The role of action-effects in intention-based and stimulus-based movements

An examination of action-effects in intention-based and stimulus-based actions, with a 4-key movement sequence

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Abstract

The theory of event coding claims that when an action and its sensory effect consistently happen in close temporal proximity, we will associate the action with that effect. This effect is called an action-effect. Nevertheless it is argued that this framework is not appropriate for all kinds of actions. Actions based on voluntary movements, called intention-based actions, and the actions in which people need to respond to a given stimuli, called stimulus-based actions, are controlled by different neural substrates. It is thought that the action-effects develop only in actions that are carried out voluntarily. Findings have demonstrated this with a single-key press movement. The present study investigated this effect with a more complex key movement sequence. The experiment consisted of three phases. The participants practiced two sequences in the first practice phase. The second practice phase made a difference between intention-based and stimulus-based actions. In this phase, tones were given to the participants after they pressed their sequence to create an action-effect. The test phase consisted of an congruent and incongruent block in which the tones were given before they needed to press their sequence. The tones were congruent or incongruent compared to the second practice phase. Results showed no difference between the congruent and incongruent group in stimulus-based actions nor in intention-based actions. The tone did not act as an action-effect in the intention-based group nor in the stimulus-based group.

Introduction

Performing an action will always have an effect and this effect will always be the same for a specific action. Because a specific action will always have the same effects, it would make sense if we could learn and remember the action through the effects. One major theory that describes the association between actions and effects, is the Theory of Event Coding (TEC: Hommel, 1996; Hommel, Müsseler, Achsersleben & Prinz, 2001).

The theory of event coding, or TEC, is a framework that explains how events are cognitively represented and how these representations interact with generating perception and action. The TEC claims that when an action and its effect consistently happen in close temporal proximity, we associate the action with the effect. If you, for example, hit the desk with your fist, you will associate this action with the effects (the sound, the feeling and so on). When later these effects occurs again, it can activate the intended action associated with these effects (Hommel, 1996). It is believed that the stimulus representation of the event (which could be the desk) and the action representation (hitting it with your fist) are not coded separately in the brain (Hommel, Müsseler, Aschersleben & Prinz, 2001). Therefore cognitive representations of events do not only hold information about the stimuli of the event itself, but also holds information about the actions related to the event.

TEC also claims that the cognitive representation of an event, is constructed from a composition of event features. Important event features will be stored in the brain, and it is possible that one of these features is enough to activate the information of the whole cognitive representation about the event. With activation of the event representation the associated action can be activated to.

According to Herwig, Prinz and Waszak (2007), human actions can be driven in two ways. One way is to carry out movements to produce a desired environmental effect, that means that the movements are produced voluntarily or intentionally. Those are intention-based actions. The second way in which people can produce movements is based on reacting to stimuli, which are called stimulus-based actions. This raises the question whether the TEC framework applies to both, intention-based and stimulus-based actions. Before answering this question let’s take a look at the actual differences between intention-based and stimulus-based actions.

According to Waszak, Wascher, Keller, Koch, Aschersleben, Rosenbaum and Prinz (2005), the key feature of intention-based actions is their goal-directedness. Basically most definitions of intention-based or voluntary action agree with this. So an action is seen as voluntarily if it is performed to produce some sort of internally desired effect. And according to the ideomotor theories, the intended action-effects are causally responsible for the selection of the appropriate actions. They claim that performing an action voluntarily will leave an association between the action's motor code (information about how to produce the action) and the sensory effects that will be produced by this action. These associations are bidirectional, which means that someone can use the sensory effects in order to select the appropriate action .

Stimulus based actions are triggered by a stimulus from the environment, but in order to plan an appropriate response, an intentional set is needed. Unlike reflexes, a stimulus-based action always derives from two functional sources. These are the stimulus itself and the intentional set to respond to that stimulus, which in experimental settings, is usually specified through instructions (Waszak, Wascher, et al., 2005). A stimulus-based action can be: "if you see a red circle press the mouse button and if you see a green circle press a key". To execute this you need 1) the stimulus, which in this case can be a red or a green circle and 2) the intentional set to respond, which in this case can be pressing the mouse button or a key.

It is suggested that intention-based actions and the stimulus-based actions are controlled by different neural substrates (Herwig, Prinz and Waszak, 2007). Both actions are based on different kind of learning theories. Stimulus-based actions are based on stimulus-response (sensorimotor) rules. This means that selecting and executing an action in response to a stimuli creates a representation that connects the information about the stimuli attributes with the information about the corresponding action. These bindings are called "stimulus-response" bindings. Intention-based actions are based on action-effect (ideomotor) rules. These approaches claim that performing an action leaves behind an association between the information about how to produce the action and the sensory effects that are produced by the action. These bindings are "action–effect bindings" (Herwig, Prinz and Waszak, 2007). If stimulus-based actions are based on "stimulus-response" bindings and intention-based actions are based on "action-effect" bindings, the action-effects demonstrated by Elsner and Hommel (2001) should only occur if people select actions based on action-effect rules. Their findings strongly suggest that action-effect learning takes place in intention-based actions only (or at least to a larger degree).

All together it seems that only intention-based actions will be triggered by activation of action-effects. Yet both experiments (Elsner and Hommel, 2001; Herwig, Prinz and Waszak, 2007) tested single movement actions. Both experiments used only one key press with an associated tone. For example they used a left key press followed by a high pitch tone, and a right key press followed by a low pitch tone. The tones were given to create an action-effect. The question that emerges is, can we find the same effects with a more complicated movement? There has been evidence that repeatedly executing a complicated movement sequence leads to a content-specific representations in our memory. These are called *motor chunks* (Lashley, 1951). These motor chunks can then be selected and executed as if they were a single response.

Findings of Mommer (2012) suggest that the first key of a key press sequence can be associated with the whole sequence. It suggests that when people are pressing their first key, they have already selected the appropriate motor chunk as a whole. So when people have formed a motor chuck and will receive a tone after pressing their sequence , the tone will become the action-effect of the whole movement.

In short, there is evidence that supports the idea that action-effects will only be learned if an action is intention-based. However, these findings were only based on a single-key press movement. The purpose of this paper is to examine action-effects in intention-based and stimulus-based actions with a 4-key movement sequence. Because of the more complex movement, the participants first needed to practice this movement and needed to form a motor chunk. Therefore all participants went through the same practice phase, in which they practiced two different sequences. In the second part of the practice phase, we split the participants into two groups. One group needed to execute the sequences in response to a stimulus. This was called the stimulus-based group. The other group could respond with one of the sequences they had practiced. They could voluntarily choose which sequence they wanted to execute. This was called the intention-based group. Both groups received an particular tone after pressing one of their sequences. The third and last phase was the testing phase and was meant to reveal whether the two different groups have learned the tone as an action-effect. Therefore we created a congruent and incongruent block for every single participant. In the congruent block the participants received the tone before they needed to execute the sequence that was learned along with the tone in the second practice phase. In the incongruent block the tone that we gave, before they had to execute the sequence, did not match the sequence that was learned along with the tone. In order to create two different motor chunks which are activated with the first key press, both sequences started with a different key.

The aim of this study was to answer the question whether a tone can act as an action-effect in intention-based and stimulus-based movements when people perform a more complicated movement. According to Herwig et al. (2007) the action-effects would only occur if people select actions in a intention-based ‘mode’. The obvious hypothesis was that the tones would act as an action-effect in intention-based movements but not in stimulus-based movements.

Method

Participants

24 participants were recruited from the SONA participant-system of the University of Twente. Because there was not much time to collect participants, there were also participants recruited from social networks and social media like Facebook. Students that signed up via SONA-system were rewarded with 1,75 study credit for participating in this experiment. There were 5 male and 7 female in the intention-based group and 6 male and 6 female in the stimulus-based group. The study was approved by the ethics committee of the University of Twente. Requirements which the participants had to meet were that they had normal vision and hearing, and did not have any motor issues with their hands. They also had to be between 18 and 40 years of age.

Materials

E-Prime© 2.0 was used to achieve stimulus presentation, timing and data collection. The experiment was controlled by a Pentium© IV class PC and all unnecessary Windows 7 services were turned off. Stimuli were presented on a 15-inch Phillips 107T5 CRT monitor. The monitor’s resolution was 1640 by 480 pixels in 32-bit colour. Responses were made on a standard QWERTY keyboard. We used an instruction to inform the participants about the experiment and we also gave them an informed consent. The instruction and informed consent are shown in the appendix. We set up a camera to check the progress of the experiment.

Tasks

For each participant, the experiment involved executing two different keying sequences. Those two sequences both consisted of four key presses. None of the participants received two sequences starting with the same key. So for example the sequences VCBN and CBVN. Responses were made with the left middle- and index finger, pressing the ´C´ and ´V´ keys respectively, and the right middle-and index finger pressing the 'N' and 'B' keys respectively. Every time a participant made an error in executing their sequence, the program told them they were wrong and the next sequence was given. The experiment consisted of three phases, the first practice phase, the second practice phase and the test phase.

First practice phase

This phase involved practicing a sequence in response to key-specific stimuli. The screen showed 4 squares. When a square became green, the participants had to press the corresponding key. After they pressed the proper key, the next square became green and the former square turned back to the background colour (white) like the other squares. After they pressed the proper 4 keys in a row (one sequence) all the squares became white again, and a new sequence started.

The participants practiced two different sequences. The sequences were given randomly, but each sequence was given a 100 times to make sure each of them was equally well learned. This means that the participants carried out 200 sequences. There was a short break (40 seconds) after the first 100 sequences.

Second practice phase

In this phase the participants received a tone after pressing the last key of the 4 key sequence. The pitches we used were 440 Hz and 880 Hz and lasted 100 ms. There were 2 groups in this phase, the <u>stimulus-based group</u> and the <u>intention-based group.</u>

The stimulus-based group continued to produce sequences in response to the stimuli. Only the first key response was shown on the screen. The first square became green and once the participants pressed the proper key, the squares remained white and the participants had to finish the corresponding sequence (the remaining 3 key presses). Pressing the last key of one of the learned sequences produced a particular tone (for example 440 Hz). Pressing the other sequence produced the other tone (880 Hz). This was the stimulus-based group since the participants in this group could not voluntarily choose their sequences. The tone was only given when the whole sequence had been carried out correctly.

The intention-based group was free to choose one of the sequences they learned in the first practice phase. Since they were free to choose, no square became green. They received a Go-signal, which was a bigger square that was presented above the four squares that were representing the keys. This square was not always given at the same moment, so anticipation was avoided. When the Go-signal emerged, the participants choose which of the sequences they wanted to press. After they pressed the last key of the chosen sequence, they heard a particular tone (440 or 880 Hz) depending on the sequence just executed. Since we did not want them to press the same sequence too many times in a row, we asked them to randomly choose one of the learned sequences. When the participants kept repeating one sequence all the time, the program warned them to choose more randomly. This group represented the intention-based group since they were free to pick their sequences.

Test phase

In this phase, participants from both groups, took part in a congruent and incongruent block. Which block (congruent or incongruent) they had to carry out first, was balanced between the groups.

In the congruent block the tone and the sequence matched each other. The participants needed to respond to the tone with the sequence that was learned along with this tone. Since they needed to respond to the tone, the tone was given before they had to press the sequence. The square that symbolized the starting key of the corresponding sequence became green at the same moment the tone was given and disappeared after the participants pressed the proper first key. They finished the rest of the sequence (the next 3 key presses) without any stimuli.

In the incongruent block we reversed this. The participants had to respond to a tone with the sequence that was learned with the other tone. The square that symbolized the starting key of the not corresponding sequence became green at the same moment the tone was given and disappeared after the participants pressed the proper first key. They finished the rest of the sequence (the next 3 key presses) without any stimuli.

For example, a participant that just finished the intention-based phase, was given a tone before he or she needed to press a given sequence. First the tone matched the learned sequence according to the practice phase, this was the congruent block. After finishing the congruent block, this participant took part in the incongruent block in which he or she needed to respond to the tone with the not corresponding sequence. The tone did not match the learned sequence from the practice phase. The second participant, which also finished the intention-based test phase, may have started with the incongruent block.

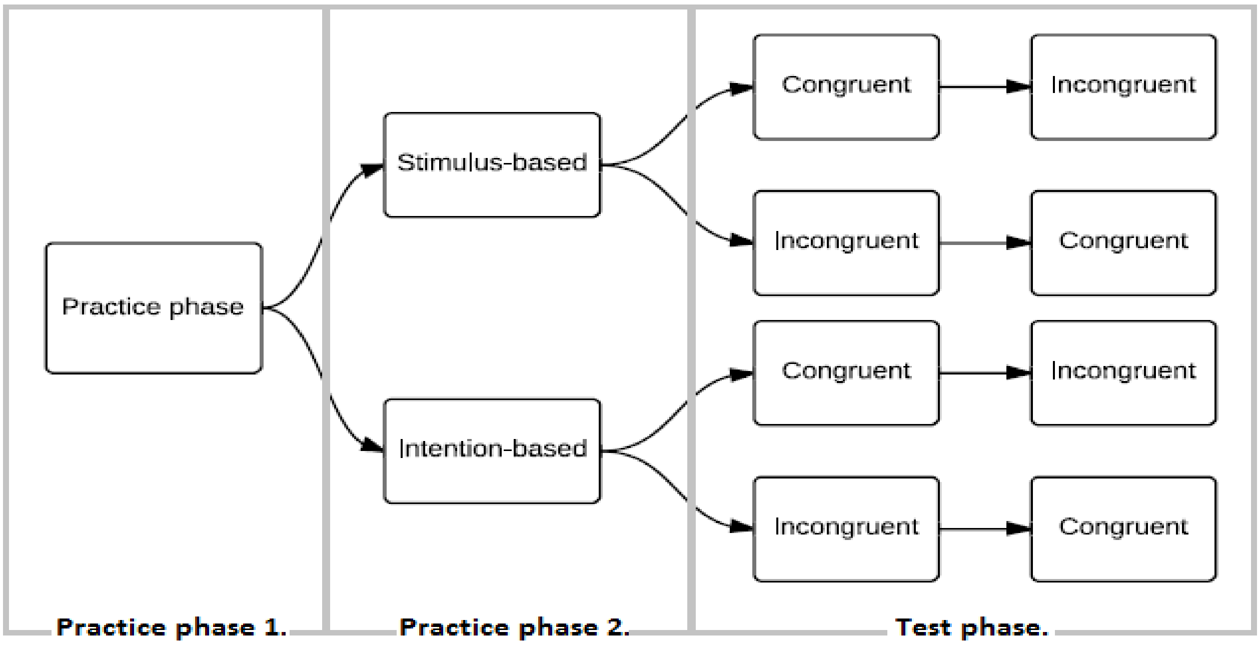

Figure 1. Design of the phases in the experiment, the first practice phase, the second practise phase with 2 different groups for stimulus-based and intention-based actions, and the test phase with the congruent and incongruent blocks.

Procedure

The participants first read the instructions. This included information about how long the experiment would take and when there would be pauses. It also contained some information about the fact that it was important to minimize mistakes. The participants instructions are shown in the appendix. After they read the instructions, they read the informed consent which is also includedd in the appendix. The informed consent contained information about the rights of the participants. After the participants signed the informed consent the first practice phase started. There was some extra verbal instruction in which the participants were told to remember the sequences and that the two sequences started with a different key (so the participants were able to distinguish between the sequences and it would be easier for them to remember it). The participants were also told that the researchers used a camera to see when the pause between the phases started.

The first practice phase took about 25 minutes and after half the phase the participants received a break of 40 seconds. After they finished the practice phase they had a break for about 180 seconds. The researcher saw, by camera, when the participants reached the pause and they helped them with starting the next phase. The second practice phase looked a lot like the first practice phase and also took about 25 minutes with a break of 40 seconds on half of the phase. This phase also ended with a 180 second break. The test phase was a bit shorter and took about 10 minutes to complete, but also had a 40 second break halfway through the phase. After this phase the participants were done with the experiment.

Results

First practice phase

We carried out a repeated measures ANOVA on reaction time (RT) with Keys (4; the 4 keys of the 4–key sequence) as within-subject variables and Group (2; stimulus-based and intention-based) as a between-subject variable. We found that there was a significant effect of Keys $F(3, 66) = 325.2$, $p < .001$, and a interaction effect between Keys and Group $F(3, 66) = 4.763$, $p = .005$. These effects are shown in figure 2. The main effect of Group was not significant $F(1, 22) = 482.7$, $p = .367$.

The errors were investigated to ensure participants did not make too many errors. We carried out arcsine transformations on the mean proportions of errors made on each key, so we could carry out a repeated measure ANOVA with Keys (4; errors on each key) as a within-subject variable and Group (2) as a between-subject variable. This revealed a significant difference in Keys $F(3, 66) = 27.52$, $p < .001$, and a significant interaction effect between Keys and Group $F(3, 66) = 3.10$, $p = .033$. Taking a look at the normal error proportion, we could see that the stimulus-based group made more errors on the second and third key press. The mean proportion of errors made on key 1, 2, 3 and 4 in the stimulus-based group are respectively 1%, 3,5%, 2,4% and 0,5%. The intention-based group also made more errors on the second and third key. The mean proportion of errors made on key 1, 2, 3 and 4 in the intention-based group are respectively 0,9%, 1,6%, 1,6% and 0,4%.

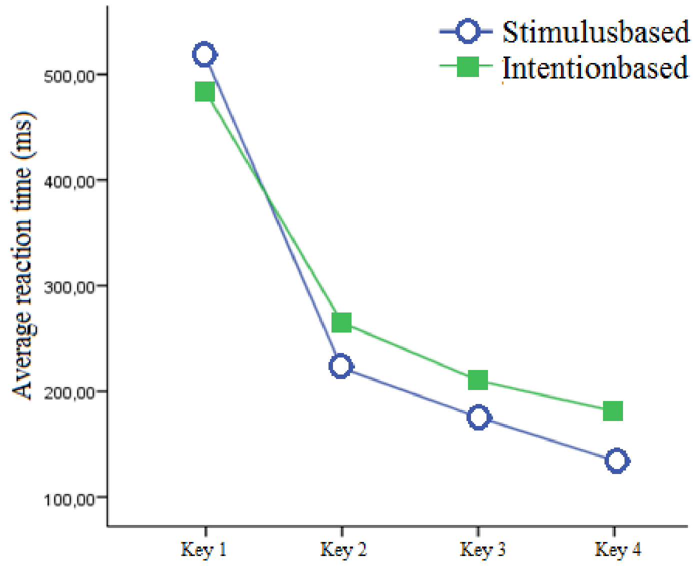

Figure 2: Reaction time of the keys in the 4-key sequence in the practice phase for the stimulus-based and intention-based groups.

Second practice phase

We also carried out a repeated measures ANOVA on reaction time (RT) with Keys (4) as within-subject variables and Group (2) as a between-subject variable for the second practice phase. A significant difference was found between Keys, $F(3, 66) = 319.78$, $p < .001$. The average reaction time on the first key ($M = 533.2$, $SD = 130.3$) was higher than on the second ($M = 174.5$, $SD = 67.2$), third ($M = 148.3$, $SD = 94.7$) and last ($M = 127.1$, $SD = 51.1$) key. There was no significant difference between the Group, $F(1, 22) = 246.5$, $p = .134$, nor an interaction effect between Group and Keys, $F(3, 66) = 658.7$, $p = .870$.

In phase 2 the errors were not calculated for each key press. Because the intention-based group had a free choice, their first key press was more likely to be correct then it is for the stimulus-based group. The number of error sequences was calculated and we carried out arcsine transformations on these. We carried out an One-way ANOVA with the arcsine transformed error proportions as a dependent variable and Group as the factor. This revealed no significant differences in errors made between the stimulus-based and intention-based groups $F(1, 22) = 2.398$, $p = .136$.

Test phase

The most interesting results of this experiment lies in the difference in reaction time between the stimulus-based and intention-based groups in the congruent and incongruent block. We used a repeated measures ANOVA on reaction time (RT) with Congruency (2; congruent and incongruent) and Keys (4) as within-subject variables, and Group (2) as a between-subject variable. The results showed a significant difference between the incongruent and congruent block $F(1,22) = 8.856$, $p = .007$, and a significant difference between Key,s $F(3, 66) = 523.6$, $p < .001$. Taking a closer look at the data showed us that the reaction time in the congruent block was higher (*M* = 197.1, *SD* = 43.29) than the reaction time in the incongruent block (*M* = 190.3, *SD* = 43.60). And that the reaction time for the first key (*M* = 440.2, *SD* = 85.0) was higher than the reaction time on the second(*M* = 136.7, *SD* = 46.7), third (*M* = 101.4, *SD* = 40.1) and last key (*M* = 96.5, *SD* = 29.1).

There was no significant difference between Group $F(1, 22) = 1.70$, $p = .205$. There was no interaction between Congruency and Group $F(1,22) = 3.323$, $p = .082$, and between Congruency and Key $F(3, 22) = 0.531$, $p = .663$. There was an interaction effect between Keys and Group $F(3, 22) = 5.191$, $p = .003$.

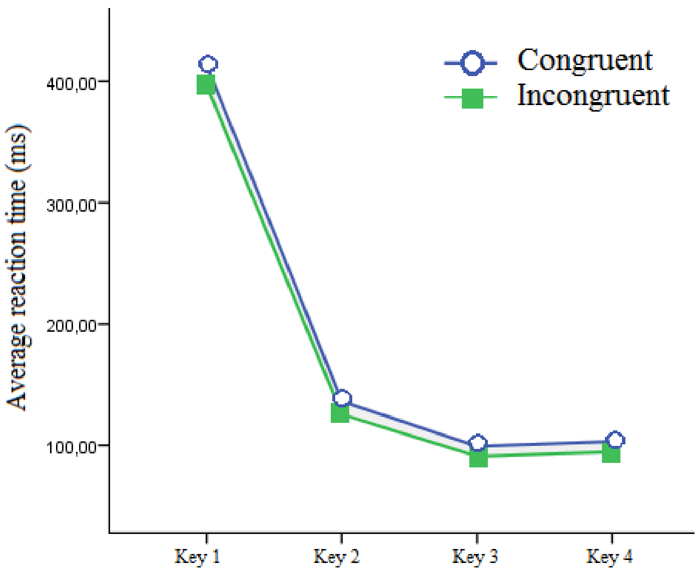

Figure 3: Reaction time of the key presses in the Stimulus-based group in the Congruent and Incongruent block.

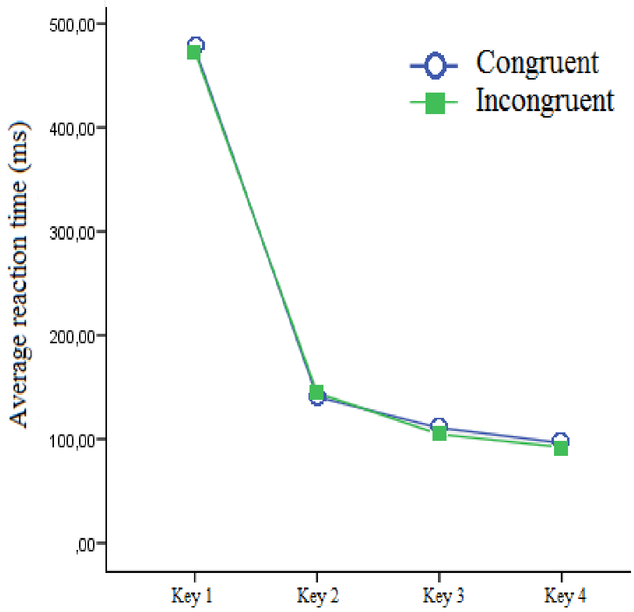

Figure 4: Reaction time of the key presses in the Intention-based groups in the Congruent and Incongruent block.

The errors were investigated to ensure participants did not make too many errors. We carried out arcsine transformations on the mean proportions of errors made on each key, so we could carry out a repeated measure ANOVA with Keys (4) and Congruency (2) as within-subject variables and Group (2) as a between-subject variable. This revealed a significant interaction effect between Congruency and Group $F(1, 22) = 4.826$, $p = .039$. A significant difference was found on Keys, $F(3, 66) = 9.770$, $p < .001$. The error proportions made in the congruent block on key 1, 2, 3 and 4 are respectively 1,3%, 1,3%, 3,8% and 0,3%. The error proportions made in the incongruent block on key 1, 2, 3 and 4 are respectively 0,6%, 2,2%, 0,2% and 0,02%. There was no difference in the amount of errors between the groups, $F(1, 22) = 3.942$, $p = .060$.

Discussion

The aim of this study was to find out if there is an action-effect in intention-based and stimulus-based actions when people perform more complicated movements. Elsner and Hommel (2001) and Herwig, Prinz and Waszak (2007) tested single movement actions, and their findings suggest that action-effect learning only takes place in intention-based action. Our hypothesis was that an action-effect develops in intention-based actions and that those action-effects do not develop in stimulus-based actions.

The main interest of this experiment lies in the difference in reaction time between the stimulus-based and intention-based groups in the congruent and incongruent block. The test phase revealed whether there was a difference between the both groups according to learning an action-effect and using this as a reminder to select the appropriate action.

First, we expected that the intention-based group would perform better (had a shorter reaction time) in the congruent block compared to their incongruent block. The results showed that there were no differences in reaction time between the congruent block and the incongruent block for the participants in the intention-based group. We expected to see no differences in reaction time between the congruent en incongruent block for the stimulus-based group. The results confirmed that there was no difference between the congruent and incongruent block for the participants in the stimulus-based group.

Second, we expected the intention-based group to be faster in the congruent block than the stimulus-based group. Besides that we expected the intention-based group to be slower in the incongruent block compared to the stimulus-based group. This means that we expected to find a interaction between the groups and the congruent and incongruent blocks. Although there was a difference between the congruent and incongruent block, this could not be explained by the stimulus-based and intention-based group. The intention-based group did not perform better in the congruent block compared to the stimulus-based group, and the participants from the intention-based group were also not slower the incongruent block compared to the people from the stimulus-based group. The overall reaction time in the congruent block was higher than the reaction time in the incongruent block. This means that participants, no matter if they took part in the stimulus-based or intention-based group, performed better in the incongruent block. These results contradict the findings of Elsner and Hommel (2001) and Herwig, Prinz and Waszak (2007).

Before we can conclude that participants in the intention-based group did not learn the action-effects, we have to take into account that we already found a difference between the groups in the first practice phase. The stimulus-based group made more errors during this phase. This could have led to more difficulties with learning the sequences in the stimulus-based group, and thus with learning the motor chuck. A solution to this problem could be to include more participants so the variation between the groups would be minimized.

Taken together, these results could not support the findings of Elsner and Hommel (2001) and Herwig, Prinz and Waszak (2007). The tone did not act as an action-effect in the intention-based group nor in the stimulus-based group. Before we can be sure that a tone cannot act as an action-effect in more complicated movements, we have to take into account that we already found a difference between the groups in the first practice phase. For further research we recommend to include more participants to overcome this problem.

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Appendix

GEÏNFORMEERDE TOESTEMMING

GW.07.130

Ik, ………………………………………………………………….. (*naam proefpersoon)*

Stem toe mee te doen aan een onderzoek dat uitgevoerd wordt door

Sarissa van Swam & Marten Korf onder leiding van prof. W.B. Verwey

Ik ben me ervan bewust dat deelname aan dit onderzoek geheel vrijwillig is. Ik kan mijn medewerking op elk tijdstip stopzetten en de gegevens verkregen uit dit onderzoek terugkrijgen, laten verwijderen uit de database, of laten vernietigen.

De volgende punten zijn aan mij uitgelegd:

1. Het doel van dit onderzoek is inzicht te krijgen in de manier waarop kennis van bewegingssequentie in het geheugen is opgeslagen.
2. Er zal mij gevraagd worden een tweetal toetsdruksequenties uit te voeren.
   Aan het einde van het onderzoek zal de onderzoeker uitleggen waar het onderzoek over ging.
3. Er behoort geen stress of ongemak voort te vloeien uit deelname aan dit onderzoek.
4. De gegevens verkregen uit dit onderzoek zullen anoniem verwerkt worden en kunnen daarom niet bekend gemaakt worden op een individueel identificeerbare manier.
5. De onderzoeker zal alle verdere vragen over dit onderzoek beantwoorden, nu of gedurende het verdere verloop van het onderzoek.

Handtekening onderzoeker: …………………… Datum: …………………..

Handtekening proefpersoon: …………………………………… Datum: …………………..

Maart 2014

Proefpersonen Instructie

Je gaat straks meedoen aan een onderzoek naar de manier waarop toetsdruksequenties in het geheugen zijn opgeslagen

Dit experiment duurt ongeveer 1,5 uur, en bestaat uit 3 blokken. Je verdient hiermee 1,75 proefpersoonpunten die via het Sona-systeem worden opgeslagen.

Het is belangrijk dat je probeert zo weinig mogelijk fouten te maken. Na een fout moet je opnieuw drukken, dit kan alleen als de (rode) foutmelding weer verdwenen is.

Tijdens ieder blok krijg je 1 pauze van 40 seconden, en na iedere blok heb je een pauze van drie minuten, tijdens de pauzes mag je lezen of gewoon ontspannen. We vragen echter aan jou tijdens te pauzes gewoon te blijven zitten, de proefleider komt na afloop van de pauze en start dan het volgende blok opnieuw.

De instructies verschijnen op het scherm, als er iets niet duidelijk is, meld je dan even bij de proefleider. Als je al eerder meegedaan hebt aan zo'n soort experiment met **dezelfde** sequenties, laat het de proefleider dan ook weten.

Alvast bedankt voor het meedoen!

Sarissa van Swam
Marten Korf