



**Universiteit Twente**  
*de ondernemende universiteit*

**Bachelor Thesis**

in Psychology

**The Role of Context Dependent Memory on  
Perceptual Motor Learning in a DSP go/nogo Task**

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**Abstract.** The present study was designed to address the role of context on perceptual–motor learning. Further it was of interest if and how practice might act as a mediation factor in developing these dependencies. Context was manipulated by changing the incidental context stimuli during retention due to the three different conditions [Same, Switched, Different]. Practice was manipulated during acquisition with one versus five practice(s) –block condition. The results revealed changing context had an effect on performance but only if context switched during retention rather than changed completely. Also practice did affect performance in any case eventhough it did not interact with context manipulations.

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## Chapter 1

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# Introduction

This work addresses the role of context on perceptual motor learning. It can be defined as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement." (Schmidt & Lee, 2005 as cited in de Kleine, E., 2009). In perceptual motor learning this includes the processing of nonverbal stimuli.

Anid K. Dey & Gregory D. Abowd (2001) define context as: "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." In our case context describes information about the surrounding (an accumulation of entities) in which the experiment is conducted. As cited above this includes only information about entities relevant to the experiment, e.g. while conducting a computer-aided study a picture behind the user would be a non-relevant entity and thus not part of the context. However, in perceptual motor learning, context must not only include information deemed as relevant. Instead there exist more refined definitions (than the one above) where it is divided into *incidental* and *intentional* cues (explained in detail further below).

As a matter of fact context can influence everyone's life - consciously and/or unconsciously. Imagine the loss of an object and the hope of finding it back by returning to the place where we remember having seen it the last time. The key idea is: Surrounding enhances our memory. This example demonstrates that context

can have a subconscious effect on memory performance. Early research in this area focused on the *verbal memory domain*. It has been found that "superior recall of material is retrieved when retention performance is required in the original learning environment." (S. M. Smith, 1994). This is illustrated by one of the first and most striking facts psychology students learn about proper exam preparation: One should always revise in an environment which is similar to that in the exam itself. Thus, not only the amount of studying the material influences our performance – a common misconception - but also the surrounding in which we acquire it (Steven M. Smith & Edward Vela, 2001).

Regarding these facts, one interesting question comes to mind: Is the idea of context dependent memory also transferable onto perceptual motor learning? A study by Wright and Shea (1991) focuses on this matter using a sequence key-pressing experiment. Subjects had to learn series of three/four - key sequences. This was done in an environment of changing context stimuli. Wright and Shea (1991) differentiated between *intentional* and *incidental* stimuli. Intentional stimuli are defined as "those stimuli that are explicitly identified as essential to task acquisition" whereas incidental stimuli are defined as "[...] those that have the potential to become associated with a specific task because of their selective presence in the learning environment" (Wright and Shea, 1991). The emphasis here lies on the incidental cues. Intentional cues are measured in numbers, which indicate the sequence of keys pressed by the subjects. They are always combined with a set of incidental cues (e.g. sound and colour). The latter however, is not intentionally brought to the subject's attention.

In the original experiment (Wright and Shea, 1991) the situation of contextual cues was altered in subsequent setups. These are defined as: *same* context condition, *switched* context condition and *intentional-only* context condition. A typical experiment is divided into two phases, *acquisition* and *retention*. Acquisition depicts the preliminary experiment exercise in which a motor task is learned, whereas retention describes the actual process of assessing the adoption performance of the motor task. To obtain insight into context change, data sampling takes places in both phases where context is only altered during retention phase. In Wright and Shea's (1991) experiment the subject's performance did not change significantly when same

context was preserved. In switched context however the amount of mistakes rose tremendously. This was even more so when using four-key sequences opposite to three-key sequences.

Anderson, Wright and Immink (1998) correctly questioned this assumption by arguing that not only the amount of mistakes should be regarded but also the reaction time (RT). As they found in the data from Wright and Shea (1991) there was an observable effect of context even in the three-key sequence pressing condition. It was not the amount of mistakes that changed but rather the increase in RT when the incidental context was altered during retention. Task difficulty had no effect. In the 1991 experiment of Wright and Shea participants were not briefed to respond as fast as possible. To counter this deficit Anderson, Wright and Immink (1998) had to conduct a follow up experiment. As assumed RT is prominently influenced by context. These results put an emphasis on the importance of RT rather than the amount of mistakes that were made during the different experimental conditions.

Although Wright and Shea (1991) as well as Anderson, Wright and Immink (1998) focused on the importance of task difficulty they also mentioned the effect of practice (on the influence of context on perceptual motor learning). Wright and Shea (1991) suggested, that "[...] after subsequent practice, an association develops between the intentional and incidental stimuli. This relationship can support successful performance of the task if the relationship remains consistent. If the relationship is disrupted, however, performance will deteriorate." Further Verwey (1996) noticed that practice is generally viewed as a major determinant of proficient motor performance.

This poses multiple questions: Does context have an influence on memory performance in the perceptual motor domain? If so, can practice time be seen as a mediating factor in the development of contextual dependencies? And, if present, how are these dependencies expressed?

The attempt to answer these questions led to the composition of the present study. Individuals performed a fixed six-key DSP<sup>1</sup> go/nogo experiment. Following the line of investigation the idea of using fixed sequences on perceptual motor learning was already conducted by Verwey (1991, 1994) as was the use of DSP go/nogo

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<sup>1</sup>Discrete Sequence Production

experiments (Rosenbaum, 1980).

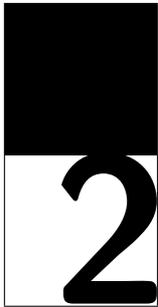
In a standard discrete sequence pressing experiment (DSP) subjects learn a limited number of distinguishable fixed, discrete sequences, mostly two. Each sequence is made up of 3-7 keys and hence as many visual stimuli. In a DSP task all but the first stimulus are presented immediately after the response to the previous stimuli (De Kleine, 2009). In the special case of a go/ nogo DSP task the whole sequence is presented prior to execution. Subjects only respond if a go signal appears. The motive is to separate motor preparation from motor action. This is in line with Verwey's (2001) principle of the dual processor theory, which states that motor learning consists of a *cognitive processor* as well as a *motor processor* (Verwey,2001). The cognitive processor initially selects a representation of a sequence based on a symbolic representation. It involves planning and organizing of the goal and the structuring of movement. The motor processor loads representation into the *motor buffer*<sup>2</sup> and executes the movement subsequently. The initial movement has high demands on the cognitive processor, which become less through practice. Thus through extensive practice (Inhoff,1991) we form some integrated and unified memory representation that is called *motor chunks* (Verwey, 1996). According to this model, the formation of motor chunks reduces the load in planning and organization and hence the demand on the cognitive processor. *Chunking* generally refers to a strategy to code multiple items in a relational structure and goes beyond motor control in that the concept is used for central knowledge representations, too (Abrahamse, Verwey, Jiménez, 2009).

In our study we solely focus on the effect of practice and context differences. Individuals take part in either of two practice levels, one composed of five and the other composed of two blocks. Intentional stimuli are combined with incidental stimuli during acquisition. In retention the incidental context changes due to the three different conditions (consistent with Wright and Shea (1991)). Individuals are subject to one of these six conditions: short-practice same context, short-practice switched context, short-practice intentional-only context, long-practice same context, long-practice switched context or long-practice intentional-only context.

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<sup>2</sup>If sufficient time is available, sequences can be programmed in advance in a short term buffer.

Corresponding with findings of Wright and Shea (1991) we expect a measurable effect of context on memory performance in all of the above mentioned conditions. Most critical findings should be revealed by the RT data. Following Wright and Shea's (1991) suggestion of a correlation between intentional and incidental stimuli under same context conditions, we assume long practice to have the most significant impact on memory.



## 2.1 Subjects

Participants in this study were 48 students, either of the University of Münster and the University of Twente. Age ranged between 19 and 27 years with a mean age of 22. They either received student credit points or participated voluntarily. As subjects were either of Dutch or German heritage, instructions of the experiment were available in both languages

## 2.2 Apparatus

The apparatus consisted of a computer with a colour monitor and a standard keyboard.

## 2.3 Design

The design of this experiment is a 2x3 between-subject design. Subjects are randomly assigned to one of two different practice conditions and three different context dependent groups (Table 1).

In the short practice condition the subjects are divided into three different treatment conditions, indicating the between-subject variables. These are same, switched and intentional-only context conditions. Each subject has to finish one practice

block followed by a test block, which depends on the condition the subject is in. Subsequently each subject has to fill in a questionnaire.

In the long practice condition the between-subject variables of test are the same as in the short practice condition [same, switched, intentional-only]. The length of practice, though, differs tremendously. In this design subjects have to finish five practice blocks before doing the test block. Finally as in the short practice design, subjects have to fill in the questionnaire.

<b>Subject Number</b>	<b>Amount of Practice Blocks</b>	<b>Test Condition</b>
1 t/m 8	1	Same Context
9 t/m 16	1	Switched Context
17 t/m 24	1	Intentional-only Context
25 t/m 32	5	Same Context
33 t/m 40	5	Switched Context
41 t/m 48	5	Intentional-only Context

Table 1: Design of the Experiment.

The dependent variables are RT and number of correctly performed sequences (PC), whereas practice and context conditions indicate the independent variables.

## 2.4 Stimuli and Task

Participants were asked to place their index and middle fingers of the left and the right hand on the keys c, v, b, n of a computer keyboard. To allow us to study the preparation phase of sequence learning in isolation from motor execution each trial of the experiment started with a fixation cross on the middle of the screen. Right below it four squares were aligned next to each other. Due to the fact that this was a Discrete Sequence Production (DSP) go/no go experiment, the fixation-cross turned either red or blue. Red indicated a no go trial, which asked the participant to wait without repeating the trial and thus attend until the next sequences was presented, whereas blue indicated a go trial, which asked the subjects to correspond to the presented sequence of the colored squares. Accordingly the subjects were presented with a block of trials including a random repetition of two fixed sequences à six stimuli, which had to be followed by the execution or the ignorance of six consecutive

key presses. The sequences were presented as the squares enlightened six times in a consecutive order. All stimuli till now represent the intentional cues, thus cues of which the subjects were aware of. Further each of the two sequences was identified by colour. During the practice phase one was always presented in blue whereas the other was presented in yellow. During the test phase the colour of the two sequences corresponded to the different conditions. Colour is here the incidental cue. Hence the subjects were not aware in which condition they were in. In the *same context condition* the incidental cues were equal to those in the practice phases. Therefore the yellow sequence was presented in yellow colour whereas the blue one was presented in blue colour. As the name already indicates the incidental cues in the *switched context condition* were switched. The yellow coloured sequence in the practice phases was presented in blue colour in the test phase and vice versa. In the *intentional-only context condition* subjects were stimulated only by red sequences, which followed after the initial blue and yellow sequences during acquisition. Thus the incidental cues were completely changed. Participants were instructed to respond as fast and as accurately as possible. Feedback was given after the end of a response sequence when the participant reacted before the go/no go signal, or when a false button press was conducted. At the end of each block the subjects were given information about their progress (in RT and correct responses).

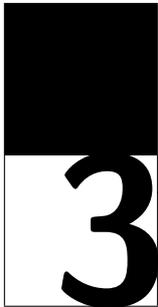
## 2.5 Procedure

Participants were seated in front of the microcomputer and asked to read the given instructions carefully before starting the experiment. In the short practice condition participants started with the practice block which lasted about 20 minutes. Within the 20 minutes there was a 30 sec break after ten minutes of practice. Each practice block consisted of 100 go and 20 no/go trials. After participants finished the practice block the researcher had to start the test block on the computer, which was made up of ten go and two no/go trials.

The procedure in the long practice condition was similar to the one in the short practice condition except for the fact that the researcher had to start the practice

program five times in total instead of only one practice session. Furthermore due to the condition in which the subject was, the researcher started one of the three test conditions. After the subjects had finished the test they were asked to fill in a questionnaire. This was an additional measure of the experiment. The questionnaire was divided into three parts. The first part included recall strategies where the subjects had to name the two practiced sequences off the top of their head. The second questionnaire asked the participants to choose the sequences out of twelve given choices. Thus recognition was the requested aspect here. Finally the third questionnaire consisted of additional questions such as retrieval cues participants used to memorize.

Finally the researcher thanked the subjects for participating and those who were registered in the student system of the University of Twente received their credit points

A large, bold, black number '3' is centered within a white square. The top half of the square is filled with black, creating a high-contrast graphic element.

## Chapter 3

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# Results

Performance was measured in correct responses (PC) and RT. A correct response was defined as the subject pressing the appropriate keys in the correct order right after the occurrence of the DSP go/signal [cross turning blue]. Reaction time was assessed as the six intervals the subject needed in between pressing the relevant six keys in order to render the previously shown sequence. The first interval being the period of time that passed between the appearance of the go/nogo signal and the subject pressing the first key. The other intervals being the periods that passed in between the subject pressing each of the five subsequent keys. Mean PC and RT were calculated for each subject for each of 1 or 5 trial blocks during acquisition and for the one trial block during retention.

## 3.1 Acquisition

For the mean PC an ANOVA with repeated measures on practice blocks (5) was used.

The analysis of PC during acquisition revealed a significant effect of practice blocks with  $F(4, 92) = 19.336, p < .01$ . Going into more detail it can be seen that the main reason for this significance can be attributed to changes between the first and the second practice block. Comparing the Mean PC of the practice blocks with  $M1 = 89.6, M2 = 96.5, M3 = 96.3, M4 = 96.7$  and  $M5 = 96.2$  underlines this assumption.

For the acquisition a ANOVA with repeated measures on keys (6) and practice blocks (5) was used for the RT.

The analysis of acquisition blocks for RT revealed a significant effect of practice blocks with  $F(4, 88) = 11.55, p < .01$ . This was done by evaluating the progress from one practice block to the next, seen in the below Figure 1. As shown the Mean RT decreases along with an increase in practice. Regarding the mean RT's for the practice blocks with  $M1 = 587.5, M2 = 275.9, M3 = 238.2, M4 = 222.2$  and  $M5 = 217.6$  gives an inside in how this effect is expressed. The RT stagnates from practice block 2-5 which can also be seen in Figure 1. This effect is comparable to the one of mean PC of practice blocks.

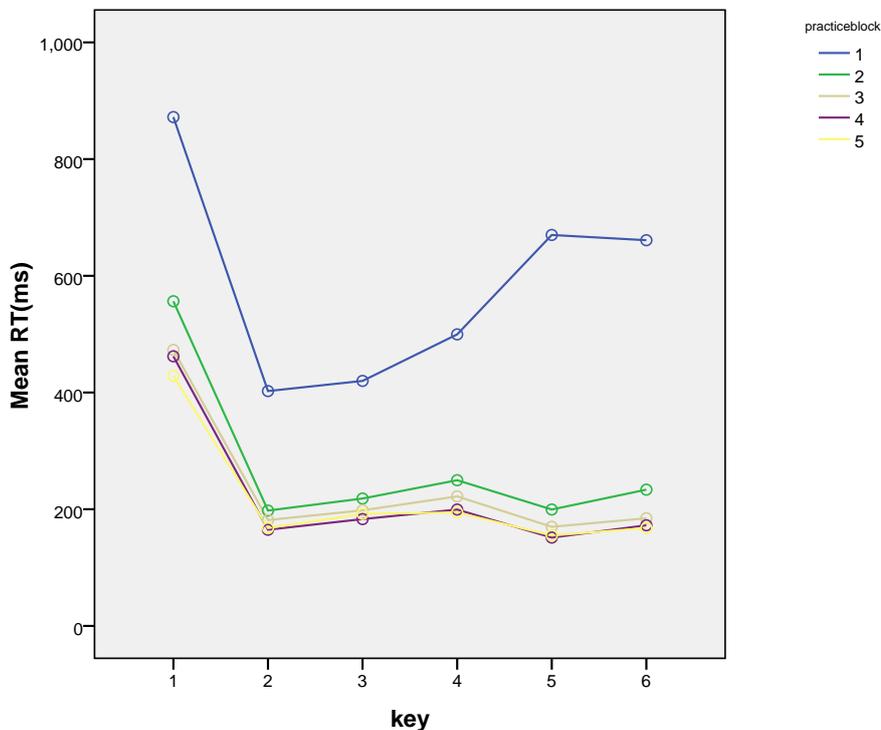


Figure 1: Reaction Times per Key during Acquisition.

Furthermore the analysis of acquisition blocks for RT revealed a significant effect of key, with  $F(5, 110) = 14, 639, p < .01$  indicating the fact that the time needed for pressing the first key took far longer than the time it took for pressing the other five keys (Figure 1).

An interaction between key and practice block was not found.

## 3.2 Retention

For the retention a One way-way ANOVA was used to test the effects on PC.

The analysis of mean PC from retention block failed to reveal any significant results for both the effect of test condition with  $F(2, 42) = 0.908$  and  $p > .05$  (.388) and the effect of practice with  $F(1, 42) = 2.343$ . The overall Means of the different test conditions with  $M = 96\%$  for same context,  $M = 94\%$  for intentional context and  $M = 92\%$  show that, although there is a difference, it is very small and thus can be due to chance.

For the RT a 2 (short versus long practice) x 3 (same/ switched/intentional test) ANOVA with repeated measures on the keys (6) was used.

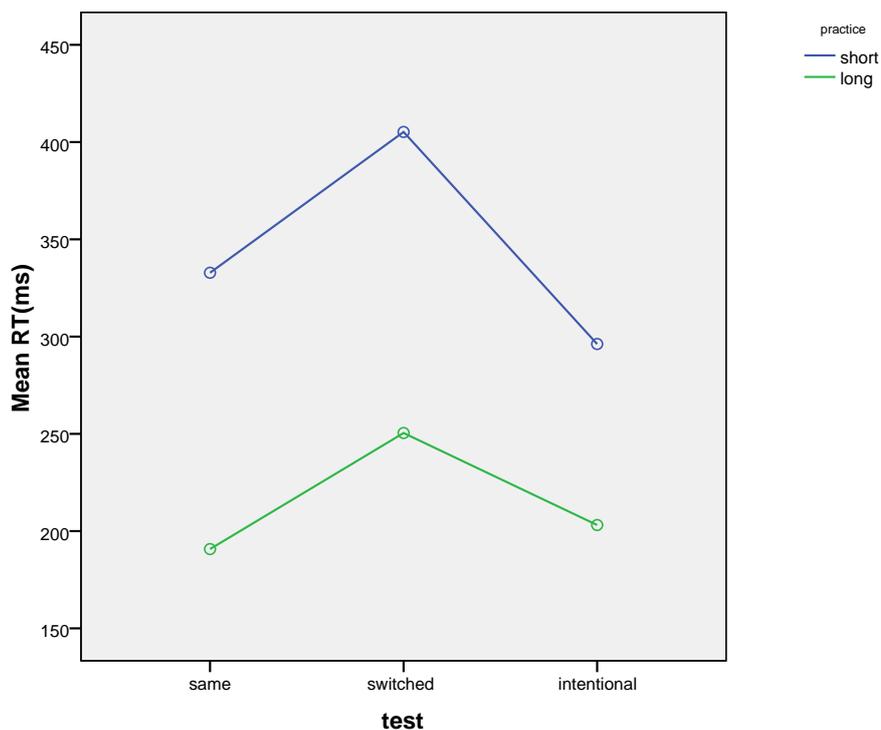


Figure 2: Mean RT during Test Block.

The analysis of RT data revealed a significant effect of practice with  $F(1, 42) = 22.613$  and  $p < .01$  with an  $M = 214.778$  for long practice and  $M = 344.736$  for short practice as can be seen in Figure 2. In all conditions the subjects score lower in RT when having sufficient prior practice.

The effect of test context has a strong affinity towards being significant with  $F(2, 42) = 3.159$  and  $p = .053$ . This leads us to have a closer look at the differences between the test conditions. As seen in Figure 2, the switched context does have higher a RT in both low practice and short practice condition than do the other test conditions.

Thus three separate ANOVA's are conducted to have a view on the difference between the single test conditions.

To compare the same and switched test condition we tested one sided due to the specific expectation that same context condition will score lower in RT. This expectation was supported by revealing a significant effect with  $F(1, 28) = 3.212$  and  $p = .042$  (two sided:  $p = .084$ ) as also seen in Figure 3.

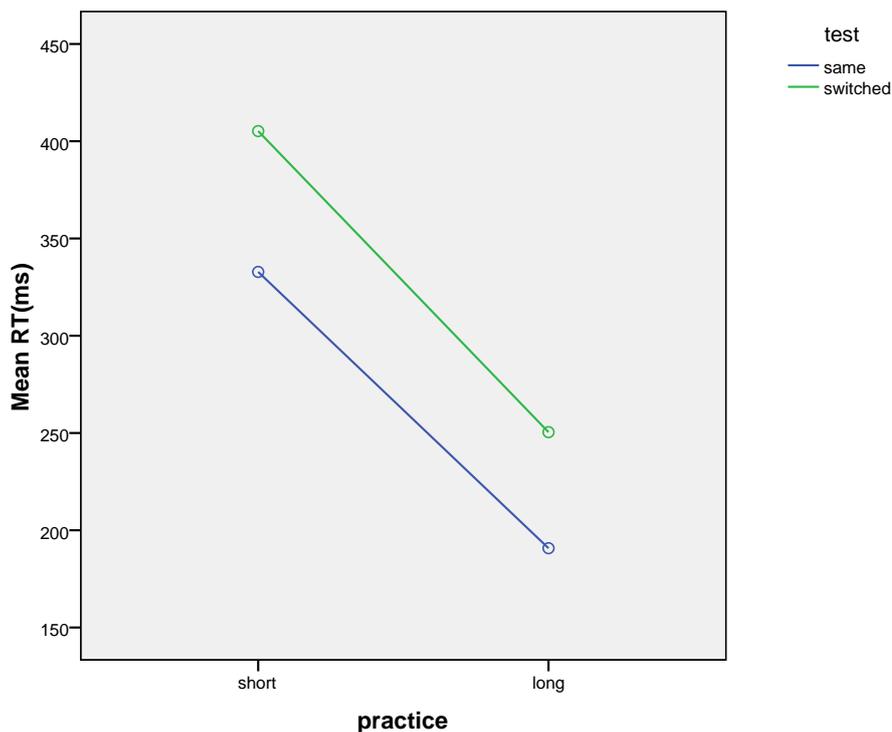


Figure 3: Same vs. Switched Test Condition.

In addition a very significant effect was found when comparing the switched and intentional test conditions with  $F(1, 28) = 6.611$  and  $p < 0.05(0.016)$  (Figure 4).

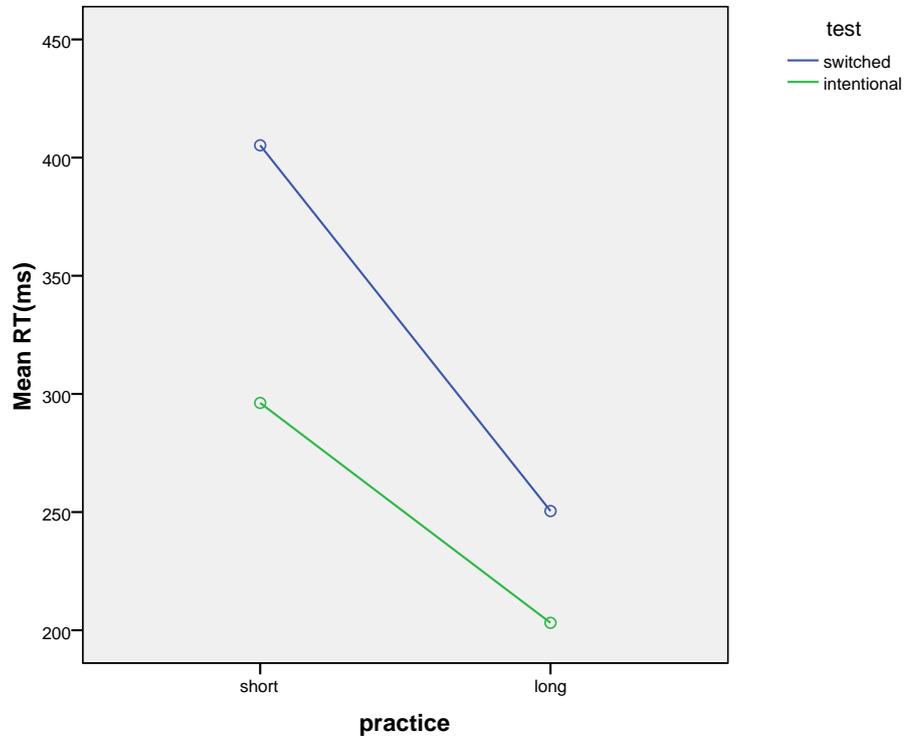


Figure 4: Switched vs. Intentional Test Condition.

As seen in Figure 5 the difference between the same context and intentional context is not of significance with  $F(1, 28) = 0.136$  and  $p > 0.05(0.715)$ , meaning that they do not significantly differ in RT.

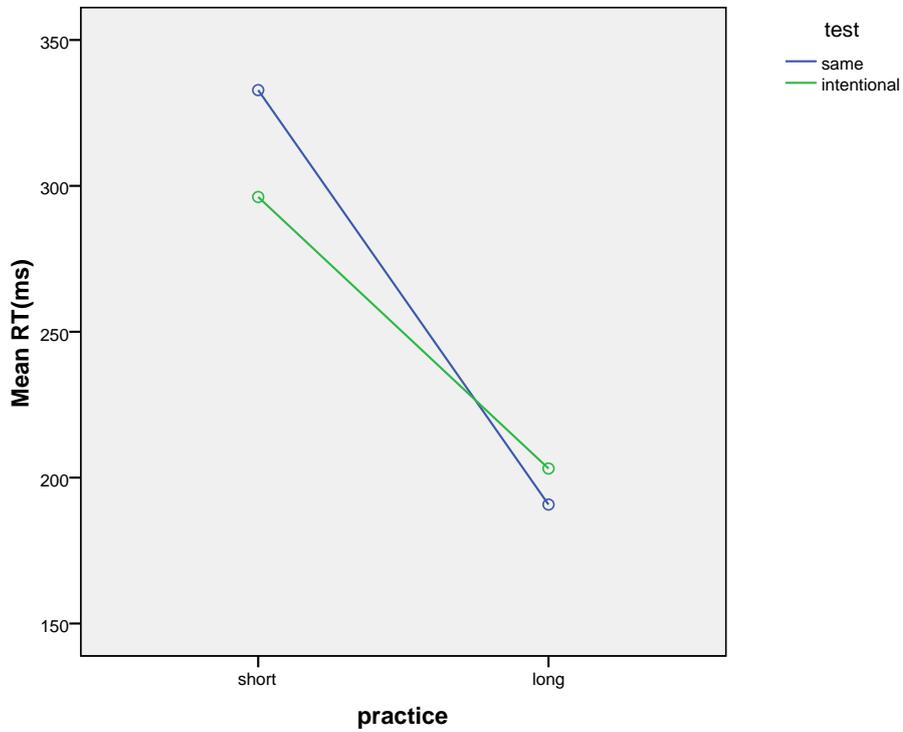


Figure 5: Same vs. Intentional Test Condition.

### 3.3 Questionnaire

Analysis of the questionnaire revealed that practice has a significant effect on both recall with  $F(1, 42) = 5.6$   $p < .05$  and  $M = 1.583$  for short practice and  $M = 1.917$  for long practice. The same is true for recognition with  $F(1, 42) = 6.0$   $p < .05$  of the 2 fixed sequences. This means that through extensive practice the recognition as well as recall becomes better. As one would expect recognition scores slightly better than recall in any case (Table 2).

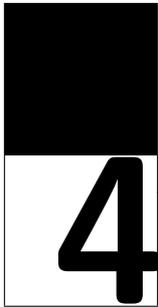
Recall	Recognition	Practice
1.583	1.667	short
1.958	1.987	long

Table 2: The overall Means for Recall and Recognition.

Context condition on the other hand neither influences recall nor recognition. It was found that there is a positive correlation between recall and recognition with  $r = .613$ . In the below Table 3 the percentage of correct remembered sequences is shown, indicating that recognition reveals slightly better results than does recall.

Sequences	Recall	Recognition
None Correct	4.2%	2.1%
One Correct	16.7%	14.6%
Both Correct	79.2%	83.3%

Table 3: Questionnaire's Percentages of Correctly Remembered Sequences.



## Chapter 4

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# 4 Discussion

The primary purpose of the study was to find out whether context had a significant effect on perceptual motor learning and if so how it would be expressed. Initially then it was of interest if and how practice had its effects on this issue. To extend this idea it was intended to see whether practice is a mediating factor of context in terms of the different context-test conditions.

Inspection of RT data revealed that practice affects perceptual motor learning significantly. RT decreased with increasing practice. This effect, however, stagnated after the second practice block. As expected, the changing context situations revealed significant results that were in line with former studies (Wright and Shea, 1991). During retention, switched context condition expressed longer RT opposite to intentional-only and same context condition.

However, against former assumptions the difference in RT between same context and intentional-only context was not one of significance. Interestingly no interaction was found in RT between practice and context. The PC data underlined our expectations. As it was the case in former studies PC data revealed no significant effect for changing context. Instead the amount of practice had a strong influence on performance. Not surprisingly the effect was very similar to the one in RT data; Performance increases with increasing practice. Again, this effect stagnated after the second practice block. In all of these conditions a significant effect of key was found. Evidently, RT before the first key press was eminently longer than subsequent ones.

Regarding Verwey's(1996) theory of motor chunks, this effect is not surprising.

Verwey(1996) found out that in a DSP task the response to the first item of a chunk slowed. This explains why the first item took longer to respond to. Furthermore the *dual processor theory* underlines this effect as it states that initial movements have high demands on the cognitive processor. This is why reaction time is expected to be longer for the first item of a sequence.

The effect of practice, which was found in the present study also reveals support for the dual processor theory. As already mentioned the cognitive processor plans the movement whereas the motor processor executes it. With extensive practice the load on the cognitive processor becomes less as motor chunks develop and sequences become more familiar. Hence RT will slow down and performance will become better. As expected, this effect was found in our study and shows how practice enhances perceptual motor learning.

In line with former studies concentrating on the influence of context on motor learning, we expected an effect on context in all conditions. As seen above this hypothesis could not be confirmed albeit significant effects of context were found when context situation was switched. This is in line with findings of Wright and Shea (1991) as well as Anderson, Wright and Immink(1998). They suggested, that "early in learning subjects have poorly specified memory networks that do not include separate associations between intentional and incidental information and the appropriate responses. It is when subjects are sufficiently practiced or encounter relatively simple responses that these direct associations are made, and the intentional and incidental cues can act independently as retrieval cues to support retention. To extend this thinking, one might argue that in the absence of such direct associations between the intentional stimuli and the incidental stimuli to the task-specific information, the subject may be forced to use relatively greater data-driven processes in order to produce the correct response." (Anderson, Wright, Immink , 1998, p.220)

However, this leaves us wondering why in spite of extensive practice, our study displays a significant increase in RT during switched context condition. On the other hand it was surprising that no significant difference was found between intentional-only and same context condition. This might also be due to the formation of motor chunks. Verwey(2001) concluded that chunks are robust, meaning they can also be

used in different situation than the one they were practiced in.

This explains why the effect between intentional-only and same context condition was not of significance. Obviously one practice block must have been sufficient to create motor chunks which then could be used in any situation for retrieval. However, as we noted above this was not true when context situation switched. The only explanation for the development of context dependency when context is switched and practice is sufficient might be, that although extensive practice is given motor chunks might lose their robustness when the contextual situation is not as strictly different as it is in e. g the intentional-alone situation. This assumption could be prone to future study, concentrating on this finding in closer detail.

Finally an effect of practice was found on both recall and recognition strategies of the subject's memory. Test condition on the other hand did not affect any of the two. In addition a positive correlation between recognition and recall was found. This was not surprising since remembering sequences by heart should likewise enable us to make the right choices of sequences out of twelve possibilities.

In summary the present study provides a demonstration that development of context dependent memory for stimuli, which are not explicitly identified to be critical to task learning, can develop in the perceptual motor domain. Further it can be concluded that practice positively affects memory performance in any case although it does not interact with context. Hence it cannot be assumed that practice operates as a mediating factor in the development of context dependent memory in the perceptual motor domain.

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# Thesis declaration

I hereby declare that the whole of this bachelor thesis is my own work, except where otherwise stated in the text or bibliography. This work has not been submitted in similar or identical form, in whole or in part, for any other degree.

Münster, den

Nadiya El-Sourani