Chunking in young adults:

A comparison between the flexion-extension task and the discrete sequence production task

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Abstract

Research done by Verwey (2010) showed that young adults use motor chunks performing a discrete sequence production task (DSP). The present study examined whether the Flexion-Extension (FE) task used motor chunks. Young adults participated in an experiment which repeated practice of two different familiar sequences for both the DSP and FE-task. A questionnaire to determine explicit knowledge and a visuaspatial working memory-test were performed. Results showed no indication of motor chunks being used. Chunking indexes based on theory by Verwey (2010) which measured possible motor chunking showed no correlation between the FE and DSP task. Participants did improve on test scores but showed no use of motor chunking.

Table of contents

1. Introduction

In 2019 more than half of the population in the Netherlands will be 50 years or older (Centraal bureau voor de statistiek [CBS], 2014). Aging of the population can be found almost all around the world. It's not just the Netherlands where it is happening; it's also present in the rest of Europe. Another phenomenon called 'double aging' is rising quickly. 'Double aging' refers to the group of elderly people who are over 80 years old. In the Netherlands this group consisted of 4% of the total population in 2011, in the year 2060 this group will have grown to 11% of the total population (Harbers & de Beer, 2013). This increase of people over 80 years old is also prominently present in surrounding countries like Belgium, Germany, Luxembourg and the United Kingdom. The European Union as a whole will see the people over 80 more than double, as will the United States and Japan (OECD/European Union, 2013).

This development of double aging has a considerable effect on society. Costs for healthcare will rise further. In 2012 Nyfer, a forum for economic research, came to the conclusion that healthcare costs doubled in the period 2000 till 2012 (Berenschot & Geest, 2012). Most of the aging however will take place after 2012. If healthcare for the elderly remains the same as it is now it will result in unsustainable high healthcare costs. According to Nyfer the healthcare system should focus more on effectiveness. This opinion is shared with the Raad voor Volksgezondheid & Zorg (Council for Public Health and Care). According to this independent scientific advisory body the motto of the next decennium should be: from sickness and care to health and behaviour (Raad voor Volksgezondheid & Zorg [RVZ], 2010).

In order to prevent high healthcare costs elderly people will have to become more independent, they should be able to do more on their own. This means they should learn new skills and master new technologies. These skills/technologies cover a wide spectrum of different possibilities. For example assistive devices to keep mobility high (Roelands, Van Oost, Buysse, & Depoorter, 2002), and devices to improve the social environment which have positive consequences for the elderly (Broekens, Heerink, & Rosendal, 2009).

But skill learning in the elderly reaches beyond mastering assistive devices. When older people are involved in an accident and break something like a leg or a wrist, they must rehabilitate, relearn skills they previously had and learn new skills.

However, it's harder for elderly people to learn new skills compared to young people. Several basic cognitive aspects like perception, attention, working memory and long-term memory are age-related and decline over time. Also higher-level cognitive functions like

executive control and decision-making decline as people get older (Glisky, 2007). A meta-analysis covering 91 studies showed that speed of processing, reasoning, working memory, and spatial ability deteriorate with age (Verhaeghen & Salthouse, 1997). Verneau et al. showed that younger people perform better on learning tasks than the elderly (Verneau, Van Der Kamp, Savelsbergh, & De Looze, 2014).

Besides declining cognitive functions older people also experience a downturn in motor skills (Ketcham & Stelmach, 2004). The speed at which information is processed decreases which increases the movement duration, thus the movement takes longer. The phases of acceleration and deceleration change too. These phases are bell-shaped in young adults while older people show trajectories which are asymmetrical and have a longer deceleration. Elderly people have more difficulty to perform consistently on trials compared with young adults because movement variability increases with age. Coordination and force control are two areas which also decline. Not only is it harder to initiate movements, it is also more difficult to execute them fast and accurately (Ketcham & Stelmach, 2004).

Motor tasks can be divided into two different categories. The first category shows a distinction between fine and gross motor skills. Gross motor skills require movement of the total body which involves a lot of muscular involvement (for example playing soccer). Fine motor skills need very little movement of the body (for example writing a letter). The second category in which motor tasks differ is the aspect of complex versus simple. Simple motor skills can be learned in a single practice session, such as throwing a ball. Complex motor skills on the other hand cannot be mastered in one session such as doing a cartwheel or handstand (Voelcker-Rehage, 2008). When people get older performance differences in complex tasks become larger compared to simple tasks. It does not matter if the tasks demands fine- or gross-motor skills. However learning tasks that involve complex and fine motor skills are more difficult for elderly than for young adults (Voelcker-Rehage, 2008).

In order to improve the independence of the elderly they must be able to learn complex tasks that include fine motor skills. A literature review done by Voelcker-Rehage (2008) showed that this is more difficult, but not impossible. There are differences in learning tasks when comparing old people to young people. To further investigate these differences Verwey (2010) analysed sequential tasks which are complex and demand fine motor skills. The discrete sequence production (DSP) task registers timing and accuracy. The individual movements can be used to acquire the underlying control process. Verwey (2010) used a task which involved a display with a 3-key sequence and a 6-key sequence, with two familiar repeating sequences and unfamiliar sequences. Results showed that young adults at first react

to each stimulus in a key-specific way, which is called the reaction mode. After practicing the sequence young adults switched to the sequencing mode. This sequencing mode results in faster execution of practiced sequences. Older people also improved on the tasks. However the elderly never switched from reaction to sequencing mode. The elderly kept pressing the keys in the reaction mode and thus depending on the stimuli that were shown. As a result the response times of the elderly were longer than the response times of the young adults, thus elderly were slower than young adults.

Shifting from reaction to sequencing mode happens through the use of 'motor chunks'. After repeated practicing a series of key sequences integrated memory representations of these sequences are stored in memory as motor chunks. Motor chunks are limited from three to about five key presses. The young adults were faster than the elderly because of the use of motor chunks. To check whether an individual used motor chunks, a chunking index was computed. The chunking index is based on the difference between sequence initiation and mean sequence intervals; a higher chunking index indicates a higher use of motor chunks. The younger elderly (younger than 80 years old) had a higher chunking index then the older elderly (who were over 80 years old). At the end however the elderly as a group did not make the transition to the sequencing mode, in contrast to the group of young adults who did switch to the sequencing mode (Verwey, 2010).

Learning complex fine motor skills is not limited to pressing keys, it can involve more body movement. The Flexion-Extension task (FE task) is quite similar to the DSP task. Like the DSP task, the FE task involves stimuli shown on a display. One stimulus at a time lights up and the goal is to use the lever to move the cursor to this stimulus. Once that is done the next stimulus becomes active. Just like the DSP task it has predetermined familiar sequence and unfamiliar sequences. The difference between the two tasks is that the FE task demands more of the participant in terms of using forces. Moving a lever requires more storage, utilization and dissipation of forces (Panzer, Gruetzmacher, Fries, Krueger, & Shea, 2011). Research done on using the FE task by Panzer et al. (2011) indicated that the elderly were slower in sequence production than young adults.

The research question for the current study is whether motor chunks also appear in learning the FE task. Verwey (2010) concluded that young adults become faster and exhibit motor chunks. Panzer et al. (2011) have shown that people performing a FE task learn and become faster, however the degree of improvement depends on age. Combining Verwey (2010) and Panzer et al. (2011) results in the hypothesis that motor chunks will appear in both

the FE- and DSP-task because of the similarities between the two tasks regarding the demanded cognitive processes.

Assuming motor chunks will turn up, the second hypothesis is that if the chunking index is high in the FE task, the chunking index of the DSP task will be high too. A positive relationship is suspected between these two tasks, because of the earlier mentioned similarity between the two regarding demanded cognitive processes.

2. Method

2.1   Participants

For the analyses the results of 26 participants were used. The mean age was 22, range 17-36, 6 males and 20 females. 27 People took part in the study. One participant had to be excluded from analysis because this participant did not complete the experiment due to insufficient time. Participants were mainly recruited through an online system designed for psychology students of the University of Twente.

There were two selection criteria: participants had to be right-handed and young. The ethics committee of the Faculty of Behavioural Sciences of the University of Twente approved this study.

2.2   Tasks

The FE task involved a lever which controlled a cursor position (diameter 9 mm) and was moved with the right arm. With the DSP task participants used their right hand to press a key on the keyboard; index finger on C, middle finger on V, ring finger on B and pink on N. The FE task and the DSP task both displayed four red placeholders (placeholders were 38 mm * 38 mm with 64 mm between each placeholder) against a black background on a computer display. A sequence always started with a red bar on the left side of the screen. When the participant pressed the space bar during the DSP task, or moved the controlled cursor to the red bar in the FE task, the sequence was initiated and showed the first green placeholder after 500-1000 ms. As soon as a red placeholder changed to the color green, participants pressed the associated key or moved the cursor of the lever to the green placeholder. When the correct key had been pressed, or when the controlled cursor completely entered the correct placeholder, the color of the placeholder changed back to red. When a sequence was

completed the placeholders were removed and after 1000 ms the red bar was presented again on the left side.

The stimuli that the participants responded to were presented in fixed 7-key sequences (S_1-S_7), yielding responses in fixed 7-key sequences (R_1-R_7). The two familiar fixed 7-key sequences used in the DSP task were different from the two familiar sequences used in the FE task. Response time between stimulus n and response n is indicated by T_n (for example the response time between S_4 and R_4 is T_4).

If a false key was pressed in the DSP task there was an error message. An error message was also presented in the FE task if the participant moved the controlled cursor too far and surpassed the stimulus. In both task the error message lasted 500 ms.

The experiment consisted of 1 familiarization block, 7 practice blocks and 2 test blocks. Data from the practice blocks were essential and used in analysis. The familiarization block presented a 7-key sequence 5 times. The 2 test blocks presented the two familiar fixed sequences, plus other unfamiliar sequences that were not used during the practice blocks. Because of a programming error some participants got 2 times a familiar or two times an unfamiliar sequence during the test blocks.

The practice blocks used two different fixed sequences for each task. 1323124 and 3141342 in the FE task, 2434231 and 4212413 (vnbnvbc and nvcvncb) in the DSP task, which were the same sequences as De Kleine and Verwey (2009) had used. Each practice block included 40 7-key sequences, randomly showing 20 times one sequence and 20 times the other sequence. No unfamiliar sequences were used during the practice blocks. After each block the participant had a break of 2 minutes. During this break the computer display showed how the participant was performing.

After performing the tasks, participants filled out a questionnaire to determine explicit knowledge. It tested if the participant remembered the familiar four sequences (short-term memory), and how they had remembered it (method of retrieval). Participants were first asked about the two familiar sequences of the last performed test. They were asked to write down the two familiar sequences followed by guessing the 2 familiar sequences out of 18 different sequences. The second part of the questionnaire was about the two familiar sequences of the first performed test. Again they were asked to write down the two familiar sequences followed by guessing the 2 familiar sequences out of 18 different sequences. At each 7-key sequence they were asked how sure they were about their answer, and how they had remembered this sequence.

Working memory was tested with the visual array comparison test (VAC), which Bo, Borza, & Seidler, (2009) used in their research. The VAC test is a visuospatial working-memory task that is constructed of a 9x9 inch array with between 2 to 10 1x1 inch colored squares with seven possible colors (black, white, red, blue, green, violet and yellow). No color is used more than 2 times when there are 8 to 10 squares. The first screen presented the sample array for 100 ms, followed by 900 ms blank screen and finally showing the test array for 2000 ms. The locations of the squares were the same for the sample array as the test array; the only difference could be that one of the squares changed color. The participant had two options; pressing 'L' for detecting a color-changed square between the sample and test array, or press 'A' for the sample and test array being the same.

2.3   Procedure

All participants carried out the experiment in the same room. Before the experiment they were welcomed and asked to fill out an informed consent form. When completed the participants received instructions on the computer screen. The experimenter extended on these instructions orally.

Next, half the participants started with the FE task, and half started with the DSP task. Following the familiarization block the experimenter left the room and the participant performed the next 7 practice blocks and 2 test blocks. After the first task had been completed the experimenter entered the room again and started the other task (FE task or DSP task). Again, following the familiarization block the experimenter left the room and the participant performed the next 7 practice blocks and 2 test blocks.

When the two tasks had been completed the participant was asked to fill in the questionnaire. Following the questionnaire the participant performed the VAC-test. The experimenter gave instructions which were also presented on the screen. After the familiarization block the experimenter left the room.

After completing the VAC-test, a debriefing was provided and any questions were answered.

2.4   Apparatus

The test was shown on a 22 inch LCD screen with a refresh rate of 60 Hz and a resolution of 1680*1050 px. The FE task was executed using Matlab R2013b with PsychToolBox 3.0.11. The DSP task and the VAC-task were performed using E-Prime 2.0.10.

2.5   Analyses

To test if participants performed the familiar sequences faster after repeated practice a one-way ANOVA with repeated measures was calculated.

The score of the questionnaire was computed by giving a point for each familiar sequence that was written down and a point for each sequence which was correctly chosen out of 18 different possible sequences. The maximum score was 8: 4 correct written down sequences and 4 correct chosen sequences.

The score of the VAC-task was computed through the formula S(H-F) where S is the array size, H is the hit rate and F is the false alarm rate. The VAC score of a participant was the average of all the calculated arrays. The VAC-task was correlated with both chunking indexes to examine working memory.

To test the first hypothesis a chunking index based on Verwey (2010) was calculated by first subtracting the mean execution times $T_2T_3T_4$ from T_1 for the first and last practice block. Second, the result of the last practice block was subtracted from the first block. If the chunking index is high, the use of motor chunks is high. This also means that if the chunking index is low, the use of motor chunks is low. In order to test the second hypothesis the FE chunking index was correlated with the DSP chunking index.

3. Results

3.1   Sequence times

First of all both sequences in the DSP- and FE-task were on average performed quicker over time. The practiced sequences in the FE task took on average 238 milliseconds less during the last practice block than during the first practice block (939 ms the first practice block, 701 ms the last practice block). All participants except one showed improvement over time. This effect in improving times and thus decreasing the time it took to finish a fixed sequence was significant using a one-way ANOVA with repeated measures, degrees of

freedom were corrected using Greenhouse-Geisser-corrected estimates of sphericity (F(2.44, 61.1) = 34.36, *p* < .001). A gradual decline in total average response time per FE practice block is shown in figure 1.
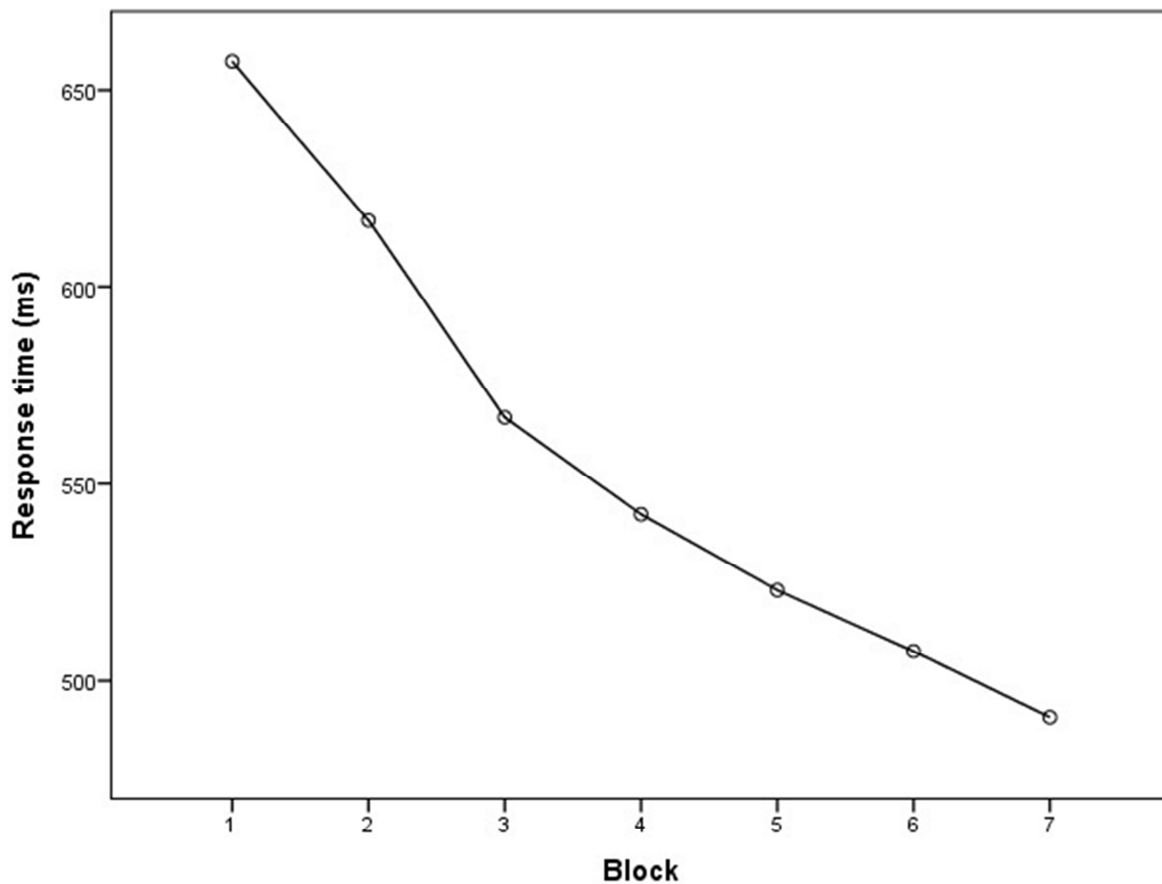

Figure 1. Profile plot of the FE practice blocks and total average response time per block.

The practiced sequences in the DSP task took on average 155 milliseconds less during the last practice block than during the first practice block (500 ms the first practice block, 345 ms the last practice block). All participants showed improvement during the practice block. This effect of decreasing sequence times was significant using a one-way ANOVA (F(2.38, 59,4) = 178.34, *p* < .001. A gradual decline in total average response time per DSP practice block is shown in figure 2.
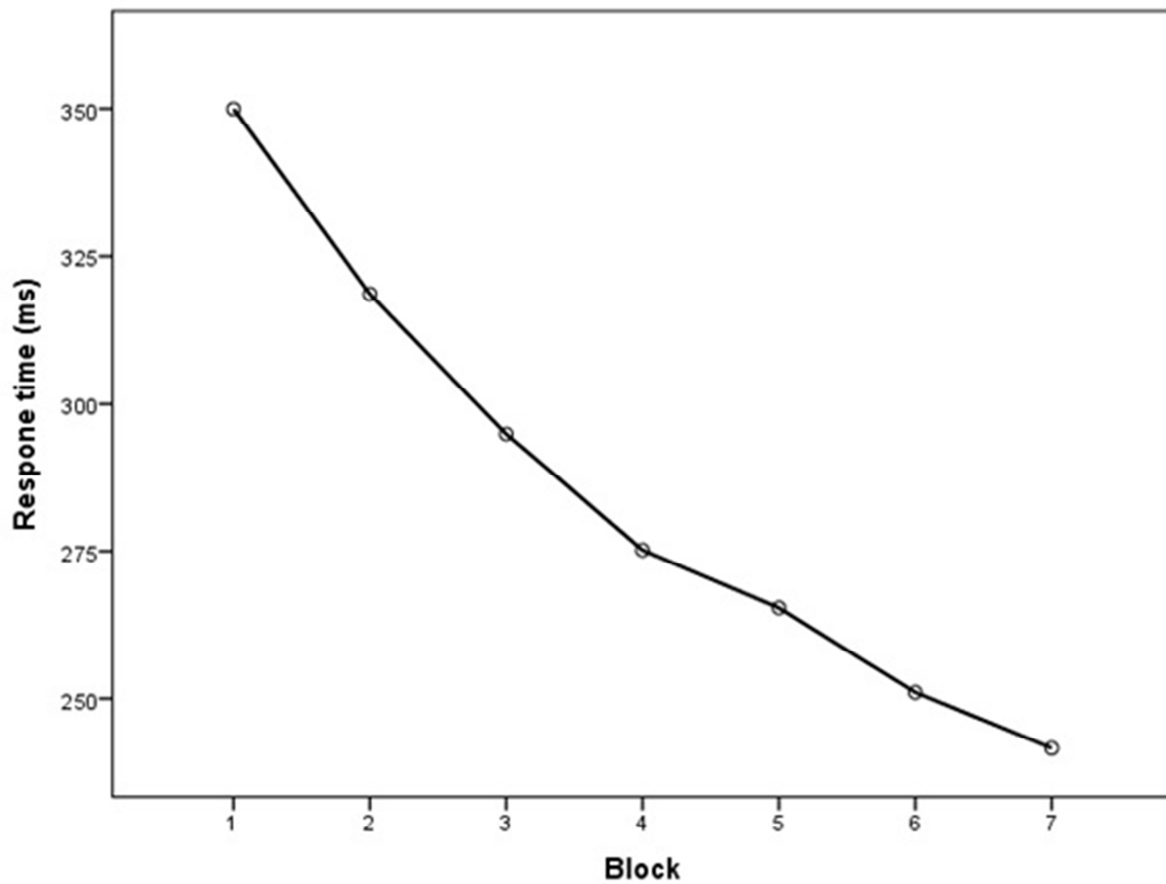
Figure 2. Profile plot of the DSP practice blocks and total average response time per block.

3.2   Chunking indexes

Both the FE task and the DSP task were tested for chunking. There was no indication in either tests that pointed to the use of motor chunks. Chunking is not ruled out and a chunking index was calculated based on the research done by Verwey (2010). This index measured the amount of chunking.

3.3   Correlation between FE- and DSP- chunking index

The scatterplot (figure 3) shows the relation between the FE- and DSP-chunking index. Although both indexes were normally distributed, the scatterplot showed no indication of a strong relationship between the indexes.
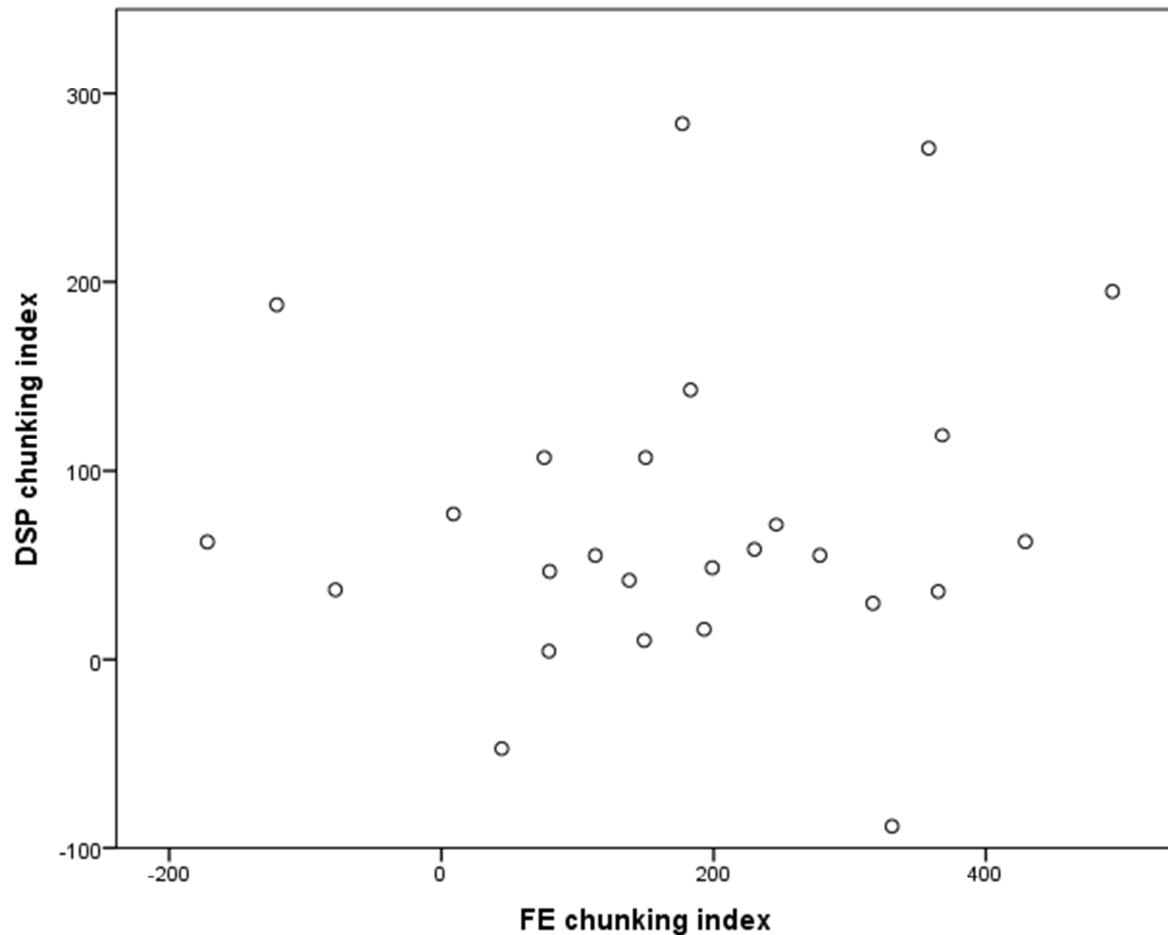
Figure 3. Scatterplot of the DSP chunking index and the FE chunking index.

To determine if there was a relationship between the FE- and DSP- chunking index a Pearson product-moment correlation coefficient was calculated. Results showed what the scatterplot indicated. There was no statistically significant correlation between the FE- and DSP chunking indexes, $r(24) = .12$, $p > .05$. This meant that there wasn't an indication of a relationship between the chunking indexes of the DSP- and FE-task.

3.4   Correlation between VAC-test and FE chunking index

Results indicated a positive correlation between the VAC-test and the FE chunking index. Pearson's correlation coefficient was significant and showed a strong positive relationship ($r(24) = .41$, $p < .05$) as can be seen in figure 4. Following this result it can be said that the VAC tends to be high when FE is, and when the FE index is low the VAC is also low. In other words: people with a large working memory tend to show a high FE chunking index.
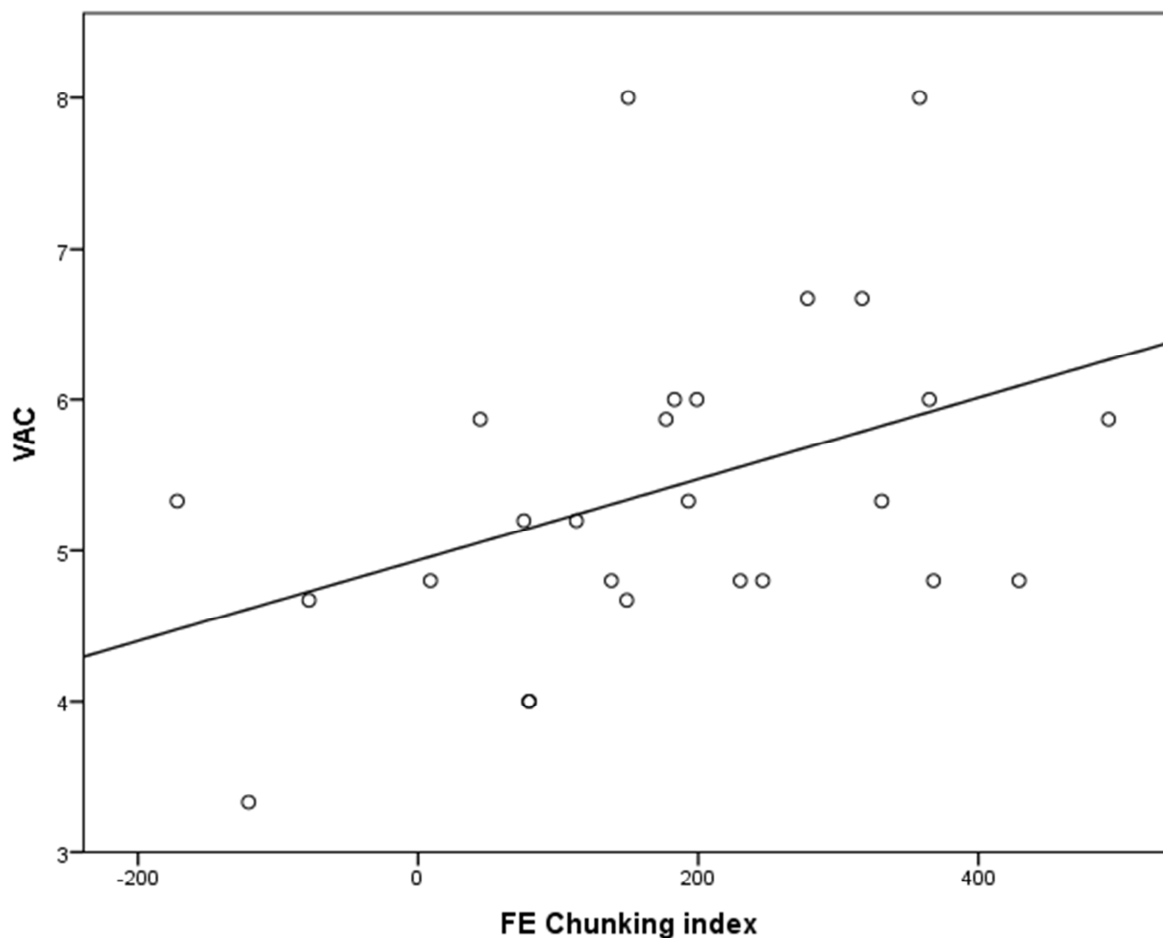
Figure 4. Scatterplot of the VAC score and the FE chunking index.

3.5   Correlation between VAC-test and DSP chunking index

Comparing the DSP chunking index with the VAC-test resulted in a less clear relationship than comparing the VAC-test with the FE chunking index, as seen in figure 5. This is also consistent with the score on Pearson's correlation, $r(24) = .26$, $p > .05$. The coefficient is not significant which means that there is no indication of a relationship between the VAC and the DSP.
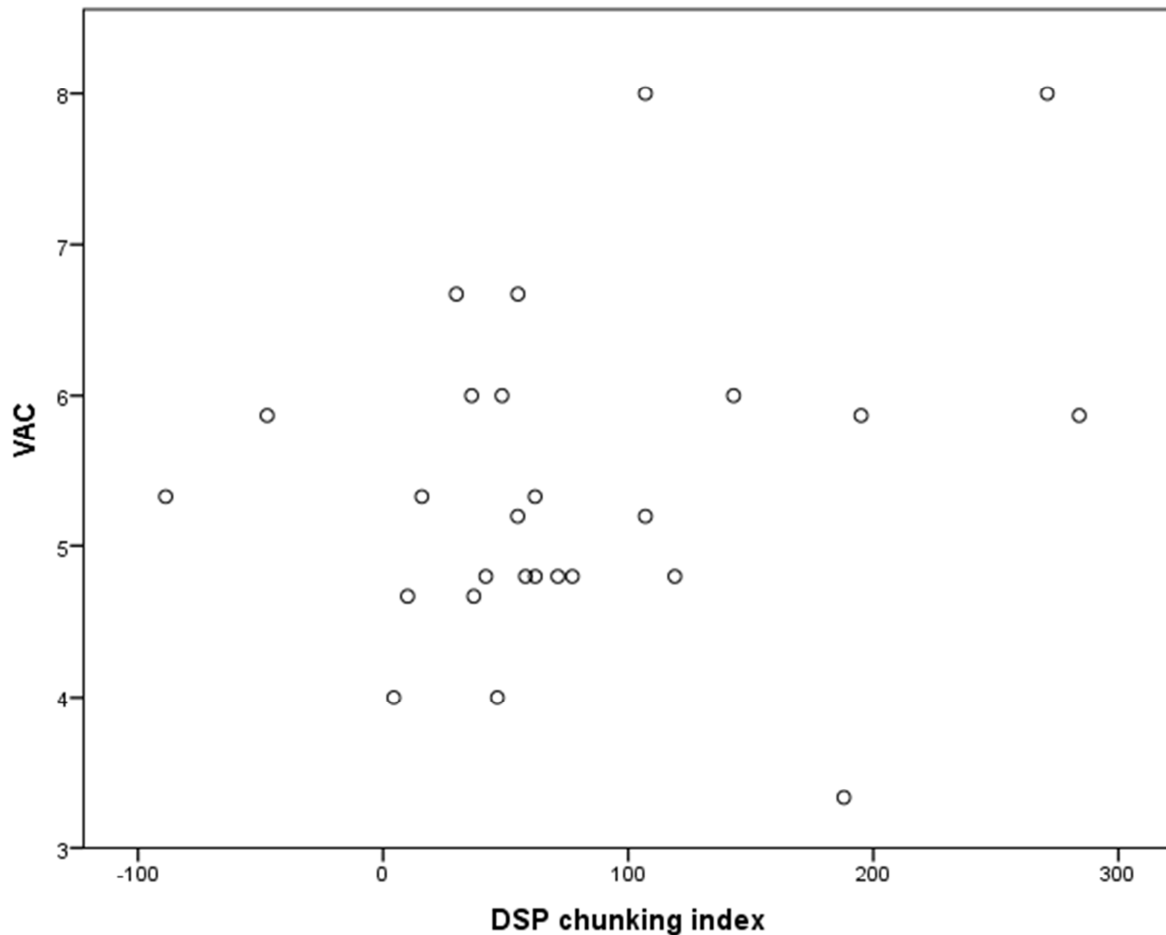
Figure 5. Scatterplot of the VAC score and the DSP chunking index.

3.6 Correlation between VAC-test and questionnaire

The VAC-test tested working memory and the questionnaire tested explicit memory. These two tests should have correlated positive with each other because both tests measured the same construct. Indeed the correlation was positive and significant, $r(23) = .35$, $p < .05$. Someone who had a good visuospatial working memory (VAC-test score) will also be good at remembering performed sequences (questionnaire).
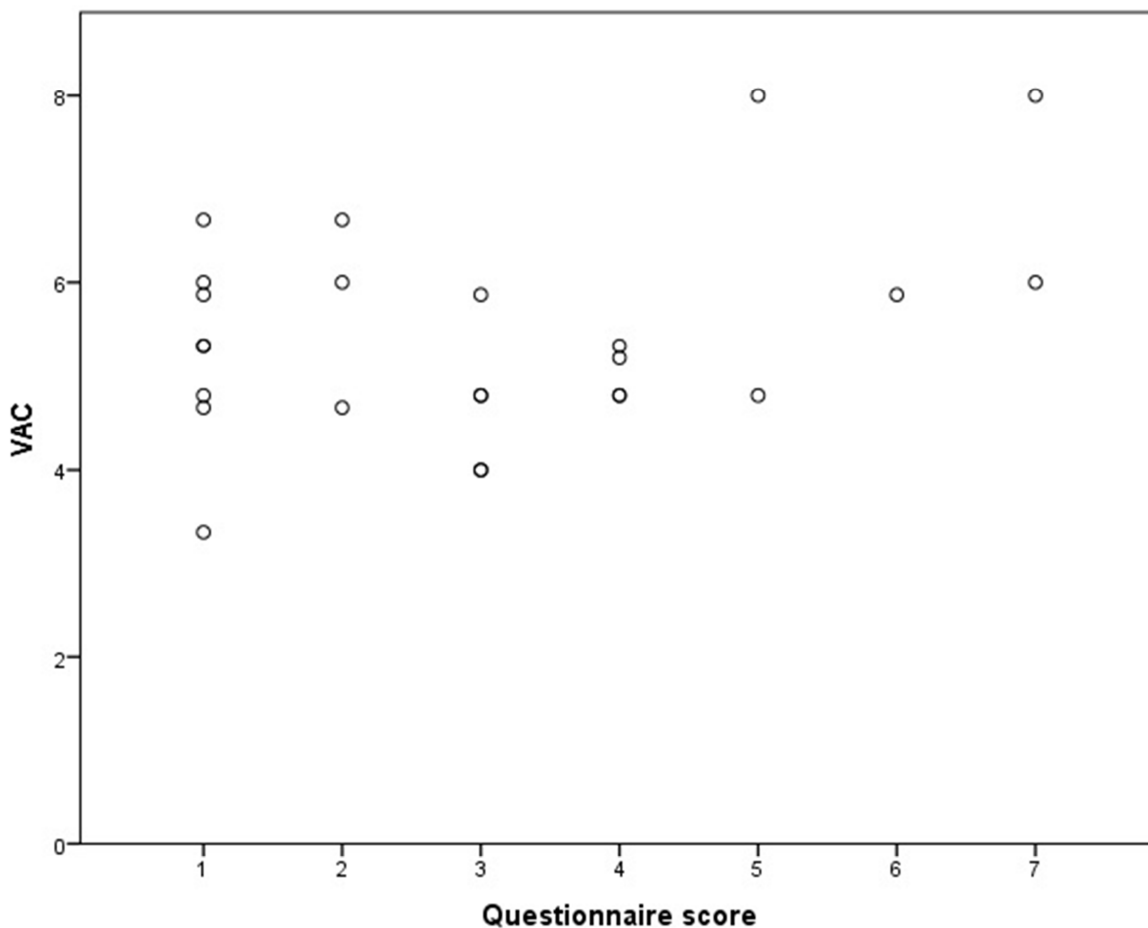
Figure 6. Scatterplot of the VAC score and the questionnaire score.

4. Discussion

4.1   Chunking indexes FE- and DSP- task

The central question in this study was whether chunking appears in the FE task. Verwey (2010) showed that motor chunks are used when young adults learn a DSP task. The tasks are similar in terms of demanded cognitive processes. Therefore the hypothesis was that motor chunking will be used in both tasks.

The second hypothesis was that both chunking indexes should correlate. Logically it is expected that when people score high on the FE task, they also should score high on the DSP task. This was expected because of the similarities between the two: cognitive processes, stimuli, sequences, conditions. Simplified there was only one big difference between the two tasks: the FE is performed with a lever, the DSP with a keyboard. Results showed otherwise, in contrast to what was expected. We found no indication of motor chunking being used. Also

with the calculated indexes, which measured the amount of chunking, we found no correlation between the FE chunking index and the DSP chunking index. There is no indication to expect a high FE chunking index if there is a high DSP chunking index, or vice versa.

4.2   Correlation between VAC-test and chunking indexes

Other aspects were investigated. Since the VAC-test measures visuospatial working-memory, and the motor chunks also are part of the working memory, they should correlate positive (Verwey, 2010). The results showed that the VAC and FE chunking index do significantly and positive correlate, however the DSP chunking index shows no correlation with the VAC-test. This is not what was expexted. Looking at the missing link between the two chunking index it is reasonable to say that this missing correlation between the DSP and VAC-test is expected. To check if the VAC-test itself does indeed measure working memory it was correlated with the questionnaire. This was a positive and significant correlation.

4.3   Further research

It would be interesting to see if elderly people show chunking or not on the FE task. If this effect is present it would be in contradiction to what is expected.

Beyond that maybe it can be said that moving a lever differs more from pressing a keyboard than expected. The motoric part could be that big that it undermines the chunking index, which in turn destroys any positive correlation with the DSP task. Another possible explanation is the use of a different visual-spatial code like Panzer et al. (2001) suggested.

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