Masterthesis

25-8-2016

Motor skill transfer in older adults

Behavioural, Management and Social Sciences – Psychology

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Abstract

The present study examines the ability of older adults to transfer the knowledge of a learned motor sequence from one motor task to a different motor task. Transfer can be used to test which representations a person uses while doing a motor task. When a person uses a visuospatial representation instead of a motor representation, that person will have more transfer from one motor task to a different motor task. In this study the older adults (65-74) and younger adults (19-30) practiced with the Discrete Sequence Production (DSP) or Flexion-Extension (FE) task to learn two motor sequences in the practice phase. After the practice phase with one of the tasks, the participants were tested with the other task to see whether there was transfer from one motor task to another. The results showed that older adults did have transfer from one motor task to another, but that the amount of transfer is not as much as seen with the younger adults. Furthermore the results demonstrate that participants show more transfer from the FE task in the practice phase to the DSP task in the test phase than vice versa. Detailed analyses showed that older adults as well as younger adults show more transfer when they practiced with the FE-task instead of with the DSP-task.

The results suggest that younger adults develop visuospatial representations more efficient in the practice phase than older adults and that visuospatial representations were developed better in the FE task than in the DSP task. This means that the practiced task can be of influence on the amount of transfer and this might be important for developing a training or practices for older adults, so that they can learn complicated movements more efficiently.

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1. Introduction

In daily life different motor sequences are used. Think about playing an instrument, riding a car, dancing a ballroom dance or even something as daily as getting out of bed. These motor skills are learned with (sometimes a lot of) practice. Motor sequences are interesting from a theoretical as well as a practical point of view. Theoretically they are important because motor skill learning can be studied with motor sequences to get a better understanding of how people use their cognitive and motor abilities and how these abilities are represented in the brain. Practically it is important because motor skills make up a big part of the actions and movements every person performs on daily basis. If the representations of motor sequences are better understood, it might be possible to make it easier for a person to learn more complicated movements and actions more efficiently.

Motor sequences are represented in two ways, the visuospatial representation and the motor representation (Hikosaka, Nakamura, Sakai, & Nakahara, 2002). One way to study the contributions of these types of representations is to test the transfer of learned sequences from one task to another. During the last years studies have been carried out that focused on motor sequence learning in older adults (Panzer, Gruetzmacher, Fries, Krueger, & Shea, 2011), but studies with the focus on transfer of motor skills between tasks are not conducted very often.

The goal of this study is to examine the transfer of motor skills between tasks in older adults in comparison to young adults, because transfer can be used to test which representations a person uses while doing a motor task.

1.1. Older adults

Older adults experience difficulties performing complex tasks, because of deterioration in cognitive, perceptual and sensorimotor functioning (Voelcker-Rehage, 2008). That means that the tasks performed will be executed slower and in most cases less accurately. This could become a problem in the future, because the population is aging (Central Bureau for Statistics, 2016). There will be relatively more older adults in the Dutch population in the coming years. Older adults have more problems with learning, executing and reproducing learned sequences than younger adults (Panzer, Gruetzmacher, Ellenbürger & Shea, 2014). It looks like visuomotor performance reduces when a person ages (Voelcker-Rehage, 2008).

Both, Shea & Kovacs (2012) and Verwey, Abrahamse, Ruitenberg, Jiménez, & de Kleine (2011) state that aging affects the development of representations used to perform motor sequence learning.

Voelcker-Rehage (2008) states that the difference in performance between older and younger adults grows with practice when looking at fine motor skills, but this result is not noticed when looking at gross-motor skill learning. Motor skill learning can be explained with the dual processor model, which will be explained in the next paragraph.

1.2. Dual processor model

Motor sequence learning is acquiring the skill to execute a sequence of movements as quickly and accurately and with as little attention or effort as possible. When presented with visuospatial stimuli that need to be translated into movements, a person can do this in three different modes according to the dual processor model (DPM): the reaction, associative and chunking mode (Abrahamse, Ruitenberg, de Kleine, & Verwey, 2013).

The movement sequences can be represented in memory by different sequence representations, these sequence representations can be divided into cognitive (or visuospatial) representations and motor representation (Verwey, 2003, Hikosaka, Nakamura, Sakai, & Nakahara, 2002). The cognitive processor processes sensory input and reacts to each single stimulus and influences the motor processor to carry out the appropriate response. The cognitive and motor processor are used in all three different modes of the DPM.

When first presented a certain sequence of stimuli, a person reacts to this sequence in the reaction mode. In the reaction mode each single stimulus is evaluated and acted upon apart from any of the other stimuli. With practice, young adults switch from reacting to each key-specific stimulus in the reaction or associative mode to preparing and executing the entire sequence as a whole in the chunking mode (Verwey, 2003).

In the associative mode the reactions to stimuli are faster than in the reaction mode. This is due to associations between the subsequent stimuli and responses in a sequence (Abrahamse, Ruitenberg, de Kleine, & Verwey, 2013). The associations develop after succesful repeated execution of the same sequences and prime the response to each next stimulus, based on the response to the first stimulus. This also occurs at the visuospatial level of the model Hikosaka et al. (2002) developed. Therefore, the visuospatial level of this model can be related to the associative mode of the DPM. When the association becomes stronger at the motor level a motor chunk can be developed that is then loaded in the motor buffer and the mode is then switched to the chunking mode.

In the chunking mode the motor processor makes use of motor chunks (sets of different movements that belong together) that are loaded into the motor buffer by the cognitive processor (Verwey, 2010). The chunking mode of the DPM model can be related to the motor level of the Hikosaka et al. (2002) model.

However, there will always be a race between the motor processor that executes motor chunks from the motor buffer, and the sequence representation read by the cognitive processor as mentioned in the associative mode. Hikosaka et al. (2002) state that the visuospatial level and the motor level do not race, but develop simultaneous. The better developed representation will then be used to execute the movement sequence.

1.3. Tasks

In this paragraph, the tasks used in this experiment in order to study transfer of motor skills, will be described.

One of the tasks is the discrete sequence production (DSP) task (Rhodes et al., 2004; Verwey, 2001). This task involves the sequential display of discrete series of two to seven stimuli in a fixed order. Each stimulus is responded to by a key press on a keyboard. The next stimulus is displayed only after pressing the required key to the previous stimulus.

The second task used is the Flexion-Extension (FE) task as described by Park and Shea (2005). There are multiple potential target areas, visible as squares, on the screen. One of the squares becomes filled with a color which will make the square become a target. The participant is instructed to move a lever in an attempt to reach targets with a cursor projected onto a table top or on a computer screen. Park and Shea (2005) report that a 16-element movement sequence was presented to the participants, who did not know that there was a specific sequence. Participants were simply instructed to move the cursor from target to target as quickly and smoothly as possible with the lever.

Both, the DSP and the FE, tasks have the same visuospatial, but different motor skill requirements in this study and are used to test motor skills. Due to this, the combination of these two tasks can be used to measure any transfer of motor skills.

1.4. Transfer

With the two tasks mentioned in the last paragraph it is possible to study whether there is transfer from one motor skill to another. Transfer is the extent to which practice in the past on a certain task affects the outcome on a different task and is interesting, because transfer can be used to test which representations a person uses while doing a motor task. Panzer et al. (2014) conducted an experiment in which two groups (older and younger adults) practiced a sequence with their right hand on the first day and with the left hand on the second day. The sequences the participants learned with their right hand where the same for both groups, but the sequence the participants learned with their left hand were different for the two groups. The first group learned a sequence that was visuospatially mirrored relative to the first day (mirror group), and the second group learned the same visuospatial sequence with their left hand as they had learned with their right hand on the first day (non-mirror group). Both groups showed improved performance during retention tests, but the older adults had less improvement than the younger adults. Panzer et al. (2011) found that the use of a specific coding system is age dependent, because older adults reproduced the learned sequences slower than younger adults in interlimb practice. The older adults do not develop visuospatial representations early in practice, where younger adults do develop these representations. This indicates that older participants experience difficulties with forming a structure for the sequences they are learning. This structure is important to form accurate representations of the learned sequences. Older participants seem to produce the sequence using a serial processing scheme, which means that they respond to each stimulus separately. This suggests that older adults experience more problems reproducing a learned sequence and that they do not use the associative mode of the earlier mentioned DPM. To study how sequences are represented in the memory of older adults it would be good to know more about transfer of learned sequences from one motor task to another different motor task. There is still little known about how motor skill sequences are represented with older adults and as stated earlier transfer can help finding out which representations are used. Transfer can be explained on the basis of the DPM. As mentioned in the DPM there are three modes. When a person does another motor skill task than the motor skill task with which sequences are practiced, it is not possible for the person to be in the chunking mode. The reason for this is that there cannot be a motor representation on which the motor skill task is based. If there is transfer from one task to another, a person has to be in the associative mode, because the visuospatial representation of the sequence is used to execute the unknown task. If there is no transfer of representations from the practiced task to a different task, the person will be in the reaction mode and there is no, or little, use of sequence representation.

1.5. Goal and hypotheses

The goal of this study is to find how well learned representations of sequences can be transferred from one task to a different task and whether this is affected by a person's age. Transfer can be used to test which representations a person uses while performing a motor task. With the outcome of this study it might be possible to give more insight in how sequences are represented by older and younger adults.

We first hypothesize that both young and older adults execute random sequences in the test phase slower than learned sequences. This is because in the random sequences the older and younger adults cannot use the visuospatial representations that are formed during practice, but in the learned sequences they can use these visuospatial representations. The second hypothesis is that younger adults will show more transfer than older adults. This can be derived from the study of Panzer, Gruetzmacher, Ellenbürger, & Shea (2014), where they conclude that older adults tend to have more problems with learning, executing and reproducing learned sequences, than younger adults. The last hypothesis is that a higher visuospatial working memory, learning rate and processing speed will translate into a higher amount of transfer for older and younger adults, because these attributes all influence how fast and accurately sequence representations are formed.

2. Methods

2.1. Participants

The results of 32 older adults (mean age 69, range 65-75, 20 woman) and 32 younger adults (mean age 22, range 19-30, 23 woman) were used for analyses. The older adults were recruited through advertisements in local newspapers and were paid. The younger adults took part in exchange for course credits. Inclusion criteria were that the participants needed to be right-handed and healthy.

2.2. Tasks

In all phases of the experiment four black bordered square (38 x 38 mm) placeholders were presented horizontally in the center of the screen. These four squares were equally separated from each other by 65mm. In the flexion-extension (FE) task a black dot (8 mm diameter) was presented as a cursor. In the Discrete Sequence Production (DSP) task participants used the fingers of their right hand (excluding the thumb) for the C, V, B and N keys of a regular computer keyboard. In the FE task the participants used their right arm to control a lever that rotated in an arc approximately 45 degrees in the horizontal plane. This lever controlled the cursor position on the screen. The participant moved the cursor on the screen from right to left by moving the lever towards him/her and from left to right by moving the lever away from him/her. One of the placeholders became active by turning green and the participant responded to this. In the DSP task the participants responded by pressing the key corresponding to the target location, while in the FE task the participants moved the cursor to the target with the lever. When the correct key was pressed or the cursor was moved to the active placeholder, the placeholder became inactive again by changing back to white and the next target was activated.

There were two different types of errors that the participant could make in the DSP task. The first error was that the participants waited more than 2000 ms before a reaction to the stimulus and the second that the participants pressed the wrong key. The FE task had three different errors a participant could make during a sequence. First, the participants' reaction to the target took more than 3000 ms; second, the participants moved the cursor to the wrong placeholder and last, the participants overshot the target by more than 65 mm. The reason for this was that otherwise a none active placeholder would be hit. In all the error situations a red exclamation mark was displayed and the sequence was ended.

During the experiment sequences of six stimuli were presented to the participants, requiring the participants to perform six key presses in the DSP task and six arm movements in the FE task. In the familiarization phase the participants performed ten random sequences with both, the FE and the DSP task. In the practice phase participants learned two fixed sequences. These sequences always had the same order of stimuli presented to the participant. The two orders were respectively 413243 and 132412, where the numbers are the active targets counted from the most left placeholder being 1 and the most right placeholder being 4. The participants performed either the FE task or the DSP task in the practice phase. In the test phase the participants performed 2 blocks of sequences, one with the fixed sequences and one with random sequences. The order of the blocks in the test phase were counterbalanced and performed with the task participants had not been using in the practice phase (e.g. participants that learned the sequences with the DSP task in the practice phase, would execute the sequence with the FE task in the test phase).

2.3. Procedure

The older participants received a package at home with information about the experiment, the informed consent (that would be signed on the test day), a questionnaire about physical activity and a test for handedness. The younger participants received the information about the experiment online when they signed up for the experiment and received the informed consent, the questionnaire and the test for handedness on the day of the experiment. The older participants were asked to fill out the forms and bring them on the test day. At the lab, the Dutch version of the Montreal Cognitive Assessment (MOCA) (Nasreddine, 2004) was administered first to determine cognitive ability. The MOCA was used to exclude older participants from the results if the score indicated signals of earlier dementia. After the MOCA the participant executed a Visual Array Comparison (VAC) task of 100 trials (Luck & Vogel, 1997) to test working memory capacity. With every trial of the VAC a number of colored squares appeared on the screen, after this the screen turned blank for 900ms, followed by the same squares on the same place on the screen but now with one of squares circled. The participants assessed whether the circled square had changed color. After the VAC the participants performed a digit-symbol substitution task and before the short break they were asked to rate their fatigue on a scale from 1 to 10 for the first time.

Subsequently, the familiarization phase started. In this phase the participants performed 10 random sequences with the DSP task and the FE task. This phase was meant to give the participant an introduction to how both tasks worked and what they could expect during the rest of the experiment. The task they ended the familiarization phase with was also the task the participants were going to perform during the practice phase.

In the practice phase participants performed six blocks of 48 sequences (24 times one sequence and 24 times the other sequence, the order of the two sequences was randomized) with after each block a break of 120 seconds. So, each participant practiced each sequence 144 times. Each block contained a smaller break of 60 seconds after 24 sequences. At the end of the practice phase a questionnaire about these movement sequences was filled out to test the explicit knowledge of the participants about the sequences and the participants were again asked to rate their fatigue to monitor the degree of fatigue during the experiment.

The test phase was performed with the task the participant had not been practicing with 24 trials per block per sequence. After the test phase the participants were asked to rate their fatigue for the third and last time. The experiment concluded with a short post experiment interview and the debriefing.

3. Results

First, a measure for learning rate and for transfer was calculated. Transfer was calculated as the relative difference between the RT's of the random and the familiar blocks in the test phase. Learning rate was calculated as the relative difference between the mean RT of the first and last block in the practice phase.

3.1. Practice phase

Response times of the practice blocks were first analyzed with a mixed 2 (Age) x 2 (Practice Task) x 12 (Block) ANOVA with Age and Practice Task as between-subjects variables. Mauchly's test indicated that the assumption of sphericity had been violated (χ^2 (65) = 408.29, p < .001), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.32). The results show that there was an effect of practice block on reaction time $F(3.51, 210.63) = 111.74$, $p < .001$, $\eta_p^2 = .651$. All groups show that the reaction time becomes less during practice blocks.

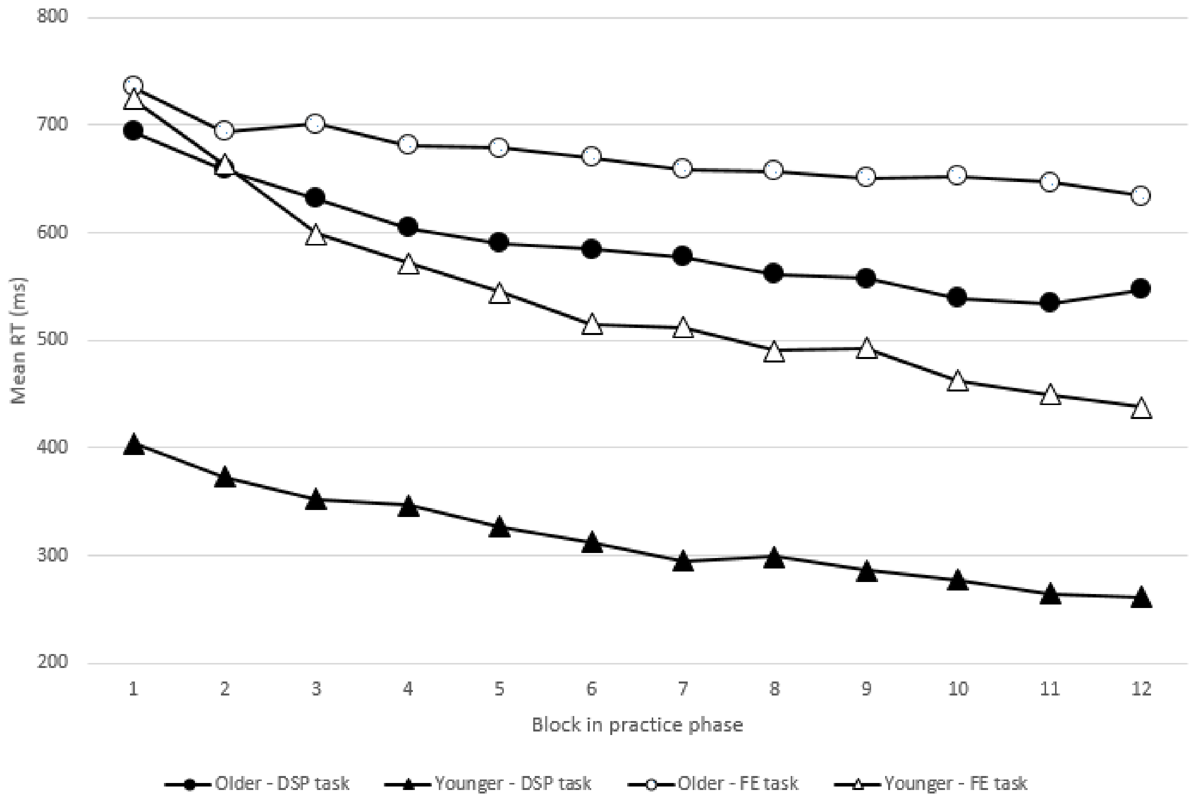

Fig. 1 Response times in the practice phase as a function of block, age and practice task.

The results also show an interaction effect of age group and block on the reaction time $F(3.51, 210.63) = 8.15$, $p < .001$, $\eta_p^2 = .120$ and an interaction effect of age group, practice task and block on the reaction time $F(3.51, 210.63) = 11.52$, $p < .001$, $\eta_p^2 = .161$. There was also a main effect of age group on reaction time $F(1, 60) = 68.29$, $p < .001$, $\eta_p^2 = .532$ and a main effect of practice task on reaction time $F(1, 60) = 38.05$, $p < .001$, $\eta_p^2 = .388$. This means that younger adults improve faster than older adults and that this effect is larger for the participants who practiced with the FE task than with the DSP task, Fig. 1.

Accuracy of the participants in the practice blocks was conducted with a mixed 2 (Age) x 2 (Practice Task) x 12 (Block) ANOVA with Age and Practice Task as between-subjects variable. Mauchly's test indicated that the assumption of sphericity had been violated (χ^2 (65) = 195.83, p < .001), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.56). The results show that there was an effect of practice block on the accuracy F(6.192, 371.548) = 3.29, p = .003, η_p^2 = .052.

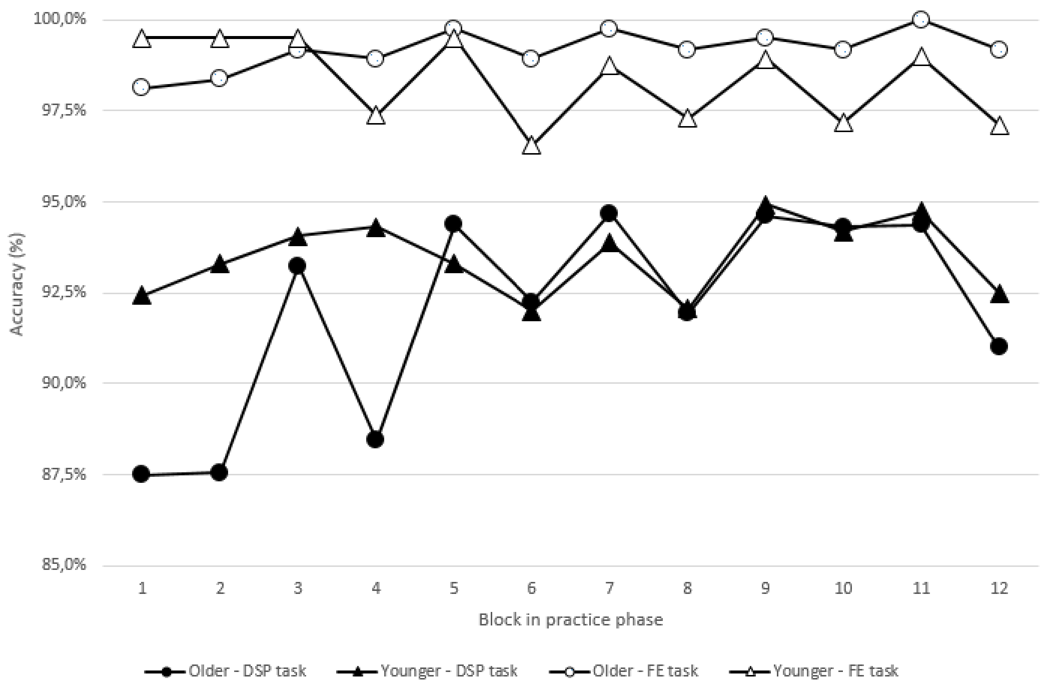

Fig. 2 Accuracy in the practice phase as a function of block, age and practice task

The results also show that there is an interaction effect of age group and block on the accuracy, F(6.19, 371.55) = 2.24, p = .037, η_p^2 = .036. There was no significant interaction effect of age group and practice task on accuracy, F(1, 60) = 1.43, p = .236, η_p^2 = .023 and no significant main effect of age group on accuracy, F(1, 60) = .08, p = .779, η_p^2 = .001. There is however a significant main effect of practice task on the accuracy, F(1, 60) = 39.23, p < .001, η_p^2 = .395. This means that participants made more errors during the DSP task in the practice phase than during the FE task, Fig. 2.

3.2. Learning Rate

A 2 (Age group) x 2 (Practice task) ANOVA on the above mentioned learning rate with Age group and Practice task as between-subjects variable was conducted. The results showed that younger adults (M = 37.189) scored higher on learning rate than older adults (M = 17.381), $F(1, 60) = 52.66$, $p < .001$, $\eta_p^2 = .467$. There was no difference in learning rate between practiced tasks, $F(1, 60) = .32$, $p = .575$, , $\eta_p^2 = .005$. There was an interaction effect of age group and practice task on the learning rate $F(1, 60) = 4.22$, $p = .044$, $\eta_p^2 = .066$. This means that younger adults learned faster than older adults, but that the practice task had no significant influence on the learning, Fig. 3.

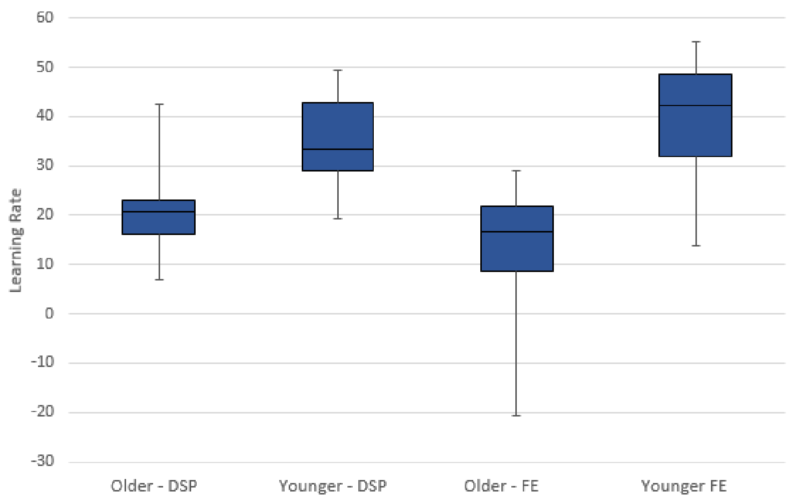

Fig. 3 Learning rate per age group and practice task

3.3. Visuospatial working memory

An ANOVA was conducted for Age Group and visuospatial working memory, Fig. 4. The results showed that younger adults (M = 4.675) scored higher on visuospatial working memory than older adults (M = 2.354), $F(1, 62) = 76.15$, $p < .001$, $\eta_p^2 = .551$.

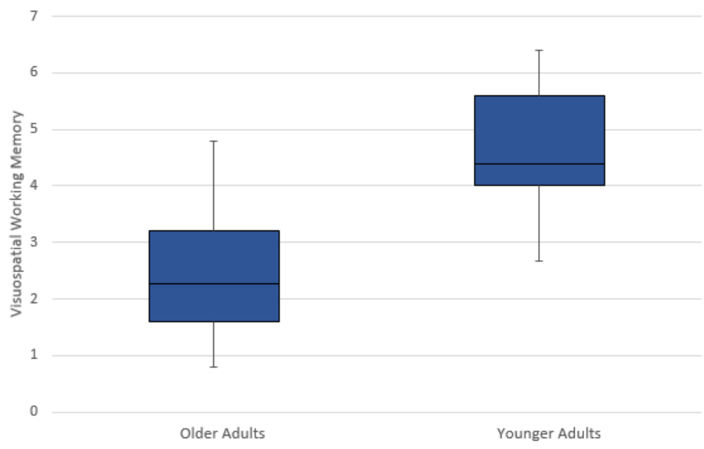

Fig. 4 Visuospatial working memory per age group

3.4. Processing speed

An ANOVA was conducted for Age Group and processing speed, Fig 5. The results showed that younger adults (M = 71.656) scored higher on processing speed than older adults (M = 48.594), $F(1,62) = 76.810$, $p < .001$.

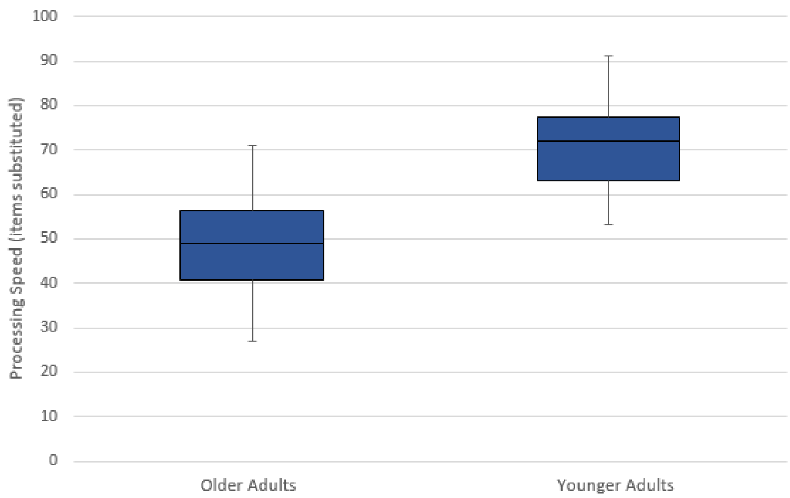

Fig. 5 Processing speed per age group

3.5. Test Phase

A mixed 2 (Age group) x 2 (Practice task) x 2 (Sequence: familiar vs. random) ANOVA was conducted on reaction times with Age group and Practice task as between-subjects variables. The analysis showed that there was a main effect of sequence on the reaction times, $F(1, 60) = 39.22$, $p < .001$, $\eta_p^2 = .395$ and also showed that there was an interaction effect of age group and sequence on the reaction times, $F(1, 60) = 6.03$, $p = .017$, $\eta_p^2 = .091$. There also was an interaction effect of the practice task and the sequence on the reaction times, $F(1, 60) = 23.74$, $p < .001$, $\eta_p^2 = .284$. There however was no significant interaction effect between the age group, the practice task and the sequence on the reaction times, $F(1, 60) = .72$, $p = .401$. There were main effects for the age group on the reaction times in the test phase, $F(1, 60) = 96.67$, $p < .001$, $\eta_p^2 = .617$ and for the practice task on the reaction times in the test phase, $F(1, 60) = 61.46$, $p < .001$, $\eta_p^2 = .506$. Altogether this means that younger adults were faster than older adults in the test phase. The reaction times from the participants who performed the DSP task in the test phase were shorter than from the participants who performed the FE task in the test phase.

A mixed 2 (Age group) x 2 (Practice task) x 2 (Sequence: familiar vs. random) ANOVA on accuracy with Age group and Practice task as between-subjects variable was conducted. The analysis showed that there was a difference between the accuracy of the random and familiar sequences, $F(1, 60) = 9.82$, $p = .003$, $\eta_p^2 = .141$. The analysis also showed that there was no main effect of age group on the accuracy in the test phase, $F(1, 60) = .03$, $p = .872$, $\eta_p^2 = .000$. There however was a main effect of the practice task on the accuracy in the test phase, $F(1, 60) = 77.10$, $p < .001$, $\eta_p^2 = .562$. There were no significant interaction effects between, age group, practice task and/or sequence on the accuracy in the test phase. This means that accuracy of younger adults was not different than of older adults, but that the accuracy of the DSP task in the practice phase was lower than of the FE task in the test phase.

A 2 (Age group) x 2 (Practice task) ANOVA was conducted on the above mentioned calculated transfer with Age group and Practice task as between-subjects variable. The analysis showed younger adults had more transfer ($M = .139$) than older adults ($M = .047$), $F(1, 60) = 14.25$, $p < .001$, $\eta_p^2 = .192$. And that the participants had more transfer from the FE task to the DSP task ($M = .167$) than from the DSP task to the FE task ($M = .019$), $F(1,60) = 35.90$, $p < .001$, $\eta_p^2 =$

.374. There was no significant interaction effect between the age group and practice task on transfer, $F(1,60) = .61$, $p = .437$, $\eta_p^2 = .010$. This means that younger adults have more transfer than older adults and that both groups have more transfer from the FE to the DSP task than vice versa, Fig. 6.

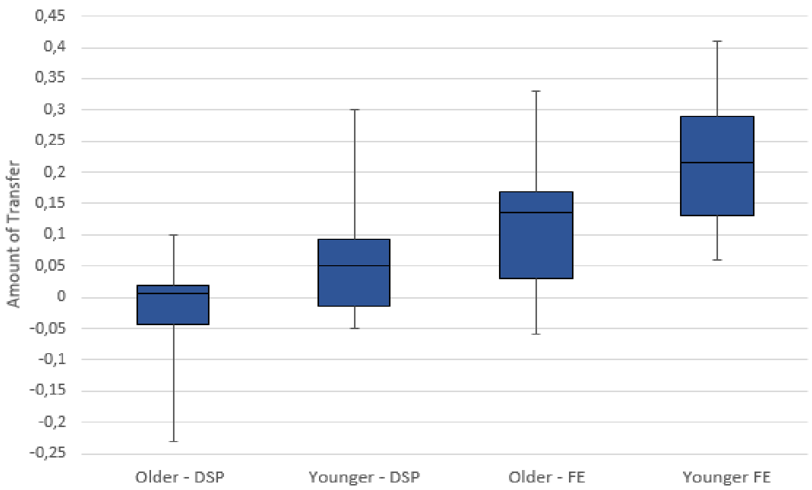

Fig. 6 Transfer per age group and practice task

For the younger adults there was a medium positive association between transfer and learning rate, $r(31) = .301$, $p = .047$. For the older adults there was no significant evidence of a correlation between transfer and learning rate, $r(31) = .067$, $p = .359$. This means that more learning is associated with a higher level of transfer for younger adults but not for older adults.

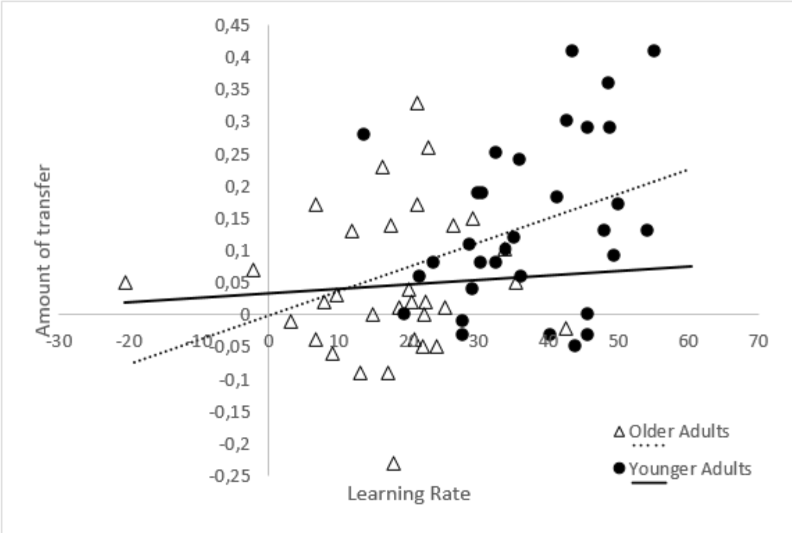

Fig. 7 Learning rate and transfer for younger and older adults with trend lines

For the younger adults there was no significant association between transfer and visuospatial working memory, r(31) = -.064, p = .364. For the older adults there was also no significant evidence of a correlation between transfer and visuospatial memory, r(31) = .232, p = .101. This means that a higher level of visuospatial working memory is not associated with a higher level of transfer for younger adults or older adults, but it is for the whole group of participants, Fig. 8.

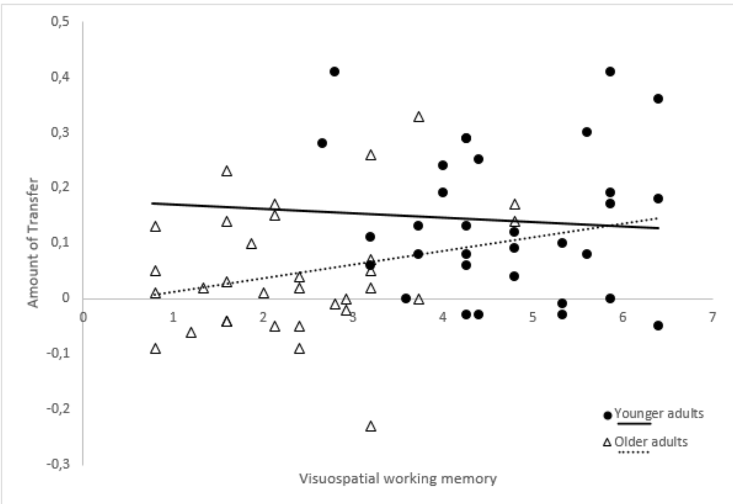

Fig. 8 Visuospatial working memory and transfer for younger and older adults with trend lines

For the younger adults there was no significant association between transfer and processing speed, r(31) = -.044, p = .811. For the older adults there was no significant evidence of a correlation between transfer and processing speed, r(31) = .161, p = .380. This means that a higher level of processing speed is not associated with a higher level of transfer for younger adults or older adults, but it is for the whole group of participants, Fig. 9.

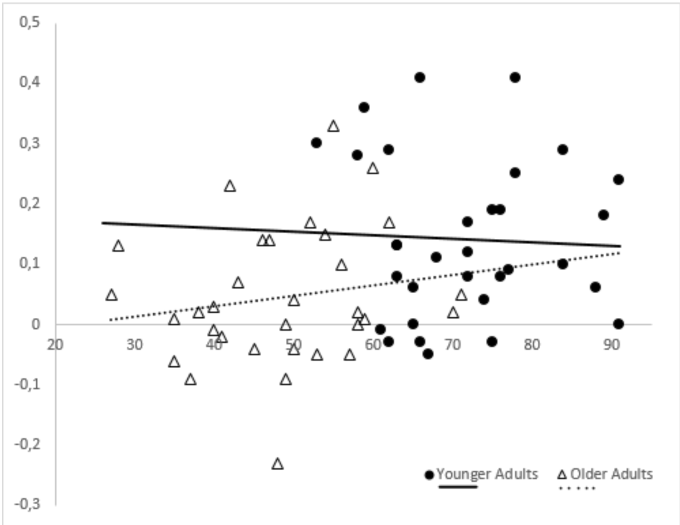

Fig. 9 Processing speed and transfer for younger and older adults with trend lines

4. Discussion

This study examined whether older adults have the same amount of motor skill transfer as younger adults when presented with the same visual stimuli during two different motor tasks. Furthermore this study examined whether learning rate, visuospatial working memory and processing speed are of influence on the amount of transfer.

The results show that, as Voelcker-Rehage (2008) stated in her article, older adults are slower in learning a motor-skill during practice than younger adults, but older as well as younger adults do improve during practice. This is also supported by the findings of Panzer et. Al (2014), who stated that older adults have more difficulties learning, executing and reproducing learned sequences than younger adults. The improvement of younger and older adults can be explained by the DPM, in terms of a switch from reactive mode to associative mode (Abrahamse, Ruitenberg, de Kleine, & Verwey, 2013). Besides the improvement in speed the younger and older adults also showed an improvement in accuracy during the practice phase. This means that the participants not only became faster in executing the sequences, they also made less mistakes. Another result that was found in this study is that younger adults have more transfer in the test phase than older adults. With this result the hypothesis that younger adults have more transfer from one motor skill to another than older adults is confirmed. This suggests that younger adults switch from the reaction mode to the associative mode of the DPM more than older adults. The data also shows that for younger as well as for older adults there is transfer from one motor task to a different motor task. That there is transfer in both age groups suggests that both groups do use visuospatial representations, but that younger adults use visuospatial representations more efficiently than older adults. Verwey (2010) argued that the improvement of younger adults was sequence-specific and the improvement of older adults was sequence-unspecific, because older adults did not perform much better in the random sequences than in the learned sequences. With the results of this study it could well be that the improvement of older adults is also sequence-specific, instead of sequence-unspecific.

Younger adults also scored higher on learning rate, visuospatial working memory and processing speed than older adults. This result is in line with the findings of Voelcker-Rehage (2008), that older adults experience difficulties performing complex tasks, because of deterioration in cognitive, perceptual and sensorimotor functioning.

The results also show that there is a difference in transfer between the participants who practiced with the FE task and the participants who practiced with the DSP task. The participants had more difficulties learning the sequences in the DSP than in the FE task, which suggests that the DSP task is harder to learn than the FE task. Even though this might be true, the participants who performed the DSP task in the practice phase showed more transfer than the participants who performed the FE task in the practice phase. This, together with the results of a better learning rate with the FE task in the practice phase, suggests that there is a difference in developing visuospatial representations between different motor skills. This indicates that the nature of the practice could be important for older adults to form visuospatial representations that can be used in other motor skills.

The last hypothesis that visuospatial working memory, learning rate and processing speed are of influence on the amount of transfer shown by older and younger adults is not supported by the data. There was only a medium association between transfer and learning rate for younger adults. This suggests that a younger adult or an older adult with a higher visuospatial working memory and/or a higher processing speed is not more likely to develop visuospatial representations faster and more efficiently than adults of the same age group with lower scores on these abilities.

One of the limitations of this study is the recruitment of the group of participants. Due to the nature of the recruitment it is possible that older adults responded who are better in motor tasks than other older adults, because for these older adults the step to participate in an experiment could be smaller. The group of younger adults were largely students who participated and this could also be of influence on the scores of this group. Therefore it could be that even though the results showed more transfer in younger adults than in older adults, this gap is larger than indicated by the data in this study.

A point of interest for future research which is not addressed in this study is the age group of adults between 35 and 60 years and adults older than 75 years. It could be of interest to see whether transfer declines to a certain point where there is none at all, or that there will always be a minimum amount of transfer observable. For future research it might also be interesting to take a look at the visuospatial representations that older adults form in other tasks than the FE- and DSP task. This study showed that there was a difference in transfer between the FE task and the DSP task, but it might well be that there are other tasks, which result in even more transfer of motor skill.

In conclusion, this study provides evidence that younger adults have more transfer than older adults and the suggested reason is that younger adults develop visuospatial sequence representations faster and more efficiently than older adults. This means that there is in fact a difference between younger and older adults in how developed representations during sequence based learning are of influence in different motor skills. Another explanation could be that younger adults use already formed visuospatial representations that are not a hundred percent correct for the motor skill, but are better than not use any representation at all. There was only little influence of learning rate, visuospatial working memory and processing speed on the amount of transfer.

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