamics of willpower [J]. Psychol Rev, 1999, 106(1): 3-19

[34] Pocheptsova A, Amir O, Dhar R, et al. Deciding without resources: Resource depletion and choice in context [J]. J Mark Res, 2009, 46 (3): 344-355

[35] Diamond A. Executive Functions [J]. Annu Rev Psychol, 2013, 64: 135-168

[36] Mullane JC, Corkum PV, Klein RM, et al. Interference control in children with and without ADHD: a systematic review of Flanker and Simon task performance [J]. Child Neuropsychol, 2009, 15 (4): 321-342

高/低冲突不同的决策任务影响后续的执行控制表现*

王 艳[1] 杜 晓[2] 唐一源[2△]

（1 东北财经大学 社会与行为跨学科研究中心 辽宁 大连 116025;2 大连理工大学 神经信息学研究所 辽宁 大连 116024）

摘要 目的:探索高/低冲突不同的决策任务对其后执行控制的影响。**方法:**40 名被试随机分配到高冲突涉及个人情感的道德两难任务组和低冲突与道德无关的决策任务组,而后分别考察两组人执行控制成绩的差异。**结果:**相比做出与道德无关决策的被试,完成涉及个人情感的道德两难决策任务后的被试在后续的多源冲突任务中表现更差。而且,在多源冲突任务难度最大的条件下,组间差异更大,完成涉及个人情感的道德两难决策任务的被试表现更加不如完成与道德无关决策的被试。**结论:**该研究表明冲突不同的决策任务对其后执行控制影响不同,冲突越大,其后的执行控制成绩越差。该研究有助于进一步加深我们对道德与非道德决策差异以及决策与执行控制关系的理解。

关键词:道德决策;执行控制;多源冲突任务

中图分类号:B842 **文献标识码:**A **文章编号:**1673-6273(2015)01-114-06

* 基金项目:国家自然科学基金项目(60971096);国家重点基础发展计划 "973" 项目(2012CB518200)

作者简介:王艳(1983-),女,博士研究生,主要从事认知神经科学领域研究

△通讯作者:唐一源,E-mail: yy2100@126.com

(收稿日期:2014-07-05 接受日期:2014-07-29)