The Effect of Cognitive Conflict on the Development of a Motor Sequence

Benjamin Moll (s1109987)

University of Twente

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First supervisor: Dr. M.F.L. Ruitenberg

Second supervisor: Dr. E. De Kleine

Contents

Abstract

Research has shown that automatic processes can have a positive influence on cognitive control. We investigated whether this effect is also valid in the reverse direction. The present study examines the effect of cognitive conflict on the development of a motor sequence. 48 participants completed a combination of the Stroop task and a discrete sequence production task. The responses to the Stroop stimuli formed two motor sequences that participants learned over the course of six training blocks. Participants were assigned to one of three conditions with varying amounts of conflict: a neutral condition, a low conflict condition and a high conflict condition. We looked for differences in the improvement of the reaction times over the course of six training blocks between the three conflict conditions. A faster decrease in reaction times would indicate a faster learning of the motor sequences. After the training blocks, two test blocks were conducted. In one of the test blocks, the same sequences as in the training blocks were used, whereas in the other test block, two new sequences were used. All conditions completed the same test blocks with a high amount of cognitive conflict. Although no significant proof was found to support our hypothesis that cognitive control does have influence on the development of a motor sequence, there was a difference in the improvement of reaction time between the low and the high conflict condition in the training blocks. The reaction times decreased faster for participants in the high conflict condition compared to the low conflict condition. This indicates that cognitive conflict can have an influence on the development of a motor sequence. Although the difference between the three conflict conditions was not large enough to be considered significant, our observations went in the by our hypothesis expected direction and so it seems promising to further investigate the relationship between cognitive conflict and motor learning.

Introduction

Imagine you carry an object like a book and you accidentally drop the book while walking. The automatic reaction would be to try to catch the falling book before it hits the ground. But if you carry a knife instead of a book, the reaction would be different. Instead of trying to catch a sharp knife and taking the risk of being injured, most persons would take a step back so that the knife will not hit their feet. This illustrates that there is a process that monitors which reaction is appropriate in a given situation. This process is called cognitive control and includes mechanisms that monitor and regulate actions like action selection, response inhibition and performance monitoring (Purves et al., 2008). Cognitive control is considered to be a controlled process and can therefore be contrasted with automatic processes that take place without a person's conscious awareness. For a long time, controlled and automatic processes were thought of as separate processes that had no influence on each other. But recent research suggests that automatic processes can have a positive influence on cognitive control (Hommel, 2007; Koch, 2007; Tubau & López-Moliner, 2004). One example is that studies including subliminal priming showed that the cognitive control functions in automatically processed events can be increased, even though they were not recognized consciously (van Gaal, Ridderinkhof, Fahrenfort, Scholte & Lamme, 2008). This means that events that are processed automatically and even without being consciously aware of them, they can have an influence on higher cognitive control functions like inhibitory control (van Gaal et al., 2008) and task switching (Lau & Passingham, 2007). So it seems that there is an interaction between automatic and controlled processes.

Research thus shows that automatic processes can have a positive influence on cognitive control. In this study, we examine whether this relationship is also valid in the reverse direction, namely: Does cognitive conflict have an influence on automatic processes? More specifically, how is the amount of conflict related to the performance of automated movement sequences?

A well-known task for assessing cognitive control is the Stroop task, in which incongruence between two features within one stimulus induces a conflict that has to be resolved by cognitive control. In the Stroop-task, names of colours (e.g. blue, red, yellow) are shown to the participant. These words are themselves written in different colours and can thus be congruent with the meaning of the word (e.g. the word “blue” written in blue ink) or incongruent (e.g. the word “blue” written in yellow ink). The task for the participant is then to name the colour of the ink and ignore the meaning of the word. In incongruent trials, there is a conflict between the word and the ink in which it is written. Participants typically need more time to react and make more mistakes in these incongruent trials. The reason is that they must thus inhibit the automatic response to read the word and instead name the colour of the ink. This delay in reaction time on incongruent trials compared to congruent trials is called the Stroop effect. It shows that the monitoring of conflict and suppressing of a response takes its time and costs cognitive resources (Deroost, Vandenbossche, Zeischka, Coomans and Soetens, 2012; MacLeod, 1991).

Research indicates that cognitive conflict can have an influence on the performance in conflict tasks (Gratton, Coles & Donchin, 1992). Gratton et al. (1992) found that the performance on a given trial is influenced by the relationship of conflict from the current and preceding trial. Conflict effects are reduced following high conflict (incongruent) trials compared to low conflict (congruent) trials (Gratton et al., 1992). The effect after completing high conflict trials differs, depending on the nature of the subsequent trial. For incongruent trials, the responses are faster and more accurate. This effect is interpreted to reflect a reduction in conflict due to cognitive control. For congruent trials on the other hand, responses are slower and less accurate, which is interpreted as reflecting the elimination of a facilitation effect due to cognitive control (Botvinick et al., 1999, 2001). The reduction in conflict effects (like the decreased reaction time) after training with high-conflict trials compared to low-conflict trials is called the conflict adaption effect (Gratton et al., 1992).

The effect of cognitive control in conflict tasks like the Stroop task is usually explained by “conflict-triggered adaptive mechanisms that increase the efficiency of task-relevant information processing” (Deroost et al., 2012, p.1243). So rather than inhibiting task-irrelevant information, cognitive control mechanisms enhance the performance by increasing cortical responses to information that are relevant to the task (Egner & Hirsch, 2005). This focus on the important information of a task results in less cognitive conflict for the participants and thus leads to faster responses. In the example of the Stroop task, the conflict between the word and colour representation seems to bias colour processing in favour of word processing (Botvinick, Braver, Barch, Carter, & Cohen, 2001). By shifting their attention away from the meaning of the word, which often stands in conflict with the color, and focusing on the color of the word alone, participants are able to give faster responses after practicing the task.

In an experiment by Deroost et al. (2012), evidence was found that the amount of conflict in a cognitive control task can have an influence on the implicit learning of a perceptual sequence. They found that participants showed better results in the Stroop task when the training sets included a defined sequence of perceptual events even though participants were not informed about the sequence. This effect seemed to be influenced by the amount of conflict that the training set included. In the case of the Stroop task, the number of trials in which the colour is incongruent with the word had an influence on the performance of the respondents. Participants who experienced more conflict in the word-colour pairs performed better in the post test whereas participants with only few conflicting pairs did not show better results than the control group without an implicitly learnable sequence of colours. The explanation that the authors give for this effect is that in a task which requires the controlled processing of stimuli, the cognitive system looks for more efficient ways to improve performance, like exploiting sequence knowledge as much as possible (Deroost et al., 2012).

The present study aims to examine whether conflict related improvements that were observed with respect to the development of a perceptual sequence (Deroost et al., 2012) also apply to the development of a motor sequence. Specifically, we examine the effect of different amounts of conflict on the development of a motor sequence. To study the development of a motor sequence, we employed a modified version of the discrete sequence production task (DSP task). The DSP task consists of a serial number of key presses, usually less than seven or eight. The discrete sequences are produced by responses to cues which are presented in a fixed order. The participants thus respond with the same series of key presses over and over again. Longer practice leads to an automated response where “key- dependent cues are no longer needed; once the first cue is presented, it acts as an imperative stimulus for the entire sequence” (Verwey & Wright, 2004, p.64). To integrate a cognitive control task into our experiment, we used a combination of the Stroop task and the DSP task. The participants were confronted with a Stroop task that contained a pre-assigned sequence of response keys. The colours in which the words were presented thus form a repeating sequence that is six elements long.

Participants were assigned to one of three groups that differed in the amount of conflict they experienced during training. In the first group, neutral words were used in the Stroop task. So in this group, there will be no conflict at all. The second group experienced a low amount of conflict. 75% of the words were incongruent with the color in which they were displayed and the remaining 25% were be congruent. The third group experienced the greatest amount of cognitive conflict. 50% of the words were incongruent with the displayed color and 50% were congruent. Although one might think that the second group experienced the most conflict, because this group had the greatest number of incongruent word – color pairs, this is not true. Participants in this condition noticed that the stimuli were incongruent most of the time and therefore adapted to the fact that the word of a stimuli is no valid cue for a response. Participants in the third condition on the other hand had an equal amount of congruent and incongruent stimuli. They experienced the most conflict of all groups, since it was the least possible to predict if the following stimulus would be congruent or incongruent. Participants in the second group experienced less conflict since they expected the stimuli to be incongruent. This effect of higher conflict when incongruent stimuli are equal to congruent stimuli compared to lower conflict when there are more incongruent than congruent stimuli is known as the “proportion-congruent effect” (Logan & Zbrodoff, 1979).

After completing six training blocks, there was a test stage which was further divided into two blocks. In both test blocks, the conflict amounted to 50% incongruent and 50% congruent words like in the training blocks of the third group. The difference was that in the first test-condition, the sequence of colours (and therewith responses) were the same as in the training trials whereas in the second test condition there were two new colour sequences.

The present study examines whether the development of a motor sequence is affected by the amount of cognitive conflict that is experienced during learning. We hypothesize that the reaction times of participants in the high conflict condition decreases faster compared to the reaction times of participants in the neutral and the low conflict condition (H1). A faster decrease in reaction time would be an indication for faster learning. As observed by Deroost et al. (2012), the amount of conflict can have an influence on the performance. A second hypothesis is that the reaction times in the test blocks will be different across the three conditions (H2). According to conflict adaption effect (Gratton et al., 1992), the group with the highest conflict should be adapted to the task in the test blocks and thus show the fastest reaction times. The medium conflict group will be less adapted due to the presence of less conflict and thus show slower reaction times than the high conflict group. The neutral condition with no conflict will show the slowest reaction times, since they had no opportunity to adapt to the conflict of the test blocks like the other two groups.

Method

Participants

Participants in our study were 48 students of the University of Twente (20 male, 28 female) with an average age of 22.75 years (SD = 2.08; 19 – 29 years). All the participants were native German speakers. None of them had problems with their hand coordination or sight (e.g. color blindness). Participants could receive credits in exchange for their participation. The study was approved by the ethical committee of the Faculty of Behavioral Sciences of the University of Twente.

Apparatus

The experiment took place in the laboratory rooms of the University of Twente. The room we used was roughly 5m² and contained only a desk, a chair and a computer. The participants sat on the chair approximately 50cm away from a 22” monitor (LG Flatron E2210). The computer that was used contained an Intel core i7-3370 processor and 8Gb RAM. A standard computer keyboard was used as an input device for the responses of the participants. The software used for stimulus presentation and data collection was E-Prime (version 2.0).

Task

In the task, participants were confronted with words that were displayed in four different inks, namely red, green, yellow and blue. The goal was to respond as fast as possible to the color of the word by pressing one of the four corresponding keys on the keyboard (cf. figure 1). Each key represented one of the four used colors (C = red; V= green; B = yellow; N = blue). A sheet of paper that showed the sequence of the colors as ordered on the keyboard was placed on the bottom of the screen so that it was easier for the participants to remember which key belonged to which color. Depending on the condition, the words used in the task were either the names of the four used colors (“Grün” = green, “Rot” = red, “Blau” = blue and Gelb = yellow; in the two conditions with cognitive conflict) or neutral words (“Müll” = trash, “Boot” = boat, “Held” = hero and “Frau” = woman; in the neutral condition). The words were presented in Courier New and a size of 18-point. When the respondents gave a correct response to a stimulus the next word was presented immediately. After incorrect responses, the word “Falsch” (in English “wrong”) was presented for 1000 milliseconds to inform the participant about the incorrect response and the stimulus where the mistake was made is presented again. The participant then had to respond to the stimulus again until the response was correct.

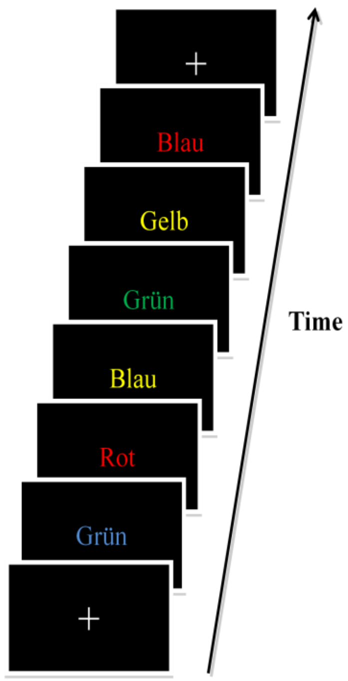

Figure 1: Illustration of a sequence we used in the task.

The correct responses to the stimuli formed two sequences that were repeated in the course of each block. So for each participant, there were two response sequences that were the same over all training blocks. Each sequence was six key presses long and after completing such a sequence, a white cross was presented for 1000 milliseconds in the middle of the screen, after which the next sequence of stimuli started. Four different combinations of sequences were used and they were the same in all three conditions. This means that in each condition there were four sub-groups with different sequences. These different sequences were used to minimize a possible effect of using one specific sequence only. The following sequences were used: ncbvbc/vnbcnv, bnvcvn/cbvnbc, vbcncb/nvcbvn, cvnbnv/bcnvcb.

The amount of cognitive conflict that the participants experience while conducting training blocks was manipulated, so that three conflict conditions were created. First, in the neutral condition, participants were presented words that did not induce any conflict to the corresponding color in which they were displayed. For example the word “Boot” is presented, written in red ink. In the other two conditions, the words the names of the colors that we used for our response sequence (red, green, blue and yellow). If the word was incongruent with the color (e.g. , the word “Blau” presents in red), the stimulus induced a cognitive conflict because participants had to suppress the automatic response of reading the word and instead give a response corresponding to the color of the stimulus. In these two conditions that induced cognitive conflict, a different amount of incongruent word-color stimuli was used so that we were able to compare a low- and a high-conflict group. In the low conflict condition, participants were confronted with 75% incongruent word-color stimuli. Finally, in the high conflict condition, 50% of the stimuli were incongruent and participants in this condition thus experienced the greatest amount of conflict as they were least able to predict if the following stimulus would be congruent or incongruent.

After completing the training blocks each participant completed two test blocks. The stimuli in these test blocks were the same for all three conditions. More specifically, the test blocks contained color names only as stimuli and 50% of the stimuli were incongruent with the color in which they were presented (like the high conflict condition in the training blocks). The two test blocks differed only in the sequences they contained. For every participant there was one test block that contained the familiar sequences from the training blocks and another block that contained two completely new sequences. The order of the two test blocks was counterbalanced across participants in each practice condition.

After completing the two test blocks the participants were given a questionnaire which contained questions about their knowledge of the presented sequences. Participants were first asked to recall the sequences freely, by writing down the order of key presses. Next, they were asked to recognize their sequences from a table with 12 different sequences. Furthermore, participants were asked how they tried to remember the sequences and if they had already participated in an experiment with a key pressing sequence task. Finally the respondents were given room to comment on the task or anything else they thought was worth mentioning.

Procedure

After arriving, the participants were asked to enter the laboratory room. The participants started by signing the informed consent form and filled in a questionnaire about their demographic information and their preferred hand usage (Annett's (1970) Handedness Inventory). The participants were then given a text which explained the experiment to them and how they should respond to the presented stimuli. Participants were asked to respond as fast as possible to the color of the stimuli and to ignore the meaning of the words. Before starting the experiment, the participants had the opportunity to ask questions if anything was unclear to them. The experimenter then started the experiment and left the room. The participants completed six training blocks which consisted of stimuli that matched their assigned condition. Each block consisted of 24 trials of each sequence resulting in a total of 144 practice trials per sequence across the six practice blocks. Halfway through each block there was a break of 30 seconds where the respondent had the opportunity to relax for a brief moment. In this break, and also at the end of each block, the number of errors made and the average reaction time was presented to the participants as feedback on their performance. Upon the completion of each block, the researcher entered the room and started the next block.

Results

Analysis of the training blocks

A 6 (training block) x 6 (key in the sequence) x 3 (conflict condition; neutral vs. 75-25 vs. 50-50) ANOVA with repeated measures (training block and key in the sequence as within-subject variable and conflict condition as between-subject variable) was used to test for differences in the reaction times (RTs) between the different training blocks, keys in the sequence and conditions.

A significant main effect was found for the key in the sequence $F(5, 225) = 95.52$, $p < .001$, suggesting that the RTs differed between the six responses of a sequence (cf. Figure 2). This effect was expected and shows that the participants had knowledge about the sequence. The first key served as a cue and lead to shorter reaction times for the following keys. When looking at the graph, it is also noteworthy that there is a peak in reaction time for key 5. The reason for this increase in reaction time is probably because participants used chunks to help themselves remember the sequence. Chunking means that participants grouped the responses so that they, for example, only have to remember two chunks of movements instead of the six single movements of a response sequence. It seems likely that participants in our task grouped the first four responses as one chunk and were therefore able to respond very fast to the first four key. But when the second chunk began, they had to spend more cognitive effort to start the second chunk and thus needed longer to respond on the fifth key.

In addition, significant main effect for training block was found, $F(5, 225) = 111.51$, $p < .001$. This difference in training blocks was expected and shows the learning effect that takes place when the participants realize that there is a sequence in the responses. Participants became faster in their responses due to this learning which resulted in lower RTs in later blocks (cf. Figure 3).

A significant interaction between training block and key in the sequence was found $F(25, 1125) = 10.87$, $p < .001$. So the differences in reaction times of the keys were not the same in the different training blocks (cf. Figure 2). This effect was expected in a task that contains a sequence that could be learned. The drop in reaction time from the second key on due to the knowledge of the sequence became larger the more the respondents were aware of the sequence. So the difference between the first key press of a sequence and the subsequent key presses became larger as more training blocks have been completed.

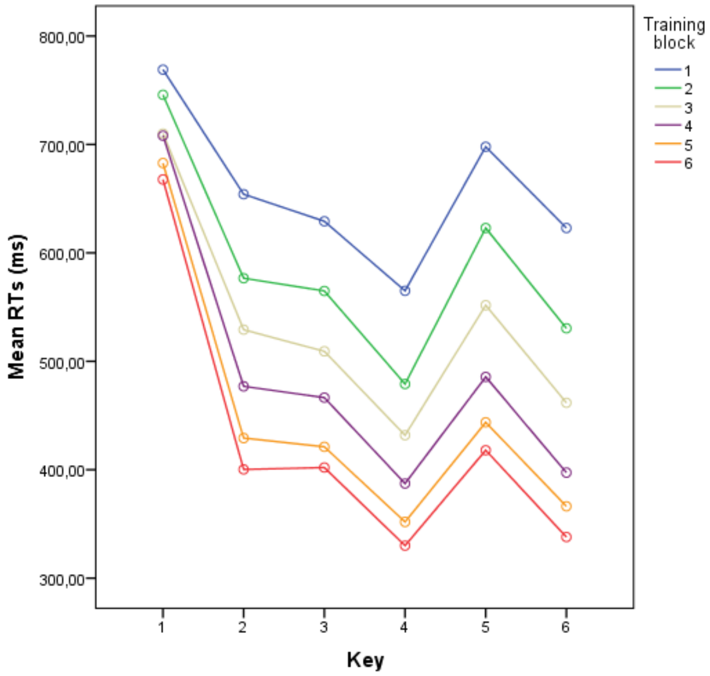

Figure 2: Mean RTs per key within the sequence for each of the six training blocks

Results showed no significant interaction between training block and conflict condition F(10, 225) = 0.98, p = .464, or key and condition F(10, 225) = 1.31, p = .225. This indicates that there were no differences found between the three conditions when compared on the decrease of reaction time in the training blocks or the keys in the sequence.

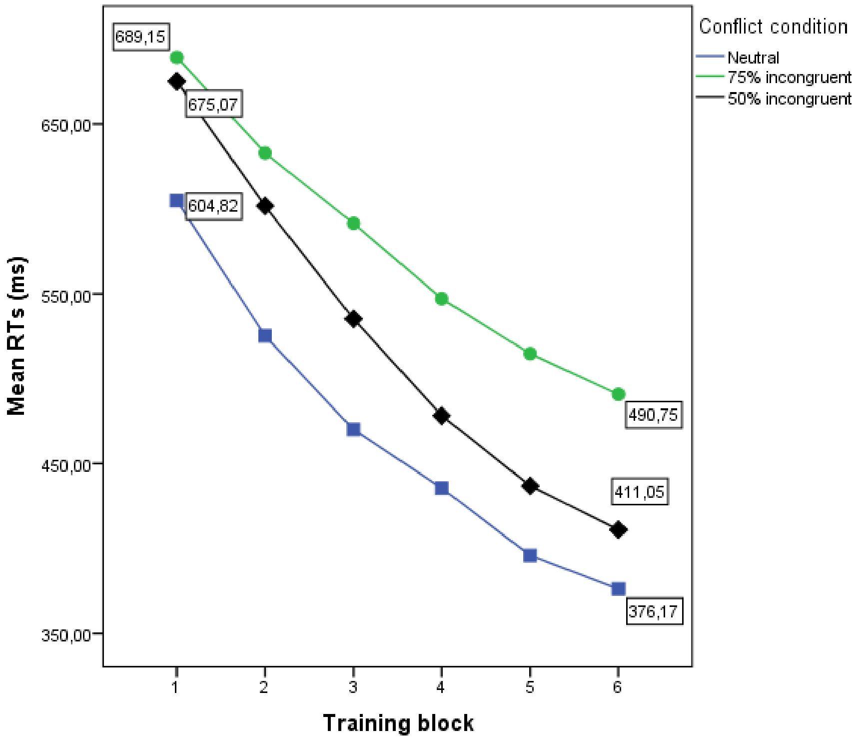

Figure 3: Mean RTs per training block for the three conflict conditions.

Although the interaction between training block and condition was not significant, Figure 3 seems to suggest that there was a difference in the decrease in RT between the two conditions that induce cognitive conflict to the participants, namely the 50-50 and the 75-25 condition (given that no actual conflict was present in the neutral condition). We therefore proceeded by only comparing these two conflict conditions. In Block 1 there was no significant difference between the 75-25 and the 50-50 condition (689ms vs. 675ms), $F(1, 30) = 0.28$, $p = .30$ (one-tailed). In block 6 on the other hand, there was a significant difference between the RTs of the two conditions (491ms vs. 411 ms), $F(1, 30) = 3.01$, $p < .05$ (one-tailed). This seems to indicate that the RT of the 50-50 condition decreased faster than in the 75-25 condition.

Analysis of the test blocks

To analyze the data from the test blocks a 2 (sequences: familiar vs. unfamiliar) x 6 (Key) x 3 (Conflict condition) ANOVA analysis with repeated measures on sequences and key was performed. Results showed a significant main effect of key, $F(1, 45) = 77.68$, $p < .001$. Like in the training blocks, this effect was expected since knowing the sequence lead to faster reaction times from the second key press of a sequence on.

The results also showed that sequences were performed faster in the familiar block than in the unfamiliar block (418 ms vs. 601 ms), $F(1,45) = 136.43$, $p < 0.001$ (cf. Figure 4). We expected this difference because the participants have an advantage in the block containing the familiar sequence leading to a faster reaction time compared to the block containing an unfamiliar sequence.

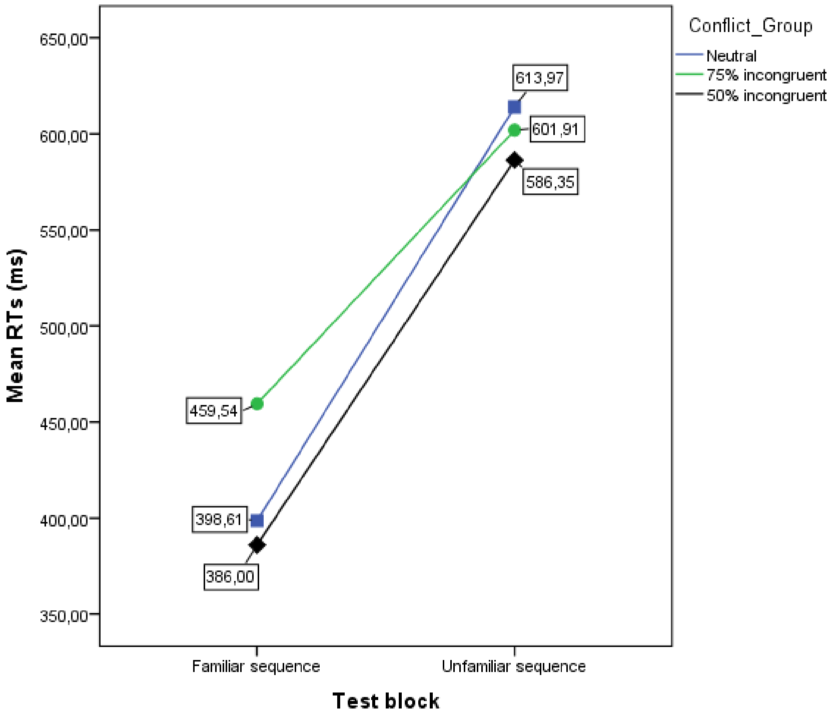

Figure 4: Mean RTs of the familiar and unfamiliar blocks for each of the three conflict conditions.

A significant interaction was found between the block and the key from the test blocks, $F(5, 225) = 13.47$, $p < .001$. This interaction shows that there was a difference in the reaction time per key in the two different blocks. In the familiar block, participants showed a sharp drop in reaction times after the first key because they knew the sequence that followed.

Contrary, in the unfamiliar condition the participants could not make as much use of the sequence since it was the first time they were confronted with this sequence and they had to learn the new sequence first.

Like in the analysis of the training blocks, there was no significant interaction found between the block and the condition $F(2, 45) = 1.95$, $p = .154$, or the key and the condition $F(10, 225) = 1.64$, $p = .095$ for the test blocks. It seems thus that the amount of conflict had no significant influence on the reaction times in the test blocks (cf. Figure 4).

We also analyzed performance in terms of accuracy, using the percentage of erroneous key presses. Participants in the neutral condition made on average 4.01% errors, participants in the 75-25 condition 4.28% errors and participants in the 50-50 condition 3.21% errors. A 2 (Block; familiar vs. unfamiliar) x 6 (key) x 3 (conflict condition) ANOVA on errors showed no significant main or interaction effects of conflict condition (ps > .09).

Analysis of the questionnaire

We started the analysis of the questionnaire with an overview of the participants' ability to recall and recognize the sequences that we used in the experiment (see Table 1).

Conflict condition	Recalled sequences			Recognized sequences		
	0	1	2	0	1	2
Neutral	5 (31%)	6 (38%)	5 (31%)	1 (6%)	6 (38%)	9 (56%)
75-25	10 (63%)	4 (25%)	2 (13%)	5 (31%)	6 (38%)	5 (31%)
50-50	8 (50%)	0 (0%)	8 (50%)	2 (13%)	4 (25%)	10 (63%)

Table 1: Number of correct sequences that participants were able to recall and recognize

We analyzed if the number of correct elements from the two used sequences that the participants were able to recall could be linked to the improvement in their reaction time. We therefore computed the difference in RT between the familiar and unfamiliar sequences and correlated this with the number of correctly recalled elements as measured in the questionnaire. In the neutral condition the correlation was significant, $r(14) = 0.856$, $p < .001$, but no significant correlations were found in the medium conflict, $r(14) = 0.485$, $p = .057$, and in the high conflict conditions, $r(14) = 0.373$, $p = .155$. We tested this correlation to check if more explicit knowledge of the sequence leads to a higher learning effect, which is measured by the difference between the familiar and the unfamiliar condition. This seems to be true only in the neutral condition.

Discussion

The purpose of our research was to examine the effect of cognitive conflict on the development of a motor sequence. To investigate this effect, we set up an experiment in which participants learned a motor sequence under varying amounts of cognitive conflict, depending on the condition they were assigned to. The analysis did not confirm our first hypothesis that participants in the high conflict condition (50-50) would show a faster decrease in RTs than participants in the 75-25 and the neutral condition. However, when comparing only the two conflict conditions, it seems that the conflict had an effect on the RTs in the expected direction. While there was no difference in RTs at block 1 between the two conditions, participants in the high conflict condition did have significantly lower RTs compared to the low conflict condition in block 6. This indicates that the RTs of participants in the high conflict condition decreased faster than in the low conflict condition.

This effect can be explained by an improved processing of task-relevant information. According to Deroost et al. (2012), the cognitive conflict that is experienced during a task triggers adaptive mechanisms which improve the efficiency of task-relevant information processing. In the task we used, conflict lead to a shift in attention, away from the meaning of the word, towards more useful cues for finding a correct response. In the case of a normal Stroop task, this leads to a shift from word- to color-processing (Botvinick et al., 2001). But in our task, there was another source of information that could be used to find the correct response, namely the response sequence. By focusing on the response sequence, participants had an additional cue apart from the color that helped them to find a correct response. It seems that when participants experienced more cognitive conflict, they also focused more on the response sequence of the task. By exploiting the additional information from the response sequence, participants in the high conflict condition had a faster decrease in reaction time compared to the low conflict condition. This indicates that participants in the high conflict condition learned the sequence faster than participants in the low conflict condition.

These results are in accordance with the findings of Deroost et al. (2012), who found that the amount of cognitive conflict can have an influence on the development of a perceptual sequence. In their research, a higher amount of conflict in the training trials lead to a better performance in the test trials compared to groups who experienced less conflict. It seems that this effect of conflict could also be present in the development of a motor sequence.

It should be noted that the current results only partially support our first hypothesis, since the overall difference between the three conflict conditions was not significant. They only suggest that there is an effect of conflict in the expected direction and this possible effect should be further investigated in the future.

The data also showed that our second hypothesis, namely that there will be a difference in reaction times between the three conflict conditions for the test blocks, was not correct. There was a small difference between the conditions, but it was not large enough to be considered significant.

Although we were able to find an effect of cognitive conflict that went in the expected direction, we have to be cautious about the interpretation of the data. We did find a significant difference between the first and the last training block of the two conflict conditions, but the difference was not strong enough to yield a significant interaction between conflict group and training block. The observed difference between the groups thus went in the expected direction, but was not strong enough to allow for the conclusion that a high amount of conflict does have a positive influence on the development of a motor sequence. So there definitely is a need for further research on the relationship between cognitive conflict and the development of a motor sequence.

In the process of our research, we came across some factors that could help future researches in finding significant results. The first factor that should be noted here is the number of participants. We only used 48 participants, which is a relatively small sample size. With a greater number of participants, even small differences between the conditions could yield significant differences. So by using a greater sample size, the chances of discovering a significant relationship should be increased.

A second factor is the amount of time that the participants are able to practice the sequences. As can be seen in Figure 3, the difference between the two conflict conditions becomes larger, the more the participants train the sequence. So we could hypothesize that with more training blocks, the difference between the conditions should become larger. By using more training blocks, participants are given more time to practice the sequence and the difference between the conditions will probably become larger.

A third possibility is to adjust the difference of conflict between the two conflict conditions. We could increase the difference of cognitive conflict by changing the ratio in the low conflict condition from 75% to 90% incongruent stimuli. This change would decrease the amount of conflict in the low conflict condition. As stated by the “proportion-congruent effect” cognitive conflict is reduced when it is easier for the participant to predict if the following stimulus will be congruent or incongruent (Logan & Zbrodoff, 1979). By increasing the number of incongruent stimuli, the amount of cognitive conflict should therefore be decreased. A higher difference in conflict between the high and the low conflict condition should also increase the difference in RTs between those two conditions if there is indeed an influence from conflict on the development of a motor sequence.

A fourth point would be to increase the contrast of the colors so that they are easier to distinguish. Four participants noted that they found it difficult to see the difference between green and yellow. So by changing the intensity of one color (e.g. use a darker tone of green), participants should be better able to discriminate between the four used colors.

A last point that should be considered is that the sample we used consisted mostly of psychology students, who are familiar with the Stroop task and other sequence tasks. It is thus likely that many of them expected the task to include a sequence. Although it is not clear if this expectancy would have an influence on the results, it should be noted that it could have an influence on their performance.

Summarizing, the present study showed a faster decrease in RTs for participants in the high conflict condition compared to participants in the low conflict condition. This effect could be explained by a conflict induced improvement of task-relevant information. Participants look for more efficient means to find the correct response and therefore a high amount of conflict leads to a greater focus on the response sequence. This increased focus can ultimately lead to a faster learning of the response sequence. Our results thus indicate that cognitive conflict has an influence on the development of a motor sequence, but the effect was not strong enough to be considered as a proof for our hypothesis. Therefore, further research is necessary to validate our assumption that motor learning is influenced by the amount of cognitive conflict.

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