Predictors of working memory training progress

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Master's Thesis in Psychology

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Subject: Psychology	
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Title: Predictors of working memory training progress	
Supervisors: Matti Laine and Daniel Fellman	
Abstract: Computerized adaptive working memory (WM) training has been extensively studied in cognitive psychology. Initial studies were promising and showed transfer effects to even untrained tasks and domains. Subsequent studies and meta-analyses have painted a more realistic picture indicating that the effects of training are short-lived and task-specific. Inter-individual differences in the as such limited training effects are considerable, but little is known about who benefits from training. These benefits have often been explained with either the Magnification or Compensation hypothesis. The Magnification hypothesis implies that high-functioning individuals benefit the most from training, while the Compensation hypothesis states that individuals with more room for improvement will benefit more from cognitive training. The present study examined predictors of progress on a WM training task in a large sample of 116 healthy adults from the ages 18—50. The online WM training program ran for four weeks. The participants practiced with an adaptive WM updating task (digit n-back) during twelve 30-minute sessions. Of the predictors included in the present study, some have previously been studied (age, education, motivation and baseline WM performance), while some were novel (level of strategy detail, metacognition, training expectations). Growth curve analysis was implemented as the method for statistical analysis. The dependent variable was participants' average n-back level on the training task. Results showed that participants with less perceived WM deficits, a higher baseline performance and a more detailed strategy description at pretest gained most from training. The remaining predictors did not have any impact on the training progress. These results support the Magnification hypothesis, according to which high-performing individuals are the ones that benefit more from cognitive training. These results highlight the role of specific background characteristics in the outcomes of cognitive training.	
Keywords: Working Memory Training, Cognitive Training, Magnification Hypothesis, Individual Differences, Mnemonic Strategies	
Date: 26.2.2020	**Page Count:** 51
Level: Master's Thesis	

ÅBO AKADEMI – Fakulteten för Humaniora, Psykologi och Teologi

Ämne: Psykologi	
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Avhandlingens Titel: Prediktorer för framgång i arbetsminnesträning	
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Abstrakt: Adaptiv datoriserad arbetsminnesträning är tämligen utforskat inom kognitiv psykologi. De första studierna var lovande och visade överföringseffekter (eng. transfer) till andra uppgifter och kognitiva domäner. Metaanalyser som följde visade en mer realistisk bild av träningseffekterna och det framkom att dessa var kortlivade och uppgiftsspecifika. Interindividuella skillnader i de begränsade träningseffekterna är betydande, men man vet fortfarande väldigt lite om vem som gynnas av träning. Fördelarna med kognitiv träning har ofta förklarats med antingen Magnifikations- eller Kompensationshypotesen. Magnifikationshypotesen innebär att redan kognitivt välfungerande individer gynnas mest av träning, medan Kompensationshypotesen antyder att de som har större utrymme för förbättring kommer att gynnas mer av kognitiv träning. Föreliggande studie undersökte prediktorer för framgång i arbetsminnesträning. Samplet bestod av 116 friska vuxna mellan 18 och 50 år. Arbetsminnesträningen genomfördes på en onlineplattform och sträckte sig över en period på fyra veckor. Deltagarna fick öva sig på en n-back uppgift med siffror som hade en adaptiv svårighetsgrad under 12 stycken 30 minuters sessioner. Av prediktorerna var vissa sådana som tidigare undersökts (ålder, utbildning, motivation och basnivå i arbetsminnesuppgifter) och några var nya (detaljnivå av strategibeskrivning, metakognition och förväntningar). Tillväxtkurveanalys användes som statistisk analysmetod. Deltagarnas medelnivå på n-back uppgiften användes som beroende variabel i analyserna. Resultaten visade att deltagare med mindre subjektiva minnessvårigheter, en högre basprestation i uppgiften samt en mer detaljerad strategibeskrivning gynnades mest av träningen. Resterande prediktorer hade ingen inverkan på träningsframgången. Dessa resultat visar stöd för Magnifikationshypotesen, vilket innebär att högpresterande individer är de som gynnas mest av kognitiv träning. Dessa resultat belyser rollen som individuella skillnader spelar i kognitiv träning.	
Nyckelord: Arbetsminnesträning, Kognitiv Träning, Magnifikation, Individuella Skillnader, Minnesstrategier	
Datum: 26.2.2020	**Sidantal:** 51

ACKNOWLEDGEMENTS

First off, I would like to give thanks to my supportive and very knowledgeable supervisors, Matti Laine and Daniel Fellman. Thank you for sharing your invaluable expertise, input and feedback during the process. A special thanks to Daniel Fellman for his help with the statistical analyses. Thank you to Liisa Ritakallio for helping code the substantial dataset that this thesis is based on. Thanks to all the participants in the seminar group who took the time to read and comment on my text.

I would also like to give a huge thanks to all my nearest and dearest friends and family for supporting me through the sometimes, arduous process of writing a thesis. Especially my friends, for giving me advice and providing a space to ventilate the many thought processes you face when writing a thesis and are nearing the end of studies. A special thanks to my dad for always believing in me, this one's for you.

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1 Introduction

Working memory (WM) refers to our ability to maintain and manipulate information for a short time in our mind (Baddeley, 2003), and it is one of the most extensively studied domains in cognitive psychology and cognitive neuroscience. WM is related to many other domains of cognition and mental activities, for example reading, general intelligence, executive functioning, and visuospatial cognition (Miyake & Shah, 1999). WM also plays a pivotal role in everyday tasks such as reading comprehension (Carretti, Caldarola, Tencati, & Cornoldi, 2014) and literacy skills (Payne & Stine-Morrow, 2017). WM has also been shown to play a role in academic achievement (Blankenship, O'Neill, Ross, & Bell, 2015).

Due to the central role WM bears in our cognitive system, an extensive research effort during the past decades has been directed to the investigation of possible enhancement of WM functioning through training. A parallel commercial interest for WM training has emerged in the form of numerous so-called “brain games”, allowing individuals to “train their brain” at home e.g. via a smartphone application. However, the efficacy of such programs remains unclear (Strobach & Huestegge, 2017).

WM training is typically carried out over the course of 4-6 weeks where participants practice on one or several WM tasks with an adaptively changing level of difficulty (e.g., Soveri, Antfolk, Karlsson, Salo, & Laine, 2017; Morrison & Chein, 2011). The principal aim of training is to achieve transfer effects, that is improvement on other untrained tasks that also engage WM (near transfer) and tasks that taps on other cognitive domains (far transfer) (Shipstead, Redick, & Engle, 2010).

The initial WM training studies were very promising by showing transfer effects even to other cognitive domains such as fluid intelligence (Au et al., 2014; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008), cognitive control (Chein & Morrison, 2010), reading comprehension and everyday attention (Richmond, Morrison, Chein, & Olson, 2011). In addition to this, some studies suggested that WM training can alleviate a plethora of symptoms, such as impulsivity and hyperactivity in children with ADHD (Klingberg et al., 2005), symptoms of learning disabilities (Chen, Ye, Chang, Chen, & Zhou, 2018), cognitive symptoms after stroke (Westerberg et al., 2009) and even problems in emotional regulation (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013).

However, subsequent WM training studies have painted a less favorable picture of the transfer effects. In contrast to some of the early studies presented above, more recent meta-analyses have concluded that WM training programs elicit only short-term (Melby-Lervåg, Redick, & Hulme, 2016) and task-specific (Soveri et al., 2017; Melby-Lervåg & Hulme, 2013; Schwaighofer, Fischer, & Bühner, 2015) transfer effects within the WM domain.

Although recent meta-analyses indicate that in general, transfer effects are very limited, it is nevertheless possible that some groups or individuals benefit more from cognitive training than others. Therefore, an interest for individual differences in training progress has emerged. In fact, it seems as if training gains largely depend on individual characteristics (Lanfranchi & Carretti, 2016).

Individual characteristics in training contexts have typically been related to two opposing hypotheses, namely the *Magnification* hypothesis and the *Compensation* hypothesis. According to the Magnification hypothesis (sometimes titled as the Matthew effect in scientific literature), individuals who at the outset show a better performance on cognitive tasks will gain more from the training. In contrast, the Compensation hypothesis suggests that individuals with less cognitive assets have more room for improvement and therefore show more training benefits. For example, individuals who do not have an efficient mnemonic strategy may benefit more from being taught a new one than those who spontaneously come up with a good strategy (Lövdén, Brehmer, Li, & Lindenberger, 2012). Both the Magnification hypothesis (e.g. Verhaeghen & Marcoen, 1996; Kliegl, Smith, & Baltes, 1990; Guye, De Simoni, & von Bastian, 2017; Bissig & Lustig, 2007; Wiemers, Redick, & Morrison, 2019) and the Compensation hypothesis (e.g. Titz & Karbach, 2014; Dorbath, Hasselhorn, & Titz, 2011; Park et al., 2018; Reuter-Lorenz & Cappell, 2008; Borella, Carbone, Pastore, De Beni, & Carretti, 2017) have received support, the latter one especially in neuroimaging studies (e.g. Ji et al., 2018, Scheller et al., 2017).

Most of the studies examining the relationships between individual characteristics and WM training progress have focused on the effect of age (e.g. Karbach & Verhaeghen, 2014; Borella et al., 2017; von Bastian et al., 2013; Bissig & Lustig, 2007). Other individual factors that have been examined to a lesser extent are education (Park et al., 2018), personality traits (Studer-Luethi, Jaeggi, Buschkuehl, & Perrig, 2012), motivation (Zhao, Xu, Fu, & Maes, 2018), general cognitive ability (Foster et al., 2017; Wiemers et al., 2019) and baseline working memory performance (Guye et al., 2017; Wiemers et al., 2019), among others. Although several studies examining background factors impacting WM training progress exist, there is still a number of potentially relevant individual differences variables that have not been considered as predictors, for example use of memory strategies prior to training. Thus, a feasible step forward is to test the predictive value of further possibly relevant variables. Identifying predictors of training progress could also provide a chance to optimize WM training protocols according to what is most beneficial for a certain demographic group (Morrison & Chein, 2011).

1.2. Individual predictors of WM training progress

The effect of age on WM training outcomes has been examined in several studies. In a meta-analysis by Karbach & Verhaeghen (2014), the authors found that age had no effects on WM training gains. Similar results were found in studies by Guye et al. (2017) and Borella et al. (2014). An earlier meta-analysis by Verhaeghen, Marcoen, and Goossens (1992) concluded that older adults gained less from cognitive training, supporting a magnification effect. Some more recent studies also support the Magnification hypothesis (Bürki, Ludwig, Chicherio, & de Ribaupierre, 2014; and von Bastian et al., 2013). Bissig and Lustig (2007) conducted a training study which included an encoding task requiring self-initiation of strategies in order to support later memory. Participants were instructed to study a list of words and later correctly identify studied words among lures from a list. Results showed that age had a negative association with training efficacy, with older participants showing less training gains. This effect was, however, not significant after accounting for the time participants had spent practicing on the encoding task. These results indicate that older participants' gain in WM training was highly reliant on their ability to form strategies (Bissig & Lustig, 2007). Borella et al., (2017) examined the impact age had on the WM training outcomes, showing that age significantly predicted gains in some of the pre-post WM tasks. In more complex WM tasks (e.g. backward digit span), younger participants were more likely to gain from the training. On the contrary, in more simple WM tasks (e.g. digit span), older participants gained more from the training. All in all, age seems to have varying effects on WM training gains.

Another predictor that has received attention in previous studies is education. Park et al. (2018) found in their study on older adults that education significantly predicted training gains following 15 hours of multi-strategic memory training (MMT), with a lower level of education leading to higher gains from the training. The MMT program is however slightly different from traditional WM training as it emphasizes participants' metacognitive knowledge about their memory. The less educated participants might have shown less training gains due to their lesser experience in monitoring their memory, in comparison to those with a higher level of education (Park et al., 2018). In a six-session training study by Borella et al. (2017), with the first and fifth session serving as a pretest and posttest and the sixth as a follow-up session (6–8 months later), individuals with a limited education (education ranged from 8–24 years) showed slighty better improvements in their WM performance, as compared to those with higher education. Albeit this effect was only noticeble at posttest and not during the course of training, it still lends some support for the Compensation hypothesis.

To the best of the author's knowledge, metacognition (i.e. awareness of and understanding of one's own thought processes) has not yet been studied as a direct predictor of progress on the WM training task(s), albeit some studies have examined the role of metacognition on transfer effects. According to the general learning model put forth by Chein and Schneider (2012), the metacognitive system is at the top of a hierarchy of systems responsible for learning. The metacognitive system is crucial for establishing new behavioral routines, task preparation and task monitoring, and it is especially active during novel tasks and contexts. Individuals with a highly developed metacognitive system may have advantages in novel tasks, as they can rapidly acquire new behavioral routines and can more easily recognize effective learning strategies (Chein & Schneider, 2012).

In one study focusing on WM transfer effects, by Jaeggi, Buschkuehl, Shah and Jonides (2014), two questionnaires were used as predictors for transfer, namely Need for Cognition[1] (NFC; Caccioppo & Petty, 1982), Theory of Cognitive Abilities[2] (TOCA; Dweck, 1999). The results showed that those with higher beliefs that intelligence is malleable (as measured with TOCA) showed larger far transfer effects, supporting a magnification effect. NFC did not predict any transfer effects. Although the Jaeggi et al. (2014) study primarily focused on associations between individual differences and far transfer effects that have turned out to be hard to replicate, their results indicate that metacognition might have some impact on WM training improvements. Contrary to these results, Guye et al. (2017), found that participants who reported higher beliefs that intelligence is malleable gained less from WM training, supporting a compensation effect.

Some studies have also investigated the relationship between baseline WM performance and training gains. For instance, both Wiemers et al. (2019) and Guye et al. (2017) found that baseline WM performance was positively related to progress in training performance, suggesting that participants with a better WM performance at the start of training improved more over the course of time. Zinke et al. (2014) also found that baseline WM performance significantly predicted training gains. These results support the Magnification hypothesis. As previously noted, Borella et al. (2017) found that baseline WM performance interacted with the WM task: participants with a weaker WM performance gained more from training with simpler tasks, and vice versa.

Participants' expectations and motivation towards training, may also be related to the actual outcomes of WM training as both of them have a substantial role in many psychological processes. In recent years, an interest has emerged e.g., for interactions between motivation and cognition (for a brief review on this topic, see e.g. Braver et. al., 2014). Guye et al. (2017) found no associations between motivation and WM training outcomes. However, in a study conducted by Zhao et al. (2018), higher motivation was associated with larger WM training gains, thus supporting a magnification effect.

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[1] NFC measured participants' propensity to enjoy cognitively challenging tasks.
[2] TOCA measured the degree to which participants believed intelligence is malleable or fixed.

Another predictor of possible WM training gains is the use of strategies during the training. Mnemonic instructions in WM tasks have been found to improve training performance. Lövdén et al. (2012) found that strategy instructions were associated with training gains in older adults. Similarly, Bissig & Lustig (2007) found that self-initiated strategies were associated with more gains. Participants who performed poorly had little insight in their strategies and provided only rudimentary strategy descriptions. Fellman et al. (2020) demonstrated that an enhanced strategy use elicited by WM training was related to improved WM task performances following intervention. This is in accordance with the results from Laine, Fellman, Waris, & Nyman (2018), where strategy use was associated with a higher performance on an n-back task. The level of strategy detail (i.e. how comprehensive the participants' description of his/her strategy was, see Section 2.7. for a description) was significantly linked to participants' performance at posttest. Thus, these studies support the Magnification hypothesis, since individuals with better outlined strategies gained more from the training.

1.3. Aims of the study

The aim of the present study was to examine whether certain individual differences variables predicted the outcome of WM training on the trained task in a sample of healthy adults. As the results of WM training studies have been highly variable, it is important to identify factors that could explain why some individuals gain from training while others do not. The aim of WM training is to achieve transfer, and according to Jaeggi, Buschkuehl, Jonides, & Shah (2011), individuals who gain most from training (as measured by the progress on the training task or tasks) are also the ones most likely to show more transfer effects. It is therefore of great value to identify factors affecting training gains.

The predictors included in the present study consisted of some previously studied predictors (age, education, baseline WM performance, motivation) along with some novel predictors (level of strategy detail, metacognition, training expectations). As the current body of research has been quite mixed as to whether WM training favours cognitively high- vs. low-performing individuals, no clear stance was taken as to whether results would support the Magnification hypothesis or the Compensation hypothesis. Thus, the present study is to a large part exploratory. However, in terms of the specific predictors, especially a higher pretest level of strategy detail (Fellman et al., 2020; Laine et al., 2018) and a higher pretest WM performance (Guye et al., 2017; Zinke et al., 2014; Borella et al., 2017) should lead to a higher training gains. Moreover, more metacognitive awareness and higher expectations of the benefits of training was anticipated to lead to more training gains.

2 Method

2.1. Procedure

The present data are part of an online randomized controlled WM training trial which the participants completed at home (Fellman et al., 2020). The whole study spanned over a total of four weeks and was conducted with an in-house web-based testing and training platform called Soile. The study included three cognitive assessment points (i.e., pretest, intermediate test, posttest). Participants were randomized to one out of three possible conditions:

1. Strategy training group: participants received 12 x 30 minutes of single n-back[3] training with a provision of an externally given strategy. This group was included in the original study to gather evidence for a causal role of strategies in WM training progress.
2. Traditional training group: participants received 12 x 30 minutes of single n-back training without any external strategy instruction. This corresponds to traditional WM training.
3. Control group: participants did not practice at all, but completed only the pretest, intermediate test and posttest sessions.

As the aim of the present study was to examine individual predictors of training task gains in traditional WM training, this study focused solely on the traditional training group. The dominant practice in WM training is to have the participants complete the training without any strategy instructions (e.g. Borella et

[3] The n-back task is commonly used in WM training studies (see e.g. Soveri et al., 2017). In this version, digits are presented one at a time. Participants were instructed to determine for each digit, by clicking yes/no, if it was the same as the digit presented *n* digits back in the sequence.

al., 2017; Guye et al., 2017). The Strategy Training group was left out from the present analyses as previous results indicate that strategy provision enhances training progress (Laine et al., 2018), and this could potentially obscure or modulate the effects of individual background variables. As the control group did not partake in any type of WM training, their results were not analyzed in this study either.

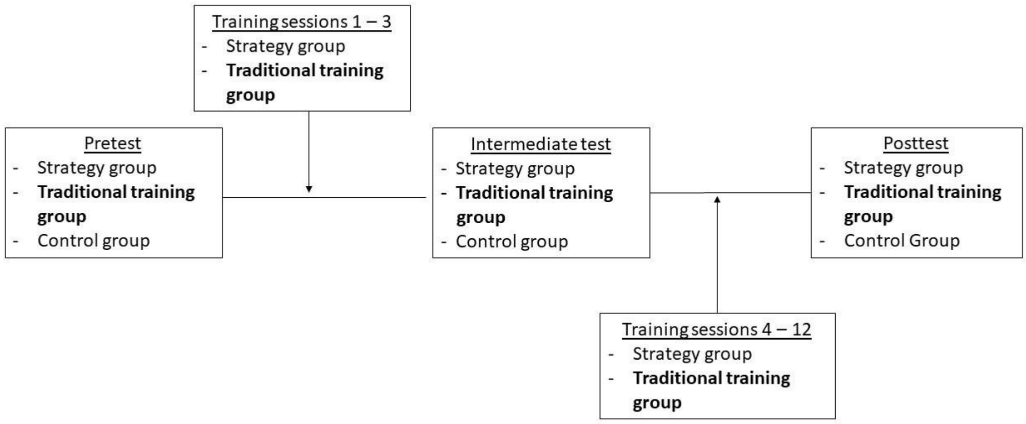

Fig. 1 Schematic illustration of the experimental design. The traditional training group (marked with bold text) completed 12 training sessions over a period of four weeks, coupled with three cognitive assessment points (pretest during week 1, intermediate test during week 2 and posttest during week 6).

The participants were recruited in batches during a 5-week period through Prolific Academic (https://www.prolific.ac/), a crowdworking website for online studies that connects researchers with volunteering study participants. A prescreening was conducted via the Soile platform to exclude participants who were not eligible for the study due to exclusion criteria. Criteria for exclusion were non-native English speaker, current psychiatric and neurological illness, current use of medication affecting the CNS, and current psychotropic drug use.

The participants that met the inclusion criteria were invited to take part in the study. The first phase of the study encompassed a pretest session, including ten

WM tasks with an approximate duration of two hours. Besides the WM tasks, the pretest session also included background questionnaires (see below, 2.4 and 2.5) which the participant responded to prior to the pretest session. Informed consent was also acquired at the beginning of the pretest. The participants received monetary compensation for a completed pretest session (10£, approx. 11€). The study was approved by the Institutional Review Board of the Departments of Psychology and Logopedics, Åbo Akademi University, and was in accordance with the Helsinki Declaration.

2.2. Participants

The participants were healthy adults in the age range of 18—50 years (*M* = 35.2, *SD* = 8.9). The majority of participants, 74 (63.8 %), were women. Years of education ranged from 7 to 25 years[4] (*M* = 15.8, *SD* = 3.3). As mentioned above, the sample was collected through the website Prolific Academic. Initially 419 participants registered for the study, but after accounting for participants that either withdrew before the pretest session, did not complete the pretest session, or had technical difficulties interfering with the pretest, a total of 341 participants completed the pretest (see Figure 2). After excluding those participants who did not fulfill the criteria for inclusion (see 2.1) and those participants who withdrew after the pretest, 322 eligible participants were left to be randomly allocated to one of the three groups (i.e. strategy group, traditional training group or control group) as illustrated in the figure below. As regards the study attrition specifically concerning the traditional training group, participants who withdrew from the study during the training period and who used external aids during training (e.g., writing down the answers) were excluded from the data analysis. Participants with incomplete data (i.e., missing data in one or more training sessions), were also excluded from the analyses. Thus, the final sample in the traditional training group consisted of 116 participants.

[4] One participant reported having only 3 years of education (but simultaneously reported having an education class corresponding to a median of 12 years). As 3 years of education is highly unlikely, it is probable that the participant misunderstood the question, and therefore the median value of 12 was used instead.

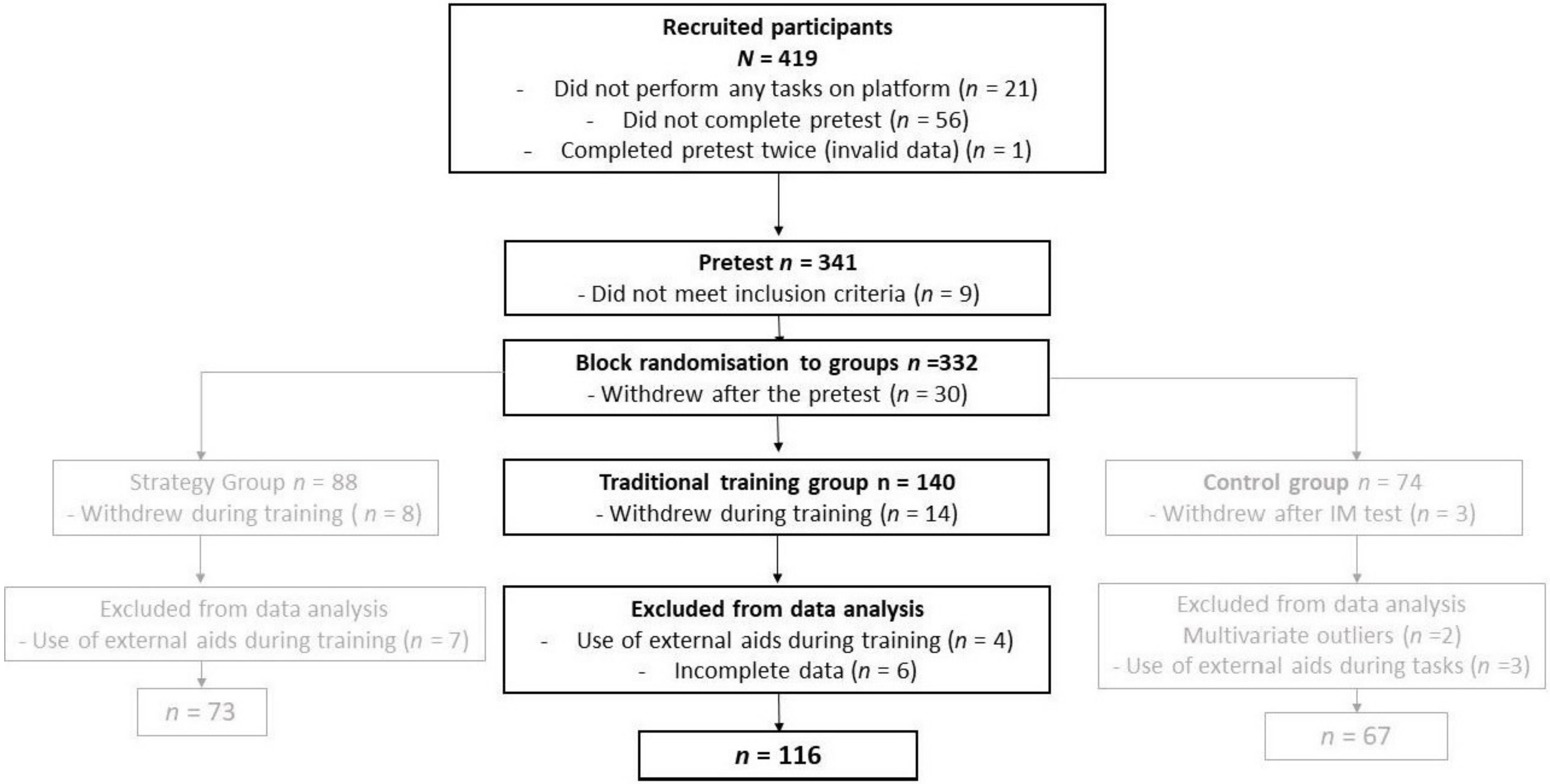

Fig. 2 Flowchart depicting the participant recruitnent. The selection process pertaining to the traditional training group is found in bold.

2.3. Pretest WM Tasks

The ten WM tasks included in the pretest encompassed four n-back tasks, four simple span tasks, and two running memory tasks. As the present study only focused on performance outcome on the trained n-back digit task and its predictors, a rudimentary description of the remaining tasks is presented in Table 1.

Table 1. Description of WM tasks included in the pretest.

N-back digits	Digits were presented one at a time. Participants were instructed to determine for each digit, by clicking yes/no, if it was the same as the digit presented *n* digits back in the sequence. The task was adaptive. Dependent variable: average level of *n* reached.
N-back letters	Letters were presented one at a time. Participants were instructed to determine for each letter, by clicking yes/no, if it was the same as the letter presented *n* letters back in the sequence. The task was adaptive. Dependent variable: average level of *n* reached.
N-back colors	Colors were presented one at a time. Participants were instructed to determine for each color, by clicking yes/no, if it was the same as the color presented *n* colors back in the sequence. The task was adaptive. Dependent variable: average level of *n* reached.
N-back boxes	Locations of boxes within a 3 x 3 matrix were presented one at a time. Participants were instructed to determine for each location, by clicking yes/no, if it was the same as the location presented *n* back in the sequence. The task was adaptive. Dependent variable: average level of *n* reached.
Forward digit span	Digits were presented one at a time. The sequences of digits were of varying length. Participants were to recall the sequence of digits in the order which they appeared. Dependent variable: total amount of digits recalled correctly.
Backward digit span	Digits were presented one at a time. The sequences of digits were of varying length. Participants were to recall the digits in the opposite order of which they appeared. Dependent variable: total amount of digits recalled correctly.
Forward box span	Locations of boxes within a 3 x 3 matrix were presented one at a time. Participants were to recall the locations in the order which they appeared. Dependent variable: total amount of box locations recalled correctly.
Backward box span	Locations of boxes within a 3 x 3 matrix were presented one at a time. Participants were to recall the locations in the opposite order of which they appeared. Dependent variable: total amount of box locations recalled correctly.
Running memory with digits	Digits were presented one at a time. The sequence of digits is of varying length. When the sequence of digits suddenly ends, participants were to remember the last four digits. Dependent variable: total amount of correct items.
Running memory with boxes	Locations of boxes within a 3 x 3 matrix were presented one at a time. The string of locations was of varying length. When the locations suddenly ceased to appear the participant was to remember the last four locations. Dependent variable: total amount of correct items

2.4. Working Memory Questionnaire

In addition to the ten WM tasks included in the pretest and the demographic questionnaire, the participants filled out the Working Memory Questionnaire (WMQ; Vallat-Azouvi, Pradat-Diehl, & Azouvi, 2012). WMQ is a scale consisting of 30 questions, capturing perceived everyday deficits in WM functioning. The scale has been validated in groups of both healthy adults and adults with a background of brain injury. (Vallat-Azouvi, Pradat-Diehl, & Azouvi, 2012).

The questions included in the WMQ are purported to tap three separate domains of WM, namely executive functioning, storage and attention. Each domain is covered by 10 questions. Higher points indicate more WM difficulties and/or more complaints relating to WM deficits. Included questions are for example "*Do you find it difficult to remember the name of a person who has just been introduced to you?*" and "*Do you have difficulty in organising your time with regard to appointments and your daily activities?*". The questionnaire can be found in its entirety in the supplementary material.

In the original study, the questionnaire was found to have a high internal consistency. The correlations between subscales (i.e. executive, storage and attention) were significant, as were correlations between the subscales and the total WMQ score. (Vallat-Azouvi, Pradat-Diehl, & Azouvi, 2012). In the present study, participants' mean score of the WMQ was used as the dependent variable.

2.5. Metacognitive Awareness Inventory

Prior to the pretest, the participants also filled out the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994). MAI is constructed to measure adults' and adolescents' metacognitive awareness. The inventory consists of 52 items. The items are broadly divided into two larger domains: knowledge of cognition and regulation of cognition, which were used as two separate dependent variables. Factor analyses conducted in the original study corroborated this division, showing that the internal consistency of the subscales were excellent (Schraw & Dennison, 1994). The 52 items included in the MAI are scored as either true or false, with more points indicating a higher metacognitive awareness (i.e. knowledge of cognition and regulation of cognition). Items included in the MAI are for example "*I ask myself periodically if I am meeting my goals*"; "*I focus on the meaning and significance of new information*" and "*I have a specific purpose for each strategy I use*". The questionnaire can be found in its entirety in the supplementary material.

2.6. Motivation and expectations

The participants were asked to rate their motivation throughout the training process. Motivation was assessed on three separate occasions (training session 1, 6 and 12) during the training period using a five-point Likert-type scale, with 1 being least motivated and 5 being most motivated. Participants' expectations of the WM training were also assessed during the first training session. They were asked to estimate how much they expected to improve on the training task during the course of the 12 half-an-hour training sessions on a 10-point Likert scale (1 = "not at all", 10 = "very much").

2.7. Level of detail of memory strategies

The use of mnemonic strategies in the WM tasks at pretest was assessed through open questions. The participant was first asked whether he/she had adopted a strategy for the task at hand. If the participant answered yes, he/she was then asked to freely describe the strategy in a comment field. The level of detail (i.e. how detailed participant's description of his/her strategy was) in the strategy reports was then coded independently by two raters. Discrepancies between the ratings were thereafter solved through consensus. The coding of level of strategy detail followed the system introduced in Laine et. al. (2018) and is described below. The classifications indicated strong to almost perfect agreement between the raters (κ_w ranging from 0.86 – 0.96).

Reports of no strategy use were coded as zero points. Vague strategy reports were given one point (i.e., "I tried to keep up but got confused"; "I tried"). Fairly non-specific strategy reports were given two points (e.g., "Just tried to concentrate on the numbers", "I tried to mentally memorize the digits"). A general strategy description with a maximum of one strategy detail was given three points (e.g., “Repeating the digits in my head”, “Grouping the numbers in three”). A general description of the strategy including two or more details yielded four points (e.g., “Repeating the digits out loud and grouping them in threes”, “Grouping the digits and replacing them while a new one appeared”).

2.8. Training task

The WM training task in the present study was a single n-back task using digits as stimuli. The digits (1—9) were presented one at a time on a computer screen. The participants were instructed to determine for each digit, by clicking yes/no, if it was the same as the digit presented *n* digits back in the sequence (see Figure 3 for an illustration).

Every training session was composed of 20 blocks with each block containing 20 + *n* trials. The sequences in a block started with a blank screen (presented for 450 ms). Then a stimulus was displayed (for 1500 ms) followed by another blank screen (presented for 450 ms), and so on, until the end of the block. The task was adaptive so that the level of n-back could vary from 1-15. If the participant recalled 18-20 trials correct in one block, the level of *n* was increased with 1. If the participant recalled 15-17 trials correctly, the level of *n* remained the same. Five or more incorrectly recalled trials during a block resulted in the level of *n* being decreased by 1. In order to adjust the difficulty over the training sessions, an *n* – 2 rule was implemented. For example, if a participant reached 6-back on a previous training session, the new session started at 4 back.

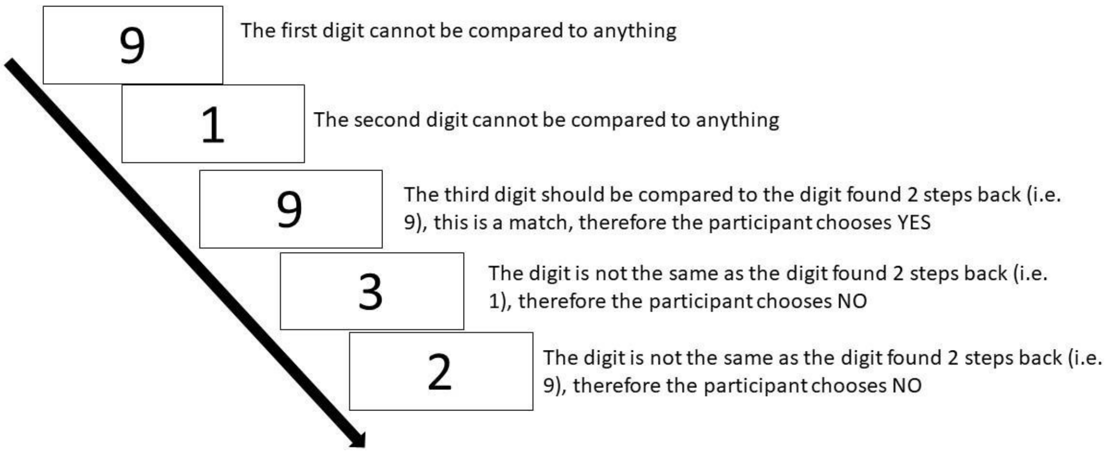

Fig. 3 An illustration of the trained n-back task (here the level of *n* is 2).

2.9. Statistical Analyses

Descriptive analyses were conducted using IBM SPSS Statistics version 25, and all remaining analyses were conducted in R version 3.5.2 using the packages lme4 (Bates, Mächler, Bolker, & Walker, 2015), and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017).

Growth curve analyses (Mirman, 2014) were used to examine changes in the training task by specifying the 12 training sessions as a linear contrast using the average level in the WM task (n-back digits) as the dependent variable. Participant on the intercept served as the random effect and the predictor variables as fixed effects. Main effects were computed for each predictor variable together with the interaction term between training session and the predictor in question. The interaction term is of most importance here, as it tests whether a specific predictor is related to improvement across time.

To avoid problems with multicollinearity, the predictors were split into three separate models (cf., Guye, De Simoni, & von Bastian, 2017).[5] The three models were the following:

1. *Demographic predictors:* Age, education in years
2. *Metacognitive predictors:* Working memory Questionnaire (WMQ) mean score, Metacognitive Awareness Inventory (MAI) mean scores of knowledge of cognition and regulation of cognition.
3. *Initial WM performance, expectations and motivation*: n-back digits performance at pretest, level of strategy detail for n-back digits at pretest, training expectations and motivation.

As mentioned earlier, the dependent variable used in all three growth curve models was the participants' average level on the trained WM task (n-back digits). The task also allowed the use of the maximum n-back level achieved at a given training session as a dependent variable. However, the former measure was expected to give a clearer picture of the actual performance (not highlighting possible sporadic high scores, as would be the case if the maximum n-back level was used). Therefore only the average n-back level reached was used in the analyses.

As previously mentioned, participants were entered as random effects in all three models. Treating participants as random effects means that the parameter estimates reflect both the individual participants' data as well as the group data. This gives a picture of overall trends within the group data, as it reflects the assumption that participants are randomly drawn from a population. On the contrary, treating participants as fixed effects (i.e. fully independent) leads to a risk of the model overfitting the data (Mirman, 2014).

In an exploratory setup such as in this study, one wants to evaluate the contribution of each predictor. Thus, following the guidelines proposed by Mirman (2014), a baseline model including all predictors for each of the three models

[5]Correlations between the different variables in each three models varied from $r = 0$ to -0,86, indicating multicollinearity. The highest correlation of $r = -0{,}86$ was between the variables training expectations and pretest level of strategy detail. However, the variable training expectations did not have any predictive value in the model and was thus not included in the final most parsimonious model, eliminating the problem of collinearity between the two predictors.

described above was computed. A backwards elimination procedure was then implemented (see e.g. Fellman et al., 2018) meaning that those predictors with least predictive value on the slope (i.e., training improvement over time) were removed. Removal of predictors was handled using the -2 times the change in log-likelihood, which is distributed as χ^2 with degrees of freedom equal to the number of parameters (Mirman, 2014). In order to obtain the parameter estimates of significant terms from the most parsimonious models, the Restricted maximum likelihood (REML) estimation method was used.

A total of 10 participants' data was excluded from analyses. Four of these were left out due to use of external aids during training sessions (e.g. writing down answers) and six due to missing data in one or more training sessions, due to technical difficulties.

3 Results

General results from the present study indicate that participants became better at the WM task over time. Figure 4 depicts the learning curve of participants over the 12 training sessions. The pattern of the training progress corresponds to a quite typical representation of a learning curve, with a rapid initial improvement followed by a slight plateau, indicating less improvements with practice (over time) (Ritter & Schooler, 2001).

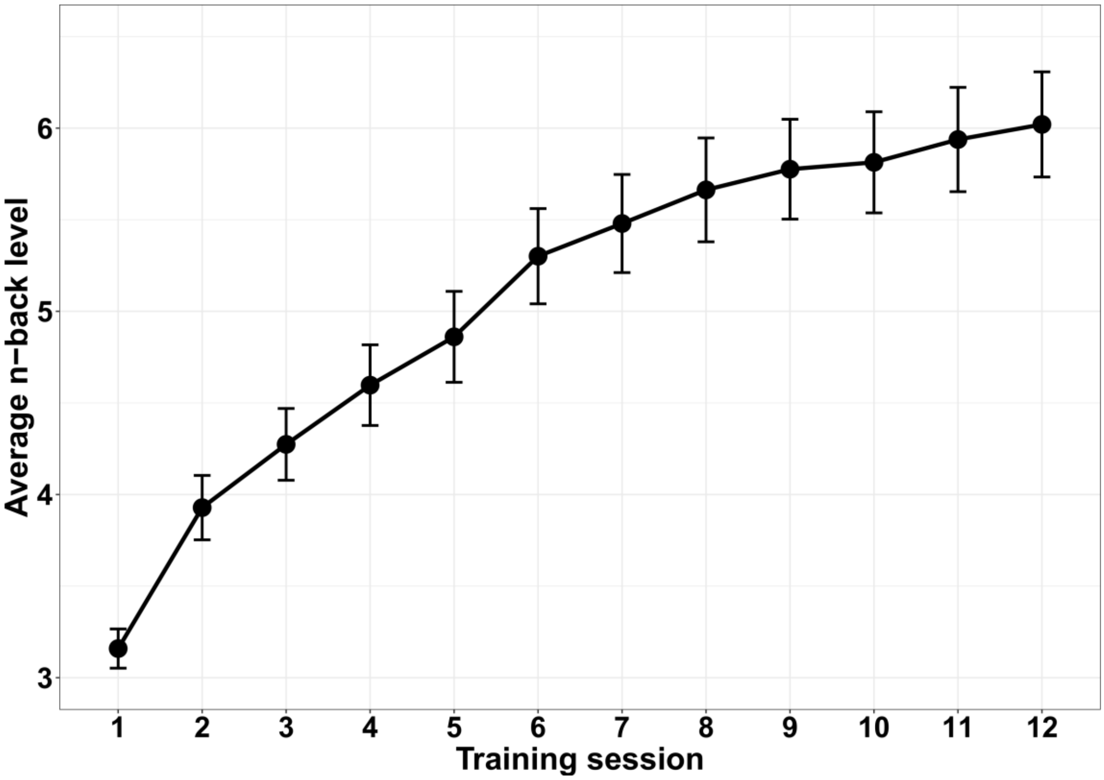

Fig 4. A growth curve analysis with time as the predictor and average level on n-back digits as the dependent variable. There was a significant effect of time on the average n-back level $B = 0.240$, $SE = 0.008$, $t = 27.17$, $p < 0.001$, showing the expected performance increase on the trained WM task over time.

3.1. Demographic predictors

Predictors included in the full model were age and education in years. Participants' age ranged from 18 to 50 years (*M* = 35.2, *SD* = 8.9) and education from 7 to 25 years (*M* = 15.8, *SD* = 3.3).

As regards the main effects, neither age $B = -0.016$, $SE = 0.026$, $t = -0.618$, $p = 0.53$, nor education $B = 0.024$, $SE = 0.070$, $t = 0.348$, $p = 0.72$, were statistically significant. This suggests that these demographic variables did not have an impact on the overall performance on the trained n-back task during the course of training. No significant interaction terms were found for time and age, $B = 0.0003$, $SE = 0.001$, $t = 0.31$, $p = 0.75$ or time and education in years $B = 0.001$, $SE = 0.002$, $t = 0.42$, $p = 0.67$, indicating that participants improved equally well in the training task across time irrespective of their age and years of education (see Table 2).

Table 2. The full model including the demographic predictors.

		Value	
Predictors	*Estimates*	*CI*	*p*
(Intercept)	3.68	0.90—6.46	0.010
Time	0.21	0.10—0.32	**<0.001**
Age	-0.02	-0.07—0.03	0.538
Education in years	0.02	-0.11—0.16	0.728
Time × Age	0.00	-0.00—0.00	0.754
Time × Education	0.00	-0.00—0.01	0.672
Random Effects			
σ^2	1.30		
τ_{00} participant	5.69		
ICC participant	0.81		
Observations	1392		
Marginal R^2/Conditional R^2	0.093/0.831		

3.2. Metacognitive predictors

Predictors included in the full metacognitive model were the mean score for WMQ and the mean scores for the two MAI domains (knowledge of cognition and regulation of cognition).

The participants' mean scores on the WMQ ranged from 1 to 3.6 (M = 1.69, SD = 0.53), with higher scores indicating more WM-related problems. The mean scores on the MAI domain knowledge of cognition ranged from 1.3 to 5 (M = 3.6, SD = 0.74) and mean scores on the MAI domain regulation of cognition varied from 1.9 to 5 (M = 3.44, SD = 0.70), with higher scores indicating more metacognitive awareness.

In accordance with the backwards elimination model, the least significant predictor, MAI knowledge of cognition ($p = 0.82$) was excluded, and a new model was computed without it. In the subsequent model, MAI regulation of cognition was least significant ($p = 0.10$), and therefore dropped, leaving only the WMQ mean score as a predictor. No main effect of the WMQ mean score in the final model was observed $B = -0.45$, $SE = 0.42$, $t = -1.06$, $p = 0.28$, indicating that the WMQ mean score did not have an impact on the performance on the trained n-back task during the course of training. However, the analysis of the final model showed a statistically significant interaction between time and WMQ mean score $B = -0.07$, SE =0.016, $t = -4.41$, $p < 0.001$, indicating that individuals with less perceived executive deficits according to the WMQ sum score (i.e., lower points on the WMQ) had higher success in the training task over time (see also Figure 4). Results from the full model and the most parsimonious model are presented in Table 3 and Table 4.

Table 3. Results from the full metacognitive model.

	Full Model		
		Value	
Predictors	*Estimates*	*CI*	*P*
(Intercept)	4.84	1.51—8.16	0.005
Time	0.28	0.14—0.41	**<0.001**
WMQ mean	-0.35	-1.25—0.55	0.447
MAI knowledge	0.67	-0.28—1.61	0.168
MAI regulation	-0.92	-1.86—0.03	0.059
Time × WMQ mean	-0.07	-0.10—0.03	**<0.001**
Time × MAI knowledge	0.00	-0.03—0.04	0.82
Time × MAI regulation	0.02	-0.02—0.05	0.347
Random Effects			
σ^2	1.28		
τ_{00}	$5.33_{participant}$		
ICC	$0.81_{participant}$		
Observations	1392		

Table 4. Results from the final, most parsimonious metacognitive model, after backwards elimination.

		Final Model	
		Value	
Predictors	*Estimates*	*CI*	*P*
(Intercept)	4.27	2.79—5.75	**<0.001**
Time	0.36	0.31—0.42	**<0.001**
WMQ mean	-0.45	-1.28—0.38	0.289
MAI knowledge			
MAI regulation			
Time × WMQ mean	-0.07	-0.10—0.04	**<0.001**
Time × MAI knowledge			
Time × MAI regulation			
Random Effects			
σ^2	1.28		
τ_{00}	$5.47_{participant}$		
ICC	$0.81_{participant}$		
Observations	1392		
	0.124/0.834		

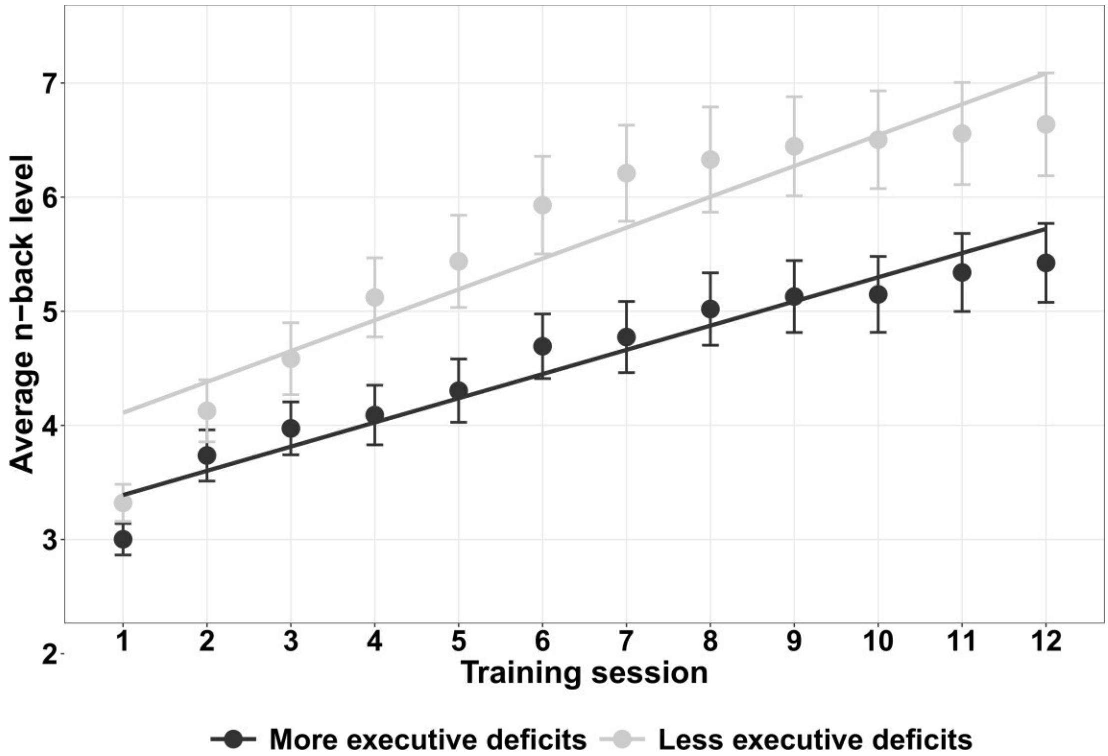

Fig. 5. The observed data from the most parsimonious model separated into participants with more vs. less executive problems (according to the WMQ), divided by median split. The median split was done only for illustrative purposes, as all variables were treated as continuous in the analyses. Symbols and error bars indicate ± standard errors.

3.3. Initial WM performance, expectations and motivation as predictors

Predictors included in the model were average pretest n-back level on the trained task, pretest level strategy of detail on the trained task (see 2.7.), training expectations and motivation (see 2.6). The participants' average pretest n-back level ranged from 1 to 5, (*M* =2.47, *SD* = 0.79), with higher values indicating a higher level of success. The pretest level of strategy detail ranged from 0 to 4 (*M* = 1.51, *SD* = 1.64) with higher values suggesting a more detailed strategy. The training expectations ranged from 1 to 10 (*M* = 6.16, *SD* = 1.9), with higher values indicating higher expectations of improvement during the course of training. Motivation during the training sessions varied from 1 to 5 (*M* = 4.08, *SD* = 0.97), with higher points indicating higher motivation for the WM training.

In the analysis, the sequential backward elimination function first eliminated the non-significant time and training expectations interaction ($p = 0.15$), and then the time and motivation interaction ($p = 0.13$), leaving the pretest n-back level and the pretest level of strategy detail in the most parsimonious model. Concerning the pretest n-back level, results showed both a significant main effect of pretest n-back level $B = 1.50$, $SE = 0.24$, $t = 6.24$, $p < 0.001$ and a significant interaction of time and pretest n-back level $B = 0.04$, $SE = 0.01$, $t = 4.23$, $p < 0.001$, indicating that those with higher pretest performance not only performed better across training, but also improved more in the training task over time.

No main effect of pretest level of strategy detail was observed $B = -0.04$, $SE = 0.11$, $t = -0.34$, $p = 0.72$. However, the results showed a statistically significant time and level of strategy detail interaction $B = 0.029$, $SE = 0.005$, $t = 5.24$, $p < 0.001$, suggesting that participants with more detailed strategies at pretest gained more over time in the training task compared to those with less detailed strategies. Visualisations using the median split method were employed to illustrate differences in the pretest n-back level (see Figure 6) and pretest level of strategy detail (see Figure 7).

Table 5. Results from the full training-related model, prior to backwards elimination.

	Full Model		
		Value	
Predictors	*Estimates*	*CI*	*p*
(Intercept)	0.19	-1.96—2.34	0.862
Time	0.05	-0.05—0.15	0.346
Pretest n-back level	1.51	1.04—1.98	**<0.001**
Pretest Level of strategy detail	-0.05	-0.28—0.18	0.696
Training expectations	0.02	-0.18—0.21	0.859
Motivation	-0.11	-0.55—0.33	0.621
Time × pretest n-back level	0.05	0.03—0.07	**<0.001**
Time × pretest level of strategy detail	0.03	0.02—0.04	**<0.001**
Time × training expectations	-0.01	-0.02—0.00	0.152
Time × motivation	0.02	-0.00—0.04	0.099
Random Effects			
σ^2	1.23		
τ^{00}	3.31 $_{participant}$		
ICC	0.73 $_{participant}$		
Observations	1380		
Marginal R^2/Conditional R^2	0.409/0.840		

Table 6. Results from the final, most parsimonious model after backwards elimination.

	Final Model		
	Value		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	-0.17	-1.33—0.99	0.777
Time	0.08	0.02—0.13	**0.008**
Pretest n-back level	1.51	1.03—1.98	**<0.001**
Pretest Level of strategy detail	-0.04	-0.27—0.19	0.728
Training expectations			
Motivation			
Time × pretest n-back level	0.05	0.03—0.07	**<0.001**
Time × pretest level of strategy detail	0.03	0.02—0.04	**<0.001**
Time × training expectations			
Time × motivation			
Random Effects			
σ^2	1.24		
τ^{00}	$3.32_{participant}$		
ICC	$0.73_{participant}$		
Observations	1392		
Marginal R^2/Conditional R^2	0.409/0.840		

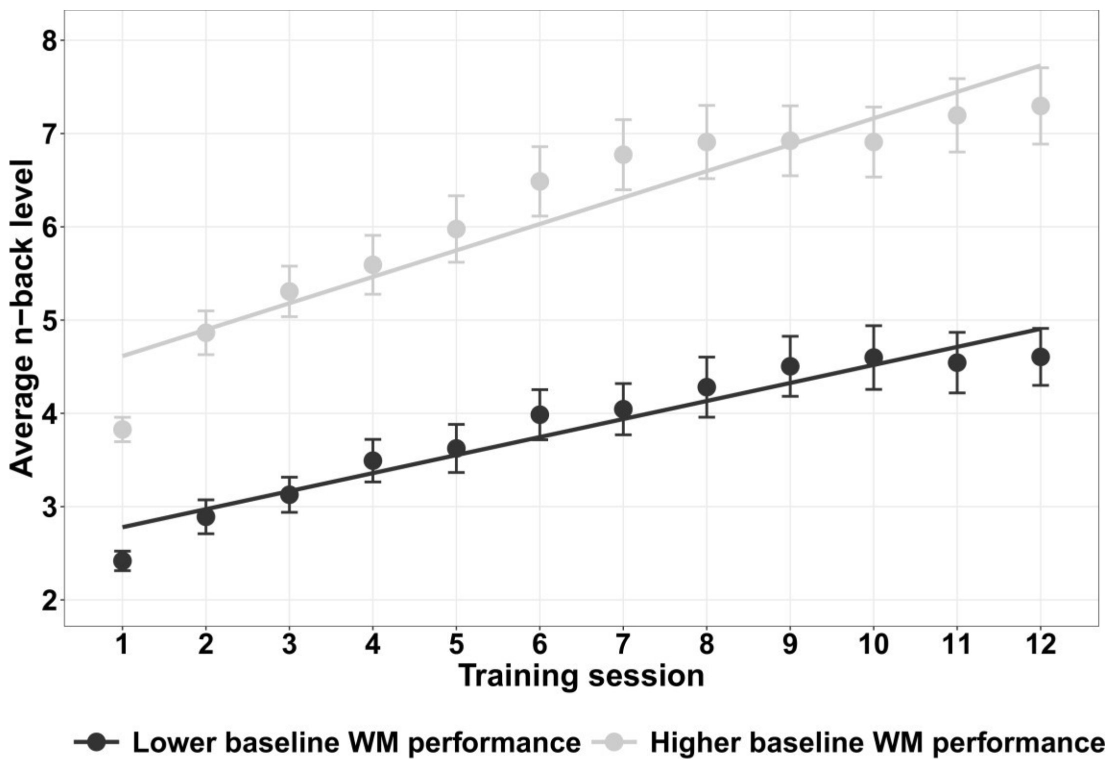

Fig. 6. Data from the most parsimonious model split into participants with higher and lower baseline performance in n-back digits, divided by median split. Those with a lower baseline WM performance tended to have a lower rate of training success during the twelve sessions. The median split was done only for illustrative purposes, as all variables were treated as continuous in the analyses. Symbols and error bars indicate ± standard errors.

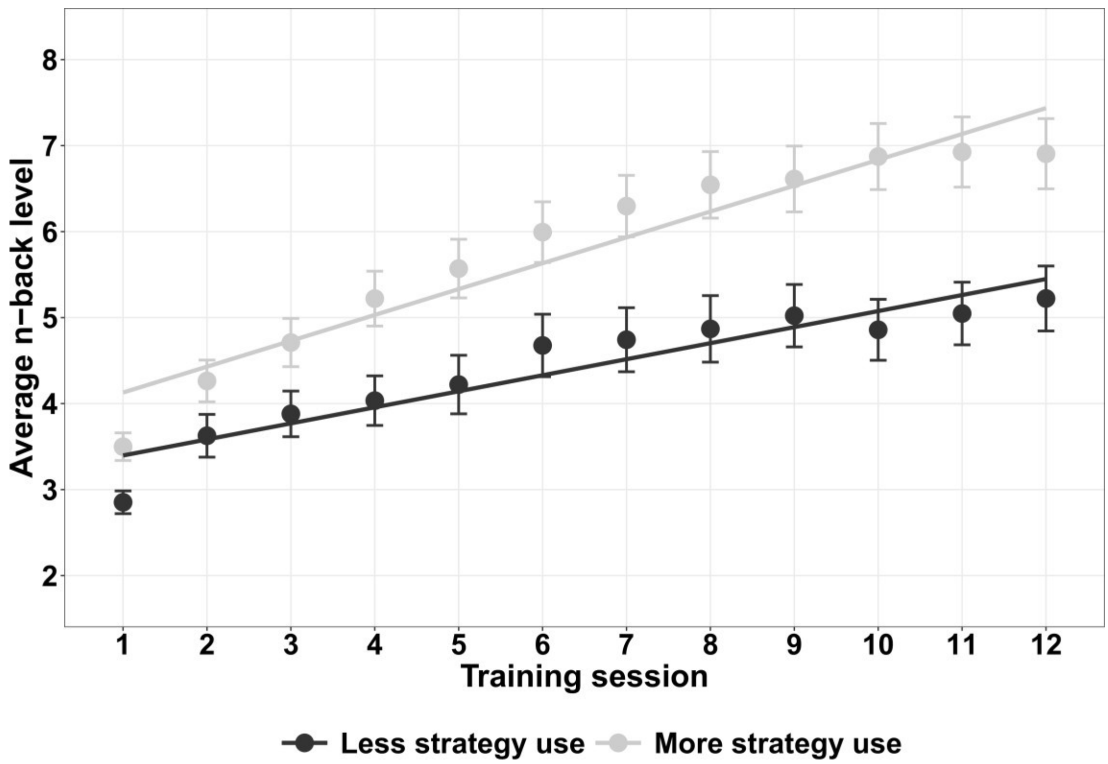

Fig 7. Data from the most parsimonious model split into participants with more vs. less strategy use (higher/lower level of strategy detail at pretest) divided by mean split. Participants with more detailed strategies during the pretest tended to progress better on the trained WM task over time. The mean split was done only for illustrative purposes, as all variables were treated as continuous in the analyses. Symbols and error bars indicate ± standard errors.

4 Discussion

The effects of working memory (WM) training have been extensively investigated during the past two decades. The typical training protocol encompasses adaptive and repetitive training across four to six weeks (Morrison & Chein, 2011; Shipstead et al., 2012) with the aim to not only elicit improvements within the WM domain, but even to yield transfer to untrained tasks tapping on other cognitive domains such as fluid intelligence (Jaeggi et al., 2008; Jaeggi et al., 2014) and literacy skills (Chein & Morrison, 2010; Payne & Stine-Morrow, 2017). However, the results concerning the efficacy of WM training have been highly mixed, with the most recent meta-analyses indicating performance improvements only within the WM domain (Melby-Lervåg et al., 2016; Schwaighofer et al., 2015; Soveri et al., 2017). Despite the fact that generalization following WM training appears to be limited, it is possible that persons with specific background characteristics might benefit more than others from WM training (Jaeggi et al., 2017).

As the existing literature probing for background factors that predict training gains is scarce, the aim of this study was to examine the effect of selected individual predictors on WM training progress on the trained task in a sample of healthy adults. Participants underwent WM training which entailed 12 training sessions with the task n-back digits, during a period of four weeks. The predictor variables encompassed some that have previously been studied (age, education, baseline WM performance, motivation) along with some novel predictors (level of strategy detail, training expectations, metacognition). Growth curve analysis with backwards elimination (Mirman, 2014) was used as the method of data analysis, allowing the examination of gains on the WM training task over time. Predictors were split into three different models and the average n-back level was used as the dependent variable.

Based on the somewhat mixed results in previous studies as to whether WM training is more beneficial for cognitively low-performing individuals (the Compensation hypothesis; e.g. Titz & Karbach, 2014; Dorbath et al., 2011; Park, et al., 2018; Reuter-Lorenz & Cappell, 2008; Borella et al., 2017) or for high-performing individuals (the Magnification hypothesis; e.g. Verhaeghen & Marcoen, 1996; Kliegl et al., 1990; Guye et al., 2017; Bissig & Lustig, 2007; Wiemers et al., 2019), no a priori assumptions were stipulated regarding which of the assumptions the present data would support. However, as for the more specific predictors, baseline WM performance (Wiemers et al., 2019; Guye et al., 2017; Zinke et al., 2014; Borella et al., 2017) and level of strategy detail (Fellman et al., 2020; Laine et al., 2018; Lövdén et al., 2012; Bissig & Lustig, 2007) was expected to be positively correlated with training task gains. With respect to the novel predictors, higher levels of metacognitive awareness and higher levels of expectations of the benefits of training were also expected to predict larger training gains.

4.1. Main findings

As expected, the results demonstrated that participants' performance on the trained WM task improved steadily over the course of the training, with an increase of 0.24 in the average n-back level for each accompanying training session. Thus, the training progress pattern was on par with those obtained in previous n-back training studies (e.g. Jaeggi et al., 2008; Soveri et al., 2017) As regards the background factors related to training gains, the demographic predictors age and years of education did not predict the slope over time. Several reasons may contribute to this result. It is possible that we failed to observe an effect of age due to its limited range (18—50) in the present study. Typically, cognitive functioning declines not until at higher ages (> 70 years of age) (Aartsen, Smits, Van Tilburg, Knipscheer, & Deeg, 2002). Thus, it is possible that an effect of age would have been detected if participants older than 50 would have been included. It is also worth pointing out that the few previous studies examining the effects of age on training gains have also failed to observe an age effect on the slope of the learning curve (Guye et al., 2017; Karbach & Verhaeghen, 2014) despite including older adults (> 60). The absence of an age effect could also be related to strategies. Younger adults might gain more than older adults in strategy-based training regimes, as they are thought to have more cognitive resources to develop new strategies (Karbach & Verhaeghen, 2014). A recent study showed that younger adults had a significantly better performance than older ones early in training, but interestingly, this effect diminished at later stages of training (Iordan et al., 2018). One could therefore speculate if the effect of age had been more prominent if training outcomes at different stages during the training had been examined.

In the present study, no relationship was found between educational attainment and WM training progress. This stands in contrast to findings from a previous study, showing that individuals with less formal education improved slightly more in their WM performance as compared to those with a higher formal education (Borella et al., 2017). However, it is worth mentioning that this improvement was only noticeble at posttest and not during the course of training (Borella et al., 2017). The results from another study showed that a lower level of education predicted training gains in which participants received multi-strategic memory training that prompted participants' metacognitive knowledge about their memory (Park et al., 2018). Training gains in less educated participants were perhaps due to their lesser experience in monitoring their memory, in comparison to those with a higher education, allowing for more room to gain from the task (i.e. a compensation effect) (Park et al., 2018). Due to ambiguous results from previous research, the absence of education effects in the present study is perhaps not too surprising. Further research is needed to clarify whether education is a relevant predictor for WM training gains. It is also possible that other factors, such as occupation, mediate the role of education in cognitive abilities (Fujishiro et al., 2019).

In the metacognitive model including the WMQ mean score and the MAI mean scores of knowledge of cognition and regulation of cognition, a significant interaction between the WMQ mean score and time was observed. This indicated that participants with a lower amount of subjective WM problems (i.e. a lower mean score on the WMQ) improved more on the WM training task across time. The remaining metacognitive variables, the MAI mean scores, did not have any predictive value on the slope. One can only speculate why WMQ, but not MAI, exhibited some predictive value on the training gains. It is quite possible that MAI is not as applicable in the present study as WMQ. WMQ taps the WM domain by measuring subjective everyday WM problems, while MAI measures a broader spectrum of metacognition.

In the model including initial WM performance, level of strategy detail, motivation and expectations as predictors, the variables baseline WM performance and level of strategy detail were predictive of training gains. Both a main effect of baseline WM performance and a baseline WM performance interaction with time suggested that those with a higher pretest performance not only performed better across the training period, but also improved more in the training task over time. A significant interaction between level of strategy detail and time indicated that participants with more detailed strategies at pretest gained more over time in the training task compared to those with less detailed strategies. These results align well with results from previous studies, showing that a higher level of strategy detail (see e.g. Fellman et al., 2020; Laine et al., 2018) and a higher baseline WM performance (see e.g. Guye et al., 2017; Wiemers et al., 2019) predict better training progress. The remaining predictors, motivation and training expectations, failed to predict gains on the training task. While no previous studies have examined how training expectations are related to gains on a WM training task, a few have done so for motivation (Guye et al., 2017; Zhao et al., 2018). However, the results have been mixed; Guye et al. (2017) did not observe any association between motivation and the outcome of WM training, while Zhao et al. (2018) concluded that higher motivation was associated with larger WM training gains.

4.2. Theoretical considerations

Two hypotheses have been put forth for explaining which individuals benefit most of WM training, namely the *Magnification* and the *Compensation* hypotheses. The Magnification hypothesis claims that individuals who perform well at the beginning will continue to do so over the course of training. The Compensation hypothesis proposes the opposite: individuals with a weaker initial performance gain more from the training (Lövdén et al., 2012). Results from previous studies have provided evidence for both the Magnification (e.g. Verhaeghen & Marcoen, 1996; Kliegl et al., 1990; Guye et al., 2017; Bissig & Lustig, 2007; Wiemers et al., 2019) and the Compensation hypothesis (e.g. Titz & Karbach, 2014; Dorbath et al., 2011; Park et al., 2018; Reuter-Lorenz & Cappell, 2008; Borella et al., 2017).

As for the present study, the results provide support for the Magnification hypothesis. Here, individuals reporting less WM problems, a higher WM performance at pretest and a more detailed strategy description showed better progress on the training task. However, it is worth noting that the Compensation hypothesis has been mostly related to studies with children (Lövdén et al., 2012). Studies supporting the Compensation hypothesis have been also criticized for shortcomings in statistical analyses, and the evidence supporting the Compensation mechanism consists mostly of correlative data on associations between pretest scores and training gains (Smolén, Jastrzebski, Estrada, & Chuderski, 2018). According to Smolén et al., (2018), such results increase the risk for obtaining undesirable statistical phenomena such as regression to the mean. Thus, more sophisticated statistical methods are needed for examining the complex interplay between individual background characteristics and training gains.

4.3. Strengths and Limitations

A particular strength of the present study is the sizeable sample which consisted of 116 healthy adults. Many WM training studies have been conducted in clinical populations, limiting the ability to generalize to healthy populations. The included questionnaires (WMQ; Vallat-Azouvi, et al., 2012, MAI; Schraw & Dennison, 1994) have been previously validated, which can be perceived as a psychometric strength. Furthermore, growth curve analysis was employed as the method of statistical analysis. This method avoids several problems associated with other statistical methods used for analysing time series data (e.g. ANOVAs or t-tests), such as the trade-off between statistical power and temporal resolution, experimenter bias, and exaggeration of normal variability in the data (Mirman, 2014). Lastly, this study included an array of unexplored predictors (level of strategy detail, metacognition and expectations) as well as scarcely studied ones (education and motivation), thus contributing to the existing research.

Some possible limitations of this study concern the sample. For instance, the age range did not include adults over 50 years of age. As previously mentioned, this could have led to age effects being undetected. Another particular dilemma in WM training studies is the possibility that certain individuals are more prone to sign up and complete the training, leading to a sampling bias. Thus, there is a possibility that motivation among the individuals who participate in a WM training study is higher than in the average population (Appelgren, Bengtsson, & Söderqvist, 2016).

Another limitation is the online nature of this study, which may lead to problems with unreliable effort, cheating and not understanding the task (Smith, Roster, Golden, & Albaum, 2016). However, in a study by Germine et al. (2012), participants' performance in cognitive and perceptual experiments conducted both online and in laboratory settings had largely comparable results, indicating that an online study does not necessarily reduce data quality. As the present study focused merely on training task gains, transfer (i.e., improvements in untrained cognitive tasks) was not examined. Thus, one cannot draw conclusions from the present results as how background characteristics affect gains in untrained cognitive tasks. It is possible that different individuals gain in different tasks (Borella et al., 2017). Lastly, the individual trajectories of training gains were not analyzed, albeit these could allow for a closer look at changes in the learning curve and predictor effects at specific learning stages.

4.4. Conclusions

In the present study, selected individual differences variables were examined to determine if they were related to gains on the WM training task (n-back digits) following four weeks of WM training. The predictors included in the analyses were baseline WM performance, age, education, motivation, level of strategy detail, metacognition, and training expectations. The results showed that individuals with less perceived WM deficits, a higher baseline performance and a more detailed strategy description gained most from training. These results support the Magnification hypothesis, according to which high-performing individuals benefit more of training. These findings contributes to the existing literature by providing more knowledge about individual characteristics that are relevant in the context of WM training. This knowledge paves the way to customization of training protocols to suit certain individuals, e.g. by providing strategy instructions to individuals that initially exhibit a lower performance in WM tasks and are thus less likely to benefit from training. Another future direction for research would be to look at the trajectories of different predictors, for example with linear spline models (as in Iordan et al., 2018). This would allow the exploration of the effects of predictors at different times during the training. Another future direction could be to probe for mediating factors of different predictors of WM training gains such as occupation and socioeconomic status (e.g. Fujishiro et al., 2019). Lastly, it is of importance to determine which individuals benefit from certain types of tasks to be able to tailor effective individual WM training protocols (Borella et al., 2017). Thus, different tasks must be examined in different populations to be able to verify the efficacy of different types of training.

Swedish Summary

Prediktorer för framgång i arbetsminnesträning

Arbetsminnet omfattar vår förmåga till att hålla och bearbeta information under en kort tid (Baddeley, 2003). Arbetsminnet är relaterat till ett flertal andra kognitiva förmågor och vissa vardagliga uppgifter såsom läsning, intelligens, exekutiva funktioner, visuospatiala förmågor (Miyake & Shah, 1999), läsförståelse (Carretti m.fl., 2014) och läs- och skrivkunnighet (Payne & Stine-Morrow, 2017). Arbetsminnet har även visat sig spela en roll i akademisk framgång (Blankenship m.fl., 2015).

Eftersom arbetsminnet fyller en väsentlig funktion i vårt kognitiva system så har det forskats mycket om det under de senaste årtionden. Av särskilt forskningsintresse har varit huvuvida man kan förbättra arbetsminnet genom så kallad arbetsminnesträning. Arbetsminnesträningsupplägg sträcker sig oftast över 4—6 veckor där deltagare övar på en eller flera arbetsminnesuppgifter med en adaptiv svårighetsgrad (t.ex., Soveri m.fl., 2017; Morrison & Chein, 2011). Huvudsyftet med träningen är att åstadkomma överföringseffekter (eng. transfer) till andra otränade uppgifter. Dessa uppgifter kan vara sådana som också involverar arbetsminne (s.k. near transfer) eller uppgifter som involverar andra kognitiva processer (s.k. far transfer) (Shipstead m.fl., 2010).

De allra första arbetsminnesträningsstudierna visade lovande resultat i.o.m. att man upptäckte överföringseffekter till andra kognitiva domäner såsom flytande intelligens (Au m.fl., 2014; Jaeggi m.fl., 2008), kognitiv kontroll (Chein & Morrison, 2010), läsförståelse och uppmärksamhet (Richmond m.fl., 2011). Vissa träningsstudier har också föreslått att en uppsjö av symptom kunde lindras med hjälp av arbetsminnesträning, såsom impulsivitet och hyperaktivitet hos barn med ADHD (Klingberg m.fl., 2005), symptom relaterade till inlärningssvårigheter (Chen m.fl., 2018), kognitiva symptom efter en hjärninfarkt (Westerberg m.fl., 2009) och även problem med känsloreglering (Schweizer m.fl., 2013). Trots dessa initiala lovande resultat så har träningsstudier efter dessa målat upp en mer realistisk bild vad gäller överföringseffekterna. I kontrast till de tidigaste studierna visar de efterföljande metaanalyserna att arbetsminnesträningprogram endast framkallar korttids- (Melby-Lervåg m.fl., 2016) och uppgiftsspecifika överföringseffekter (Soveri m.fl., 2017; Melby-Lervåg & Hulme, 2013; Schwaighofer m.fl., 2015). Trots indikationerna att överföringseffekter är tämligen begränsade, så är det fortfarande möjligt att vissa individer kan förbättra sina kognitiva förmågor med hjälp av träning. Därför har ett intresse för individuella skillnader i träningsframgång framträtt. Det verkar i själva verket som om träningsframgång i stort beror på individuella skillnader (Lanfranchi & Carretti, 2016).

Individuella skillnader i kontexten av arbetsminnesträning har ofta relaterats till två motsatta hypoteser, Magnifikations- och Kompensationshypotesen. Enligt Magnifikationshypotesen (ibland kallad *Matteuseffekten*, eng. *Matthew effect*) så är de individer som gynnas mest av kognitiv träning, sådana som redan har en bra basprestation. Däremot, enligt Kompensationshypotesen så tanker man att individer som har en bättre kognitiv förmåga redan fungerar ”optimalt” och har därmed mindre utrymme för förbättring. Ifall individer t.ex. redan har en fungerande minnesstrategi så gynnas de inte så mycket av att lära sig en ny strategi (Lövdén m.fl., 2012). Både Magnifikationshypotesen (t.ex. Verhaeghen & Marcoen, 1996; Kliegl m.fl., 1990; Guye m.fl., 2017; Bissig & Lustig, 2007; Wiemers m.fl., 2019) och Kompensationshypotesen (t.ex. Titz & Karbach, 2014; Dorbath m.fl., 2011; Park m.fl.., 2018; Reuter-Lorenz & Cappell, 2008; Borella m.fl., 2017) har fått stöd i forskning kring arbetsminne. Trots att ett antal studier redan granskat individuella skillnaders inverkan på framgång i arbetsminnesträning, så finns det fortfarande flera relevanta bakgrundsfaktorer som inte blivit studerade som prediktorer, exempelvis skillnader i strategirelaterade aspekter. Ett möjligt steg vidare vore att identifiera andra relevanta variabler som kunde predicera träningsframgång i arbetsminnesuppgifter.

Effekten av ålder på framgång i arbetsminnesträning har studerats av flera. En metaanalys av Karbach & Verhaeghen (2014) visade att ålder inte hade någon effekt på träningsframgången. Motsvarande resultat upptäcktes i Guye m.fl. (2017) och Borella m.fl. (2014). Vissa studier har funnit stöd för en Magnifikationseffekt, d.v.s. att äldre gynnades mer av träningen (Verhaeghen m.fl., 1992; Bürki m.fl., 2014; von Bastian m.fl. 2013). I en studie av Borella m.fl. (2017) fann man att äldre deltagare gynnades mer av träningen då det gällde mer simpla arbetsminnesuppgifter (t.ex. sifferserier), medan yngre deltagare gynnades mer i komplexa uppgifter (t.ex. sifferserier baklänges). Ålder verkar således ha en varierande effekt på framgång i arbetsminnesträning.

Utbilding är en annan faktor som väckt intresse i fråga om träningsframgång. Park m.fl. (2018) och Borella m.fl. (2017), fann att utbildning signifikant predicerade träningsframgång via en Kompensationsmekanism, d.v.s. att de med mindre utbildning gynnades mer av träningen.

Metakognition (d.v.s. medvetenhet och förståelse för sina egna tankeprocesser) har inte tidigare studerats som en direkt prediktor för arbetsminnesträning. Vissa studier har dock granskat effekten av metakognition på överföringseffekter. Enligt inlärningsmodellen som Chein & Schneider (2012) tagit fram, så är det metakognitiva systemet i toppen av en hierarki av subsystem ansvariga för inlärningsprocesser. Det metakognitiva systemet är speciellt viktigt då man lär sig nya beteendemönster, förbereder sig för uppgifter och övervakar genomförande av uppgifter. Systemet är speciellt aktivt i nya sammanhang och uppgifter. Personer med ett välutvecklat metakognitivt system har möjligen fördelar i nya uppgifter, eftersom de snabbt kan förvärva nya beteendemönster och kan snabbare identifiera effektiva inlärningsstrategier. (Chein & Schneider, 2012).

I en studie som fokuserade på metakognitionens effekt på överföring i arbetsminnesträning, (Jaeggi m.fl., 2014), visade resultaten, att deltagare som var mer benägna att tro att intelligens är formbart, uppvisade större överföringseffekter. Detta tyder på en Magnifikationseffekt. I motsats till detta fann Guye m.fl. (2017) att deltagare som var mer benägna att tro att intelligens är formbart, gynnades mindre av arbetsminnesträning, vilket tyder på en Kompensationseffekt. Trots att dessa studier kollat på effekten av metakognition på överföring, så tyder resultaten på att metakognition kunde tänkas spela en roll i träningsframgång.

Wiemers m.fl. (2019), Guye m.fl. (2017) samt Zinke (2014) fann att basprestation i arbetsminnesträning var positivt relaterat till framgång, vilket tyder på att deltagare som klarat sig bra i början av träningen, förbättrades mer över tid. Dessa resultat visar stöd för Magnifikationshypotesen. Borella m.fl. (2017) fann att individer med en lägre basprestation gynnades mer av träningen då det gällde simplare uppgifter och vice versa.

Motivation är en aspekt som ofta spelar en roll i psykologiska och kognitiva processer och har därmed studerats i förhållande till träningsframgång. Guye m.fl. (2017) fann ingen association mellan motivation och träningsframgång. Zhao m.fl. (2018) fann däremot att högre motivation associerades med en mer träningsframgång, vilket stöder Magnifikationshypotesen.

Minnesstrategier har påvisats förbättra träningsprestation. Lövdén m.fl. (2012) fann att strategi instruktioner var associerat med träningsframgång hos äldre vuxna. Även andra studier (Bissig & Lustig, 2007; Fellman m.fl., 2020; Laine m.fl., 2018) har funnit att strategianvändning, eller en mer sofistikerad minnesstrategi predicerar framgång i arbetsminnesträning. Resultaten ur dessa studier ger stöd för Magnifikationshypotesen.

Deltagares förväntningar inför träningen är också möjligen relaterat till träningsframfången. Sådana aspekter har inte tidigare blivit studerade i relation till träningsframgång.

Studiens syfte

Syftet för föreliggande studie var att granska ifall individuella skillnader predicerar träningsframgång på en arbetsminnesuppgift. Samplet bestod av 116 friska vuxna. Eftersom resultaten ur tidigare studier har varit tvetydiga, är det viktigt att identifiera faktorer som kunde förklara varför vissa individer gynnas mer av träning än andra. Målet med många tidigare arbetsminnesstudier har varit att åstadkomma överföring till andra kognitiva domäner (Shipstead m.fl., 2010). Enligt Jaeggi m.fl. (2011), så är de individer som gynnas mest av arbetsminnesträning, mer sannolika att uppvisa överföringseffekter. Det är därför tänkbart att faktorer som inverkar på träningsframgången fungerar som modererande faktorer för överföring. Att identifiera prediktorer för träningsframgång kunde bidra till mer skräddarsydda arbetsminnesträningsprotokoll som justeras beroende på vad som skulle passa bäst för en given individ (Morrison & Chein, 2011).

Prediktorerna som inkluderades i denna studie bestod av såna som tidigare studerats (ålder, basprestation i arbetsminnesuppgifter och motivation) tillsammans med sådana som inte tidigare studerats (detaljnivå av strategibeskrivning, metakognition och förväntningar för träningsframgång). Eftersom resultat ur tidigare forskning varit oklar, är denna studie av en mer explorativ natur. Då det gäller specifika prediktorer förväntades det att detaljnivå av strategibeskrivning (Fellman m.fl., 2020; Laine m.fl., 2018) och en högre basprestation (Guye m.fl., 2017; Zinke m.fl., 2014; Borella m.fl.., 2017) skulle predicera mer träningsframgång. Även en högre nivå av metakognitiv medvetenhet och högre förväntningar för träningsframgången, förväntades predicera mer träningsframgång.

Metod

Datat för denna studie härstammar från ett nätbaserat arbersminnesträningsexperiment, som deltagarna genomförde hemma (Fellman m.fl., 2020). Studien sträckte sig över fyra veckor och inkluderade tre bedömningssessioner (pretest, mellantest och posttest). Deltagarna randomiserades till en av tre möjliga betingelser:

1. Strategiträningsgrupp: deltagarna fick 12 x 30 minuter av träning på en n-back uppgift. Gruppen fick en strategi instruktion.

2. Traditionell träningsgrupp: deltagarna fick 12 x 30 minuter av träning på en n-back uppgift utan någon strategi instruktion.

3. Kontrollgrupp: deltagarna övade inte alls, utan genomförde endast pretest, mellantestet och posttestet.

Eftersom målsättningen med föreliggande studie var att granska individuella prediktorers inverkan på träningsframgång, så fokuserar denna studie endast på den traditionella träningsgruppen.

Deltagarna rekryterades under en femveckors period genom webbsidan Prolific Academic (https://www.prolific.ac/). Exklusionskriterierna i föreliggande studie var att inte ha engelska som modersmål, aktuella psykiska och neurologiska störningar, pågående bruk av läkemedel som påverkar centrala nervsystemet eller pågående bruk av psykoaktiva droger. Deltagarna som mötte inklusionskriterierna erbjöds att delta i studien.

Deltagarna fick därefter delta i pretestet som omfattade tio arbetsminnesuppgifter. I samband med pretestet fyllde deltagarna i enkäter som kartlade bakgrundsinformation. Informerat samtycke skaffades även i början av pretestet. I samband med pretestet fick deltagarna fylla i frågeformulären Working Memory Questionnaire (WMQ; Vallat-Azouvi m.fl., 2012) samt Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994) som båda användes som prediktorer i denna studie. Formuläret WMQ mäter individers subjektiva problem relaterade till arbetsminne. Formuläret MAI mäter metakognitiv medvetenhet. Båda frågeformulären är validerade och kan hittas i sin helhet som bilaga. Formuläret MAI innehöll två subskalor "knowledge of cognition" och "regulation of cognition". Båda subskalornas prediktiva värde granskades skilt i denna studie.

Deltagarnas motivation kartlades under träningens gång (sessionerna 1, 6 och 12). Deltagarna skattade sig själv på en skala från 1—5 (där 5 indikerade högst motivation). Deltagarnas förväntingar för framgång under träningen kartlades under den första träningssessionen. Skattningsskalan gick från 1—10 där 1 indikerade att deltagaren inte alls förväntade att de skulle bli bättre på uppgiften under träningens gång och 10 att deltagaren hade väldigt höga förväntningar att de skulle förbättras under träningen.

Deltagarnas detaljnivå av strategibeskrivning granskades vid pretestet genom öppna frågor. Deltagaren svarade först ifall de hade använt sig av en minnesstrategi i uppgiften. Ifall hen svarade ja, ombads hen beskriva strategin fritt i textform. Detaljnivån i strategibeskrivningen kodades av två oberoende bedömare. Kodningen följde systemet introducerat i Laine m.fl. (2018). Strategiklassificeringarna indikerade stark till nästintill perfekt överrensstämmelse mellan bedömarna (κ_w mellan 0.86 – 0.96). Ingen strategianvändning kodades som noll poäng. Oklara strategibeskrivningar gav ett poäng (t.ex. ”jag försökte men blev förvirrad”). Ganska ospecifika rapporter gav två poäng (t.ex. ”försökte fokusera på siffrorna”). En generell beskrivning av en strategi med en detalj (t.ex. ”upprepade siffrorna i huvudet”) kodades som tre poäng, medan en generell beskrivning med två eller fler detaljer (t.ex. ”räknade siffrorna och grupperade dem”) gav fyra poäng.

Träningsuppgiften som användes i denna studie var en n-back uppgift med siffror. Siffrorna (1—9) presenterades en åt gången på en skärm. Deltagarna instruerades att avgöra för varje siffra (genom att klicka på ja/nej) ifall det var samma siffra som presenterades *n* siffror bakåt i sekvensen. Uppgiften hade en adaptiv svårighetsgrad. Deltagarna var friska vuxna mellan 18—50 år (M = 35,2, SD = 8,9). Majoriteten av deltagarna, 74 (63,8 %) var kvinnor. Deltagarnas utbildning varierade mellan 7 till 25 år[6] (M = 15,8, SD = 3,3). Samplet bestod inledningsvis av 419 deltagare. Efter

[6] En deltagare rapporterade endast 3 år av utbildning (men samtidigt att hen hade en utbildningsnivå som motsvarade ett medianvärde på 12 år). Eftersom 3 år av utbildning är högst osannolikt, rör det sig antagligen om ett missförstånd eller inmatningsfel, därmed ersattes deltagarens svar med medianvärdet 12.

beaktande av deltagarna som drog sig ur innan pretestet, inte slutförde pretestet eller hade tekniska svårigheter under pretestet, bestod andelen av 314 personer som slutförde pretestet. Efter att ha exkluderat deltagare som inte mötte inklusionskriterierna, och de som drog sig ur efter pretestet, återstod 322 deltagare som randomiserades till de tre grupperna (strategigruppen, traditionella träningsgruppen eller kontrollgruppen). Gällande träningsgruppen, så exkluderades vissa från dataanalyserna. Till dessa hörde deltagare som drog sig ur studien under träningen, deltagare som använde externa hjälpmedel under träningen, eller deltagare som hade bortfall av data (i en eller fler träningssessioner). Således bestod träningsgruppens slutliga sampel av 116 deltagare.

Statistiska Analyser

Deskriptiva analyser gjordes i IBM SPSS Statistics version 25, resterande analyser gjordes i R version 3.5.2, paketen lme4, lme4 (Bates m.fl., 2015), and lmerTest (Kuznetsova m.fl., 2017) användes. Tillväxtkurveanalyser (Mirman, 2014) användes för att granska förändringar i träningsframgången i n-back uppgiften över spannet av de 12 sessionerna. Träningsframgången över tid specificerades som en lineär kontrast. Medelnivån i uppgiften n-back med siffror användes som beroende variabel. Medelnivån användes eftersom det antogs ge en klarare bild av den faktiska prestationen (inte t.ex. sporadiska höga poäng). I modellen specificerades deltagare som en slumpmässig effekt medan prediktorerna specificerades som fixerade effekter. Att sätta in deltagarna som slumpmässiga effekter innebär att parameterestimaten reflekterar både den individuella deltagarens data och gruppdatat. Det get en bild av trender överlag inom gruppen, eftersom det speglar antagandet att deltagare är slumpmässigt dragna ur en population (Mirman, 2014). Huvudeffekter beräknades för varje prediktorvariabel tillsammans med interaktionstermen mellan träningssession och den prediktorvariabeln i fråga. I föreliggande studie är interaktionstermen är av yttersta intresse, eftersom den visar huruvida en specifik prediktor är relaterad till träningsframgång över tid. För att undvika problem med multikollineäritet delades prediktorerna in i tre skilda modeller (se t.ex., Guye m.fl., 2017). De tre modellerna var följande:

1. Demografiska prediktorer: Ålder, utbildningsår

2. Metakognitiva prediktorer: Working memory Questionnaire (WMQ) medelpoäng, Metacognitive Awareness Inventory (MAI) medelpoängen från subskalorna "knowledge of cognition" och "regulation of cognition".

3. Basprestation, förväntningar, motivation och strategibeskrivning: prestationen på n-back med siffror vid pretestet, strategibeskrivningens detaljnivå för n-back med siffror vid pretest, förväntningar för träningsframgång och motivation.

I en explorativ studie vill man granska bidraget från varje enskild prediktor. I enighet med riktlinjerna föreslagna av Mirman (2014), beräknades en basmodell som innehöll alla prediktorer för de tre olika modellerna. En omvänd elimineringsprocedur implementerades därefter (se t.ex. Fellman m.fl., 2018), som innebär att prediktorerna med minst prediktivt värde på träningsframgång över tid, togs bort. Sammanlagt exkluderades 10 deltagares data från analyserna.

Resultat

Övergripande resultat från föreliggande studie visade att det fanns en signifikant effekt av tid på medelnivån i n-back med siffror $B = 0{,}240$, $SE = 0{,}008$, $t = 27{,}17$, $p < 0{,}001$, vilket innebar att deltagare blev bättre på n-back uppgiften över tid.

Resultaten ur den demografiska modellen visade inga huvudeffekter för varken ålder $B = -0{,}016$, $SE = 0{,}026$, $t = -0{,}618$, $p = 0{,}53$, eller utbildningsår $B = 0{,}024$, $SE = 0{,}070$, $t = 0{,}348$, $p = 0{,}72$. Detta tyder på att de demografiska variablerna inte hade någon inverkan på prestationen i n-back uppgiften under träningens gång. Som förväntat, fanns det inga signifikanta interaktionstermer för varken tid och ålder $B = 0{,}0003$, $SE = 0{,}001$, $t = 0{,}31$, $p = 0{,}75$ eller tid och utbildning $B = 0{,}001$, $SE = 0{,}002$, $t = 0{,}42$, $p = 0{,}67$. Detta betyder att deltagarna förbättrades lika mycket på träningsuppgiften över tid, oberoende av deras ålder eller utbildningsår.

I den metakognitiva modellen fanns ingen huvudeffekt av WMQ medelpoäng i den slutgiltiga modellen $B = -0{,}45$, $SE = 0{,}42$, $t = -1{,}06$, $p = 0{,}28$. WMQ medelpoäng hade därmed ingen inverkan på prestationen på n-back uppgiften under träningens lopp. En interaktion fanns dock mellan tid och WMQ medelpoäng $B = -0{,}07$, $SE = 0{,}016$, $t = -4{,}41$, $p < 0{,}001$, vilket indikerade att personer med mindre upplevda problem med arbetsminne (lägre poäng på WMQ), klarade sig bättre på träningsuppgiften över tid.

I den sista modellen återstod basprestation och strategibeskrivningens detaljnivå efter den omvända elimineringsproceduren, som prediktorer i den mest lämpliga modellen. Gällande basprestationen på n-back i pretestet, fanns både en signifikant huvudeffekt $B = 1{,}50$, $SE = 0{,}24$, $t = 6{,}24$, $p < 0{,}001$ och en signifikant interaktion mellan basprestation och tid $B = 0{,}04$, $SE = 0{,}01$, $t = 4{,}23$. Detta betydde att personer med en högre basprestation i n-back uppgiften klarade sig bättre över tid och blev bättre över tid (jämfört med deltagare som hade en lägre basprestation).

Ingen huvudeffekt för strategibeskrivningens detaljnivå observerades $B = -0{,}04$, $SE = 0{,}11$, $t = -0{,}34$, $p = 0{,}72$, vilket tyder på att strategibeskrivningarnas detaljnivå inte inverkade på prestationen på träningsuppgiften över träningens gång. Resultaten visade dock en significant interaktion mellan tid och strategibeskrivningens detaljnivå $B = 0{,}029$, $SE = 0{,}005$, $t = 5{,}24$, $p < 0{,}001$. Deltagare med mer detaljerade strategibeskrivningar vid pretest blev bättre på n-back uppgiften över tid, jämfört med deltagare med mindre detaljerade strategibeskrivningar.

Diskussion

Studier som granskat generaliseringseffekterna efter arbetsminnesträning har varit många under de senaste två decennierna. Ett typiskt träningsupplägg sträcker sig över fyra till sex veckor (Morrison & Chein, 2011; Shipstead m.fl., 2012). Målet med träningen är inte endast att bli bättre på uppgifter inom arbetsminnesdomänen, utan även i andra kognitiva domäner och uppgifter, såsom flytande intelligens (Jaeggi m.fl., 2008; Jaeggi m.fl., 2014) och läs- och skrivkunnighet (Chein & Morrison, 2010; Payne & Stine-Morrow, 2017). Resultat ur metaanalyser visar att förbättrningen endast sker inom arbetsminnesdomänen (Melby-Lervåg m.fl., 2016; Schwaighofer m.fl., 2015; Soveri m.fl., 2017). Trots att generaliseringen verkar vara begränsad, är det möjligt att vissa personer med vissa karaktäristika gynnas mer av arbetsminnesträning (Jaeggi m.fl., 2017).

Forskning som undersöker bakgrundsfaktorer som prediktorer för framgång i arbetsminnesträning är snävt. Målet för denna studie var att undersöka effekten av individuella prediktorer på framgång i arbetsminnesträning i ett sampel med friska vuxna. Vissa av prediktorerna har granskats tidigare (ålder, utbildning, basprestation i arbetsminnesuppgifter och motivation) medan vissa var helt nya (strategibeskrivningens detaljnivå, förväntningar och metakognition). Tillväxtkurveanalys med en omvänd elimneringsprocedur användes som metod för dataanalyserna (Mirman, 2014). Prediktorerna delades in i tre skilda modeller och medelnivå på n-back uppgiften användes som beroende variabel. Av de tidigare undersökta prediktorerna förväntades basprestation (Wiemers m.fl., 2019; Guye m.fl., 2017; Zinke m.fl., 2014; Borella m.fl., 2017) predicera framgång i träningen. Gällande de nya prediktorerna förväntades strategibeskrivningens detaljnivå (Fellman m.fl., 2020; Laine m.fl., 2018; Lövdén m.fl., 2012; Bissig & Lustig, 2007), metakognition och högre förväntningar inför träningen leda till större framgång i träningen.

Som förväntat, blev deltagare bättre på n-back uppgiften över träningens tid, med en ökning på 0.24 på medelnivån för varje session. De demografiska prediktorerna, ålder och utbildning, hade ingen inverkan på träningsframgången över tid. Detta möjligen som en följd av studiens begränsade åldersomfång (18—50), då kognitiva svårigheter oftast uppstår i en högre ålder (> 70) (Aartsen m.fl., 2002). Vissa studier har dock konstaterat att åldern inte inverkade på träningsframgången (Guye m.fl.., 2017; Karbach & Verhaeghen, 2014) trots att äldre individer (> 60) inkluderades. Resultat från tidigare studier har varit blandade med tanke på utbildning som prediktor för träningsframgång, så mer forskning behövs för att säkerställa dess roll. Det är möjligt att andra faktorer medierar utbildningens effekt med tanke på kognitiva förmågor (Fujishiro m.fl., 2019).

I den metakognitiva modellen visade resultaten att de personer med mindre subjektiva minnesproblem, klarade sig bättre på träningsuppgiften över tid. De övriga prediktorerna hade ingen inverkan på träningsframgången. Man kan endast spekulera över orsaken till detta. Det är möjligt att MAI formuläret inte är lika tillämpbar för just den här uppgiften, och att WMQ mäter mer konkreta vardagliga minnesproblem.

I den sista modellen hade basprestation och strategibeskrivningens detaljnivå prediktivt värde på träningsframgång. Individer med en högre basprestation klarade sig bättre under träningen och förbättrades mer på uppgiften över tid, jämfört med personer med en lägre basprestation. Personer med en mer detaljerad strategibeskrivning förbättrades på uppgiften över tid, jämfört med personer som hade mindre detaljerade strategibeskrivningar. Dessa resultat är i enlighet med tidigare studier som visat att en mer detaljerad strategibeskrivning (t.ex. Fellman m.fl., 2020; Laine m.fl., 2018) och en högre basprestation (see e.g. Guye m.fl., 2017; Wiemers m.fl., 2019) predicerar träningsframgång. De övriga prediktorerna hade inget prediktivt värde på träningsframgång. Tidigare studier där motivation specificerats som prediktor har påvisat blandade resultat (Guye m.fl., 2017; Zhao m.fl., 2018).

Resultat ur denna studie visar stöd för Magnifikationshypotesen, d.v.s. tanken att de som inledningsvis klarar sig bättre, gynnas mer av träningen. Personer med mindre subjektiva minnesproblem, en högre basprestation och en mer detaljerad strategibeskrivning klarade sig bättre i träningsuppgiften.

Denna studie har flera styrkor bl.a. den stora sampelstorleken på 116 friska individer som granskades för inklusions/exklusionskriterier innan träningen påbörjades. Många tidigare arbetsminnesträningsstudier har genomförts i kliniska sampel, som försvårar generaliserbarheten. De använda frågeformulären (WMQ; Vallat-Azouvi, m.fl., 2012, MAI; Schraw & Dennison, 1994) har blivit validerade, vilket kan anses vara en psykometrisk styrka. Tillväxtekurveanalys användes som statistisk analysmetod. Denna metod undviker flera problem associerade med andra metoder som används för tidsserieanalyser (t.ex. ANOVA eller t-test) samtidigt som den tillför mera statistisk styrka (Mirman, 2014). Slutligen undersökte denna studie några nya prediktorer (strategibeskrivningens detaljnivå, metakognition och förväntningar) samt vissa snävt studerade prediktorer (utbildning och motivation) och bidrar därmed med viktig kunskap till forskning.

Vissa begränsningar i denna studie berör samplet. Åldersspannet för deltagarna sträckte sig endast till 50 år. Detta kan ha lett till att ålderseffekter gått obemärkta. Vissa personer kanske är mer benägna till att delta i en arbetsminnesstudie, vilket också förvränger resultaten till viss del (t.ex. Appelgren m.fl., 2016). Att studien var nätbaserad kan ha lett till problem med otillförlitlighet i deltagarnas prestation (trötthetseffekter, fusk och missförstånd) (Smith m.fl., 2016). Som en motargument till nätbaserad minnesträning och dess otillförlitlighet, påvisade en studie av Germine m.fl. (2012), att deltagares prestation i kognitiva experiment i nät- och labbaserade miljöer i stort motsvarar varandra. Eftersom denna studie endast fokuserade på träningsframgång kan slutsatser inte dras gällande hur bakgrundsfaktorer påverkar framgång i otränade kognitiva uppgifter. Det är möjligt att olika individer har varierande mycket framgång i olika uppgifter (Borella m.fl., 2017). De individuella banorna för träningsframgång analyserades inte, men detta kunde möjliggöra granskning av effekter av prediktorer vid olika stadier under träningen.

Slutsatser

Denna studie visade att personer med mindre subjektiva minnesproblem, en högre basprestation och en mer detaljerad strategibeskrivning gynnades mest av träningen. Resultaten ger stöd för Magnifikationshypotesen som menar att högpresterande individer gynnas mest av träningen. Dessa fynd bidrar till den existerande forskningen genom att ge kunskap om vilka individuella karaktäristika som kunde vara relavanta i arbetsminnesträning. Denna kunskap kan också bidra till skräddarsydd anpassning av träningsprotokoll för att maximera träningseffekterna för samtliga individer t.ex. genom att bidra med strategi instruktioner åt personer som förväntas klara sig sämre i arbetsminnesuppgifter.

I framtida forskning kunde det vara fruktbart att separat undersöka personer som har en mindre sannolikhet att gynnas av träning. Effekten av att ge strategi instruktioner åt dessa kunde granskas. En till riktning för framtida studier kunde vara att undersöka de individuella banorna för skilda prediktorer (som t.ex. i Iordan m.fl., 2018). Detta kunde möjliggöra en undersökning av prediktorernas effekter under olika stadier i träningen. Medierande faktorer för prediktorer av träningsframgång kunde också studeras (t.ex. Fujishiro m.fl., 2019).

Slutligen är det viktigt att fastställa vilka individer som gynnas av olika typer av uppgifter, för att kunna anpassa träningsprotokoll till olika individer (Borella m.fl., 2017). För att uppnå detta behöver olika uppgifter granskas i olika sampel för att kunna verifiera effektiviteten av olika typer av träning.

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Appendix A

The Working Memory Questionnaire

Questions are presented here in the order given to each patient. For each question, patients have to choose one of the following response boxes:

Not at all A

little

Moderately

A lot

Extremely

Not relevant

Storage domain: Questions 3,5,7,11,15,17,21,25,27,30

Attention domain: Questions 1,4,8,10,13,16,19,22,24,28

Executive domain: Questions 2,6,9,12,14,18,20,23,26,29

1. Do you feel that you tire quickly during the day?

2. Do you find it difficult to carry out a project such as choosing and organising your holidays?

3. Do you have problems with remembering sequences of numbers, for example, when you have to note down a telephone number?

4. Do you need to make an effort to concentrate in order to follow a conversation in which you are participating with many other people?

5. Do you find it difficult to remember the name of a person who has just been introduced to you?

6. When you shop, do you often spend more than the budget you set for yourself? (Aside from the change of currency to the euro!)

7. Do you have difficulty remembering what you have read?

8. When you are interrupted during an activity by a loud noise (door slam, car horn) do you have difficulty in getting back to the activity?

9. Do you find it difficult to carry out an activity with chronological steps (cooking, sewing, DIY)?

10. Do nearby conversations disturb you during a conversation with another person?

11. Do you need to re-read a sentence several times to understand a simple text?

12. Do you have difficulty in organising your time with regard to appointments and your daily activities?

13. Do you find it difficult to do two (or several) things at the same time such as: - DIY and listening to the radio at the same time? - Cooking and listening to the radio at the same time?

14. When you are carrying out an activity, if you realise that you are making a mistake, do you find it difficult to change strategy?

15. Do you have difficulty understanding what you read?

16. Do you feel that fatigue excessively reduces your concentration?

17. When you pay cash for an item, do you have difficulty in realising if you have been given the correct change? (Aside from the change of currency to the euro!)

18. Do you find it difficult to follow the different steps of a user's guide (putting kit furniture together, installing a new electrical device)?

19. Do you find it difficult to carry out an activity in the presence of background noise (traffic, radio or television)?

20. Are you particularly disturbed if an unexpected event interrupts your day or what you are in the process of doing?

21. If a character in a text is designated in different ways (he, him), do you have difficulty in understanding the story?

22. Do you feel embarrassed when you have a conversation with an unfamiliar person?

23. Do you find that you hesitate for a long time before buying even a common item? (Aside from the change of currency to the euro!)

24. Do you feel that you are very slow to carry out your usual activities?

25. Do you have to look at a written phone number many times before dialling a number that you don't know off by heart?

26. Do you have difficulty in managing your paper work, sending social security papers, paying bills, etc.?

27. If somebody speaks quickly to you, do you find it difficult to remember what you were told or asked?

28. Do you find that you tire quickly during an activity which demands a lot of attention (for example, reading)?

29. After doing your shopping, are you surprised to find that you have bought many useless items?

30. Do you find it difficult to participate in a conversation with several people at once?

Appendix B

Metacognitive Awareness Inventory (MAI)

Think of yourself as a learner. Read each statement carefully. Consider if the statement is true or false as it generally applies to you when you are in the role of a learner (student, attending classes, university etc.) Check True or False as appropriate.

1. I ask myself periodically if I am meeting my goals.
2. I consider several alternatives to a problem before I answer.
3. I try to use strategies that have worked in the past.
4. I pace myself while learning in order to have enough time.
5. I understand my intellectual strengths and weaknesses.
6. I think about what I really need to learn before I begin a task
7. I know how well I did once I finish a test.
8. I set specific goals before I begin a task.
9. I slow down when I encounter important information.
10. I know what kind of information is most important to learn.
11. I ask myself if I have considered all options when solving a problem.
12. I am good at organizing information.
13. I consciously focus my attention on important information.
14. I have a specific purpose for each strategy I use.
15. I learn best when I know something about the topic.
16. I know what the teacher expects me to learn.
17. I am good at remembering information.
18. I use different learning strategies depending on the situation.
19. I ask myself if there was an easier way to do things after I finish a task.
20. I have control over how well I learn.
21. I periodically review to help me understand important relationships.
22. I ask myself questions about the material before I begin.
23. I think of several ways to solve a problem and choose the best one.
24. I summarize what I've learned after I finish.
25. I ask others for help when I don't understand something.

26. I can motivate myself to learn when I need to
27. I am aware of what strategies I use when I study.
28. I find myself analyzing the usefulness of strategies while I study.
29. I use my intellectual strengths to compensate for my weaknesses.
30. I focus on the meaning and significance of new information.
31. I create my own examples to make information more meaningful.
32. I am a good judge of how well I understand something.
33. I find myself using helpful learning strategies automatically.
34. I find myself pausing regularly to check my comprehension.
35. I know when each strategy I use will be most effective.
36. I ask myself how well I accomplish my goals once I'm finished.
37. I draw pictures or diagrams to help me understand while learning.
38. I ask myself if I have considered all options after I solve a problem.
39. I try to translate new information into my own words.
40. I change strategies when I fail to understand.
41. I use the organizational structure of the text to help me learn.
42. I read instructions carefully before I begin a task.
43. I ask myself if what I'm reading is related to what I already know.
44. I reevaluate my assumptions when I get confused.
45. I organize my time to best accomplish my goals.
46. I learn more when I am interested in the topic.
47. I try to break studying down into smaller steps.
48. I focus on overall meaning rather than specifics.
49. I ask myself questions about how well I am doing while I am learning something new.
50. I ask myself if I learned as much as I could have once I finish a task.
51. I stop and go back over new information that is not clear.
52. I stop and reread when I get confused.

PRESSMEDDELANDE

Högpresterande individer gynnas mest av arbetsminnesträning

Pro gradu-avhandling i psykologi

Fakulteten för humaniora, psykologi och teologi, Åbo Akademi

Resultaten ur en pro-gradu avhandling vid Åbo Akademi visar att högpresterande individer gynnas mest av arbetsminnesträning. Avhandlingen granskade individuella skillnaders inverkan på framgång i arbetsminnesträning. Samplet bestod av 116 friska vuxna mellan 18-50 år. Arbetsminnesträningen sträckte sig över en period på fyra veckor. Deltagarna fick öva sig på en arbetsminnesuppgift under 12 sessioner 30 minuter åt gången. Effekten av ålder, utbildning, motivation, basprestation i arbetsminnesuppgifter, nivå av individens minnesstrategier, metakognition och förväntningar undersöktes.

Resultaten visade att deltagare med mindre subjektiva minnessvårigheter, en högre basprestation i uppgiften samt en mer detaljerad beskrivning av sin minnesstrategi gynnades mest av träningen. Resterande faktorer hade ingen inverkan på träningsframgången. Ett flertal andra studier har funnit samma effekt, d.v.s. att personer som redan är kognitivt välfungerande, gynnas mest av kognitiv träning. Dessa resultat belyser rollen som individuella egenskaper kan spela i kognitiv träningsframgång.

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