Investigating the Influence of Chunk Switching on Motor Skill Learning Outcome Differences between Random and Blocked Training Schedules

by

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Bachelor Thesis

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Abstract

Motor skill learning research often investigates the effect of *contextual interference* (CI) on learning outcomes. In this field, traditionally differences between *random practice* (RP) and *blocked practice* (BP) learning outcomes are examined. RP training schedules have been associated with a high CI environment and as a result usually show less improvement over time but better retention than BP training schedules. Motor sequences are chunked such that several smaller pieces of information are integrated into a single larger one. This way a motor sequence can be executed faster. Theoretical interpretation suggests that switching between motor chunks creates a high CI environment. This would occur in sequences where more than one chunk exists. The present paper aimed to examine whether sequences long enough for chunk switching to occur would create high CI such that differences between BP and RP training schedules can be neglected. The findings suggest that by using appropriately long sequences, differences between RP and BP training schedule learning effects do not significantly differ. This would indicate that RP and BP training schedules produce similar learning effects with sequences long enough. Further, this provides a possible way to control improvement and retention effects by changing the length of sequences.

Introduction

Motor skills are essential in everyday life. Driving a car, cooking, or even brushing one's teeth in the morning would not be possible – at least in their current form – without the capability to learn motor skills. This begs the question of how the acquisition of motor skills functions and whether there is a way to facilitate it. The following introduction will first explore the human's control of automated behavior and subsequently the importance of investigating the workings of motor sequence learning. Next, a method of studying motor sequence learning will be described and outcomes found in recent literature will be discussed. Lastly, the goals and expectations of the present study will be presented.

Automated behavior describes behavior which does not require as much conscious control as non-automated behavior. Such an effect is often observed in repeatedly practiced (motor) skills. This contradictorily named "conscious automaticity" allows for fluent motor actions and sequences for which it is not necessary to consciously guide every single action (Wheatley & Wegner, 2001). This indicates that repeated practice of motor sequences leads to an improvement in the ability to reproduce a sequence efficiently. It should be noted at this point that the term motor sequence learning, in the present paper, is used in concordance with the definition given by Abrahamse, Ruitenberg, de Kleine & Verwey (2013), where it is described as learning to reproduce a sequence of motor activities based on repeated training.

Contextual interference in discrete sequence production tasks

The *contextual interference* (CI) *effect* describes the phenomenon that interference during practice is constructive to (motor) skill acquisition. Thus, when discussing the acquisition of motor skills, consideration of CI seems reasonable. High levels of CI are found to lead to better learning than lower levels of CI (Magill & Hall, 1990). CI effects in motor skill acquisition can be measured using *discrete sequence production* (DSP) *tasks* with random practice (RP) and blocked practice (BP) training groups (Kim, Verwey & Wright, 2017). During DSP tasks, participants are usually presented with series of 3-7 to-be-reproduced stimuli which result in a keypress sequence that is subsequently counted as a single response. The DSP task traditionally features a practice/acquisition phase and a test/retention phase (Abrahamse *et al.*, 2013). The stimuli can then be presented in either an RP training schedule or a BP training schedule. The RP training schedule involves several motor sequences, presented in random order, which are then reproduced. This provides a continuously changing task in which the participants must keep switching between a number of sequences. The BP training schedule, on the other hand, presents one motor sequence repeatedly before moving on to the next (Kim *et al.*, 2017). This creates a high CI environment for RP tasks and a low CI environment for BP tasks.

Motor chunks

It is assumed that motor sequences can be grouped into so-called *motor chunks* as integrated memory representations (Abrahamse *et al.,* 2013). Chunks are described as items that have been grouped and can subsequently be used as a single unit (Mathy & Feldman, 2012, p. 346), thus integrating smaller pieces of information into a single larger one. Chunking allows for the circumvention of known information processing limitations of human cognition (Verwey, 1999).

For motor chunks, however, it would not be reasonable to assume an infinite possible size. If one assumes a finite motor chunk size, longer motor sequences should not be stored as a single motor chunk, but as a number of motor chunks depending on the size of the sequence. And indeed, empirical data demonstrates that sequences with 6 stimuli, show relatively slow half-way points, so-called concatenation points, which indicate a switch between motor chunks. For sequences with less than 5 stimuli, this concatenation point is not usually observed (Abrahamse *et al.,* 2013). This suggests the existence of only a single chunk and thus no switching of motor chunks for sequences of this length. It was further found that motor chunks can become associated after repeated practice, leading to initial motor chunks priming following motor chunks in a practiced sequence, which indicates that concatenation time can decrease with practice (Abrahamse, Jimenez, Verwey & Clegg, 2010; Verwey, 2009).

The present paper

Recent unpublished research suggests that with 3-key sequences, there is a difference in improvement as well as in retention between RP training groups (high CI) and BP training groups (low CI). RP groups showed less improvement, but better retention after practice than BP groups. These results, however, could not be shown with practice groups that practiced each sequence for an extended amount of trials, in comparison to the smaller number of trials initially used (Kim *et al.,* 2017). One could argue however that with longer sequences, due to greater chunking and thus in turn switching between motor sequences, a BP training schedule might create a high CI environment as well. Should this prove to be true, it would be possible to achieve similar results in BP training groups as in RP training groups using long sequences, where switching between motor chunks occurs.

The present study aims to investigate differences between RP and BP training schedule learning effects using longer sequences than previously studied, i.e. where switching between motor chunks occurs. Similar BP training group results as with RP training groups would support the assumption that a CI increase due to switching between motor chunks negates differences in learning between training schedules to an extent. To investigate this matter, the present study employs a 2-Day 7-key DSP task focusing on limited practice with 3x24 practice trials on Day 1 and four different 3x12 test trials on Day 2. Day 1 presents an acquisition/practice phase, whereas Day 2 presents a retention/test phase. Such a design seems convenient as for this amount of (limited) training, as there already exist results in recent research that can be used for comparison (*cf.* Kim *et al.,* 2017). Inferring from the discussed current research on this topic, it is expected that using a 7-key sequence leads to a high CI environment for both BP and RP training groups, such that learning results do not differ.

Method

Participants

In total, 24 participants (n=11 males, n=13 females) were sampled by convenience sampling. These included students of the University of Twente and their acquaintances. Special attention was given to the fact that potential participants should be right-handed and non-smokers. This would allow for better comparability and to preempt decreases in cognitive motor performance due to physical and psychological nicotine dependence induced withdrawal symptoms respectively. Participants were, at this stage, notified that they should not have consumed any alcohol 24 hours prior to the experiment. Participant' ages ranged from 18 to 29 (*M*=22.27, *SD*=2.86). All participants had no previous experience with the experimental tasks they would be presented with. Each participant signed an informed consent before the experiment. Upon completion of the experiment, participants that were students of the University of Twente were compensated with a confirmation of participation in the form of digital points that contribute to their study programme's credit points. Before the start of the experiment, ethical approval was granted by the ethics committee of the University of Twente.

Apparatus and Materials

The present study made use of a computer-assisted experiment and a pen-and-paper questionnaire. For the sequence acquisition and retention phases, as well as for the digital part of the awareness test, a computer application for participant instruction, sequence presentation, and participant user input collection was developed using E-prime (version 2.0, Psychology Software Tools). This application was executed on a Dell OptiPlex 7050 PC running Windows 10 (Version 1809, October 2018). For participant-computer interaction, a 144Hz, 1080p AOC FreeSync Monitor, a simple optical Dell MS111 mouse, and a Logitech Deluxe 250 PS/2 keyboard were used. An informed consent form and initial participant instruction were presented in a simple pen-and-paper format (see Appendix A; Appendix B).

The task

The task consisted of discrete sequence production (DSP) sequences presenting stimuli and waiting for a predetermined response in the form of keyboard input in return. Four placeholders were distributed horizontally across the computer screen (see Figure 1B). This distribution corresponded to the horizontal layout of the keys ‘c’, ’v’, ’b’, and ‘n’ on a standard western computer keyboard, such that the left-most placeholder corresponds to key ‘c’ and the right-most placeholder to key ‘n’. A sequence was executed by marking each placeholder either green or white (with white being the default and the background color for the application window) such that only one placeholder at a time would be marked green. The participants were instructed in advance to always press the specific computer key corresponding to the placeholder colored green. Further, participants were asked to only use the index, middle, ring, and little finger of the right hand, for the corresponding keys ‘c’, ‘v’, ‘b’, and ‘n’, respectively (see Figure 1A).

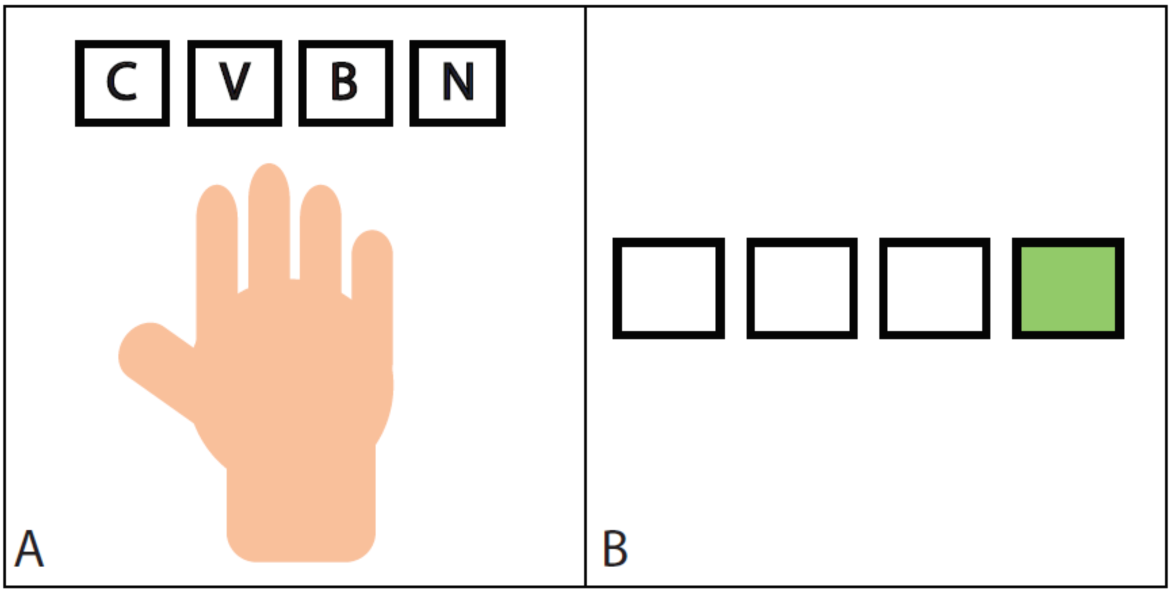

Figure 1. Illustration of the experimental setup. (A) shows computer keys ‘c’, ‘v’, ‘b’, and ‘n’ in relation to the corresponding fingers of the right hand. (B) shows an example still image of the task presenting the four placeholders.

The application consisted of four sequence blocks in either an RP schedule or a BP schedule. Blocks 1-3 were used as a motor skill acquisition phase and Block 4 to test retention. Each block of the acquisition phase consisted of 24 trials and three possible sequences. In the BP training group, each block presented a specific sequence, whereas in the RP training group, each block presented all three possible sequences in random order. The participant-training group and participant-sequence matching for the BP training group (see Table 1A) and for the RP training group (see Table 1B) were predetermined.

Table 1

(A) Participant Sequence Matching of the BP Training Group

Participant number	Block1	Block 2	Block 3	Novel sequence[a]
1,9,17	vcbncvn	nvcbvnb	bnvcnbc	cbnvbcv
2,10,18	nvcbvnb	bnvcnbc	cbnvbcv	vcbncvn
3,11,19	bnvcnbc	cbnvbcv	vcbncvn	nvcbvnb
4,12,20	cbnvbcv	vcbncvn	nvcbvnb	bnvcnbc

[a]The novel sequences were presented in addition along with the three sequences from Blocks 1-3 in the retention phase, *i.e.* Block 4

(B) Participant Sequence Matching of the RP Training Group

Participant number	Recurring sequences[a]	Novel sequence[b]
5,13,21	vcbncvn, nvcbvnb, bnvcnbc	cbnvbcv
6.14.16	nvcbvnb, bnvcnbc, cbnvbcv	vcbncvn
7.15.23	bnvcnbc, cbnvbcv, vcbncvn	nvcbvnb
8.16.24	cbnvbcv, vcbncvn, nvcbvnb	bnvcnbc

[a]All of the recurring sequences for a participant are presented in each of the three acquisition blocks, *i.e.* Blocks 1-3, in a random order.

[b]The novel sequences were presented in addition to the recurring sequences in the retention phase, *i.e.* Block 4

The fourth block was special as it was a test block containing sequences from the previous three blocks and one additional sequence (see Table 1A; Table 1B). This block also eventually showed sequences where only the first stimulus was presented. All blocks and their tasks came with prior instructions.

Awareness Test

The awareness test consisted of a digital and a pen-and-paper part. The digital part presents after one another, the horizontally aligned four placeholders also presented during the task (see Figure 1), and 4 four additional placeholders, each containing one of the letters ‘c’, ‘v’, ’b’, and ‘n’. In the latter case, the placeholders containing letters are aligned in a diamond shape (see Figure 2). Either way, the placeholders were to be selected with the computer mouse in an order corresponding to the presented sequences of the blocks of the task. Afterwards, the participant was asked questions about how they think they remembered the sequences, about their age, and whether they did or did not look at the keyboard during the test. Each task of the digital awareness test came with its own set of instructions.

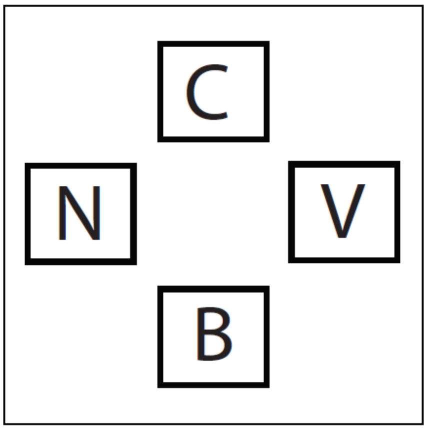

Figure 2. Diamond shape presentation of placeholders with letters representative of one of the tasks of the digital awareness test.

The pen-and-paper awareness test (see Appendix C; Appendix D) was quite similar to the digital part. At the start, participants were asked a number of demographic questions. Following, the participants were tasked to write down the sequences they practiced during the task. For each sequence, the participant had to mention their certainty regarding the correctness of the sequence at hand. This was done on a scale of 1 (unsure) to 10 (entirely sure). Afterwards, participants were, here as well, asked about how they think they remembered the sequences and whether they have already participated in such a study before. At the end, the participants were given the opportunity to note down remarks about the study. The data from the awareness test were not analyzed in the present thesis.

Procedure

During participant sampling, the participants were already informed that they would be participating in a 2-day study about motor learning. Upon arrival in the laboratory, it was explained to the participants that this experiment would be aimed at understanding how people learn movement skills and that the participant's results were to be compared with those of other participants. They were further informed about the organizational structure of the experiments, namely that the experiment was made up of four so-called blocks, three on Day 1 and one on Day 2, and that there would be a four-minute break after each block. It was further explained that participants were free to use the break as they wanted, but that they could not use their mobile phone and in fact, would be asked to give it to the experimenter for the time being. Additionally, the participants were urged to try to react as fast as possible without making a lot of errors (preferably less than 8%). They were further informed that the experiment would take longer if they made more errors. After instruction, the participants were asked to sign the pen-and-paper consent form.

The experimenter would then start block 1 of the task for the given participant number and leave the room. At this time, it was pointed out to the participants that the experimenter would be right outside the room in case any questions or problems would arise. After each post-block four-minute break, the experimenter would start the following block of the task.

When all three blocks of Day 1 were finished, the experimenter would start the digital awareness test and explain to the participants that they now had to reproduce the previously practiced sequences with the mouse and without stimuli in form of green-colored blocks *i.e.* placeholders. Prior to starting the test, the experimenter would also cover the keys ‘c’, ‘v’, ‘b’, and ‘n’ of the computer keyboard with a piece of paper. This way, participants would have to freely recall the keys that were used, and in which order they are found on the keyboard. Afterward, the pen-and-paper awareness test was handed out to the participant. Here it was noted that participants should not fill out their name on the paper. During the entire awareness test (digital and pen-and-paper), the experimenter would stay in the room with the participant to make sure that everything was done correctly, the participant did not look at the keys ‘c’, ‘v’, ‘b’, and ‘n’, and answered all questions.

At the end of Day 1, participants were reminded to show up for Day 2. Day 2 followed the exact same procedure, with the difference that instead of Blocks 1-3, only Block 4 and the awareness test had to be completed.

Results

To verify the assumption of homogeneity and the assumption of sphericity, Levene- and Mauchly-Tests were used respectively. The assumption of homogeneity was met for all analyses. In some cases, the assumption of sphericity was not met. To compensate for this, the Greenhouse-Geisser correction for the F-statistic was used in these cases.

Acquisition Phase

For the analyses of both reaction time and error for the acquisition phase, *i.e.* Blocks 1-3, 2 (Training Group) x 3 (Block) x 7 (Key) mixed ANOVAs with repeated measures on the last two factors were used.

Reaction Time

For each Block, the reaction time for each Key of each participant was analyzed as stated above. Figure 3 shows the change in mean reaction time across acquisition blocks for both training groups.

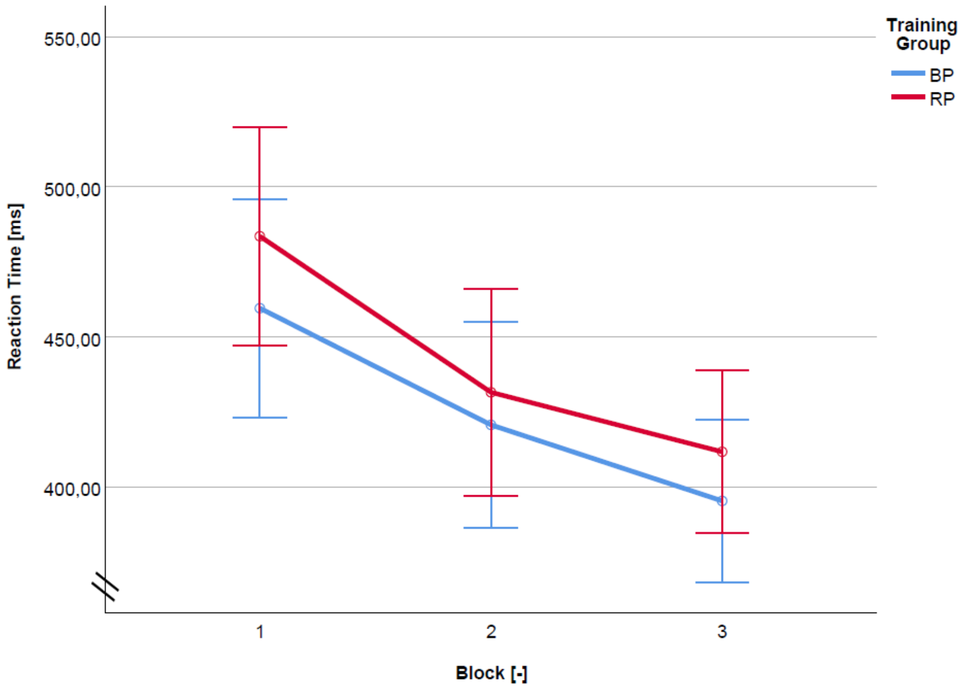

Figure 3. Mean acquisition phase reaction time as a function of Block for Blocked Practice (BP) and Random Practice (RP) training groups. The error bars show the standard error of the mean (SEM).

A significant main effect of Training Group was not found, F(1,22)=0.15, *p*=.706, indicating no significant difference between Training Groups. The analysis further showed a significant main effect of both Key, F(6,132)=9.85, *p*<.001, η_p^2=.31, and Block, F(2,44)=18.86, *p*<.001, η_p^2=.46. Reaction time values for Keys also did not differ significantly from each other as a function of Block, F (12, 264)=1.24, *p*=.304. Furthermore, no interaction effects of Key and Training Group, F(6, 132)=1.09, *p*=0.358, and no interaction effects of Block and Training Group were found, F(2, 44)=0.17, *p*=0.785. Thus, the data shows a decrease in mean reaction time across blocks (Figure 3). Differences between reaction time for Keys, furthermore, stayed consistent across Blocks. These results were found to be similar between both Training Groups.

Error

Pressing a key not corresponding to the given stimulus was counted as an error. No significant main effect of Training Group on error could be observed F(1,22)=.95, *p*=.341. Further, while this analysis, again, showed a significant main effect of Block, F(2,44)=6.86, *p*=.003, η_p^2=.24, the effect of Key was suggested to not be significant, F(6,132)=1.73, *p*=.120. This analysis suggests a significant decrease of error after Block 1 (see Table 2), but no significant changes in differences of error between Keys.

Table 2

Descriptives of error [%] during acquisition phase

	M (*SD*)	
	BP (n=12)	RP (n=12)
Block 1	1.19 (1.29)	1.83 (0.89)
Block 2	0.82 (1.10)	0.71 (0.69)
Block 3	0.92 (0.82)	1.03 (0.96)

Note. M and *SD* represent mean and standard deviation respectively. Values are rounded to 2 decimals.

Retention Phase

For the analyses of the retention phase, *i.e.* Block 4, 2 (Training Group) x 7 (Key) mixed ANOVAs with repeated measures on the last factor were used.

Reaction Time

Regarding reaction time, a significant main effect of Key was found, F(6,132)=11.36, p<.001, η_p^2=.34. No significant main effect of Training Group on reaction time, however, could be observed, F(1,22)=.011, p=.919. Additionally, again, no significant interaction effects of Training Group and Key, F(6, 132)=0.59, p=0.793, have been found. This suggests no significant difference in retention in terms of reaction time in the BP and RP Training Groups. Figure 4 shows the difference between mean reaction times across all 7 Keys for both Training Groups. To improve visual clarity, Figure 4 does not display error bars. Information on standard deviation and standard error of the mean can be found in Table 3.

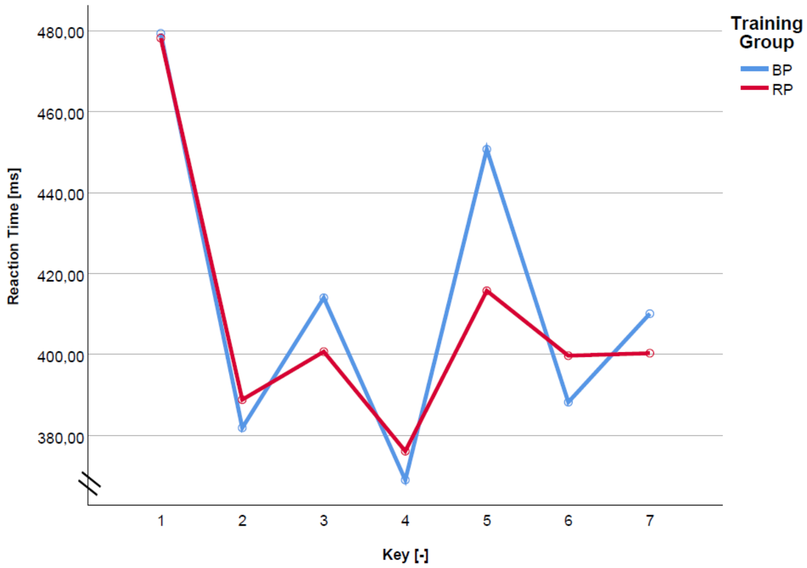

Figure 4. Mean retention phase reaction time as a function of Key for Blocked Practice (BP) and Random Practice (RP) training groups.

Error

The error analysis of Block 4 showed a significant main effect of Key, F(6,132)=2.49, p=.026, η_p^2=.102, and no significant main effect of Training Group, F(1, 22)=0.39, p=.540. Further, no significant interaction effect of Key and Training Group was found, F(6, 132)=0.52, p=.793. Table 3 summarizes descriptive retention phase data of reaction time and error for both Training Groups.

Table 3

Descriptives of reaction time [ms] and error [%] during retention phase

	M (*SD*) (*SEM*)	
	BP (n=12)	RP (n=12)
RT	413 (128.02) (36.96)	408 (97.09) (28.03)
Error	1.64 (1.43) (0.41)	1.38 (0.96) (0.28)

Note. M, SD and SEM represent mean, standard deviation, and standard error of the mean respectively. The descriptives are displayed for Blocked Practice (BP) and Random Practice (RP). Decimal values are rounded to 2 decimals. RT = reaction time.

In summary, the data suggest that both reaction time and error values for BP and RP groups did not differ significantly during the acquisition phase, as well as, the retention phase. Reaction times depended significantly on the specific Key pressed. Furthermore, a learning effect across blocks was found. The error analyses provide no reason to assume a speed-accuracy trade-off.

Discussion

A big part of contextual interference literature is focused on the differences between random practice (RP) and blocked practice (BP) training schedules, often using rather short motor sequence lengths (*cf.* Broadbent *et al.*, 2017; Boutin & Bladin, 2010; Lee & Fisher, 2019). Insight into motor chunking, however, promised a new twist on the topic: the influence of chunk switching on the CI environment (*cf.* Abrahamse *et al.*, 2013). The present study was mainly aimed at investigating whether the switching between motor chunks observed in long sequences does create a high CI environment in BP training schedules such that RP and BP learning differences are negligible. To examine this, a 2-Day DSP task with 7-key sequences was employed. In line with current research mentioned in the beginning of the present paper, BP learning effects were expected to be similarly to RP learning effects. Indeed, the data suggests that by using 7-key sequences, which were according to the literature expected to show multiple chunks and in turn switching between motor chunks (*e.g.* Abrahamse *et al.*, 2013), acquisition and retention effects seem to not depend on the training schedule. Considering this, BP training schedule effects seem to indeed be very similar to RP training schedule effects, when the sequences are sufficiently long for multiple chunks to occur. In turn, this implies that with longer sequences in a BP training schedule, improvement would decrease, and retention would increase compared to shorter sequence-BP training schedules (*cf.* Kim *et al.,* 2017). A result of these findings is that it should be possible to control improvement and retention by just varying sequence lengths of BP training schedules without the need to change training schedules.

Limitations and possible improvements

Further research in the field of motor skill learning has found a difference in learning outcomes between Random Practice (RP) and Blocked Practice (BP) training schedules when exposed to changes in the environment post-acquisition phase. BP groups showed a bigger decrease in performance than RP groups after a change of environment, such as for instance different representations of the tasks in terms of design or location (Lee & Fisher, 2017). These results pose the question whether the findings of the present study would differ given a change in environment for the retention phase. Further, this could pose problems regarding the application of the present study's findings in real-world motor skill learning scenarios. Regarding the results of the present thesis, it is expected that RP and BP training schedule learning outcomes should also behave similarly given environmental changes. However, it does seem reasonable to investigate this matter in further research.

Additionally, the present study focused solely on right-handed participants. This is among other factors favorable in order to facilitate comparability within the motor skill learning research environment. Right-left differences, however, should not be discounted. Several studies have reported differences between left- and right-handedness across various topics. Primate species often show general left-right differences (Hopkins, 2018), also movement imaginary seems to be affected by handedness (Donoff, Mada & Singhal, 2018). Furthermore, handedness seems to for instance affect the ability of pianists to adapt to change in motor mappings (Smit & Sadakata, 2018). Considering that handedness seems to have an impact on several skills associated with motor actions, it seems reasonable to consider investigating left- vs. right-handed RP and BP training group differences in different presumed CI environments. Different results as the literature provides for right-handed participants could indicate different CI loadings or even different effects of high vs. low CI on acquisition and retention of motor skills.

Finally, studies have often reported increased neuroplasticity for motor skills in musicians compared to non-musicians (*cf.* Wu, Hamm, Lim & Kirk, 2017; Johansson, 2006). A particular study, for instance, found musical training-induced changes at, among other areas, the left hippocampus, the right insula, and the supplementary motor area (Groussard, Viader, Landeau, Desgranged, Eustache & Platel, 2014). These findings indicate possible differences in motor learning and memory. It should thus prove interesting to examine differences in acquisition and retention in BP and RP training schedules between musicians and non-musicians. Following, CI effects in musicians compared to non-musicians could be investigated. It could be interesting to see whether there is a difference in CI effects on learning and retention in musicians, who may have more practice learning motor sequences, compared to non-musicians. Regarding the present study, data on whether participants are in fact musicians or not was not recorded, thus potential differences between musician and non-musician participants could not be accounted for.

Conclusion and implications for further research

To conclude, the present study suggests that with 7-Key DSP tasks, Blocked and Random Practice training schedules have the same effect on learning and retention of motor skills. Thus, switching between motor chunks seems to indeed create high CI such that CI differences between BP and RP training schedules can be neglected. However, the literature indicates differences between a limited number of trials, such as employed in the present study, and extended versions in terms of RP and BP learning effects (*cf.* Kim *et al.,* 2017). Thus, for further research, it should be interesting to see whether this effect of motor chunk switching on the CI environment also holds for extended numbers of trials. Related to this there exists reasonable incentive to investigate longer sequence RP vs. BP differences between musicians and non-musicians. Together with research on extended practice, this might provide insight into whether and if yes, how, extended practice has an effect on the CI environment or CI influenced learning effects. Finally, an important implication of the present studies' findings is that it should be possible to control acquisition and retention by varying sequence length in BP training schedules. BP training schedules with longer sequences should show less improvement, but better retention than BP training schedules with shorter sequences. Where longer sequences indicate sequences long enough for at least 2 chunks to occur and shorter sequences indicate sequences consisting of only one chunk. A reasonable next step would thus be to investigate whether this prediction holds.

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Appendix A

Informed Consent Form

Informed consent form

Title research:	Learning a sequencing skill - CI study
Responsible researcher:	**Bente Rootmensen, Maik Wigand**, prof. Willem Verwey

To be completed by the participant

I declare in a manner obvious to me, to be informed about the nature, method, target and [if present] the risks and load of the investigation.

I know that the data and results of the study will only be published anonymously and confidentially to third parties. My questions have been answered satisfactorily.

I voluntarily agree to take part in this study. While I reserve the right to terminate my participation in this study without giving a reason at any time.

Name participant: …………………………………………………………………………………………………..

Date: ……………….……………… Signature participant: ….…………………………………………………

To be completed by the executive researcher

I have given an spoken and written explanation of the study. I will answer remaining questions about the investigation into power. The participant will not suffer any adverse consequences in case of any early termination of participation in this study.

Name researcher: *Maik Joshua Wigand*

Date: ……………………………….… Signature researcher: ……………..…………………………………….

Appendix B

Initial Participant Instruction

April 2019

Participant Instruction

You will participate in an experiment that is aimed to understand better how people learn movement skills. Even if you do not always understand the meaning of certain tasks, remember these are compared with those performed by other participants.

The experiment is composed of **4** blocks, 3 on Day 1 and 1 on Day 2. After each part, you have a break of 4 minutes. You can do whatever you want during this break, but we ask you to give your phone to the experimenter to prevent intrusion of the experiment.

It is important for you to react as fast as possible without making too many errors (try less than 8%!). If you make more errors, the experiment will you longer to complete.

The instructions will be displayed on the screen. If something is not clear please ask the experimenter.

The experiment will take about 1 **hour** on Day 1 and 30 min on Day 2 and will get you 1**.5 SONA credits**. During the experiment you will be asked to fill in a short survey. Any remarks about the experiment can be made there.

Good luck with the experiment, and thanks for participating!

Prof. W.B. Verwey

University of Twente

Appendix C

Pen-and-paper awareness test

Page 1

Name ____

Participant Number ____

Age ____

Right or left handed ____

Do you smoke? ____

Did you drink alcohol in the last 24 hours? ____________________

In this experiment you reacted by pressing a key after perceiving a stimulus light. There were three fixed sequences during the experiment. Are you able for all three sequences to indicate the keys you pressed (using the letters C V B and N)?

C	V	B	N

Image of the four keys on the keyboard

One sequence was in my opinion: ____

Appendix C (Continued)

Pen-and-paper awareness test (part 1)

How sure are you about the correctness of the sequence, on a scale from
1 (unsure) to 10 (entirely sure)?:

____

The second sequence was in my opinion: ____

How sure are you about the correctness of the sequence, on a scale from
1 (unsure) to 10 (entirely sure)?:

____

The third sequence was in my opinion: ____

How sure are you about the correctness of the sequence, on a scale from
1 (unsure) to 10 (entirely sure)?:

____

Appendix D

Pen-and-paper awareness test (part 2)

Page 2

1) How were you able to recognize the sequences at the previous pages of this survey? (you may circle more than 1 alternative).

a) I remembered the order of the letters.
b) I remembered the positions of the keys
c) I remembered the positions of the squares on the screen.
d) I tapped the sequence in my mind
e) I tapped the sequence on the table top.
f) Differently, namely:

3) Have you participated before in an experiment with keying sequences?

If yes, did it contain the same sequences?

4) Do you have any remarks about the experiment?