# Sequential effects in the Simon task: conflict monitoring or memory?

Inge Lanting

**Bachelor thesis**
University of Twente
Faculty of behavioural science

Supervisors:
Dr. Rob van der Lubbe
Dr. Elian de Kleine

January 2013

## Abstract

Compatibility tasks (e.g. Simon task and flanker task) provide more information about automatism and attention. In these tasks, incompatible trials are performed slower and less accurate than compatible trials; i.e. the compatibility effect. Compatibility effects are higher after a compatible trial than after an incompatible trial. This is known as the Gratton effect. Until recently it was thought that the conflict monitoring model explained these effects. According to this model conflict arises during an incompatible trial. Conflict has been related to activity in the anterior cingulate cortex and can be detected by measuring the activity of the N2 component. When conflict occurs, control mechanisms detect conflict and adjust our behaviour. After a conflict trial (incompatible) a control mechanism is activated to reduce conflict on the following trial. However, some researchers question this model. They suggest that the Gratton effect is the result of repetitions and alternations of stimuli and/or responses. Stimulus repetitions will result in faster reaction times. In this study three Simon tasks are explored. The first task is a normal Simon task. In the second task stimulus repetitions are reduced. The third task consists of less stimulus and response repetitions. By comparing these tasks we can examine whether there is support for the stimulus-repetition model. The main analysis shows that the Gratton effect does not depend on the task. Separate analyses per task, however, show that a reversed Simon effect is present in the second task. The EEG data also shows difference in N2 activity on each task. This does not support the conflict monitoring model. More support is found for the stimulus-repetition model. Although no significant difference is found between the tasks and the Gratton effect, participants seem to behave differently on tasks which consist of less stimulus repetitions.

## Introduction

Many things happen automatically which we seem to have no effect on. Automatic responses are made, although we are asked to focus our attention on another aspect of the environment. To study automatism and attention, compatibility task have been designed. (Berthet, Kop, & Kouider, 2011). There are three kinds of compatibility tasks known that have been extensively studied; the Stroop task (Stroop, 1935), the Eriksen Flanker task (Eriksen & Eriksen, 1974) and the Simon task (Simon & Rundell, 1967). These compatibility tasks all consist of two conditions, a compatible and an incompatible condition. In the Stroop task participants have to name the ink colour in which a word is written. Participants respond faster and more accurate when the ink colour and the word correspond (compatible condition) than when the word and ink colour differ (incompatible condition). In the Eriksen flanker task, participants have to respond to the target letter while irrelevant flanker letters interfere with this response. When the flanker letters and the target letter differ (incompatibility condition) participants respond slower and less accurate than when the flanker letters and the target letter correspond (compatible condition). In the Simon task different stimuli are associated with a left or right finger response; these stimuli are displayed on the right or left side of the screen. When the location of the stimulus corresponds with the finger response that has to be made for the stimulus (compatibility condition) participants respond faster and more accurate than when the finger response differs from the location (incompatible condition). The effect observed in these compatibility tasks (participants respond slower and less accurate on incompatible conditions than compatible ones) is referred to as the compatibility effect.

## The Gratton effect

Gratton, Coles and Donchin (1992) studied the compatibility effect of the Eriksen flanker task. In the flanker task stimulus-stimulus compatibility and stimulus-response compatibility effects occur. The flanker task used in the experiment of Gratton et al. (1992) consisted of four different combinations of stimuli; HHHHH, SSHSS, SSSSS, HHSHH. When the target letter was an H, participants had to respond with the right hand. A left-handed response was made when the target letter was an S. Stimulus-stimulus compatibility effects occur when the target letter is different from the flanker letters. Besides that, both the flanker letters and the target letter are associated with a left or right hand response. When the flanker letters, which are associated with a certain hand (left or right), are incompatible with the hand that is used for the target letter, stimulus-response compatibility effects occur. Taken together, the flanker task consists of two different compatibility effects that both cause conflict; stimulus conflict and response conflict (Spapé, Band & Hommel, 2011).

## 3 | Sequential effects in the Simon task

During the flanker task participants have to respond as fast and accurate as possible. Gratton et al. (1992) suggested there were two types of attentional strategies which people use to perform the tasks as best as possible; a parallel processing strategy and a focused processing strategy. A parallel processing strategy is used when all stimuli are processed simultaneously; there is equal focus on the target letter as on the flanker letters. Participants respond fast when this strategy is used during a compatible trial. However when participants use this strategy during an incompatible trial, many errors will be made because the focus is not especially on the target letter and therefore participants will find difficulty in avoiding the flanker letters. To avoid errors, a focused processing strategy is used during an incompatible trial. During this strategy participants focus especially on the target letter and suppress the flanker letters. This results in a slower but more accurate performance. (Gratton et al. 1992; Lamers & Roelofs, 2011). The effects that occur during these strategies are the compatibility effects, as mentioned above. Gratton et al. (1992) observed during their study that compatibility effects were larger after compatible trials than after incompatible trials; the Gratton effect (Figure 1).

According to Gratton et al. (1992) this effect occurred because after a compatible trial, participants were still using a parallel strategy; which results in more errors when an incompatible trial occurs. When participants realize, during an incompatible trial, that the parallel strategy is not appropriate, reaction time (RT) increases. The strategy needs to be adjusted to a focused strategy. This adjustment costs time and therefore RT will we higher on an incompatible trial following a compatible trial than a compatible one. Following an incompatible trial participants still use a focused strategy. Participants will be more cautious after an incompatible trial. When a compatible trial follows an incompatible trial, participants will still focus their attention on the target letter, what results in a more accurate but slower response (Lamers & Roelofs, 2011).

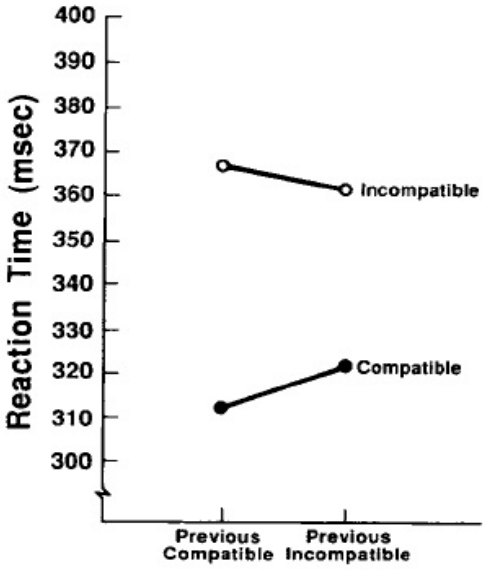


**Figure 1.** Compatibility effect is larger after a compatible trial than an incompatible trial. (Gratton et al. 1992)

The Gratton effect is also found in the Simon task, where conflict occurs at stimulus-response compatibility (Stürmer, Leuthold, Soetens, Schröter & Sommer, 2002). The Simon task consists of different stimuli which can be responded to. Participants have to focus on the middle of the screen and stimuli are displayed on the left or the right side of the screen. Every stimulus is associated with either a right or left finger which will be used to respond on the stimulus. Participants are faster and more accurate during compatible trial than incompatible trial(Simon & Rudell, 1967). During the Simon task response selection (selecting which response should be made) happens automatically. Response selection depends on the relationship between the stimulus and response. The most important feature of the stimulus in this relationship is the location of the stimulus. Binding of the stimulus location and response location provides a fast and automatic response (Notebeart, Soetens and Melis, 2002). If in the Simon task a trial is compatible, response selection will be performed automatically. When an incompatible trial occurs the automatic response has to be blocked. In this trial the stimulus and response are not bound together and therefore an automatic response is not appropriate (Hommel, 2000). This blocking takes time and therefore the reaction time on incompatible trials will be higher than on compatible trials.

However, the binding effect does not explain the Gratton effect. Stürmer et al (2002) explained the Gratton effect in the Simon task by the increase of control after an incompatible trial. According to them, the blocking of the automatic response system requires control. When control is needed participants perform slower on the Simon task than when control is not needed. When control is activated on an incompatible trial, this will still be activated until an automatic response is allowed; when a compatible trial occurs. This means that when an incompatible trial occurs, control will still be activated on the next trial. If a compatible trial follows an incompatible trial, participants will perform slower than after a compatible trial; i.e. the Gratton effect. After a compatible trial, control is not needed anymore and the participant will continue on giving automatic responses.

## The conflict monitoring model

The idea that the Gratton effect occurred because of control adjustment was introduced by Botvinick, Braver, Barch, Carter and Cohen (2001). According to them conflict is linked to the regulation of cognitive control. Cognitive control is a mechanism that adjusts people to the changing environment and helps them from doing things automatically. As described above, when an incompatible trial occurs, the automatic response has to be blocked, otherwise participants will respond with the wrong finger, which is compatible with the location of the stimulus. When an automatic response is blocked, a conflict arises. This conflict needs to be solved by cognitive control. According to Botvinick et al. (2001) the conflict monitoring system first evaluates the level of conflict and then passes this

information to the centers responsible for control; the cognitive control system. The control centers determine the strength of influence and adjust the processing. In other words, when conflicts arise, control is needed to determine the response on that conflict.

The region which is mainly associated with control processes is the Anterior Cingulate Cortex; ACC (Bush, Luu & Posner, 2000). The role of the ACC is tested a lot in compatibility tasks like the Stroop and Eriksen flanker task. Research shows that activity of the ACC is higher during conflict. Activity is higher during incompatible trials than during compatible trials (Cohen, Huston, Umiltà & Moscovitch, 1994; Carter, MacDonald, Botvinick, Ross, Stenger, Noll & Cohen, 2000).

Botvinick et al (2001) found that activity in the ACC was high after an error. An error can also occur during conflict. When an incompatible trial occurs, and participants are instructed to perform as fast and accurate as possible, errors are made. Although ACC activity is found when an error occurs, this does not peaks at the same time as when conflict occurs during a correct response. The activity in the ACC during an error peaks after the response has been made; this is later than when conflict occurs during a correct response. These results support the conflict monitoring model. (Botvinick et al, 2001)

However, when Gratton et al. (1992) discovered compatibility effects are higher after a compatible trial than an incompatible trial; this model had to be expanded. According to Botvinick et al. (2001) trials with high conflict would lead to a shift in control monitoring. After an incompatible trial, conflict will be high; this results in more control on the next trial. This applies visa versa for low conflict on the first trial. The conflict monitoring model has become an important view in the literature on attentional control processes (Lamers & Roelofs, 2011).

## Conflict in EEG

As mentioned above ACC activation has been connected to the conflict monitoring model. By measuring the activity of the ACC we can learn about conflict. One way to measure ACC activity is by using electroencephalography (EEG) ( Freitas, Banai & Clark, 2009; Clayson & Larson, 2011). Many studies suggest that during conflict the P3 component and N2 component are active in EEG (Clayson & Larson, 2011; Nieuwenhuis & Yeung, 2003). The N2 is thought to be related to conflict monitoring and is correlated with activity in the ACC measured by functional magnetic resonance imaging (fMRI) (Mathalon, Whitfield & Ford, 2003). In the present study N2 activity will be measured. According to Folstein and Van Petten (2008) there are three components of the N2; N2a, N2b and N2c. The N2a is now been replaced by the term ‘mismatch negativity’. The N2b component also referred to as the anterior N2 is often observed in combination with the P3a. This component reflects cognitive control and is generated in the ACC. The N2c component is more located in the posterior area of the brain (Folstein & Van Petten, 2008). Because anterior N2 is associated with

cognitive control, conflict can be measured by measuring the amplitude of the N2 component. The anterior N2 component is best to be measured in the frontocentral areas of the brain. In this study the amplitude of N2 activity will be measured to examine if conflict occurs during incompatible trials. By comparing the amplitude of N2 activity of incompatible trials by compatible trials, the conflict monitoring model can be tested.

## The stimulus repetition and alternations model

Many researches did not agree on the conflict monitoring model being responsible for the Gratton effect (Nieuwenhuis, Stins & Posthuma, 2006; Lamers & Roelofs, 2011). They think stimulus repetition causes a faster reaction time of a trial following another trial. Stimulus repetition means that when the stimulus in the previous trial is the same as in the current trial. For example in the Simon task there is a blue stimulus and a red one, when on the current and the previous trial the stimulus is both blue than it is referred to as a stimulus repetition. When the response is the same as the response on the previous trial it is referred to as a response repetition. An alternation means when the stimulus or response is not the same as on the previous trial.

In the standard Simon task (with two different stimuli) complete repetitions and alternation occur each in half of the compatible-compatible (CC) and incompatible-incompatible(II) trials, while in compatible-incompatible(CI) and incompatible-compatible(IC) trials only partial repetitions occur. A complete repetition is referred to if either the position, the shape and the response is the same as the previous trial. With a complete alternation, position, shape and response differ from the previous trial. A partial repetition means that not everything (position, shape or response) is the same, but just a part of all. Because of this, participants will be benefiting the complete repetition and therefore be faster in performing CC or II compared to IC and CI (Leuthold, 2011).

To examine whether the Gratton effect occurs because of conflict or because of repetition and alternations, three Simon tasks were explored in the present study. The Simon task is used to examine the effects, because this task only consists of stimulus-response compatibility effects. Using the Simon task will take out stimulus-stimulus compatibility effects as in the flanker task. Only conflict between stimuli and response will be measured. Besides that conflict only arises between stimuli and response, stimulus repetitions and alternation will be easier to manipulate than in the flanker task. The Simon task only consists of two stimuli, while the flanker task used in Gratton et al. (1992) consisted of five stimulus on each trial; four flankers and one target stimulus. To take out more stimulus repetitions in the Simon task it is only necessary to add more stimuli, while in the flanker task the target letters and the flanker letters have to be added. When in the flanker task only the target letter is changed and the flanker letters are the same as on the previous trial, there still is a stimulus repetition. So, this makes

the chance on a repetition higher on the flanker task than on the Simon task when two extra stimuli have been added.

Besides that, in the Simon task participants seem to perform faster on compatible trials because of binding effects. If binding effects decrease the reaction time than this should account for every trial. The binding effect can explain the fact that Simon effects occur, but it is just an assumption that this explains the Gratton effect.

The first task is a normal Simon task with two stimuli and two fingers to respond on the stimuli. In this task there was 50% chance of getting a stimulus repetition and 50% chance of getting a stimulus alternation. Also response repetition was 50% and a 50% chance of a response alternation. In the second task two stimuli were added to reduce stimulus repetition. In this task the chance of getting a stimulus repetition was 25% and the chance of a stimulus alternation was 75%. The chance of getting a response repetition or alternation was the same as in the first task. The third task consists also of four stimuli and two more response options were added. This will provide a chance of 25% for getting a stimulus repetition and 75% for getting a stimulus alternation. In this task the chance of getting a response repetition was reduced to 25%, which makes the chance of getting a response alternation 75%.

To support the repetition-alternation model, it is expected that the Gratton effect changes across tasks. If the Gratton effect is not found in tasks with fewer stimulus and response repetitions (task 2 and 3), this supports the repetition-alternation model.

Support is given for the conflict monitoring model if the Gratton effect is found in all tasks. Conflict seems to arise even though stimulus or response repetitions are removed. If the amplitude of the anterior N2 component in the EEG data is higher on the incompatible condition than the compatible condition, the conflict monitoring model will be supported.

# Methods

## Participants

Twenty students aged 19 to 26 from the University of Twente received course credits in exchange for their participation. Fourteen of them were female with a mean age of 22. Six of them were male with a mean age of 23. None of them had history of neurological disorders (e.g. epilepsy, stroke) and all of them, except for one, had normal (or corrected-to-normal) vision. One was classified as having red-green color blindness.

## Apparatus

The participants were placed in front of a screen en had to respond to the stimuli which were displayed on that screen under the control of Presentation software. They were seated in an armchair in a darkened room at a distance of 70cm from a 16 inch monitor. The default screen consisted of a black background and a white fixation point in the center. The stimuli used in the experiment were a square, a circle, a triangle pointing upwards, a triangle pointing downwards and a cross, all presented in white.

They made their responses on a QWERTY keyboard by pressing the left and right 'CONTROL' button in the first two blocks of the experiment. In the last block the participants had to press the left or right 'CONTROL' button or the left or right 'ALT' button to respond. During the experiments the stimulus and response timing and EEG was measured. 64 active electrodes attached on a special cap were measured: *Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, C2, C4, T8, AFz, Cp5, Cp1, Cp2, Cp6, FCz, P7, P3, Pz, P4, P8, PO9, O1, O2, Oz, PO10, AF7, AF3, AF4, AF8, F5, F1, F2, F6, FT9, FT7, FC3, FC4, FT8, FT10, C5, C1, C2, C6, FP7, CP3, CPz, CP4, TP8, P5, P1, P2, P6, PO7, PO3, POz, PO4, PO8.* The impedance was kept below 5KΩ for all EEG channels. In addition to these channels, blink and other eye movements were monitored by measuring the electrooculogram (EOG). Vertical and horizontal EOG are measured; VEOG and HEOG. EOG, EEG and behavioral responses were continuously measured with Brain Vision recorded software at a sample rate of 1000Hz. Quick Amp BrainVision amplifier was used to register the signals and save on the disk.

## Design

All participants performed three tasks. These tasks were different variants of the Simon task. Prior to each task there was a practice phase, so the participants had an impression of the tasks that were tested.

The first experiment was a normal Simon task with two stimuli; a square and a triangle. When the participants saw a square on the screen they had to respond with the left finger on the left 'CONTROL' button. When seeing a triangle they had to respond with the right 'CONTROL' button.

The second experiment was slightly different; two stimuli were added. The participants now had to respond with het left 'CONTROL' button when they saw a square or a triangle pointing up, and respond with the right 'CONTROL' button when seeing a triangle pointing down or a cross.

In the third experiment the stimuli were the same as in the second experiment. The difference between these two experiments was that in the third experiment the participants had to use four fingers to respond. The participants still had do respond to the square with the left finger on the left

'CONTROL' button. But now, when seeing a triangle pointing up they had to use the left index finger to press the left 'ALT button'. The triangle pointing down was linked to the right 'CONTROL' button and the cross was linked to the right 'ALT' button.

## Procedure

Before the experiment began the researcher told the participants they were about to perform three versions of the Simon task. The stimuli were randomly assigned and in the practice phase every stimulus would be displayed 3 times; in total 12 trials were presented. Before entering this phase the participants got instructions about the task they had to perform. They were told with which finger to respond to stimuli and that their eyes had to be directed on the fixation point, in the middle of the screen. The participants had to perform as fast and accurate as possible. After the instructions participants pressed the 'spacebar' button to begin the test. Each trial began with a fixation point lasting for 1000ms followed by stimuli presentation lasting 2300ms. Participants had to respond on the stimulus by pressing the left or right 'CONTROL' button, and the right or left 'ALT' button when performing the third task. After responding a next trial was initiated. In case of an error participants got auditory and visual feedback information.

After the practice phase the test phase began by pressing the 'spacebar' button. The test phase consisted of 320 trials per task, with a total of 940 trials in the whole experiment. In the first task every stimulus was repeated 80 times and in the second and third task 40 times. The test phase was set up the same way as the practice phase, with the same duration of fixation point and stimulus presentation. The order of the three tasks was counter-balanced. This excludes the influence of learning effects on the results.

## Data analysis

EEG analysis was carried out with BrainVision Analyzer 2.0. Analyzing EEG data was important for getting information about whether there was conflict during incompatible trials. In Brain vision Analyzer data was segmented into the right order; Compatible-Compatible, Incompatible-Incompatible, Incompatible-Compatible and Compatible-Incompatible. After that a standard routine was applied to all conditions on all the participants. First a baseline correction was done from -100 to 0. After that artifact rejection was carried out to remove artifacts that were higher than 150µv. In first instance this was done for all the channels, but it appeared that a lot of data would have to be removed because a lot of channels rose frequently above 150µv. According to the literature N2 activity was mostly found in the frontocentral area (Folstein & Van Petten, 2008) and the topographic ERP showed

most negative activity around Fz. Therefore this channel was used for further analysis. Noise by eye movements was deleted by using ocular correction. To make sure the data was not changed, another baseline correction was done. An average was taken of the twelve conditions for every participant and finally this was taken together in a grand average for every condition. In the grand average, peak latency and amplitude for N2 activity were checked. Peak latency of N2 activity appeared to be between 200ms and 400ms. Now the peak information could be exported out of the average per participant. To extract the noise a high cutoff filtering was carried out on the average. The frequency was set on 12Hz with a slope of 12Hz. The highest amplitude of N2 between the interval of 200 and 400ms was exported. This peak information was eventually imported in an SPSS file for further analysis.

To analyze the behavioural data (data of reaction time and error rate), Matlab was used to export the data into an excel file. In Matlab the data was sorted into four different conditions each task; C-C, I-I, C-I and I-C. For analyzing the behavioural data, mean RT and mean error rate of the current trial were measured, i.e. in the segment C-I, compatible is the previous trial and incompatible the current trial. A matrix was created in which the means of the twelve conditions (four each task) per participant were displayed. This matrix was imported in an SPSS file for further analysis.

## Results

One participant had a miss respond rate of 55% and was therefore excluded from analysis. This left nineteen participants for the reported analysis.

### Behaviour

Mean reaction time for each trial type and tasks are presented in Table 1. Trials in which participants failed to respond were excluded from analysis. A repeated measures ANOVA with the factors of Task (1-3), compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs.

*Table 1. Mean RT in ms by trial type and tasks*

| **Trial type** | | **Tasks** | | |
|---|---|---|---|---|
| n-1 | n | Task 1 | Task 2 | Task 3 |
| Compatible | Compatible | 471ms | 646ms | 685ms |
| Incompatible | Incompatible | 494ms | 622ms | 703ms |
| Compatible | Incompatible | 505ms | 632ms | 709ms |
| Incompatible | Compatible | 495ms | 646ms | 689ms |

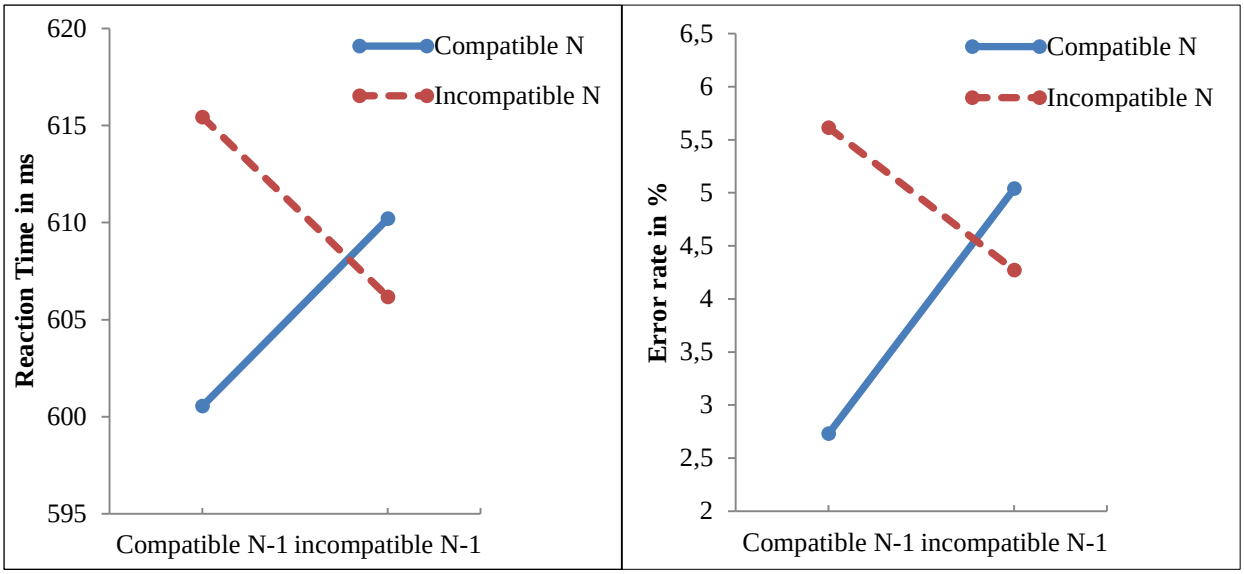


**Figure 2**. *Overall Gratton effect. Reaction Time (in ms) left and error rate (%) right for compatibility and compatibility N-1*

incompatibility) was conducted to compare the effects. The main effect of compatibility was not significant, F(1,18) =4.383 $p$=0.051. The interaction effect of compatibility and n-1 compatibility was significant, F(1,18) = 13.143 $p$=0.002. This indicates that the compatibility effect depends on the compatibility of the previous trial (i.e Gratton effect) (see Figure 2). No significance was found for the interaction effect of compatibility, n-1 compatibility and task, F(2,36)=2.237 $p$=0.121. This suggests that the Gratton effect on RT is independent of the tasks.

The three tasks were analyzed separately to check whether the Gratton effect was present in all tasks. For the first task a repeated measure ANOVA was carried out for compatibility (compatibility vs. incompatibility) and n-1 compatibility.

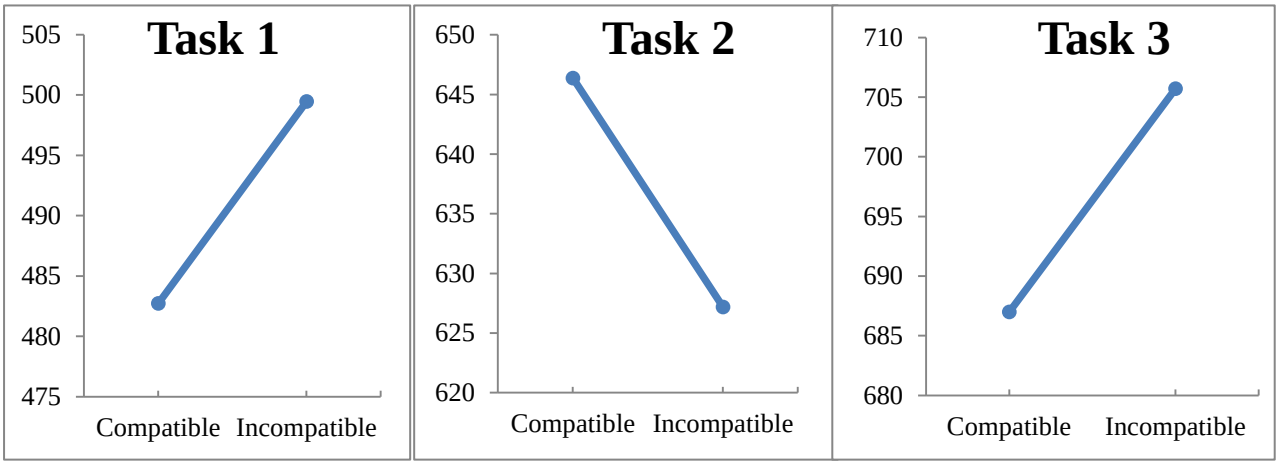


**Figure 3.** *Difference between compatibility trials and incompatibility trials per task. This shows a Simon effect in task one and three. Task two shows a reversed Simon effect.*

The mean effect of compatibility was significant, $F(1,18)=18.409$ $p<0.001$. This indicates the Simon effect (Figure 3). Significance was found for the interaction effect of compatibility and n-1 compatibility, $F(1,18)=21.032$ $p<0.001$, indicating the Gratton effect.

For the second task, which had less stimulus repetitions, a repeated measure ANOVA was carried out for compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs. incompatibility). Significance was found for the mean effect of compatibility, $F(1,18)=9.021$ $p=0.008$. However in this task the Simon effect was reversed (Figure 3). No significance was found for the interaction effect compatibility and n-1
compatibility. This indicates that the Gratton effect was not found in the second task.

For the third task which had a less stimulus and response repetitions, a repeated measure ANOVA was done for compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs. incompatibility). The mean effect of compatibility was significant, $F(1,18)=9.434$ $p=0.007$. This indicates the Simon effect (Figure 3). No significance was found for the interaction effect of compatibility and n-1 compatibility, $F(1,18)=1.985$ $p=0.176$. This gives no significance evidence for the Gratton effect.

Mean Error rate for trial type and task are presented in Table 2. To compare effects, a repeated measures ANOVA was conducted for task (1-3), compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs. incompatibility). A Mean effect of compatibility was found, $F(1,18)=8.105$ $p=0.011$. The interaction effect of compatibility and compatibility n-1 was significant, $F(1,18)=13.511$ $p=0.002$ (Figure 2). No significance was found for the interaction effect of compatibility, n-1 compatibility and task, $F(2,36)=19.154$ $p=0.058$.

Also of the Error rate data every task was analyzed separately. For task one a repeated measure ANOVA was carried out for compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs., incompatibility). The mean effect of compatibility was significant, $F(1,18)=15.034$ $p=0.001$, indicating the Simon effect. Significance was found for the interaction effect of compatibility and n-1 compatibility, $F(1,18)=13.473$ $p=0.002$. This indicates the Gratton effect.

*Table 2. Mean Error Rate by trial type and tasks*

| **Trial type** | | **Tasks** | | |
|---|---|---|---|---|
| n-1 | n | Task 1 | Task 2 | Task 3 |
| Compatible | – Compatible | 1.4% | 3.8% | 3.1% |
| Incompatible | – Incompatible | 4.3% | 3.5% | 5.0% |
| Compatible | – Incompatible | 7.6% | 4.5% | 4.8% |
| Incompatible | – Compatible | 3.6% | 6.5% | 5.0% |

For the second task a repeated measure ANOVA was done for compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs., incompatibility). Inconsistent with the RT data the mean effect of compatibility was not significant, $F(1,18)=2.984$ $p=0.101$. This indicates no Simon effect. The interaction effect between compatibility and n-1 compatibility was significant, $F(1,18)=9.084$ $p=0.007$.

For the third task a repeated measure ANOVA was carried out for compatibility (compatibility vs. incompatibility) and n-1 compatibility (compatibility vs., incompatibility). The mean effect of compatibility was not significant, $F(1,18)=3.138$ $p=0.093$. Inconsistent with the RT data there was no indication for the Simon effect. The interaction effect of compatibility and n-1 compatibility was not significant, $F(1,18)=2.214$ $p=0.154$.

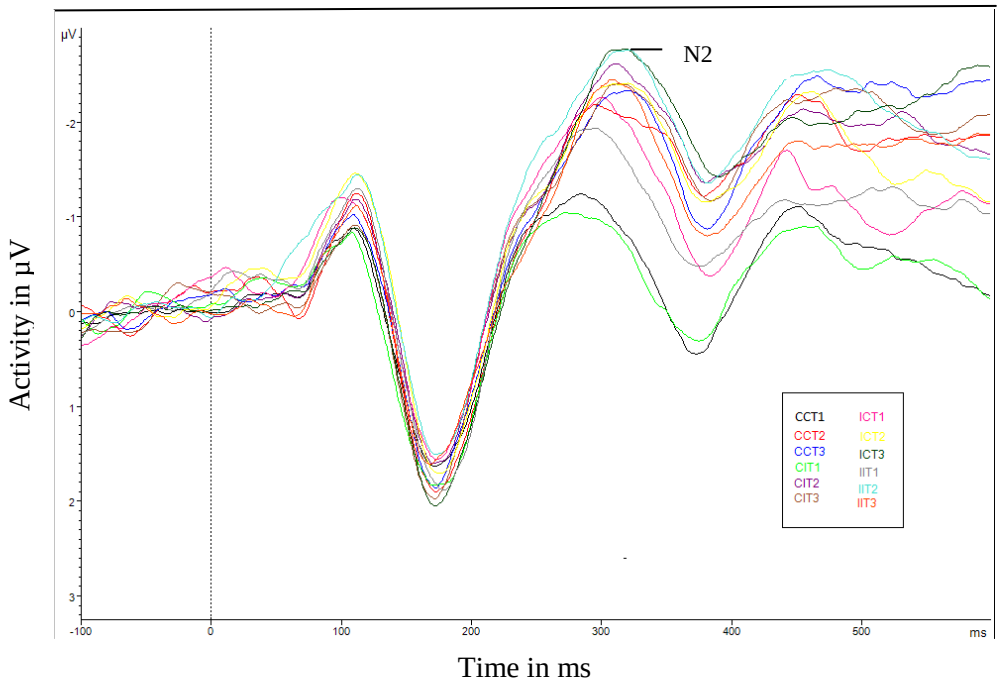


**Figure 5.** *Fz amplitude of the N2 component in µV/ms of all twelve conditions.*

## ERP

The overall amplitude of N2 activation is presented in Figure 5 and in Table 3 by trial type and task. To test whether activation in N2 was higher during conflict a repeated measures ANOVA was conducted for task, compatibility and n-1 compatibility. The mean effect of n-1 compatibility was significant, $F(1,18)=60542$ $p=0.02$. Table 3 shows that the amplitude of N2 activity was higher on incompatible trials than compatible trials. According to these results the amplitude of N2 activity is significant higher on the incompatible condition than the compatible condition. The interaction effect of compatible and n-1 compatible is not found significant, $F(1,18)=0.146$ $p=0.707$.

*Table 3. Overall N2 amplitude by trial type and task.*

| **Trial type** | **Tasks** | | |
|---|---|---|---|
| n-1 | Task 1 | Task2 | Task3 |
| Compatible | -2.125 µV | -3.097µV | -3.016 µV |
| Incompatible | -2.995 µV | -3.447 µV | -3.213 µV |

This is not surprising, because participants did not know what trial type followed on the current trial. Figure 4 shows the amplitude of the N2 component. In this figure activation of compatible conditions in the first task appear to be much more positive than the other conditions. To examine whether the activation of N2 in incompatible conditions were more negative than compatible conditions in each task, the interaction effect between compatible n-1 and task was analyzed. The interaction effect between compatible n-1 and task is showed no significance, $F(2,36)=1.603$ $p=0.217$.

However, when analyzing the task separately there seems to be a difference between the three tasks. For the first, second and third tasks a repeated measures ANOVA was carried out for compatible and n-1 compatible. The main effect of n-1 compatibility for task 1 was found significant, $F(1,18)=5.584$ $p=0.03$. Shown in Figure 6, the amplitude of the N2 component in the compatible condition is significant lower than in the incompatible condition. The main effect of n-1 compatibility for the second task was not found significant, $F(1,18)=1.534$ $p=0.231$. Incompatible and compatible conditions showed no significant difference (Figure7). For the third task also no significance was found for the mean effect n-1 compatibility, $F(1,18)=0.920$ $p=0.350$. No difference was found between compatible and incompatible conditions in the third task (Figure8). Analyzing the tasks separately shows that although an overall difference was found between incompatible and compatible conditions, this difference is not the same in all tasks.

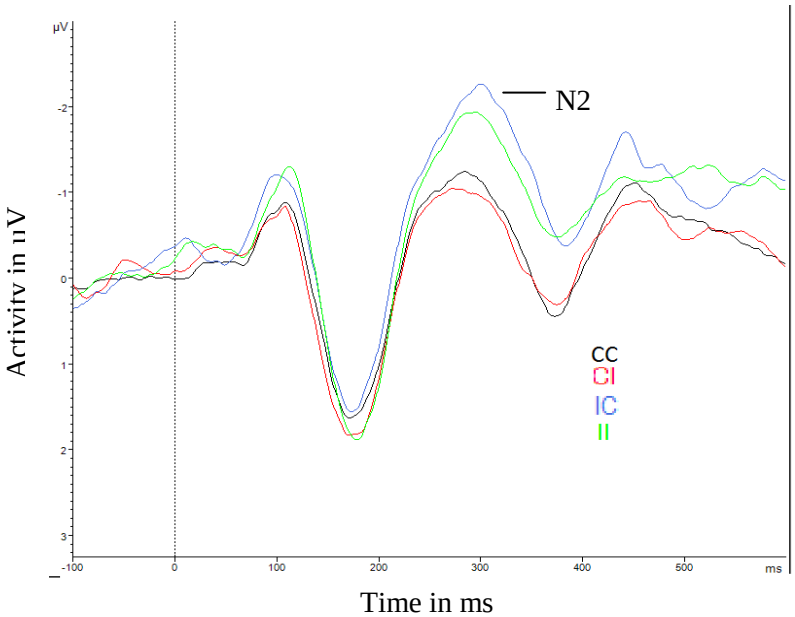


**Figure 6.** *Fz Amplitude for the N2 component in µV/ms for task 1.*

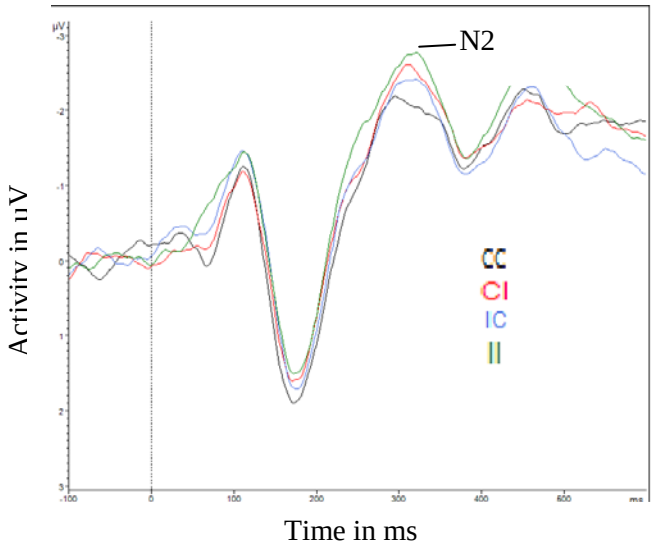


**Figure 7.** *Fz Amplitude for the N2 component in µV/ms for task 2.*

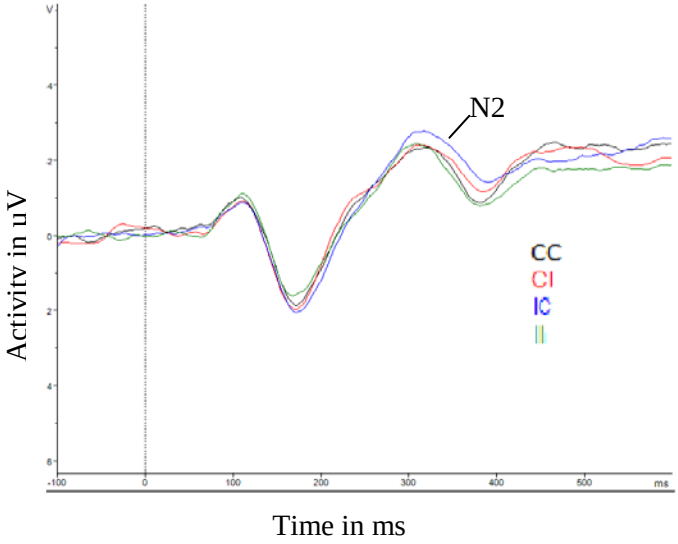


**Figure 8.** *Fz Amplitude for the N2 component in µV/ms for task 3.*

## Discussion

The aim of the present study was to examine whether the Gratton effect was the result of conflict or stimulus and response repetitions. This is still a topic of great discussion. The conflict monitoring model suggest that the Gratton effect is the result of conflict (Botvinick et al., 2001), and according to the repetition-alternation model, stimulus repetitions provide a faster response than stimulus alternations.

We expected that the conflict monitoring model was supported if the Gratton effect was found in all tasks and the amplitude of the anterior N2 component was higher on the incompatible conditions than the compatible conditions.

According to the results EEG data showed an overall n-1 compatibility effect. All tasks taken together showed that the amplitude of the anterior N2 component was higher on the incompatibility condition than the compatibility condition. However, when analyzing the tasks separately no significance difference was found between the incompatible and compatible condition in the second and third task. According to the conflict monitoring model, the anterior N2 amplitude would be higher on conflict conditions (incompatible) (Botvinick et al. (2001). Because this is not true for all tasks, this data shows no support for the conflict monitoring model.

According to the behavioural results an overall Simon effect is not found. However, there was found an interaction effect for compatibility and n-1 compatibility. This interaction effect could indicate an overall Gratton effect, but because the Simon effect was not significant it is unsure if it actually indicates that effect. Although it is unsure, Figure 2 shows clearly that compatibility effects

were larger following a compatible trial then following an incompatible trial. So based on this we assume that an overall Gratton effect is demonstrated by the results. According to our expectations, this indicates support for the conflict monitoring model. However, the tasks were also analyzed separately and this provides other results. According to these results, in task one and task three Simon effects are found. The second task shows a reversed Simon effect. The conflict monitoring model explains the Simon effect by conflict. According to this model, incompatible trials are performed slower than compatible trials, because during an incompatible trial conflict occurs (Botvinick et al., 2001). The results of task two show a reversed Simon effect which is not possible according to the conflict monitoring model. On top of that, the Gratton effect was only found in the first task and not in the second and third. We predicted that the Gratton effect is present in all tasks if we assume that the conflict monitoring model is true.

The behavioural results show that the Gratton effect changes across tasks. These results were expected according to the stimulus-repetition model. As mentioned above, in the first task, which was a normal Simon task, Simon effects and the Gratton effect were found. This was also predicted according to the literature (Stürmer et al., 2002). In the second task, with less stimulus repetitions, a reversed Simon effect was found and no Gratton effect. Further investigation is needed to examine this effect. In the third task, response repetition and stimulus repetitions were reduced. In this task a Simon effect was found, but there was no evidence for the Gratton effect. These results suggest that the Gratton effect changes across tasks. However, the changes were not sufficient for a significant interaction effect between the Gratton effect and the tasks.

Although the third task had less stimulus and response repetitions a normal Simon effect was found (Figure 3). In this task two extra response options were added. Participants had to respond with two fingers on one hand; the left middle and index finger and the right middle and index finger. Besides the hand locations, which are the same in the first and second task, also finger locations are added. On the left hand the middle finger could correspond for the stimuli which are presented on the left side of the screen, while the index finger (on the right side of the hand) would correspond for the right side of the screen. This also applies for the right hand, where the index finger corresponds for the right side and the middle finger for the left side. By adding these two extra response options this task cannot be analyzed the same way as the first and second task. For analyzing this task the data has to be divided into extra conditions. Hand response compatibility/incompatibility and finger compatibility/incompatibility should be segmented in different conditions. By dividing the data in extra conditions, behavior of participants can be examined when they have to respond with the right finger on the left hand. However for this study this task is not a good way to examine whether response repetitions and alternations have influence on the Gratton effect. This task would be

improved if the hands and feet were used as responses. The hands and feet are only corresponded to one location (left or right), there are no extra response locations (like finger locations).

Conclusive, the results show more support for the stimulus-repetition model. The Gratton effect is not found in task were stimulus and response repetitions were reduced. The same effect is found in a study of Schmidt and Houwer(2011), who examined the stroop and flanker task. The EEG data shows different results for the three tasks. In the first task support is found for the conflict monitoring model, however in the second and third tasks it is not. High activity in the N2 component does not have to be related to conflict. Activity in the N2 component can also be the result of increased attention (Folstein & Van Petten (2008).

For further research it is important to include more participants. In the present study, twenty participants were included and the tasks were counterbalanced in order. To counterbalance for all participants twenty four participants are needed. Besides that, it is better to increase the number of trials for each task. At first it is important to increase the trials per condition on the second and third task. On these tasks every condition was performed forty times, while the conditions on the first task were performed eighty times. To improve the experiment it is better to compare task with the same number of trials on every condition in each task. In the present study no evidence interaction effect is found between the Gratton effect and tasks. To further investigate the repetition-alternation model adjusting the tasks can improve this experiment. By using more stimuli in the second task the stimulus repetition will decrease, which gives a greater difference between the first and the second task. If the stimulus-repetition model is true, the results show a greater difference when this modified task is used.

## Reference

Berthet, V., Kop, J.l., & Kouider, S (2011). Response interference in compatibility tasks, effects of target strength in affective priming and Stroop. *Experimental psychology, 58*, 257-270.

Botvinick, M.M., Braver, T.S., Barch, D., Carter, C.S., & Cohen, J.D (2001). Conflict monitoring and cognitive control. *Psychological review, 108*, 624-652.

Burle, B., Sonia, A., Vidal, F., & Hasbrouq, T (2005). Sequential compatibility effects and cognitive control: Does conflict really matter? *Journal of experimental psychology: Human perception and performance, 31*, 831-837.

Bush, G., Luu, P., & Posner, M.I (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in cognitive sciences, 4*, 215-222.

Clayson, P.E., & Larson, M.J (2011). Effects of repetition priming on electrophysiological and behavioral indices of conflict adaptation and cognitive control. *Psychophysiology, 48,* 1621-1630.

Cohen, J.D., Hutson, T.A., Umiltà, C., & Moscovitch, M (1994). Progress in the use of interactive models for understanding attention and performance. *Attention and performance, 15,* 453-456.

Carter, C.S., MacDonald, A.M., Botvinick, M., Ross, L.L., Stenger, A., Noll, D., & Cohen, J.D (2000). Parsing executive processes: Strategic versus evaluative functions of the anterior cingulate cortex. *Proceedings of the national academy of sciences, 2,* 264-272.

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,* 143-149.

Folstein, J.R., Van Petten, C (2008). Influcence of cognitive control and mismatch on the N2 component of the ERP: A review. *Psychophysiology, 45,* 152-170.

Forster, S. E., Carter, C. S., Cohen, J. D., & Cho, R.Y (2011). Parametric manipulation of the conflict signal and control-state adaptation. *Journal of Cognitive Neuroscience, 23,* 923–935. doi: 10.1162/jocn.2010.21458.

Freitas, A.L., Banai, R., & Clark, S.L (2009) When cognitive control is calibrated: Event-related potential correlates of adapting to information-processing conflict despite erroneous response preparation. *Psychophysiology, 46,* 1226-1233.

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,* 480-506.

Hommel, B (2000). The prepared reflex: Automaticity and control in stimulus-response translation. *Control of cognitive processes: attention and performance,18,* 247-273.

Lamers, M.J.M., & Roelofs, A (2011). Attentional control adjustments in Eriksen and Stroop task performance can be independent of response conflict. *The quarterly journal of experimental psychology 64,* 1056-1081.

Leuthold, H (2011). The Simon effect in cognitive electrophysiology: A short review. *Acta psychologica, 136,* 203-211.

Mathalon, D.H., Whitfield, S.L., & Ford, J.M (2003). Anatomy of an error: ERP and fMRI. *Biological psychology, 64,* 119-141.

McClelland, J.L., & Rumelhart, D.E (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basis findings. *Psychological review, 88,* 375-407.

Nieuwenhuis, S., Stins, J.F., & Posthuma, D (2006). Accounting for sequential trial effects in the flanker task: Conflict adaptation or associative priming? *Memory & cognition 34,* 1260-1272.

Nieuwenhuis, S., & Yeung, N (2003). Electrophysiological correlates of anterior cingulate function in a go/no-go task: effects of response conflict and trial type frequency. *Cognitive, affective, & behavioral Neuroscience, 3,* 17-26.

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

Schmidt, J.R., & De Houwer, J (2011). Now you see it, now you don't: Controlling for contingencies and stimulus repetitions eliminates the Gratton effect. *Acta psychologica, 138,* 176-186. doi: 10.1016/j.actpsy.2011.06.002

Simon, J.R., & Rudell, A.P (1967). Auditory S-R Compatibility: The effect of an irrelevant cue on information processing. *Journal of applied psychology, 51,* 300-304.

Spapé, M.M., Band, G.P.H., & Hommel, B (2011). Compatibility-sequence effects in the Simon task reflect episodic retrieval but not conflict adaptation: Evidence for LRP and N2. *Biological psychology, 88,* 116-123.

Stroop, J.R. (1935). Studies on interference in serial verbal reactions. *Journal of experimental psychology, 18,* 643-662.

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,* 1345-1363.