

The Theory of Event Coding and Sequential Action:

Automatic associations between motor chunks and their effects.

Cornelis Bernardus Nicolaas Mommer s0121045

University of Twente

Faculty of Behavioral Sciences

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Tutors: Dr. E. Abrahamse

Prof. Dr. Ing. W. B. Verwey

Abstract

The Theory of Event Coding (TEC) posits an automatic association between a consistent effect and an action, when the effect follows the action within close temporal proximity. One would expect this association to develop between a motor chunk and an effect, but previous unpublished research (Verwey, 2008) found no such association. The possibility is explored that action–effect associations develop at a single key press or at the chunk as a whole. The results did not support this notion, but do show an association between the motor chunk and the effect, unlike Verwey (2008). The TEC appears capable of predicting an action–effect association for more complex actions as well.

1. Introduction

Every action has an effect, and that effect is by necessity always the same for a specific performed action, and therefore it makes sense if we are able to learn and remember these effects; if not consciously, at the very least at the subconscious level. Indeed, effect anticipation has been shown to affect our behavior (Koch & Kunde, 2002; Hoffman, Stoecker & Kunde, 2004). We may subconsciously associate between action and effect. The major theory describing this association is the Theory of Event Coding (TEC: Hommel, 1996; Hommel, Müsseler, Achtersleben & Prinz, 2001).

The TEC posits that when an action and its effect consistently happen in close temporal proximity, we automatically associate the action with the effect. When the effect occurs again, the association ensures rapid execution of the intended action associated with the effect (Hommel, 1996). The rationale behind the TEC is that this holds an evolutionary benefit, in that when something consistently occurs in nature, it is to our use that we expect the effect to occur again when the same action precedes it.

The TEC gives us a theoretical explanation for the problem of a person executing an action whilst being unaware of this action, because there is no expected theoretical link between perception and action (Hommel et al., 2001). We call this problem *executive ignorance*, and this has been a problem in many theories of classical information processing (e.g., Massaro, 1990; Sanders, 1980). These theories cannot fully explain how we are able to perform voluntary actions, as their focus is often on perception and action as independent and

separate domains. This separation makes it difficult to obtain an adequate account of the relation between perception (perceived effects) and action (Hommel et al., 2001), as it fails to explain how the separate domains are related to each other.

Contrary to the view that perception and action are independent domains, the TEC posits that instead of action and perception being two separate domains, they share a common domain for late perception and early motor processes. Late perception is when cognitive processes have formed cognitive products of perception that stand for and represent features in the world. Early motor processes are representations of actions that are to be executed in the environment. By having this common code, perception and action are thus functionally and representationally linked (Hommel et al., 2001). Task-relevant effects and the perceptions of these effects are posited as being automatically and spontaneously integrated into one local independent event file (a representation in memory of the action and its consequences), linking one stimulus (perception) to one response (action) (Hommel, 2007). When an action and an effect consistently occur in close temporal proximity, action and effect are automatically associated with each other in the same event file. With regard to this mechanism, the TEC provides us with an explanation for the manner in which we are able to exercise “free will”, selecting which actions we will execute at a voluntarily chosen time simply by imagining the intended effect.

1.1 Empirical support for the TEC

Studies conducted by Hommel and colleagues (Hommel, 1996; Hommel et al., 2001) have shown support for the TEC. The first stage of the 1996 experiment was a practice phase, in which participants were instructed to press a key, which was followed by a task-irrelevant tone being played. Participants were required to execute two different keys, each of which was associated with a unique sound. Participants were told the tone was there to distract them from the task at hand. The second stage of the experiment was a test phase, in which the task-irrelevant tone was presented before execution of the key press. It was found that when the sound was presented before execution, the key press was performed with a shorter reaction time compared to when no tone was presented. Furthermore, when the sounds were reversed, so that the sound no longer corresponded to the key press, reaction times got significantly longer compared to the no-tone and correspondent-tone conditions (Hommel, 1996).

These results reveal a mechanism that associates action and effect, by merit of both consistently occurring in short temporal proximity to each other (Hommel, 1996). Indeed, the action–effect coupling has been found to be a relatively robust effect (cf. Drost, Rieger, Brass, Gunter & Prinz, 2005; Elsner & Hommel, 2001; Hommel, 1996; Hommel et al., 2001; Hommel, 2007; Ziessler, 1998). In the experiments conducted by Hommel and colleagues, the association is made between one action and one effect, in their case between a key press and a sound. But would such an association also occur when the action consists of multiple integrated actions, hence with more complex action patterns?

1.2 The TEC and complex actions

When participants execute not one, but multiple actions in sequential order (e.g., key presses), we call these *movement sequences*. When movement sequences are highly practiced, they are usually deemed to be stored in memory as motor programs, or motor chunks, and subsequently executed from memory (e.g., Carter & Shapiro, 1984; Day et al., 1989). *Motor chunks* are single representations of multiple individual actions to be executed in a movement sequence or part of a larger movement sequence, which after activation drives the execution of the movement by steering and controlling lower-level units (lower levels of the motoric functions that steer individual actions) (Klapp, 1995, 2005; Verwey, 1999, 2001). A motor chunk is initiated and executed as a single response, instead of every individual action being prepared and executed separately (Verwey, 1999).

When an effect can be associated with a single action (e.g., Hommel, 1996), we would also expect such an action–effect coupling to occur with the execution of a motor chunk. Such an association is likely to be formed when a motor chunk is consistently being executed in close temporal proximity to an effect. Because in memory a motor chunk is a single representation of an action, such association forming seems plausible. Thus, the results of an experiment using a motor chunk rather than a single key press, like in the study reported by Hommel (1996), are likely to yield similar results. However, contrary to these expectations, unpublished experiments by Verwey (2008) showed no such effect in conjunction with motor chunks.

In these unpublished experiments, participants were instructed to execute two 4-key sequences shown on a screen, followed by a task-irrelevant auditory stimulus. One sequence was consistently followed by a car horn sound fragment, the other sequence by a dog bark sound fragment. After 4 practice blocks, a test block presented the task-irrelevant sounds to the participants before the execution of the 4-key sequences as a prime for the sequence. In one test block, participants heard the sounds that were usually associated with the associated 4-key sequences (congruent condition), and in the other test block the sounds were reversed; the sound that was first associated with one sequence, was now coupled with the other, dissociated sequence (incongruent condition).

If any association had occurred during practice, hearing the sound before the sequence would trigger the participants to prime the action and to select and prepare the chunk. Furthermore, because of the association with a particular sound, participants are expected to select and initiate a sequence faster when they hear the congruent (learned, associated) sound before the sequence than when they heard the incongruent (learned, dissociated) sound.

In Verwey (2008, Experiment 1), no significant difference was found between the response times of the incongruent and congruent conditions, i.e., participants did not initiate a sequence any faster when hearing the congruent sound than when hearing the incongruent sound. To exclude the possibility that participants may have simply ignored the sounds, the experiments were repeated with a specific instruction to pay attention to the sounds, as they would later be asked about them (Verwey, 2008, Experiment 2). This again yielded no

significant difference between the congruent and incongruent condition. No action–effect coupling was found for action effects with either single keys or motor chunks. Participants did not seem to make an association between the action (motor chunk) and the sound stimulus, as was predicted based on the TEC. This led to the research question: why is there no association between the chunk and the effect?

1.3 Higher-level representations

An explanation why Verwey (2008) did not find any association may be found in the motor chunk itself. A motor chunk is a higher-level representation of the action as a whole. A motor chunk is made up of several motor actions (that are lower-level units), which together make up the action to be performed (Pammi, Miyapuram, Bapi & Doya, 2008). An association with the effect may not be formed at the highest level of the chunk, but may rather occur at a lower level in the hierarchy, for instance at the level of individual actions. If, for instance, a task-irrelevant stimulus were presented after the first action in a motor chunk's execution, an association would form between the stimulus and the first motor action of the sequence.

Before a motor chunk is executed, it has to be selected from memory and loaded into the motor buffer for execution. Selection and preparation of a motor chunk is already complete before individual actions of the motor chunk are being executed. The execution of subsequent motor actions in a chunk proceeds automatically and requires little to no further attention (Proctor & Dutta, 1993; Verwey, 2001; Witt, Ashe & Willingham, 2008). This means that when subsequent actions following the first action are executed, the chunk is already fully prepared

in the motor buffer, and no further preparation is required for execution. This can potentially mean that any association between action and effect no longer influences the preparation or execution of actions beyond the first action, thus obscuring its effect in the results. In the experiments of Verwey (2008), the irrelevant auditory stimulus was always presented after the execution of the 4-key sequence during the practice phase.

Presentation of the effect before the first key press may allow the key to be affected by the action–effect coupling (after that association has been learned), unlike presentation before all following keys, because the first key press still has to be prepared in the motor buffer for execution. This may imply that when the motor chunk is selected and subsequently executed as a whole, only the first key press of a chunk is affected by the presentation of the effect before execution. Presentation of the prime before initiation of the first key may also influence chunk selection; when the prime is presented, the chunk may be automatically prepared as well, thus enabling an association between the chunk as whole and the auditory stimulus.

1.4 Hypotheses

An association between an action and an effect at the first key press of the sequence may become evident from two results. First, execution of a motor chunk's first key benefits from the presentation of the congruent prime and is executed significantly faster. Second, the chunk as a whole benefits and is performed faster because it is automatically selected when the first action is primed after presentation of the congruent effect.

This assumption was tested in an experiment. Results were compared between two groups: during practice blocks, one group was presented the auditory stimulus after the first key press of the 4-key sequence (“after first key”), and the other group was presented the auditory stimulus after the last key press (“after last key”). After several practice blocks, the auditory prime was presented before execution of the sequence in two test blocks, either the congruent stimulus or the incongruent stimulus that was previously associated with the opposing key, creating a “congruent” and an “incongruent” condition. A single key press like the one used by Hommel (1996) was also included, to ensure the results from this experiment conform to Hommel’s previous findings.

Based on the findings of Verwey (2008) and the TEC, an association between the first key of the sequence or the chunk as a whole and the auditory stimulus is expected to be formed when in the practice phase, an auditory stimulus is presented after the first key. In the test phase, execution of the first key press or the initiation of the sequence is expected to be significantly faster in the congruent condition compared to the incongruent condition with the “after first key” group. Conversely, participants in the “after last key” group may form an automatic association between the last key of the sequence and the auditory stimulus, but this will be obscured in the results. Neither is an association between the auditory stimulus and the sequence as a whole expected to become visible from the results, which means that the execution of the last key or initiation of the sequence will not be significantly faster in the congruent condition compared to the incongruent condition for the “after last key” group.

Furthermore, it is expected that participants will form motor chunks when practicing the sequence a sufficient amount of times. The results should show shorter reaction times between the key presses as the sequence becomes more learned. In addition, the reaction time for the single key press will be shorter than the first key of the 4-key sequence, due to chunk selection and preparation in the motor buffer. This is because the longer the chunk, the longer the preparation needed for the execution of the chunk (Monsell, 1986; Verwey, 2003), resulting in a higher reaction time for the first key of the 4-key sequence compared to the shorter single key press.

2. Method

2.1 Participants

Participants for this experiment were twenty-two undergraduate psychology students and one medical student as well as nine non-student volunteers (21–32 years; 32 participants total, 21 female, nine male). Participants were recruited via email and direct communication. Students of the faculty of behavioral sciences were rewarded one study credit for participating in this experiment when they signed up via a website; the remaining students did not receive a compensation.

2.2 Apparatus and stimuli

Participants were seated in front of a 19" Samsung Syncmaster 700P CRT monitor with a refresh rate of 60 Hz, a resolution of 640 × 480 pixels at 16-bit color depth. Sequences were entered using a standard US 128-key QWERTY keyboard. The left middle- and index finger and

the right index- and middle finger were placed on the C, V, B and N key, respectively. A generic unbranded headset was used for the presentation of tones. Before the experiment commenced, participants were able to adjust the volume of the headset to a comfortable yet sufficient level. The experimenter double-checked the volume to ensure sounds were not accidentally turned off by playing the sound samples, while ensuring that each participant was able to discern and clearly hear both tones. This experiment employed 440 Hz and 880 Hz beeps lasting 200 ms. The room ($2.25 \times 2.25 \times 3.50$ m) was normally lit with fluorescent light and fitted with a webcam for monitoring purposes.

2.3 Task

Participants practiced a keying sequence by responding to stimuli shown on the screen. Throughout all blocks, the display showed four homogeneously black square outlines (6×6 mm) against a white background and with a white filling. The four-key layout corresponded with the spatial arrangement of the assigned response keys. The squares were placed adjacently in a horizontal order with 4 mm spacing or about 0.4° at 60 cm face-display distance. When a square would light up with a bright green color, the participant was required to press the associated key.

Each participant learned a single key press and a 4-key sequence. The sequences chosen were counterbalanced across participants. In the experiment by Hommel (1996), both key presses were initiated with fingers of a different hand; one key with the left and one key with the right hand. In this experiment the sequence and key press also started on a different hand

for each participant. For instance, if a participant initiated a 4-key sequence with his left middle finger, the single key press would always be initiated with his right middle or index finger. This ensured the experiment previously conducted by Hommel (1996) was properly replicated, and that the location of the first response indicated which sequence had to be executed. This allowed for using the first response as an indicator for the initiation of the sequence. The 4-key sequences used were all combinations of the C, V, B, and N keys, the single key press was always either the C, V, B or N key.

Both sequences were repeated 200 times in the practice phase, which consisted of four blocks of 100 trials (block 1–4). The test phase was composed of two blocks (block 5 and 6), in which the congruent and incongruent conditions were counterbalanced. In block 5, one half of the participants encountered the congruent condition; the other half first encountered the incongruent condition. These were followed by the opposing condition in block 6. In both test blocks, the sequences were performed 40 times. Previous research using a comparable number of trials (e.g. Verwey, 2001; Wright et al., 2004) have shown this number of trials to be sufficient for the forming of motor chunks.

2.3.1 Practice phase

Participants were assigned to the “after first key” and “after last key” groups randomly, by order of participation. Participants were not informed about the auditory stimulus being presented either following the first key press or at the last key press of the 4-key sequence.

2.3.2. Test phase

During the test phase, participants did not receive visual stimuli indicating which sequence was to be executed, to increase sensitivity for the action–effect coupling. This way, participants would have to rely on the learned association, so that the tone the participant heard, indicated the sequence to be executed, thus making the tone the imperative stimulus. In the congruent condition, the tone was presented before the sequence that it was originally associated with, and in the incongruent condition, the tone was presented before the other sequence. Participants received instructions about the nature of the condition (congruent or incongruent) before the relevant part of the test block began. The test phase was thus split into two blocks; one block with a congruent tone–sequence mapping, and one block with an incongruent tone–sequence mapping. The order of these two blocks was counterbalanced between participants.

2.4 Procedure

Before the beginning of the experiment, participants signed an informed consent form, after which they were given a short verbal instruction that was the same for each participant. Participants were asked to change the volume to a setting where they could clearly discern between the two different frequencies (440 Hz and 880 Hz respectively). Before the first block, an instruction displayed on the screen informed participants of proper finger placement and of the stimuli they had to respond to. After completion of each block, participants were instructed to call for the experimenter to start the next block. After the completion of the practice phase,

participants were verbally instructed about the test phase. This instruction was read from a pre-written instruction by the researcher to ensure each participant received the same instruction. At the end of the experiment, participants were allowed to ask questions and were thanked for their participation. If the participant was eligible to receiving a credit for participation, this was granted after the experiment.

3. Results

We carried out a repeated measures ANOVA on reaction time (RT) with Block (4; practice blocks 1-4) and Keys (4; the 4 keys of the 4-key sequence) as within-subject variables, and Sequence (4; the 4 different 4-key sequences used) as a between-subject variable. The results showed a significant difference between the practice blocks $F(3, 84) = 87.58, p < .01$, and a significant difference between the key presses of the 4-key sequence $F(3, 84) = 108.70, p < .01$, showing that participants' performance improved with practice. No significant difference was found between the different versions of the 4-key sequences $F(3, 28) = 0.98, p = .42$. There was a significant interaction between Block and Keys $F(9, 252) = 15.63, p < .01$ and between Block and Sequence $F(9, 84) = 2.13, p < .05$.

The participants' performance on the single key press in the practice phase was tested using a repeated measures ANOVA with RT of the practice blocks (4) as the within-subject variable. There was a significant effect of block $F(3, 93) = 6.08, p < .01$, showing that the participants' performance improved with practice. Evidence of chunking was also found in the data. The overall RT improved with learning and inter-response RTs (between key presses of a

sequence) were shorter as the sequence became better learned (see Figure 1). Furthermore, the results show that the RT for the single key press was significantly shorter compared to the RT for the first key of the 4-key sequence.

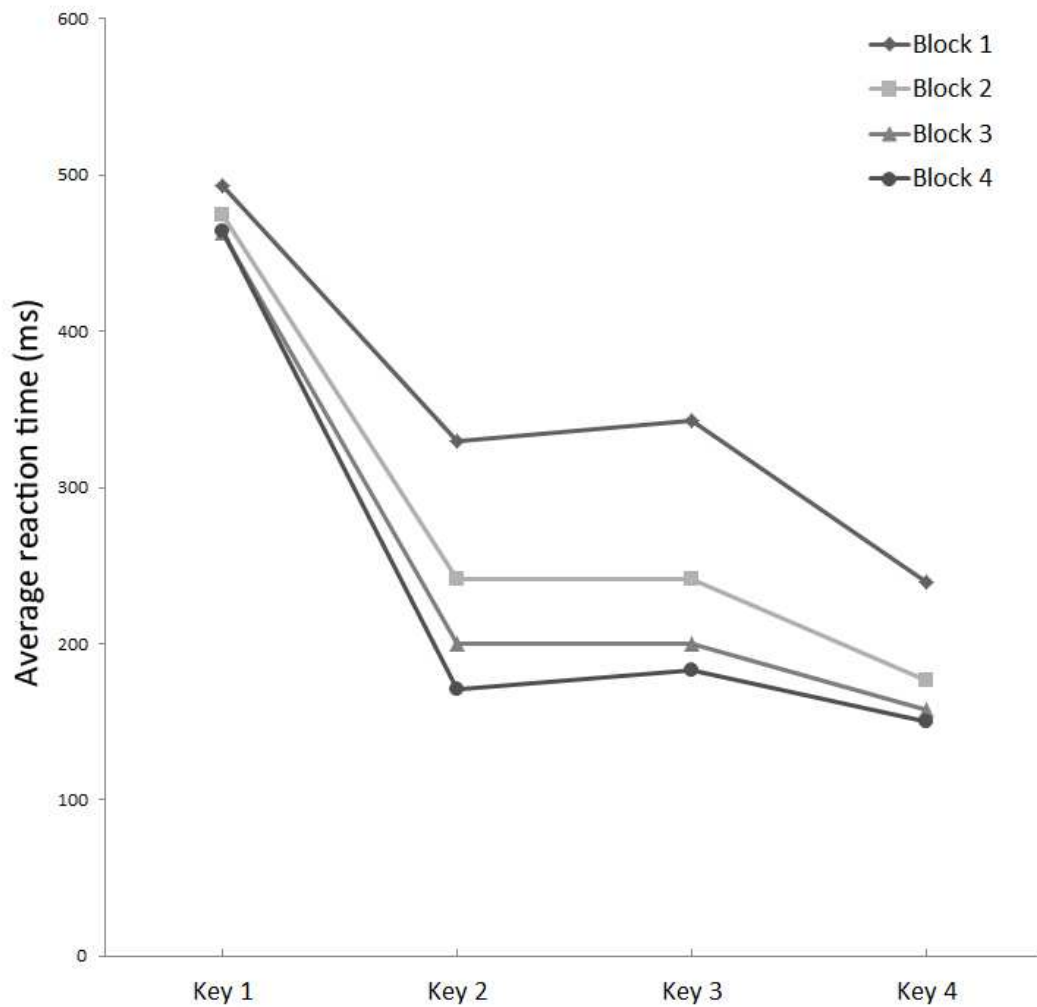


Figure 1: RTs for the 4-key sequence of the four practice blocks in ms.

3.1 Errors

Errors in the practice phase were investigated to ensure participants did not make a large amount of errors. We tested this using a repeated measures ANOVA on accuracy with Block (4) and Sequence (2; four key sequence versus single key press) as within-subject

variables. We found a significant effect of Sequence $F(1, 31) = 25.85, p < .01$, but Block was not significant $F(3, 93) = 0.68, p = .57$. The mean of the errors in the four blocks of the practice phase is .07 for the 4-key sequence, and .01 for the single key press. Unsurprisingly, most of the errors were made with the 4-key sequence. No participant made a significant amount of errors, and thus no participants were excluded from further analysis.

3.2 Test phase

The main interest in the results of this experiment lies in the difference between the congruent and incongruent condition, and between the “after first key” and “after last key” groups. To test this we used a repeated measures ANOVA on reaction times with Key (4; keys 1-4 and Condition (2; congruent versus incongruent) as within-subject variables, and Group (2; “after first key” versus “after last key”) as between-subject variable. Group showed a tendency for significance ($F[1,30] = 3.90, p = .06$), but did not reach significance, the RT for the “after first key” group had a tendency to be lower compared to the “after last key” group. No significant difference was found for Condition ($F[1,30] = 1.09, p = .30$), nor was there a significant interaction between Group and Condition ($F[1,30] = 0.72, p = .40$). Key was significant ($F[3,90] = 271.64, p < .01$) showing a significant difference between the key presses. A significant interaction was found between Condition and Key ($F[3, 90] = 5.07, p < .05$), showing that the condition does have a significant effect on the single key presses. Figure 2 shows that execution of the first key in the congruent condition is faster than execution in the incongruent condition.

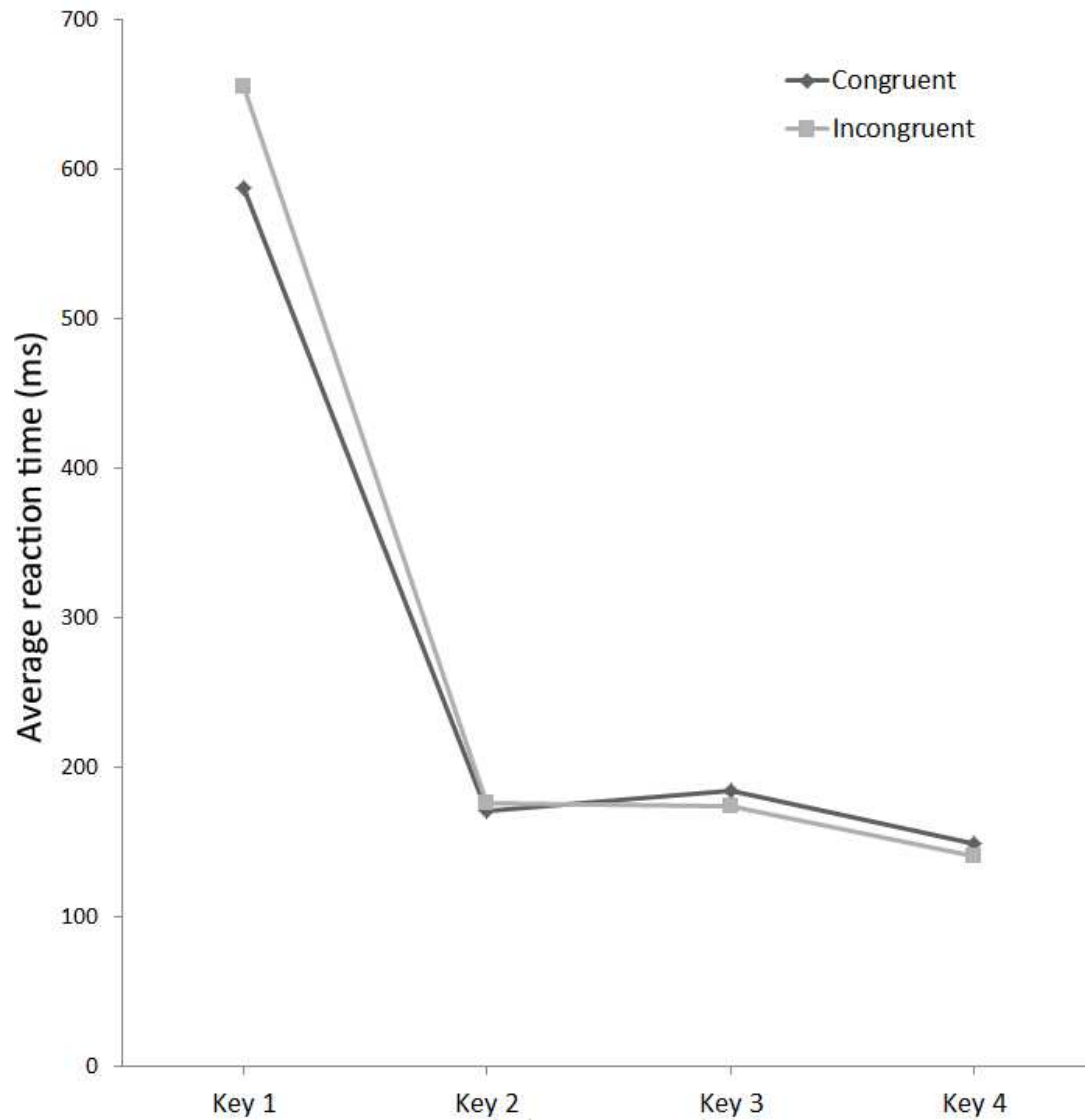


Figure 2: Reaction time of the keys in the 4-key sequence in the congruent and incongruent conditions.

Logically, the difference between the first keys across the two conditions was tested next. This was done using a repeated measures ANOVA on the first keys of the 4 key sequence (2) and Condition (2) as within-subject variables, and with tone Group (2) as between-subject variable. No significant effect of Group was found ($F[1,30] = 2.63, p = .12$), yet a significant

difference was found between the incongruent and congruent condition ($F[1, 30] = 6.09, p < .05$), showing that the execution of the first key of the 4-key sequences in both groups were significantly faster when the congruent sound was presented, than when the incongruent sound was presented.

The accuracy of the 4-key sequence during the test phase was investigated using a paired-samples t -test, comparing between the congruent and the incongruent condition. A significant difference was found for the accuracy between the congruent and incongruent condition ($t[31] = 3.66, p < .001$), which is not surprising given the heightened difficulty in the incongruent condition. The mean proportion of errors is .05 ($SD = .04$) for the congruent and .09 ($SD = .07$) for the incongruent condition.

The accuracy for the single key press for the test phase was tested with a paired-samples t -test, comparing the congruent and the incongruent condition. A significant difference between the congruent and incongruent condition was again found ($t[31] = 3.53, p < .001$). The mean proportion of errors was .04 ($SD = .04$) for the congruent and .09 ($SD = .08$) for the incongruent condition. Just as with the 4-key sequence, most errors on the single key press were made in the incongruent condition. Lastly, we compared the overall RT for the single key press in the test phase to replicate the results found by Hommel (1996), a paired-samples t -test was used to compare between the congruent and incongruent condition. A significant difference between the congruent and incongruent condition was found ($t[31] = 4.70, p < .001$),

showing that participants displayed a significantly shorter RT in the congruent condition, compared to the incongruent condition.

4. Discussion

This study set out to investigate why Verwey (2008) found that replacing single actions with a sequence formed into a single representation of an action, or motor chunk, did not lead to an action–effect association as the Theory of Event Coding (TEC) would predict. The study reported here hypothesized that there was an association, but that this association was obscured in the results of Verwey (2008), because the association between action and effect did not occur with the chunk itself, but rather at a lower level of the chunk (i.e., the individual key press).

It was predicted that when the auditory stimulus was presented after the first key during the practice phase, an association between the auditory stimulus and the first key of the sequence or with the chunk as a whole would be formed. This was tested using two test groups: one group was presented the auditory stimulus after the first key (“after first key”), and another was presented the auditory stimulus after sequence execution (“after last key”). Participants in the “after first key” group were predicted to execute the first key significantly faster or initiate the motor chunk faster compared to the “after last key” group. The test phase was separated into two conditions for all participants: a “congruent” condition, presenting the learned associated sound before execution of the sequence, and an “incongruent” condition, where the tone previously associated with the opposite sequence or key press, was presented

with the dissociated sequence or key press. A significant interaction was found between condition and key position of the sequence. Further testing showed that the congruent condition significantly shortened the reaction time on the first key of the 4-key sequence, for both groups. The condition did not have a significant effect on the second, third and fourth key. This means that presentation of the congruent tone did facilitate execution of the first key of a chunk, as was hypothesized.

The results of this study confirm the findings of Hommel (1996). Participants were able to execute the single key press with a significantly shorter reaction time in the congruent condition. This provides more evidence for the underlying mechanism of the TEC, which assumes that an automatic association is formed between an action and an effect. Participants were also found to form motor chunks, which became evident from a shorter reaction time between key presses across blocks, and an overall shorter reaction time for the sequence as a whole. Evidence for the sequence length effect (i.e., as a sequence becomes longer, participants need more time to prepare and thus the selection and preparation time of the sequence increases) was also found: initiation of the single key press was considerably faster than initiation of the first key of the 4-key sequence.

No significant difference was found between the performance of both groups on the first key, meaning that they both benefited from the presentation of the associated auditory stimulus before execution. The first key was expected to be executed faster in the “after first key” group, in comparison with the “after last key” group. If an association between the first

key of the sequence and the auditory stimulus had formed, as theorized based on the results of Verwey (2008), a significant difference between groups on the first key was expected. Rather, there appears to be an association between the chunk and the auditory stimulus, regardless of whether the tone is presented after the first or the last key during the practice phase, because an association between the last key and the tone should be obscured in the results, as opposed to an association between the tone and the motor chunk.

These findings cast doubt on the initial assumption, that posited that we would find an association between a lower level unit of the chunk and the auditory stimulus, based on research that found no effects of the association between a motor chunk and an auditory stimulus (Verwey, 2008). A motor chunk is a higher-level representation of the sequence, while an action–effect association between a lower-level unit and the chunk would be obscured in the results. The results from this experiment do adhere to the prediction of the TEC that participants would automatically associate between the chunk and a task-irrelevant stimulus, if the stimulus is consistently presented in short temporal proximity to the chunk. In the light of the TEC, the results of this study make sense and are what would have been predicted if previous research had not yielded different results. This raises the question why Verwey (2008) could not identify this association, while it does appear in the experiment reported in this paper.

One possible explanation of why an association was found between the chunk and the tone may be that skills are represented in a hierarchical fashion (Hommel, 2007; Wulf, 2007). As

skills become highly trained, the focus may shift to a higher, more integrative level (Hommel, 2007). The response selection in this experiment was easier compared to that in the study of Verwey (2008), which used two 4-key sequences. Therefore, participants may also have mastered the sequences and the response selection task more easily in this experiment. The participants' focus may have been at a higher level than with Verwey (2008), comparable to the findings of Drost et al. (2005), who compared inexperienced and experienced piano players, and found that only the experienced piano players associated a complex sequence of actions (in effect a motor chunk) with an effect (the tone).

A follow-up experiment by Drost, Rieger, and Prinz (2007) found that this was not specific to one instrument, by replicating the results with multiple instruments played by musicians at varying degrees of experience. This is in line with other research on musicians (e.g., Bangert & Altenmüller, 2003). It may be possible to test whether participants were indeed focusing on a higher level of processing in this study, by increasing the difficulty of the response selection (e.g., by replacing the single key press by a 4-key sequence) to compare between more difficult and easier response selection, as well as simpler sequences.

A second explanation of why the results from this study conflicted with those of Verwey (2008), may also lie in the design of the experiment. In the experiments conducted by Verwey (2008), participants continued to see the key-specific stimulus during the test phase. In the experiment reported here, these visual stimuli were omitted to exclude any influence of visual cues in the test phase, thus forcing the participants to solely rely on the auditory stimulus. This

may have caused the participants to consciously associate the motor chunk with the auditory stimulus. Removing the visual stimuli may have caused participants to associate the auditory stimulus more strongly with the key press and 4-key sequence. This alternative explanation requires further testing. Visual cues could be omitted in parts of the test phase to shed light on the question whether or not presenting visual cues affects performance.

4.1 Conclusion

This study found some highly interesting results. Although no association was found between the first key press of the motor chunk and the auditory stimulus (that eventually became an action effect), instead an association was found between the motor chunk and the action effect, regardless of when the action effect was presented during the practice phase. These findings partially confirm the hypotheses, but they do contradict the findings of Verwey (2008), which has interesting implications. The TEC posits that when choosing and preparing to execute an action, we imagine the desired result, and the action is prepared. According to the TEC, this is possible because action and perception share a common code (see the introduction), which can only be possible when there is a preexisting association between action and an effect. The results of this study provide evidence for an automatic underlying mechanism that enables us to not only associate between a single action and an effect, but also between a more complex set of actions (i.e., a motor chunk) and the effects of those actions.

An association between a more complex set of actions (i.e., a chunk) and its effect gives more credence to the premise of the TEC that our action–effect associating enables us to exercise “free will” (Hommel, 1996; Hommel et al., 2001), thereby giving the theory a greater

relevance. The TEC then not only provides an explanation for “free will” when executing single actions, but also for more complex sets of actions, which most of our actions are composed of. While these are exciting results, more experimenting is required to clarify why an association between the chunk and the auditory stimulus was found in this study, but not in the previous experiments by Verwey (2008).

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