Rocznik Kognitywistyczny 8/2015, s. 55–65
doi: 10.4467/20843895RK.15.005.4091
www.ejournals.eu/Rocznik-Kognitywistyczny

MARTA SIEDLECKA

Institute of Psychology, Jagiellonian University, Cracow, Poland

KAMILA ŚMIGASIEWICZ

Department of Neurology, University of Lübeck, Lübeck, Germany

Adaptation to different types of cognitive conflict. Are there common mechanisms?

Abstract: One of the functions of cognitive control is to detect difficulties in information processing and adjust the level of performance. This article presents study on conflict adaptation in which we investigated how detection of cognitive conflict influences behaviour on a subsequent trial. In two experiments we aimed to find out whether the adjustment can be carried out across two kinds of cognitive conflicts: between competing responses and requirements of two tasks. The modified version of the flanker task in switching paradigm was used so that participants had to switch between two tasks that shared the same stimulus set. The results showed that the two kinds of conflicts did not interact with each other. Furthermore, each conflict evoked conflict adaptation, but this adaptation did not occurred across conflicts. This suggests that conflict adaptation covers a set of mechanisms functioning uniquely in one domain.

Key words: cognitive control, conflict monitoring, conflict adaptation, task-switching, flanker task

Introduction

Cognitive control is the ability of human cognitive system to monitor lower-level information processing and to modify it according to its internal goals [Chuderski, Nęcka 2010]. One of its main functions is to detect and deal with occurring errors and difficulties. For example, it has been shown that when a person makes a mistake in a speeded reaction time task, in the next trial he or she reacts slower and makes fewer errors, probably adjusting the tempo to maintain required level of accuracy [Veen, Carter,2006]. More cautious mode of information processing is also implemented when task becomes more difficult [Botvinick, Braver, Barch, Carter, Cohen 2001; Gratton, Coles, Donchin 1992].

In the presented study we investigated whether detecting difficulties has global or local consequences, that is whether cognitive conflict leads to general change in processing strategy or whether it only affect processes related to the specific task or goal. Cognitive conflict results from interference between task relevant and task irrelevant information or between desired and automatic reaction [Egner, Delano, Hirsh 2007]. There are several tasks that are used to induce cognitive conflict in laboratory. Participants are usually required to respond to one of the stimulus features while ignoring others, e.g. in a Stroop task they are asked to name the colour of the font in which the word is written, without reading the actual word. In a *compatible* stimuli condition response to both features are the same (word "red" written with red ink) and in an *incompatible* condition they differ (word "red" written with green ink). Participants are typically faster and more accurate when responding to compatible stimuli. The common way of explaining this phenomenon is a dual-route model according to which compatible trials are faster because both features of stimuli lead to the activation of the same (correct) response. In incompatible trials the activation of both contradicting responses results in a conflict and conflict resolution is time consuming [De Jong, Liang, Lauber 1994; Kornblum, Hasbroucq, Osman 1990; Zhang, Zhang, Kornblum 1999; Zorzi Umiltà 1995].

There are at least three main types of conflict described in the literature. In *stimulus-based* conflict there is incompatibility between task-relevant and task-irrelevant stimulus features [e.g. Stroop task, Egner, Delano, Hirsch 2007]. *Response conflict* occurs when different stimulus features involve different motor reactions. In this case subject has to choose the most adequate response from a variety of simultaneously possible opportunities [e.g. Simon task, Egner et al. 2007; Simon 1969; Wuhr, Kunde 2008]. *Task conflict* stems from incongruence between requirements of different tasks, for instance subjects switch between two tasks and each of them requires different response to the same stimuli [Monsell, Taylor, Murphy 2001; Steinhauser, Hübner 2009].

Studies show that cognitive processing can be adjusted after the occurrence of conflict had been detected. The difference between reaction times to compatible and incompatible stimuli is usually smaller after the incompatible trial than after compatible one. This phenomenon is known as *Gratton effect* or sequential modulation [Gratton et al. 1992; Kerns, Cohen, MacDonald, Cho, Stenger Carter 2004; Notebaert, Soetens, Melis 2001; Stürmer, Leuthold, Soetens, Schröter, Sommer 2002]. One of the most popular explanations of this effect has been proposed by conflict monitoring theory [Botvinick et al. 2001]. According to this model there are two modules involved in dealing with conflict: conflict monitoring module and conflict adaptation module. The first one, located probably in anterior cingulate cortex (ACC), detects the occurrence of conflict and triggers attentional adjustments executed by the second module, located in dorsolateral prefrontal cortex (DLPFC) [Botvinick et al. 2001; Botvinick, Nystrom, Fissell, Carter, Cohen 1999; Carter, Braver, Barch, Botvinick, Noll, Cohen 1998; MacDonald, Cohen, Stenger, Carter 2000]. This adjustment is effectuated through enhancement of processing of task-relevant information and reduction of the processing of task-irrelevant information.

One of the controversies in conflict adaptation literature is whether this mechanism is specific to the conflict type or whether it is a globally working control system. In the first case, the conflict adaptation module would be sensitive to the source of detected conflict and adjust performance to deal with this type of conflict only. In the latter case, detection of conflict would lead to more controlled processing in the whole cognitive system. A number of studies have shown that the adaptation process acts locally [Akçay, Hazeltine 2008; Blais, Ribidoux, Risko, Besner 2007; Funes, Lupiáñez, Humphreys 2010; Jacoby, Lindsay, Hessels 2003; Kiesel, Kunde, Hoffman 2006; Kim, Chung, Kim 2013]. For example, Kiesel et al. [2006], using a task switching procedure, demonstrated that the *Graton effect* appeared only when the same task was repeated. When tasks were alternated the conflict detected in the previous trial did not result in conflict adaptation in the following trial. At the same time other studies have shown that conflict adaptation is a rather global process [Freitas, Bahar, Yang, Banai 2007; Kunde, Wühr 2006]. Freitas et al. [2007] observed cross-task conflict adaptation when participants alternated between the Stroop task and Eriksen flanker task (in which participants are required to respond to the letter “flanked” by distractors, i.e. FFNFF).

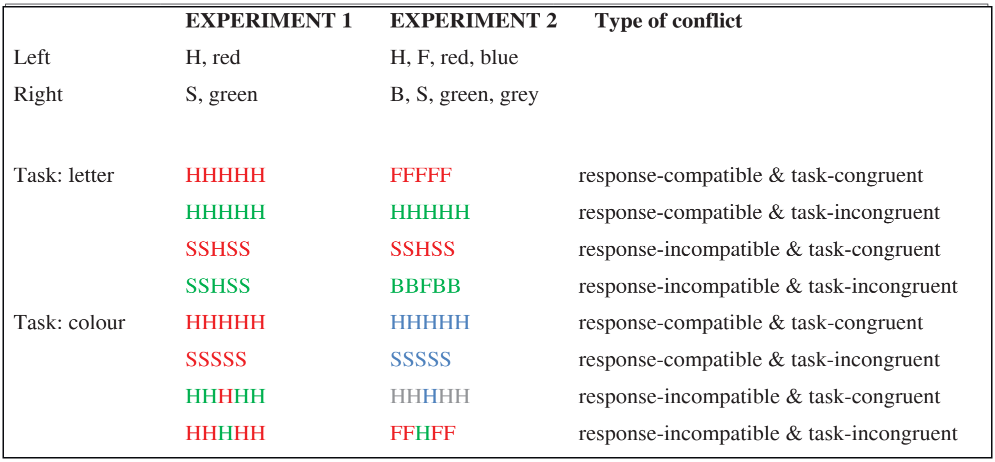
In the current study we aimed examine whether conflict adaptation occurs between two types of conflict: response-based and task-based. In two experiments we used a modified flanker task and classical task-switching paradigm. Although number of studies examined stimulus-based and response-based conflicts [Akçai, Hazeltine 2008; Egner et al. 2007; Funes et al. 2010; Notebaert, Verguts 2008] to our knowledge there are no data on the relationship between response-based and task-based conflicts. It is important to note that response and tasks conflict are conceptually separate while response-based conflict always involves stimulus conflict (incongruent stimuli). We assumed that if control process triggered by one type of conflict did not induce adaptation to the other type of conflict it would suggest that adjustments are sensitive to the conflict source. If we find conflict adaptation between different types of conflict it will point towards the conclusion that detecting one type of conflict triggers general optimization of information processing.

EXPERIMENT 1

Method

Thirty-five Jagiellonian University students participated in the study in return for course credit (13 men, mean age = 20, SD = 1.6).

A modified version of the flanker task was used [Eriksen, Eriksen 1974]. As in the original version, the stimulus consisted of five letters (e.g. SSHSS) and participants had to respond to a central one while ignoring irrelevant flankers. The stimuli set consisted of sixteen samples: red or green letter “H” or “S” flanked by other letters “H” or “S” of the same or different colour. The examples of stimuli are presented on Figure 1. The experiment was run on PC computers using E-prime software. The stimuli were presented in the centre of the scree on the white background, on LCD monitors (1280 x 800 resolution, 60 Hz refresh rate). The size of letters was about 1 x 8 cm (single spacing).



	EXPERIMENT 1	**EXPERIMENT 2**	**Type of conflict**
Left	H, red	H, F, red, blue	
Right	S, green	B, S, green, grey	
Task: letter	HHHHH	FFFFF	response-compatible & task-congruent
	HHHHH	HHHHH	response-compatible & task-incongruent
	SSHSS	SSHSS	response-incompatible & task-congruent
	SSHSS	BBFBB	response-incompatible & task-incongruent
Task: colour	HHHHH	HHHHH	response-compatible & task-congruent
	SSSSS	SSSSS	response-compatible & task-incongruent
	HHHHH	HHHHH	response-incompatible & task-congruent
	HHHHH	FFHFF	response-incompatible & task-incongruent

Figure 1. Stimuli used in both experiments, examples presented for left button response

The task induced two types of conflict: response-based (incompatibility between target and flankers) and task-based (incongruence between reactions required for the target in the context of each task). The target and the flankers could be related either to the same response (compatible trial, e.g. HHHHH) or to different responses (incompatible trial, e.g. SSHSS). Moreover, participants had to switch unpredictably between two subtasks: letter and colour task. For the letter task, they were asked to respond to identity of the central letter (press the right button for S and the left button for H). In the case of the colour task, participants were instructed to respond to the colour of the central letter (right button if the target was green and left button if the target was red).

The experiments were held in a computer laboratory. Participants were informed that they were taking part in a study of attention. Prior to the experiment they were presented with instructions (stressing both, speed and accuracy) and asked to remember how to react to each stimulus. Participants started with three practice sessions (10 trials each): the first and the second involved only one task (letter and colour, respectively) and the third session required switching between them. In the experimental session subtasks (colour or letter) and compatibility of target changed in a random order. The task consisted of 1600 trials. Each trial started with 800ms cue indicating which subtask was coming next (word “letter” or “colour”). Then the fixation point appeared for 100 ms, followed by a letter string. Participants had 1000 ms to react using the left or right mouse button. In the event of mistakes or a late response, the feedback (red screen) appeared for 200 ms. After a correct answer the next trial started immediately.

Results and discussion

The mean accuracy was 63.7% (M = 1019.40 correct trials, SD = 191.70). Only reaction times of correct answers were included into analysis. Four-way ANOVA was calculated with five factors: Task Transition (Repetition/Switch), Task Congruency

(Congruent/Incongruent), Response Compatibility (Compatible/Incompatible), Previous Task Congruency (Previous Congruent/ Previous Incongruent), and Previous Response Compatibility (Previous Compatible/Previous Incompatible).

Performance was generally faster on task repetition than on task alternation trials ($F_{1,34} = 4.9$, $p < .05$, η2 = .13), on task congruent than task incongruent trials ($F_{1,34} = 56.8$, $p < .0001$, η2 = .63) and on response compatible than response incompatible trials ($F_{1,34} = 111.4$, $p < .0001$, η2 = .77). Performance was also faster when previous trials was task incongruent (Previous Task Congruency: $F_{1,34} = 33.44$, $p < .0001$, η2 = .50) or response incompatible (Previous Response Compatibility: $F_{1,34} = 5.83$; $p < .05$, η2 = .15).

Surprisingly, we did not find the *Gratton effect* for response conflict (Response Compatibility x Previous Response Compatibility: $F_{1,34} = 1.39$, n.s.; Task Alternation x Response Compatibility x Previous Response Compatibility: $F_{1,34} = 3.3$, n.s.). The *Gratton effect* was present for conflict between tasks: the difference between task congruent and incongruent trials was smaller when the previous trial was incongruent compared to the situation when the previous trial was congruent (Task Congruency x Previous Congruency: $F_{1,34} = 14.8$, $p < .0001$, η2 = .30), but only if task was repeated (Task Transition x Task Congruency x Previous Congruency: $F_{1,34} = 7.8$, $p < .05$, η2 = .19; Task Congruency Adaptation for repetition trials: $F_{1,34} = 24$, $p < .0001$; Task Congruency Adaptation for alternation trials: $F_{1,34} = .20$, n.s.).

Furthermore, we did not find the adaptation to conflict between responses after conflict between tasks (Response Compatibility x Previous Congruency: $F_{1,34} = 3.8$, n.s.; Task Transition x Response Compatibility x Previous Congruency: $F_{1,34} = 1.40$, n.s.). There was also no adaptation to conflict between tasks after conflict between responses (Task Congruency x Previous Compatibility: $F_{1,34} < .01$, n.s.; Task Transition x Task Congruency x Previous Compatibility: $F_{1,34} = .86$, n.s.).

The results of this experiment suggest that conflict adaptation works locally – it occurs only within the same task and does not transfer from one type of conflict to another. However, it is not clear why we did not find the *Gratton effect* for response conflict. We suspect that participants might have not paid enough attention to the task, which is supported by the overall low accuracy and post-experimental reports of task being experienced as boring and tiring. We try to replicate these results in Experiment 2, in which the task was shorter, but also more difficult.

EXPERIMENT 2

Method

Forty-nine Jagiellonian University students participated in the study in return for course credit (8 men, mean age = 19.9 SD = 1.5).

The task was the same as used in Experiment 1, but here the stimulus set was extended to 96 samples. This time, for each task a subject had to choose between four rather than two alternatives. Beside the letter “S” and “H”, letters “F” (left button) and “B” (right button) were used. Similarly in case of colours, not only “red” and “green”, but also “blue” (left button) and “grey” (right button) were used (Figure 1). None of the stimulus was repeated with the same required response. The procedure consisted of three training session and then 1280 trials in the main task.

Results and discussion

The mean accuracy was 81.25% (M = 1040.78 correct trials, SD = 86.31). Similarly to the Experiment 1, only reaction times of correct answers were included into analysis.

Contrary to the results from Experiment 1, there was no general effect of task switching on reaction times ($F_{1,48} = 1.6$, n.s.). However, task congruent trials were performed faster than task incongruent trials ($F_{1,48} = 6.03$, $p < .05$, η2 = .24) and response compatible trials were performed faster than response incompatible trials ($F_{1,48} = 15.02$, $p < .0001$, η2 = .24). Performance was also faster when previous trial was task incongruent (Previous Task Congruency: $F_{1,48} = 56.9$, $p < .0001$, η2 = .54) or when previous trial was response incompatible (Previous Response Compatibility: $F_{1,48} = 199.1$, $p < .0001$, η2 = .81).

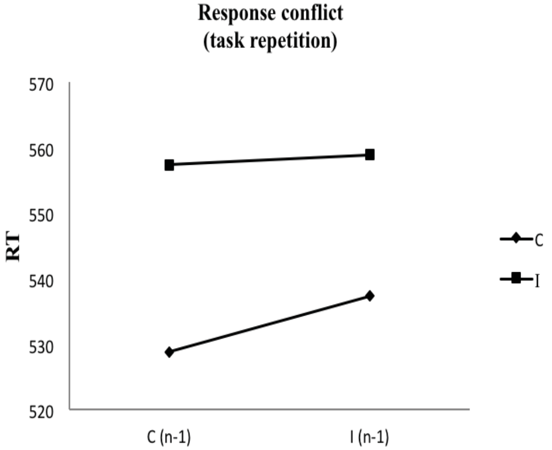


Figure 2. *Gratton effect* for conflict between responses when the task was repeated and alternated (Experiment 2; C – congruent stimuli in a current trial, I – incongruent stimuli in a current trial, C (n–1) – congruent stimuli in a previous trial, I (n–1) – incongruent stimuli in a previous trial).

Contrary to the previous study, the *Gratton effect* for conflict between responses was found: the difference between response compatible and response incompatible trials was smaller when the previous trial was response incompatible than compatible, independently from task switching (Response Compatibility x Previous Compatibility: $F_{1,48} = 9.4$; $p < .05$, η2 = .16; Task Transition x Response Compatibility x Previous Compatibility: $F_{1,48} = .81$, n.s). These results are presented on Figure 2.

The *Gratton effect* was also present for conflict between tasks: the difference between task congruent and task incongruent trials was smaller when the previous trial was task incongruent compared to the situation when the previous trial was congruent (Task Congruency x Previous Congruency: $F_{1,48} = 6.3$, $p < .05$, η2 = .12), but only if task was repeated (Task Transition x Task Congruency x Previous Congruency: $F_{1,48} = 11.2$; $p < .05$, η2 = .19; Task Congruency Adaptation for repetition trials: $F_{1,48} = 14.7$, $p < .0001$; Task Congruency Adaptation for alternation trials: $F_{1,48} = .35$; n.s.). These results are shown of Figure 3.

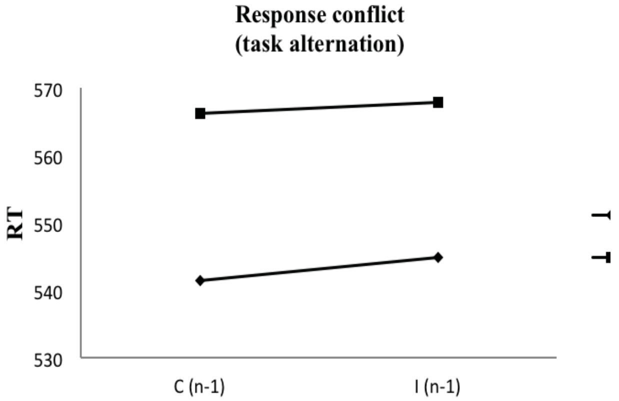


Figure 3. *Gratton effect* for conflict between responses when the task was repeated and alternated (Experiment 2).

Similarly to the Experiment 1, the adaptation to conflict between responses after conflict between tasks did not occur (Response Compatibility x Previous Congruency: $F_{1,48} = .008$; n.s; Task Transition x Response Compatibility x Previous Congruency: $F_{1,48} = 2.43$, n.s.). The adaptation to conflict between tasks after conflict between responses depended on task switching condition (Task Congruency x Previous Compatibility: $F_{1,48} = .60$, n.s., Task Transition x Task Congruency x Previous Compatibility: $F_{1,48} = 6.6$, $p < .01$, η2 = .12). However, the effects within each condition did not reach significance level (Task Congruency x Previous Compatibility for tasks alternation: $F_{1,48} = 3.3$; $p = .08$; Task Congruency x Previous Compatibility for task repetition: $F_{1,48} = 3.9$; $p = .06$, here the pattern reversed to the *Gratton effect* was observed).

Summing up, in this experiment we found the *Gratton effect* for both, task and response conflicts, but it did not occur between two types of conflict. Similarly to the Experiment 1, the results suggest the occurrence of conflict adaptation only within the same task and conflict type.

DISCUSSION

In the two experiments we studied the specificity of conflict adaptation mechanism. Participants were asked to switch between two variants of the flanker task, thus solving two kinds of conflict: between responses and between tasks. The results of the experiments seem to support the view that conflict adaptation process does occur but it is conflict-specific and task-specific. The detection of conflict did not improve general performance but was based on identifying the current conflict source and task requirement.

First of all, we found the adaptation to both types of conflicts. The response conflict has been already demonstrated many times, however task conflict adaptation has not had much support in the literature so far. While response conflict adaptation was independent from switching conditions, the *Gratton effect* for task conflict occurred only when the same task was repeated. Although both types of conflict are probably resolved by biasing response selection [Nieuwenhuis, Yeung 2005; Stürmer et al. 2002; Stürmer, Leuthold 2003], they might involve different sets of processes. For example, it has been suggested that in the basic flanker task visuo-spatial attention is required to select target among distractors [Funes et al. 2010]. Switching between tasks additionally involves resolving conflict between two task representations activated in working memory [Monsell 2003]. The results of the experiments presented in this article suggest that after detecting task conflict the adaptation system modulates processing to the actual task requirements (e.g. by enhancing the processing of task-relevant information or inhibiting the processing of task-irrelevant information). This improves the performance on the next trial but only when the task is repeated. On the other hand, response conflict is not affected by task alternations, probably because responding to the central letter and ignoring the flankers is the common requirement for both tasks.

Although conflict adaptation was present for each type of conflict, we did not find adaptation between two different conflicts: detecting stimulus incompatibility did not affect performance on the following incongruent trial, and vice versa. The results also showed that response and task conflicts are of different type, since there was no interaction between them and they prolonged response times in an additive manner. This is in line with growing body of behavioural and neuroimaging data suggesting separate and independent mechanisms of conflict detection and resolution [for review see: Egner 2008] and the existence of multiply brain systems for conflict detection [Bush, Luu, Posner 2000; Liston et al. 2006; Liu et al. 2004] and conflict adaptation [Funes et al. 2010].

However, taking into consideration that some studies obtained the results opposite to ours it seems important to mention how our experiments differed from the other ones. First, as noted by Funes at al. [2010] differences in conflict types have been often confounded with differences in tasks that were used in a given study while it seems that only a change of conflict source limits the adaptation to the specific conflict type. Second, as mentioned before, most of experiments showing the effects of general adaptation were focused on the relationship between two response-based conflicts or between stimulus-based and response-based conflict that are not completely independent and might involve the same adaptation mechanisms [Akçai, Hazeltine 2008; Freitas et al. 2007; Funes et al. 2010]. At the same time the results of experiments on task related conflict seem to support the local control view [Kiesel et al. 2006]. Also, we think it is important that in our experiments participants were engaged in conflicts within the same set of stimulus and responses. Contrary to other experiments [e.g. Freitas et al. 2007; Notebaert, Verguts 2008], here the same stimuli were relevant for both tasks and the responses sets were overlapping causing more interference (e.g. green F was mapped to right button response for the letter task but to left response for the colour task). Certainly a deeper analysis of conflict types is needed. It is important not only to classify conflict sources (i.e. differences between two dimensions of one stimuli and adjacent but separate stimuli) but also processes involved in solving given cognitive conflict [Funes et al. 2010]. We think that taking all these factors into consideration will help us to unravel the mechanisms of cognitive conflict resolution.

To sum up, the results of two experiments support the view that cognitive control in conflict adaptation acts locally and there is no one general mechanism optimizing cognitive processing. This goes against the general intuitive assumption that there is "central executive" [Baddeley, Hitch 1974] or "homunculus" [Logan 2003] responsible for monitoring and regulating distinct cognitive processes [for review see: Monsell, Driver 2000]. The data are in line with theories stating that cognitive control depends on multiple executive functions that are separable, modular processes [e.g. Miyake, Friedman, Emerson, Witzki, Howerter, Wager 2000; Nobre 2001; Salthouse, Atkinson, Berish 2003]. Although the presented results do not prove that there is no "central controller", it seems very probably that the control *homunculus* will be soon "dissolved".

ACKNOWLEDGEMENTS

We would like to thank Maciej Tarady for his help with preparing experiments and data collection.

BIBLIOGRAPHY

Akçay Ç., Hazeltine E. (2008). *Conflict adaptation and task structure*. „Journal of Experimental Psychology: Human Perception and Performance" 34 (4), pp. 958–973.

Blais Ch., Ribidoux S., Risko F., Besner D. (2007). *Item-specific adaptation and the conflict monitoring hypothesis: A computational model*. „Psychological Review" 114 (4), pp. 1076–1086.

Baddeley A.D., Hitch G. (1974). *Working memory*. „Psychology of Learning and Motivation" 8, pp. 47–89.

Botvinick M.M., Braver T.S., Barch D.M., Carter C.S., Cohen J.D. (2001). *Conflict monitoring and cognitive control*. „Psychological Review" 108 (3), pp. 624–652.

Botvinick M., Nystrom L., Fissell K., Cameron C., Cohen J. (1999). *Conflict monitoring versus selection for action in anterior cingulate cortex*. „Nature" 402, pp. 179–180.

Bush G., Luu P., Posner M.I. (2000). *Cognitive and emotional influences in anterior cingulate cortex*. „Trends in Cognitive Sciences" 4 (6), pp. 215–222.

Carter C.S., Braver T.S., Barch D.M., Botvinick M.M., Noll D., Cohen J.D. (1998). *Anterior cingulate cortex, error detection, and online monitoring of performance*. „Science" 280, pp. 747–749.

Chuderski A., Nęcka E. (2010). *Intelligence and cognitive control*. In: A. Gruszka, G. Matthews, B. Szymura (eds.), *Handbook of Individual Differences in Cognition*. New York: Springer, pp. 263–282.

De Jong R., Liang C.C., Lauber E. (1994). *Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus response correspondence*. „Journal of Experimental Psychology: Human Perception and Performance" 20, pp. 731–750.

Egner T. (2008). *Multiple conflict-driven control mechanisms in the human brain*. „Trends in Cognitive Sciences" 12 (10), pp. 374-380.

Egner T., Delano M., Hirsch J. (2007). *Separate conflict-specific cognitive control mechanisms in the human brain*. „Neuroimage" 35 (2), pp. 940–948.

Eriksen B.A., Eriksen C.W. (1974). *Effects of noise letters upon the identification of a target letter in a nonsearch task*. „Perception & Psychophysics" 16 (1), pp. 143–149.

Freitas A., Bahar M., Yang S., Banai R. (2007). *Contextual adjustments in cognitive control across tasks*. „Research Report" 18, pp. 1040–1043.

Funes M.J., Lupiáñez J., Humphreys G. (2010). *Analyzing the generality of conflict adaptation effects*. „Journal of Experimental Psychology: Human Perception and Performance" 36 (1), pp. 147-161.

Gratton G., Coles M.G.H., Donchin E. (1992). *Optimizing the use of information: Strategic control of activation of responses*. „Journal of Experimental Psychology: General" 121 (4), pp. 480–506.

Jacoby L., Lindsay D.S., Hessels S. (2003). *Item-specific control of automatic processes: Stroop process dissociation*. „Psychonomic Bulletin & Review" 10 (3), pp. 638–644.

Kerns J.G., Cohen J.D., MacDonald A.W., Cho R.Y., Stenger V.A., Carter C.S. (2004). *Anterior cingulate conflict monitoring and adjustments in control*. „Science" 303, pp. 1023–1026.

Kiesel A., Kunde W., Hoffman J. (2006). *Evidence for task-specific resolution of response conflict*. „Psychonomic Bulletin and Review" 13, pp. 800–806.

Kim C., Chung C., Kim J. (2013). *Task-dependent response conflict monitoring and cognitive control in anterior cingulate and dorsolateral prefrontal cortices*. „Brain Research" 1537, pp. 216–223.

Kornblum S., Hasbroucq T., Osman A. (1990). *Dimensional overlap: Cognitive basis for stimulus-response compatibility. A model and taxonomy*. „Psychological Review" 97, pp. 253–270.

Kunde W., Wühr P. (2006). *Sequential modulations of correspondence effects across spatial dimensions and tasks*. „Memory & Cognition" 34, pp. 356–367.

Liston C., Matalon S., Hare T.A., Davidson M.C., Casey B.J. (2006). *Anterior cingulate and posterior parietal cortices are sensitive to dissociable forms of conflict in a task-switching paradigm*. „Neuron" 50, pp. 643–653.

Liu X., Banich M.T., Jacobson B.L., Tanabe J.L. (2004). *Common and distinct neural substrates of attentional control in an integrated Simon and spatial Stroop task as assessed by event-related fMRI*. „NeuroImage" 22, pp. 1097-1106.

Logan G.D. (2003). *Executive control of thought and action. In search of the wild homunculus*. „Current Directions in Psychological Science" 12 (2), pp. 45-48.

MacDonald A.W., Cohen J.D., Stenger V.A., Carter C.S. (2000). *Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control*. „Science" 288, pp. 1835-1838.

Miyake A., Friedman N.P., Emerson M.J., Witzki A.H., Howerter A., Wager T.D. (2000). *The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis*. „Cognitive Psychology" 41 (1), pp. 49–100.

Monsell S., Driver J. (2000). *Banishing the control homunculus*. In: S. Monsell, J. Driver (eds.), *Control of Cognitive Processes: Attention and Performance XVIII*. Cambridge, MA: The MIT Press, pp. 3–32.

Monsell S., Taylor T.J., Murphy K. (2001). *Naming the color of a word: Is it responses or task sets that compete?* „Memory & Cognition" 29 (1), pp. 137-151.

Monsell S. (2003). *Task switching*. „Trends in Cognitive Sciences" 7 (3), pp. 134-140.

Nieuwenhuis S., Yeung N. (2005). *Neural mechanisms of attention and control: Losing our inhibitions?* „Nature Neuroscience" 8 (12), pp. 1631-1633.

Nobre A.C. (2001). *The attentive homunculus: Now you see it, now you don't.* „Neuroscience & Biobehavioral Reviews" 25 (6), pp. 477-496.

Notebaert W., Soetens E., Melis A. (2001). *Sequential analysis of a Simon task – evidence for an attention-shift account*. „Psychological Research" 65, pp. 170–184.

Notebaert W., Verguts T. (2008). *Cognitive control acts locally*. „Cognition" 106 (2), pp. 1071-1080.

Salthouse T.A., Atkinson T.M., Berish D.E. (2003). *Executive functioning as a potential mediator of age-related cognitive decline in normal adults*. „Journal of Experimental Psychology: General" 132 (4), p. 566-594.

Simon J.R. (1969). *Reactions towards the source of stimulation*. „Journal of Experimental Psychology" 81, pp. 174-176.

Steinhauser M., Hübner R. (2009). *Distinguishing response conflict and task conflict in the Stroop task: Evidence from ex-Gaussian distribution analysis.* „Journal of Experimental Psychology: Human Perception and Performance" 35 (5), pp. 1398-1412.

Stürmer B., Leuthold H. (2003). *Control over response priming in visuomotor processing: A lateralized event-related potential study*. „Experimental Brain Research" 153 (1), pp. 35-44.

Stürmer B., Leuthold H., Soetens E., Schröter H., Sommer W. (2002). *Control over location-based response activation in the Simon task: Behavioral and electrophysiological evidence.* „Journal of Experimental Psychology: Human Perception and Performance" 28, pp. 1345-1363.

van Veen V., Carter C.S. (2006). *Conflict and cognitive control in the brain*. „Current Directions in Psychological Science" 15 (5), pp. 237-240.

Wühr P., Kunde W. (2008). *Precuing spatial S-R correspondence: Is there regulation of expected response conflict?* „Journal of Experimental Psychology: Human Perception & Performance" 34 (4), pp. 872-883.

Zhang H.Z.H., Zhang J., Kornblum S. (1999). *A parallel distributed processing model of stimulus--stimulus and stimulus-response compatibility*. „Cognitive Psychology" 38 (3), pp. 384-432.

Zorzi M., Umilta,C. (1995). *A computational model of the Simon effect*. „Psychological Research" 58 (3), pp. 193-205.