An investigation of sequential motor learning in middle-aged and older adults
Verneau, M.M.N.

2016

document version
Publisher's PDF, also known as Version of record

Link to publication in VU Research Portal

citation for published version (APA)

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:
vuresearchportal.ub@vu.nl

Download date: 23. Feb. 2024
4

Optimising assembly learning in older adults through the manipulation of instructions

The present investigation assessed the putative benefits of reducing instructions for older adults’ learning of an assembly task. Young and older adults had to build a product by assembling six components. Two groups practiced following instruction methods that differed in the degree of explicit information they conveyed about the correct assembly order. After practice, retention, consolidation of performance (tested immediately after practice and on a separate day, respectively) and stability of performance (tested by introducing a concurrent second task) were assessed. Younger adults showed similar performance levels for both instruction methods. Older adults, however, showed similar retention but clearly weaker consolidation and stability of performance following less encompassing instructions. Contrary to expectations, enhancing the involvement of explicit processes allowed older adults to gain a more permanent and stable performance improvements. The findings are discussed relative to the characteristics of the assembly task.

Practitioner Summary: We addressed how performance and learning of older adults in an assembly task can be optimized through different types of instruction. The findings suggest that increasing awareness of task characteristics enhance not only long-term performance, but also resilience against distraction. Future work must evaluate if these findings generalise to more complex tasks.
1. Introduction

In many working environments, such as in the assembly industry, the ability to quickly learn to perform new tasks and to produce in often noisy or distracting work places is critical. Consequently, the speed or rate of learning and the stability of performance after learning are of high concern. In this respect, there is a practical interest in supporting methods that helps workers to quickly and effectively learn new assembly skills. In an ageing working population, this holds for both younger and older workers.

Research in motor skill learning has consistently shown that the rate of learning and stability of performance after learning are mediated by the learner's degree of awareness of task-relevant features (Masters, Poolton, Maxwell, & Raab, 2008; Maxwell, Masters, & Eves, 2003; Maxwell, Masters, Kerr, & Weedon, 2001; Poolton, Masters, & Maxwell, 2007). That is, young adults do not need to become aware of task relevant features (i.e., either through instruction or self-discovery) to acquire new motor skills. They can learn these tasks with a minimum accrual of explicit knowledge. In addition, this research demonstrates that with greater amounts of explicit knowledge accumulated during the learning process, performance after learning is more easily disrupted by the introduction of secondary tasks (Chauvel, Hartley, Joubert, Didierjean, & Masters, 2012; Lam, Maxwell, & Masters, 2009; Masters et al., 2008; Maxwell et al., 2003; Maxwell et al., 2001). The explanation advanced for this latter finding is that the more performance of the motor task depends on explicit knowledge, the more likely the additional cognitive load imposed by a concurrent task or distractions will degrade performance of the (primary) motor task.

These differential effects of the amount of explicit task-relevant knowledge on motor learning may become more pronounced with aging. A recent investigation by Chauvel et al. (2012), who had participant learn a golf-putting task, found that older adults performed at similar levels as young adults when the accumulation of explicit task knowledge during the learning
phase was kept low. In addition, a concurrent secondary task did not affect the older adults’ performance after learning. However, when older adults did accumulate a significant amount of explicit knowledge during learning, their performance was clearly less successful than that of young adults and strongly disrupted by a secondary task. These observations mimic findings in the learning of more artificial lab-based sequential reaction time tasks (SRTT), in which participants respond to an ordered sequence of visual stimuli by pressing corresponding keys as quickly as possible. Learning these tasks implicitly (i.e. without becoming aware of the order of the sequence) does not deteriorate with age. By contrast, learning the task explicitly does decrease with age. Older adults who are informed about the order of the sequence benefit less from these instructions than young adults (e.g., Howard & Howard, 2001; Verneau et al., Forthcoming). Thus, inducing high level of awareness of task-relevant features is not beneficial for older adults’ motor learning.

In the assembly industry, workers must learn to manually assemble components in a prescribed order to build a product. In this respect, a few reports indicate that older adults need longer practice than young adults to reach criterion performance in assembly (Hancock, 1967; Schwerha, Wiker, & Jaraiedi, 2007) and at the same time, remain more vulnerable to distractions (Wiker, Schwerha, & Jaraledi, 2009). Based on the earlier findings that rate of learning and stability after learning are mediated by the degree of awareness during learning (Chauvel et al., 2012; Howard & Howard, 2001; Verneau et al., Forthcoming), a learning method that reduces the amount of explicit instructions and presumably holds back awareness of task-relevant features may be desirable for older adults’ sequential motor learning in assembly tasks. This method would increase both the rate of learning and stability of performance after learning. However, the experiments thus far either involved lab-based sequential tasks that primarily emphasised the structure of the sequence with very low demand on movement dynamics (i.e. a button press) or tasks that involved more complex movement dynamics, without a
clear sequential movement structure (i.e. sport skills) (Steenbergen et al. 2010). Hence, the aim of the current study is to assess the effects of varying instructions for learning an assembly task, which entails a series of relatively complex movements (i.e. learning to reach, grasp, place a series of components in a pre-defined sequence). Because an assembling task is difficult to learn fully implicitly (i.e. the worker needs to know some details of the end product), the challenge is to differently tune the amount of instructions, while still eliciting sequential learning and task performance that meets the criteria for the end product.

To this end, we assessed sequential motor learning of a gross assembly task for two sets of instruction that either provided full and detailed explicit information about the task or guided the learner through the sequence to learn without conveying further explicit information. These two sets of instruction were tested on young and older adults. To assess rate of learning, performance was tested immediately after practice (i.e. retention) and on a separate day (i.e. consolidation after at least one night sleep) to verify that any learning effects were indeed relatively permanent (Kantak & Winstein, 2012).\(^1\) To assess the stability of performance after learning, we introduced a concurrent second task that mimics listening to a colleague after practice. We expected that (1) older adults would benefit less from full instructions relative to guided learning than younger adults and (2) older adults would be more severely affected by the concurrent task, especially in the fully instructed group.

**2- Method**

**2-1 Participants**

A total of 20 young adults between 18 and 30 years of age (mean age = 22.5, SD = 3.5 years) and 19 older adults between 50 and 65 years of age (mean age

\(^1\) Although it is often omitted (e.g. Chauvel et al., 2012; Howard & Howard, 2001; Verneau et al., 2014), the latter is of crucial importance as older adults exhibit a weaker consolidation than younger adults, i.e. practice-induced changes in performance seem less permanent in the elderly (Spencer, Gouw, & Ivry, 2007; Wilson, Baran, Pace-Schott, Ivry, & Spencer, 2012).
= 58, SD = 4.5 years) participated in the study. Participants of each age group were randomly assigned to either the full instruction or the guided learning group. All participants were self-proclaimed right-handers, had normal or corrected to normal vision, and reported that they did not suffer from chronic pain of the right forearm, shoulder and/or hand. The participants were naive to the purpose of the experiment and fully debriefed after completion of the study. They received a small monetary reward for participation. The local institution’s ethical committee approved the study.

2-2 Apparatus and stimuli

The Assembling Task Apparatus (ATA®, Top Productivity, The Netherlands, see Figure 1A) was used. This workstation tests workers’ ability for learning to perform different types of assembly tasks (e.g. gross and fine assembly, sorting, etc.). It is designed such that it provides workers a full set of instructions that allows them to learn to assemble various types of products. The sets of instructions differ in quantity and accessibility and can be tuned to an individual worker's need. For the present study, the gross assembly task was used. The workstation creates an environment for autonomously learn (i.e. without augmented feedback or instruction by an instructor) to repetitively construct a product by sequentially assembling (i.e. reach, grasp, orient and place) its components in a fixed order. Through dedicated PG-viewer software, the workstation monitors the worker’s actions and directs him or her through the assembly task in a step-by-step fashion. Visual (i.e. light bulbs) and auditory (i.e. a buzzer) signals can guide and provide feedback on the worker’s actions (e.g. the incorrect component is taken). The instruction set can be adapted based on the monitoring of the worker’s performance. For the gross assembling task, the workstation was organised as follows (see Figure 1B): a series of six bins, each of which filled with one kind of component, was placed directly behind the workspace where the product was to be built. Each bin was equipped with a movement sensor, which registered when the worker’s hand entered the bin, and a light bulb which,
when turned on, indicated the bin from which the next component was to be picked from. Above the row of bins (and light bulbs) stood a monitor that displayed the pictorial and text instructions. Finally, a green command button was placed to the right of the workspace. Workers had to press the command button after having placed a component. The workstation would then signal the next component.

The product to be assembled was composed of a long iron stick (13 cm in length and 1.2 cm in diameter) at which four rings of different colour, shape and size (i.e. black 1.7 cm in diameter, blue 2.5 cm, white 3 cm and red 2.1 cm) had to be placed in a prescribed order (see Figure 1E). To finish the product, a black cap (1.3 cm) was placed on top of the stick. Hence, for each product the stick was always the first component to be grasped, while the last was the cap. To ease construction, there was a hole (10 cm above its front edge) in the worktable, in which the stick had to be placed. Once a product was constructed, it was placed into a carrier (positioned behind the hole) that could stock 12 products.

An Optotrak Certus Motion Capture System (Northern Digital Inc.) was used to record the movement of the participant’s preferred, right hand with a sample frequency of 100Hz. The camera was placed horizontally, at a height of 1.8 m to the left side of the workstation. Two IREDs were attached to the participant’s right hand (i.e. the metacarpo-phalangeal joint of the thumb and on the wrist at the base of the anatomical snuffbox). For the secondary transfer task, a MacBook Pro played a soundtrack with auditory stories of various events (e.g. checking in a hotel, introducing a family) through headphones (Philips, stereo headphone SBC HP080). Finally, to assess working memory the Digital Memory Span test from the WAIS-iii was used.

2-3 Procedure and design
Participants performed the gross assembly task while standing in front of the workstation. They were required to use their dominant hand to pick and place the components (see Figure 1A). The height of the counter (i.e. workspace
with the bins) was adjusted to each participant length, while the monitor was matched to eye height. The experiment consisted of two sessions that were separated for at least 24 hours but no more than 4 days. The first session started with the completion of the Digital Memory Span test of the WAIS-iii accompanied by questions targeting levels of education and perceived health (see Table1). This was followed with a general introduction to the workstation, its use and the gross assembly task. Subsequently, participants were provided with the condition-specific instructions (i.e. the way the workstation will instruct or guide them through the task). Participants then started the practice phase. During the practice phase, they repetitively assembled the six components into one product in the order specified by the workstation. Specifically, participants first pressed the green command button to trigger the instruction regarding the target component (i.e. depending on the learning condition, detailed instructions via text and pictures shown on the monitor or turning of the light bulb above the target bin, see below); they then picked the component, placed it (i.e. the stick into the worktable’s hole, the other components over the stick) and pressed the green command button again to trigger the next instruction, and so on for the next five components. After the sixth component (i.e. the cap) was placed, the product was finished and the participants had to place it in a carrier and then press the command key to start the next object. Once the carrier was full (i.e. 12 products), the experimenter removed it from the workspace and placed a new one. In the full instruction condition, picture and text were presented on the monitor, indicating the component to be grasped and depicting the end product (see Figure 1C), whereas in guided learning condition the light bulb above the bin containing the component to assemble was switched on (see Figure 1B). In both conditions, if the participant took the wrong component (i.e. the movement sensor of the wrong bin was activated), a buzzer generated an error tone. The instructions remained until the correct component was reached (i.e. the correct movement sensor was activated). In total 10, blocks
of 12 products (i.e., $72 \times 10 = 720$ components) were completed during the practice phase. This took approximately 1 hour, including a 2-minute break between each block and a 5-minute break after the completion of the fifth block. Figure 2 depicts the different phases of the experiment.

![Figure 1: Illustration of the experiment. A - One participant during practice under guided condition. B - The participant’s view, including the monitor with instructions above the row of six blue bins containing the components. The vertical arrow indicates to the green command button. The horizontal arrow delimitate the bins filled with components. C and D - An example of the instructions displayed on the monitor for the guided instruction (C) and full instruction (D) methods. E - An end product.]

<table>
<thead>
<tr>
<th></th>
<th>50+</th>
<th>Young</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>sd</td>
</tr>
<tr>
<td>Education</td>
<td>18.7</td>
<td>3.4</td>
</tr>
<tr>
<td>Health</td>
<td>4.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Digit span</td>
<td>17.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 1: Participants characteristics: level of education (i.e. number of years spend in the scholar system), self-rated health (rated from 1 to 5 with 5 being very healthy) and the scores for the digit span. No difference for age ($p’s > 0.05$).
Because instructions on each practice trial would likely lead to the participant’s performance becoming strongly dependent on the information conveyed in the instruction, also after practice, a method was used in which the frequency of instructions gradually decreased during practice (i.e. fading, see Weinstein & Schmidt, 1990). Accordingly in practice, in blocks P1 and P2, instructions were provided for each of six components; in blocks P3 and P4, for the five first components and so on. Consequently, blocks P9 and P10 only conveyed information of the first two components.

Five minutes after the practice phase, the test phase started (see Figure 2). It consisted of one retention block and one transfer block of 12 products each. During the test phase, the workstation did not provide any instructions. For the immediate retention test (i.e. R), participants were asked to proceed as they did before and assemble 12 products. In the subsequent transfer test (i.e. T), a secondary task was introduced. Participants were told that they would hear a soundtrack while they were assembling 12 more products, and that after finishing the products they would be asked to answer several questions about the auditory stories. To ensure that participants would focus on the story and to know what kind of information to recall, they read the questionnaire shortly before the transfer test block. The story started after participants had pressed the green command button. The soundtrack lasted for 5.30 minutes and participants were instructed to continue listening even if they would have already completed the 12 products. After the transfer task was finished, the experimenter asked 13 questions regarding the stories. Participants answered verbally. This completed the first session. In the second session, a third test block of 12 products was run. This consolidation test (i.e. C) was identical to the immediate retention test.
2-4 Data analysis

Performance during practice and test phases was measured by the accuracy by which products were assembled as well as the time needed to do so. For accuracy, we calculated the percentage of correctly assembled products for each block of 12 products (i.e. during practice the workstation would correct the participant, making this measure less powerful for performance during practice). In addition, the percentage of correct initial grasps was calculated (i.e. during practice this is the total number of grasp minus times the buzzer sounded) again for each block of 12 products. As every product consisted of six components the percentage of correct initial grasps was expressed relative to the total number of components in each block (i.e. 72).

To determine movement times, the kinematic recordings were filtered with a fourth order low-pass Butterworth filter (cut-off frequency of 1.7, as graphically determined). The beginning of each object was defined as the moment the hand left the stick (after placing it in the hole) and the end as the moment the cap was placed over the stick. The movement time (MT) was calculated by taking the difference between the beginning and end for each correctly assembled product and averaged for the number of correct products within one block. Outliers in MT were removed following the outlier labeling

---

2 Due to technical problems, the workstation did not always detect the grasping of the stick (i.e. the first component), requiring the participants to re-enter the bin, which prolonged movement time for this component. Hence, we excluded the first component from our analyses.
method of Hoaglin (Hoaglin & Iglewicz, 1987; Hoaglin, Iglewicz, & Tukey, 1986).

To assess rate of learning and stability after learning, the evolution of performance during practice and performance in the retention and transfer tests was compared by submitting the accuracy measures and MT to $2(Age: \text{older adults, young adults}) \times 2(\text{Instruction: full instruction, guided learning}) \times 13(\text{Block: P1-10, R, T, C})$ analysis of variance with repeated measures over the last factor. In the case that the sphericity assumption was violated Huyn-Feldt corrections for the $p$-values are reported. Post hoc comparisons were performed using $t$-tests with Bonferroni corrections. In all analysis, the significance criterion was set at $\alpha = 0.05$. Partial eta-squared ($\eta_p^2$) values were computed to determine the proportion of total variability attributable to each factor or combination of factors.

Finally, the performance on the secondary task questionnaire was calculated by taking the percentage of the minimum of correctly answered questions that were played until the participant had completed the assembly of 12 products (i.e. only those questions that were listened to by every participants concurrently with building the products). Because Levene’s equality of variance test indicated that normality assumptions were violated, differences between groups were assessed using the Kruskal - Walis test.

3- Results

3-1 Performance accuracy

Given the procedures during practice, two measures of task accuracy were studied. The first, i.e. the percentage of correctly assembled products, was 100% during the 10 practice blocks due to the set-up during practice where participants had to correct wrongly grasped components (i.e. the auditory feedback indicated that the wrong component was grasped). Yet, also in the retention, transfer and consolidation blocks, the performance in terms of percentage of correct end products was nearly perfect, and no significant
effects for Age, Instruction or Block were revealed over this first measure of accuracy.

With regard to the percentage of correct initial grasps (i.e. second measure of accuracy), Figure 3 shows that participants did sometimes initially misdirect their grasp to the wrong component. This happened almost exclusively in the early practice blocks and not during retention, transfer or consolidation blocks. Accordingly, a significant effect of Block was found for percentage of correct initial grasps, $F(12, 396) = 6.26, p < 0.001, \eta_p^2=0.16$. A significant Instruction by Block effect, $F(12, 396) = 3.35, \ p<0.01, \eta_p^2=0.09$, shows that this effect was mediated by the type of instruction. Post hoc comparisons indicated that the guided learning groups made less initially incorrect grasps than the full-instruction groups in P1 (i.e. 1.0% and 3.0%, respectively) and P7 (0.0% and 0.5 %). No effects of age were found: young and older adults were equally accurate.

Figure 3: The evolution of the percentage of correct initial grasps (Pcig) through practice (P1 - P10), retention (R), transfer (T) and consolidation (C) for the young (a) and older (b) adults as a function of the instruction method (— full instruction, — guided instruction).
3-2 Movement time

Figure 4 illustrates the movement times to assemble one product for each block in each of the four groups. Clearly, movement times got shorter with practice, but some more subtle differences appeared as well. That is, the analysis of variance revealed main effects of Block $F(12, 396) = 103.52, p < 0.001, \eta^2_p = 0.76$, Age, $F(1, 33) = 15.20, p < 0.001, \eta^2_p = 0.31$, as well as interaction effects of Instruction by Block, $F(12, 396) = 5.70, p < 0.005, \eta^2_p = 0.15$, and Age by Instruction by Block, $F(12, 396) = 3.41, p < 0.05, \eta^2_p = 0.09$. As can also be seen from Figure 4, post hoc comparisons indicated that movement times were shorter for young as compared to older adults, but age-related differences were influenced by the instruction method. That is, early in practice (i.e. during the P1), the younger guided learning group had shorter movement times than the younger full instruction group, while no such difference occurred between the two older groups. In addition, and importantly, in the consolidation test, but not in the immediate retention test, the older guided learning group had longer movement times than the older full instruction group. By contrast, the two young groups took similar amounts of time assembling products after consolidation. Finally, with respect to the secondary tasks, post hoc comparisons indicated that for all groups the time needed to assemble a product remained unaffected, except for the older guided learning group, which showed increased movement times in transfer relative to immediate retention.

3-3 Secondary task performance

Kruskal-Wallis test indicated that there were differences between groups in the percentage correct answers, $K(3) = 8.75, p < 0.05$. Post hoc indicated that the older full instruction group was less accurate than the younger groups, while the older guided learning group performed at a similar level as the younger groups (see Figure 5).
Figure 4: The evolution of the movement time (MT) through practice (P1—P10), retention (R), transfer (T) and consolidation (C) for the young (A) and older (B) adults as a function of the instruction method (— full instruction, — guided instruction).

Figure 5: Secondary task scores for the young adults full instruction (YI), young adults guided instruction (YG), older adults full instruction (OI) and older adults guided instruction (OG) groups (* p < 0.05).
4- Discussion

The present results show that irrespective of age and instruction, participants learned the gross assembly task successfully without feedback or added directives of an instructor. Accordingly, when eventually tested without any instructions, every participant was capable of correctly assembling the product not only immediately after the practice session but also after a delay of one to four days. Moreover, performance was not easily disrupted by an attention demanding concurrent task. Nonetheless, some subtle performance differences emerged between the two age groups that were influenced by the type of instruction, especially with respect to the time needed to assemble a product. In a nutshell, and contrary to our hypothesis, the older adults’ learning was more persistent after full instruction than after guided learning. Indeed, in older adults the full instructions led to an approximately 10% faster assembly after consolidation, and performance was more resilient to distractions than after guided learning.

4-1 Rate of learning

The results show that among young adults the final performance (as revealed in the retention and consolidation tests) was independent of the type of instruction. However, although performance immediately after practice was similar for both types of instruction, one to four days after practice, older adults who had received full instructions were evidently faster than the older adults who followed a guided learning protocol. This suggests that the full instructions, which supposedly results in an increased awareness and possibly enhanced conscious control and monitoring of the assembly task, helped preventing the forgetting of task structure and/or dynamics in older adults (as compared to guided learning). Importantly, this enhanced consolidation after full instruction conflicts with our hypothesis that older adults would benefit less from full instructions relative to guided learning than young adults. That is, while in young adults full instructions did not provide an advantage, for older adults they were actually more beneficial.
In contrast to our result, previous work mostly showed that, if any differences emerge, older adults fare better with less explicit instructions about the task to learn (Chauvel et al., 2012; Howard & Howard, 2001). Possibly, differences in task (i.e. what is learned) and methodology (how learning is tested) account for this discrepancy.

For one, the sequential structure of our assembly task was relatively easy compared to the structure in the more traditional studies of sequential motor learning (i.e. SRTTs). Previous work showed that explicit instructions held back older adults’ learning, but used more complex sequential structures (e.g. second order regularities, Howard & Howard, 2001; Verneau et al., Forthcoming). Indeed, the current observation that both young and older adults made more erroneous initial moves early in practice (i.e. P1) with full instructions suggests that the sequential structure may have been so transparent that a high degree of task awareness, and likely enhanced explicit control actually hindered performance. In particular, participants in the full instruction group had to first identify and then locate the target bin and components it contained, presumably by looking back and forth between the monitor that displayed the instruction and the row of bins. This may have elicited more elaborative and strategic monitoring and processing of the elements of the assembly task (Willingham, 1998). During guided learning, participants only had to locate the bin. Initially, the more elaborative and strategic processing caused by the full instruction method may have obstructed task fluency (as attested for by a lower rate of correct initial grasps). Participants rapidly overcame this impediment, and performed as accurate and fast as the guided learning groups during the remaining practice blocks (except for a slight glitch in accuracy in P7). Following the conjecture that implicit and explicit processes normally have parallel contributions to learning (Curran & Keele, 1993; Willingham & Goedert-Eschmann, 1999), the full instruction group initially relied more strongly on conscious processes than the guided learning group. In the subsequent practice blocks, however,
the relative contribution of implicit and explicit processes (if any conscious processing did remain) in all likelihood ended up similar for both instruction methods. Also, in terms of task dynamics (i.e. controlling the reaching, grasping, orienting and placing movements), the gross assembly task may not have been very demanding. That is, adults routinely reach, grasp and move objects. In short, due to its low complexity, both in terms of movement structure and dynamics, the gross assembly task may have been relatively straightforward to perform and improve, without the need to explicitly memorise the sequence. Hence, learning following the guided instructions may largely have been implicit.\(^3\) For young adults this suffices to retain performance increments one to four days later. Yet, for older adults the downside seems to be that the memory trace became less strong, i.e. it did not fully consolidate. By contrast, the initially more elaborative processing in the full instruction setting led to more distinctive memory traces that better transferred to long-term memory despite the age-related damages of consolidation (Spencer, Gouw, and Ivry, 2007; Wilson et al., 2012). This resulted in more persistent learning effects one to four days after practice.

Second, it must be noticed that a consolidation test is often not part of this type of research (see, e.g. Chauvel et al., 2012; D. V. Howard & Howard, 2001). In all likelihood, the requirements for recall are much more marked in consolidation than for immediate retention. If this conjecture is correct, then subtle differences in consolidation of learning as function of instruction type might only become apparent in delayed retention, emphasising the need for demonstrating that learning occurred beyond immediate retention (Kantak & Weinstein, 2012). In short, we suggest that more elaborative processing invoked by explicit instructions may benefit long-term motor learning in older adults, especially for relatively easy tasks where implicit learning suffices for achieving short-term performance improvements.

\(^3\) Notice that we did not assess the amount of knowledge accumulated during practice, and hence, that the actual degree to which the two instruction methods resulted in explicit or implicit motor learning cannot be independently verified.
4-2 Stability of performance after learning

For the young adults, assembly performance was not adversely affected when they concurrently listened to short auditory stories to recall later. Assembly performance was equally stable, irrespective of the type of instruction, and also recall was not differentially affected. Among older adults, by contrast, assembly performance for the guided learning group decreased with the introduction of the secondary task. They needed more time to build the products. The older adults of the full instruction group did not suffer similar decrements in assembly performance. Hence, together with performance differences in the consolidation test, this indicates that in older adults a more elaborate and distinctive processing of task-relevant features during practice leads to more persistent and more resilient learning outcomes. At first glance, this is not consistent with Chauvel et al’s reasoning that with less accumulation of explicit knowledge during practice, older adults’ performance after learning is enhanced and less affected by a secondary task. Nonetheless, the recall scores of the older adults in the guided learning group matched those from the younger adults; the recall scores of the older adults in the full instruction group were clearly lower. It thus appears that the two groups of older adults did prioritise the assembly and listening tasks differently. The guided learning group may have focused more on the auditory stories at the expense of the assembly speed, while after full instruction older adults maintained the working rate for the assembly task, but at the cost of paying attention to the auditory task. In addition, it suggests that the full instruction regime did make it more likely to fall back on a more conscious control mode (relative to the guided learning group). This enhanced conscious control may help maintaining performance when confronted with a second task –but at the expense of secondary task performance. In fact, it cannot be ruled out this enhanced conscious control induced by the secondary task carried over into increased consolidation. Future work should assess this alternative
explanation by examining consolidation in groups that do not do the transfer test.

The older adults in the guided learning group were not used to explicitly control and plan the assembly task during practice, making them more apt to attend to a second task - but at the expense of primary task performance. In general, this underlines that the ability to simultaneously cope with two tasks is reduced among older adults (Ren et al. 2013; Salthouse, 1990). However, previous investigations revealed that learning that minimises involvement of explicit processes, more thoroughly than in the current study, may allow older adults to better deal with dual tasks, perhaps as efficiently as younger adults do (Chauvel et al. 2012). Possibly, the current design did not offer sufficient repetition to allow older participants to reach this more automatised, distraction-proof performance level (Schwerha, 2007).

4.3 Conclusion

To summarise, the type of instructions provided to older adults in learning assembly work lead to subtle difference in performance. For the uncomplicated assembly task in the present investigation, full instructions induced more persistent learning effects over a couple of days and more stable performance under divided attention situations. We suggest that this advantage may be due to the more elaborative and distinctive processing induced by the detailed instructions (perhaps reinforced by a change to a more conscious control induced by the transfer test), which leads to stronger (long-term) memory of the task. To what degree this is limited to the relatively uncomplicated movement structure and dynamics of the task and/or relatively short practice period needs further scrutiny.

On the practical side, the current findings suggest that the aims of practice should be leading, in particular that additional attention for a worker's age is warranted. To enhance assembly performance relatively permanently, providing older adults with full instructions may be most effective. It also permits to maintain performance against a background of
distractions. However, if dividing attention to surrounding events is paramount as well, lower levels of awareness such as induced by guiding learning may be more suitable for older people. In addition, a guided learning method that alleviates the amount of instruction appears to result in more accurate performance early during practice, not only in older adults but in younger adults as well. Hence, if short bouts of learning are required, a less explicit guided learning regime may be desirable. Finally, it is important to extend the present research to include retention over longer periods of time to evaluate the persistence of the benefits and disadvantages of the different instruction regimes. In doing so, proactive and retroactive transfer, e.g. (Panzer, Wilde, & Shea, 2006), to other similar, but not identical chain-industry-like tasks (e.g. assembling a slightly different product or tasks that require more fine motor skills), would need careful investigation as well.

Acknowledgements: This work was financially supported by Body@work, Research Center on Physical Activity, Work and Health. We thank Total Productivity for lending the ATA workstation and monitoring us in its use.