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Improving older adults' ability to follow instructions: Benefits of actions at encoding and retrieval in working memory

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Abstract

The ability to follow instructions is critical for learning new skills and may support successful aging. Recent evidence indicates a close link between following instructions and working memory, and that action-based processing at encoding and retrieval can improve this ability. In this study, we examined the ability to follow instructions and the benefits of action-based processing in young and older adults. In Experiment 1, participants were presented with spoken or silent demonstrated instructions, then recalled them by oral repetition or physical enactment. Older adults produced fewer correct responses in all conditions. Both age groups were better at recalling demonstrated than spoken instructions in the verbal but not the enacted recall condition. Older adults also benefited from enacted recall relative to verbal recall, but to a smaller extent than younger adults. In Experiment 2, the additional benefit of dual modalities (spoken instructions with simultaneous demonstration) relative to single modality presentation (spoken instructions, or silent demonstration) was examined. Both age groups showed superior performance in dual modality conditions relative to spoken instructions when using verbal recall. These findings suggest that although following instruction ability appears to decline with age, older adults can still benefit from action at encoding and retrieval.

Keywords: Working memory, aging, enactment, following instructions

Introduction

The ability to follow instructions is critical for effective learning (Gathercole & Alloway, 2008; Gathercole et al., 2008). Learning is not only important for children and young adults, but also compensates for declining brain functions in older adults and improves cognitive resilience to pathological aging (Park & Reuter-Lorenz, 2009). However, research has only recently started to investigate the ability to follow instructions in older adults (Charlesworth et al., 2014; Coats et al., 2021; Jaroslawska et al., 2021).

When people follow instructions, they often need to encode a series of movement-object pairs in the correct sequence positions, form and maintain the representation in memory and then recall them in the correct order. For example, older adults often attend classes to learn new skills or knowledge and need to follow a sequence of directions from the instructor (e.g., novel routines in dance or cooking classes). Alternatively, they may need to remember a doctor’s instructions on how to use an item of new medical equipment (e.g., a glucometer) by remembering multiple operation steps and pressing different buttons in the correct order. This requires both storage and manipulation of information, which is a definitive role of working memory. Indeed, experimental and correlational studies indicate that the ability to follow instruction is highly reliant on working memory (Gathercole et al., 2008; Jaroslawska et al., 2018; Jaroslawska et al., 2015; Yang et al., 2016; Yang et al., 2014). Research involving clinical populations with impaired working memory functions also indicates worse performance in tasks measuring following instructions than controls (Lui et al., 2018, patients with schizophrenia; Yang et al., 2017, children with ADHD).

In line with a deficit-view of ageing, age-related decline in working memory is now well-established (e.g., Bopp & Verhaeghen, 2007; Park et al., 2002). Given this, older adults may also have relatively greater difficulty in following instructions. In an earlier study (Kim et al., 2008), young and older adults were asked to sort pills into containers following spoken instructions (e.g., *Take 2 pills on Wednesday*), with the complexity of instruction manipulated by increasing the number of actions and components. An age difference was observed that became larger as the complexity of instructions increased.

As holding and implementing instructions may well be a key component in supporting activities that help successful ageing, it is important to understand to what extent such deficits are reliable across different task contexts, and indeed whether certain contexts offer ways to improve performance. Age-related declines might be compensated for by adjusting the task context, but we still need to establish which contexts are beneficial and which only serve to exacerbate performance decrements due to changes in cognition and motor function. Recent research has started to focus on the possible benefits of action-based processing in following instructions at both encoding and retrieval.

Self-enactment during encoding

Self-enactment during the presentation can improve working memory for spoken instructions in healthy young adults (Allen & Waterman, 2015; Lui et al., 2018) and clinical populations with impaired working memory ability (Lui et al., 2018, patients with schizophrenia; Wojcik et al., 2011, children with autism). However, this encoding-based benefit of self-enactment has been rather weak and inconsistent for children (Jaroslawska et al., 2016; Waterman et al., 2017) and older adults (Charlesworth et al., 2014; Coats et al., 2021; Jaroslawska et al., 2021). In the latter case, Charlesworth et al. (2014) found that both healthy older adults (aged 68 - 90, mean 78.6) and individuals with mild Alzheimer's disease (aged 71- 92, mean 82.4) showed a small benefit of self-enactment on a free verbal recall task, but two recent studies using serial recall have shown no such effect in healthy older adult groups (Coats et al., 2021; Jaroslawska et al., 2021). This small and unreliable self-enactment effect may be associated with the cognitive cost of physical enactment during encoding and decreased motor function in older adults (Berchicci et al., 2012; Seidler et al., 2010).

Demonstration during encoding

Demonstration offers an alternative way of introducing action to verbal instructions. Demonstrations of actions can be presented alone (i.e., silent demonstration) or simultaneously with spoken instructions (i.e., dual modality). Evidence indicates that silent video demonstration can lead to superior memory performance compared with purely spoken instruction in children (Yang et al., 2017) and young adults (Allen et al., 2020; Yang et al., 2015, Experiment 1; Yang et al., 2019). Compared to spoken instructions, observation of actions may enhance relational processing (Steffens, 2007) to strengthen the associations within an action, among actions, and between actions and contexts, which encourage the formation of a more integrated representation of action sequence. However, no prior study has examined whether older adults would also benefit from silent demonstration relative to spoken instructions.

Similar to silent demonstration, presenting demonstrated actions while people are listening to spoken instructions (i.e., dual modality) can also improve memory performance compared with pure spoken instructions in young adults (Coats et al., 2021; Lui et al., 2018; Yang et al., 2015, Experiment 2). Compared with the benefit of self-enactment, the benefits of observing actions while listening to spoken instructions tend to be larger and more stable in children (Jaroslawska et al., 2016; Waterman et al., 2017). Recent research suggests that demonstration of actions brings additional visual, spatial and motor information and allows generation of a richer memory representation for later recall (Allen et al., 2020), and this process is likely to be automatic or require minimal cognitive effort (Coats et al., 2021; Lui et al., 2018; Waterman et al., 2017). The benefit of dual modality has only been explored in older adults in one study to date, and this was limited to verbal recall. Coats et al. (2021) compared 50 young adults (aged 18-23, mean 19.4) and 40 older adults (aged 60- 89, mean 70.9) in three encoding conditions: participants listened to the spoken instructions, viewed additional demonstrations by an experimenter alongside this spoken presentation (i.e., dual modality) or enacted the actions during encoding. They found that viewing additional demonstrations led to superior verbal recall of the actions compared to spoken instruction and the self-enactment condition. Furthermore, the benefits of dual modality (relative to spoken instructions only) were larger in young than older adults.

Enactment during retrieval

Turning to action at retrieval, recall of spoken instructions is more accurate when the response format involves physical enactment compared to oral repetition (Allen et al., 2022, for a review). This enacted-recall advantage has consistently been shown in children (Gathercole et al., 2008; Jaroslawska et al., 2016; Waterman et al., 2017) and young adults (Allen & Waterman, 2015; Jaroslawska et al., 2018; Li et al., in press; Yang et al., 2016; Yang et al., 2015). Recent evidence from young adults suggests that the enacted-recall advantage arises from active action planning that helps form a more integrated motor-spatial representation of the action sequence (Jaroslawska et al., 2018; Li et al., in press). Indeed, Makri and Jarrold (2021) found that planning for enactment at recall might serve to bind actions and objects together into an integrated representation (see also Yang et al., 2016). While the precise mechanisms underlying this are yet to be mapped out, motor coding elicited during anticipation of enactment may be held in a motor output store that serves to develop and hold plans for immediate action. This might be characterised as a separate specialised buffer (Jaroslawska et al., 2018) or as part of a more detailed specification of the visuospatial sketchpad (Li et al., in press) within a multi-component working memory system (Baddeley et al., 2021). A representation of the anticipated action sequence combining verbal, visual, spatial, motoric, and perhaps semantic information would then be held in a modality-general form, served by the episodic buffer within this multi-component framework.

To our knowledge, only one single-experiment study to date has compared verbal and enacted recall in an ageing population. Jaroslawska et al. (2021) found that older adults (aged 66-81, mean 71.1) show the enacted-recall advantage in a following instruction task, though the size of this effect was somewhat smaller compared to that shown by a young adult group (aged 18-29, mean 23.3).

Interactions between encoding and retrieval

The effects of silent demonstration and enacted recall also seem to interact at least in young adults and children, emerging as a smaller demonstration advantage in the enacted recall condition and a smaller enacted-recall advantage following silent demonstration (Yang et al., 2017; Yang et al., 2015). The interaction may reflect the similar representations formed by action observation and action planning according to the common coding theory (Prinz, 1997) and evidence of similar brain networks of planning, observation, and execution of actions (Hardwick et al., 2018). This interaction mirrors a similar interactive pattern that has been observed between self-enactment during encoding and recall (e.g., Allen & Waterman, 2015; Jaroslawska et al., 2021; Jaroslawska et al., 2016).

In summary, while the ability to follow instructions draws on limited working memory capacity, action-based processing at encoding and retrieval can have faciliatory effects for children and young adults. Building on this, the limited research on following instructions in the context of healthy ageing provides preliminary evidence for older adults' ability to benefit from action-based processing in following spoken instructions. The presence of enacted-recall and demonstration benefits in older adults reflects their relatively intact function of action planning and action perception, although benefits may be smaller compared with young adults.

While these findings are intriguing, key issues remain unresolved. Firstly, only one study has examined the demonstration benefit in following spoken instructions in older adults (Coats et al., 2021). This study implemented a dual-modality condition (i.e., spoken plus demonstrated presentation) and examined verbal recall; it remains unclear whether older adults would also show the benefit of dual modality in the enacted recall. Secondly, given that healthy ageing may be associated with a particular decline in visuo-spatial working memory (Jenkins et al., 2000; Johnson et al., 2010; Verhaeghen et al., 2002), it is important to establish whether older adults would show superior performance following silent demonstration compared to spoken instructions as is typically seen in children (Yang et al., 2017) and young adults (Allen et al., 2020; Yang et al., 2015; Yang et al., 2019). Finally, no previous study has examined whether older adults would show the same pattern of single and dual-modality effects that are found in young adults on the following instruction tasks (Yang et al., 2015).

Two experiments were conducted to examine these issues. Experiment 1 provides the first experimental comparison of silent demonstration vs. spoken instruction on enacted vs. verbal recall in young and older adults. Experiment 2 is also novel in exploring whether enacted and verbal memory performance in young and older adults can be further improved by using dual modality (spoken instruction with simultaneous demonstration) compared to single modality (spoken vs. silent demonstration) presentation.

Experiment 1

The aim of this experiment was to examine the demonstration advantage and benefit of enacted recall in older adults. We used the following instruction span task that requires participants to remember a series of action steps such as *touch the blue folder and then push the red pencil* (Yang et al., 2015). Instruction sequences were presented as spoken audio or silently demonstrated videos, followed by serial recall via oral repetition or physical enactment. Consistent with previous findings (Allen & Waterman, 2015; Lui et al., 2018; Yang et al., 2016; Yang et al., 2017), we expected both an enacted-recall advantage and a demonstration advantage. We also predicted an interaction between these in young adults, such that demonstration would benefit verbal recall more than enacted recall (Lui et al., 2018; Yang et al., 2017; Yang et al., 2015).

For older adults, we hypothesised worse performance compared to young adults given the instruction task relies on working memory, an ability that declines in older adults (Park et al., 2002; Schroeder, 2014). This would be in line with overall deficits also recently observed in following instruction tasks (Coats et al., 2021; Jaroslawska et al., 2021). As older adults have been shown to have decreased ability in action planning/motor imagery (Berchicci et al., 2012; Gabbard et al., 2011), spatial representation during tool use (Costello et al., 2015) and motor control (Seidler et al., 2010), we expected a smaller enacted-recall advantage in older adults than young adults. Indeed, Jaroslawska et al. (2021) recently observed such a decrement in their study. In terms of the demonstration manipulation, Coats et al. (2021) found that adding visual demonstration to spoken presentation facilitated both young and older adults, though the benefit appeared to decrease in size with age, possibly reflecting the age-related decline in visuo-spatial working memory (Jenkins et al., 2000; Johnson et al., 2010). Therefore, we predicted that older adults would show enhanced recall following (silent) demonstration, compared to spoken presentation, though this may be smaller relative to the effect seen in the younger adult group.

Method

Design

A 2 (Presentation form: spoken vs silent demonstration) × 2 (Recall modality: verbal vs enacted recall) × 2 (Age group: young vs older) mixed design was used. Presentation form and recall modality were within-subject variables, and age group was a between-subject variable. The primary dependent variable was the number of action-object pairs correctly recalled in serial order.

Participants

Power analysis was carried out using G*Power (Faul et al., 2009) to estimate the required sample size to detect a demonstration effect in each age group. Coats et al.

(2021) observed an effect size of *d*=0.71 for the dual modality (demonstration + spoken) vs. spoken presentation conditions in their older adult group. Finding this effect size in a two-tailed test with alpha = .05 and 80% power required an estimated sample size of 18 in each age group. The final dataset[1] for analysis included twenty-one young adults (12 females and 9 males) with a mean age of 22.57 years (*SD*=2.48, range: 19-30) and mean education of 16.29 years (*SD*=1.52), and 21 older adults (13 females and 8 males) with a mean age of 67.67 years (*SD*=5.57, range: 62-75) and education of 15.24 years (*SD*=2.43). The young adults were recruited from local universities, and older participants were recruited from the local community. All participants were Mandarin speakers and right-handed. None had a history of neurological and psychiatric disease and serious hearing or visual impairments that prevented them from completing the experiment. The two age groups were matched in years of education ($t(40)=1.68$, $p=.102$) and gender ratio ($\chi^2= 0.10$, $p=.753$).

Measures

IQ. General intelligence was estimated using the Chinese short version of the Wechsler Intelligence Scale for Adults (Gong, 1992), which contained four subtests (i.e., common sense, arithmetic, similarity and digit span).

MoCA-B. The Chinese version of the Montreal Cognitive Assessment-Basic

[1] Twenty-four young adults and 27 older adults initially took part, with one older adult with a MoCA total score < 26 excluded. The two age groups were significantly different in education and IQ, and thus we created two matched sample for all reported analyses (21 young adults and 21 older adults). The results of the original sample (24 young adults, 26 older adults) on the following instruction task were the same as the final sample (21 young adults and 21 older adults).

(Chen et al., 2016; Julayanont et al., 2015) was used to estimate the general cognitive functions of older adults and exclude any participants with mild cognitive impairment. The assessment includes nine cognitive domains, namely, executive function, language, orientation, calculation, conceptual thinking, memory, visuo-perception, attention, and concentration. The total score is 30, and participants with a total score lower than 26 would be excluded from analysis (mild cognitive impairment: 23-25; dementia: lower than 23).

The following instruction span task. The following instruction span task was closely based on that used by Yang et al. (2015). There were four conditions, namely, spoken instruction-verbal recall, spoken instruction-enacted recall, silent demonstration-verbal recall and silent demonstration-enacted recall. Overall, participants listened to the spoken instructions or watched the video clips and then recalled them verbally or by physical enactment. A typical instruction contained a series of movements on two rows of objects placed on a table (e.g., for a four-action sequence, pick up the green eraser, then put it into the black bag, and touch the yellow ruler, and spin the red pencil). Six smaller objects were placed in the front row (from left to right: a white eraser, a yellow ruler, a blue ruler, a green eraser, a red pencil and a black pencil), and six containers were in the back row (from left to right: a white basket, a yellow basket, a blue folder, a green folder, a red bag and a black bag). There were five types of movements (i.e., touch, push, drag, spin and pick up… put it into…). There were four instruction lists (List A, B, C, D), and each list contained six blocks. The first block contained one-action sequences, the second block contained two-action sequences and so forth. Each block contained six instructions. If four out of six instructions in the current block were correct, the experimenter skipped the untested trials and moved on to the next block; otherwise the experimenter ended this condition and moved on to the next condition. An action was considered correct when the movement, color, object and their combinations were all correct in content and serial positions. Actions in the skipped trials were considered correct. In each condition, the number of correctly recalled actions in each block (max: 6 in Block 1, 12 in Block 2… and 36 in Block 6) were added, yielding a total action score that ranged from 0 to 126.

Spoken instructions consisted of audio recordings of instructions read by a native Chinese female narrator at a moderate speed (around 350ms per word). The demonstration instructions were silent video clips showing sequences of hand movements upon objects. The duration of the instructions was the same for spoken and silent demonstration instructions (increasing from one to six actions at 3, 5, 8, 11, 13 and 16 seconds duration, respectively).

The participant sat at a desk facing the display of objects and a computer monitor behind it. The experimenter sat at a desk away from the participants controlling the delivery of instructions. The participants were first introduced to the task and learnt the names of the objects and movements until they could name them and perform the actions correctly. In a typical instructional trial, the experimenter signaled the participants to get ready and delivered the instructions via speakers in the spoken instruction condition and silent videos in the demonstration condition. The participants were told that repeating instructions aloud, touching, operating and moving the objects were not allowed during the encoding period. After the instruction was delivered, a blank screen appeared and the participants recalled the instructions by oral repetition or physical enactment.

Procedure

The experimental procedure was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences. Each participant was tested individually in a quiet room. Participants were first introduced to the experiment and provided informed consent and basic information questionnaire then completed the following instruction span task and the IQ test. Older adults had additionally completed the MoCA-B before the IQ test. The order of the four conditions in the following instruction span task was counterbalanced using the Latin square design, and participants were given a 2-min rest between the conditions. After that, the participant completed other cognitive tasks and questionnaires for a different research project.

Results

IQ and MoCA scores

The mean IQ score was 123.33 (*SD*=10.21) for the young group and 126.52 (*SD*=13.02) for the older group, and the two age groups had no significant difference in IQ score ($t(40)=-0.88$, $p=.382$). In the final dataset, all older adults had a MoCA score higher than 26, and the mean MoCA score for the older group was 28.24 (*SD*=1.37).

Following instruction span task

Descriptive results of total action scores are displayed in Figure 1. A 2 × 2 × 2 (Age group × Presentation form × Recall modality) mixed ANOVA indicated a significant main effect of age group, with superior performance in young adults than older adults, $F(1,40)=55.13$, $MSE=468.90$, $p<.001$, $\eta_p^2=0.58$. The main effect of presentation form was significant, with better performance for silent demonstrations than for spoken instructions (i.e., a demonstration advantage, $F(1,40)=22.93$, $MSE=176.25$, $p<.001$, $\eta_p^2=0.36$). The main effect of recall modality was also significant, with better performance in the enacted-recall than the verbal-recall conditions (i.e., enacted-recall advantage, $F(1,40)=125.00$, $MSE=121.30$, $p<.001$, $\eta_p^2=0.76$). The interaction between presentation form and recall modality was significant, $F(1,40)=6.45$, $MSE=180.34$, $p=.015$, $\eta_p^2=0.14$, and this interaction was mainly driven by a significant demonstration advantage in the verbal recall condition ($t(40)=6.40$, $p<.001$, $d=1.06$) in contrast to similar performance of silent demonstration and spoken instructions with enacted recall ($t(40)=1.34$, $p=.186$, $d=0.28$).

The enacted-recall advantage was significant in both presentation conditions, but the effect size was larger for spoken than demonstrated encoding, $t(40)=10.39$, $p<.001$, $d=1.66$; $t(40)=4.60$, $p<.001$, $d=0.87$, respectively. There was no significant interaction between presentation form and age group, $F(1,40)=0.23$, $MSE=176.25$, $p=.636$, $\eta_p^2=0.01$. The interaction between recall modality and age group was significant, $F(1,40)=11.98$, $MSE=121.30$, $p=.001$, $\eta_p^2=0.23$, showing as a smaller enacted-recall advantage in the older group ($t(20)=5.46$, $p<.001$, $d=1.11$) compared with the young group ($t(20)=10.35$, $p<.001$, $d=2.01$). The three-way interaction was not significant, $F(1,40)=.98$, $MSE=180.34$, $p=.329$, $\eta_p^2=0.02$.

The two age groups differed in all conditions (*spoken instruction-verbal recall*: $t(40)=5.00$, $p<.001$, $d=1.58$; *spoken instruction-enacted recall*: $t(40)=5.48$, $p<.001$, $d=1.73$; *silent demonstration-verbal recall*: $t(40)=3.70$, $p=.001$, $d=1.17$; *silent demonstration-enacted recall*: $t(40)=6.69$, $p<.001$, $d=2.12$). The effect sizes for the action advantages in the four conditions for young and older group are shown in Table 1.

[INSERT FIGURE 1 HERE]

[INSERT TABLE 1 HERE]

Discussion

Consistent with the commonly observed age-related working memory decline in the literature (Park et al., 2002; Schroeder, 2014), and in recent work on following instructions (Coats et al., 2021; Jaroslawska et al., 2021), older adults showed an overall decrement in performance. This age effect emerged across all conditions in this experiment. It is worth noting that the observation of an age effect in verbal recall following spoken presentation is novel and contrasts with the absence of such an effect in analogous conditions in work on ageing and following instructions to date

(Coats et al., 2021; Jaroslawska et al., 2021), a difference that might reflect variation in sampling or methodology between these studies.

The frequently replicated finding of an enacted-recall advantage over spoken recall (see Allen et al., 2022) was replicated here. This advantage may arise from active action planning that helps form an integrated motor-spatial representation that facilitates recall. This finding is consistent with previous studies in young adults, children and clinical samples (Lui et al., 2018; Yang et al., 2017; Yang et al., 2015). In these studies, clinical populations (i.e., children with ADHD and patients with schizophrenia) showed a similar-sized enacted-recall advantage as controls. In contrast, older adults in the present study displayed a smaller (albeit still significant) enacted-recall advantage compared to young adults, an outcome that is broadly consistent with the only other study to examine this (Jaroslawska et al., 2021). This may be associated with age-related declines in action planning (Gabbard et al., 2011), which may lead to the formation of a less accurate representation of the action sequence during encoding. Moreover, poor working memory capacity in older adults may impair the maintenance of the representation. Finally, slowness of movement and difficulty of motor control in older adults (Berchicci et al., 2012; Seidler et al., 2010) may further reduce the enactment benefit at retrieval.

In both young and older adults, viewing a silent demonstration of action sequence facilitated verbal recall. This finding broadly replicates that of Coats et al. (2021) using dual-modality (spoken + demonstrated presentation) and extends it to the use of silent demonstration, though we did not find the age-related reduction in this benefit as was reported by Coats et al.; both age groups showed a similar benefit in the current study. A further novel finding was that the demonstration benefit was limited to the verbal and not enacted recall of instructions for both young and older adults. This interaction between action at presentation and retrieval is largely in line with recent findings in healthy samples and in clinical populations with poor working memory (Lui et al., 2018; Yang et al., 2017; Yang et al., 2015). We assume that, compared to spoken instructions, demonstration provides visual information and strengthens the links between actions (Steffens, 2007) that helps form an integrated representation of action sequence. In the enacted recall condition, action planning generates a similar representation (Prinz, 1997), and thus demonstration does not always provide an additional benefit.

While these findings are intriguing, they are limited to the use of silent demonstration in this experiment. Demonstration is often accompanied by spoken instructions in real life. Research has indicated a benefit of dual-modality presentation (i.e., spoken instruction accompanied by simultaneous/delayed demonstrations) over spoken instructions in typically developing children (Waterman et al., 2017), healthy young adults (Yang et al., 2015) and patients with schizophrenia (Lui et al., 2018). The one study to date on healthy ageing has also shown that older adults can benefit from spoken instructions with simultaneous demonstration relative to spoken instructions (Coats et al., 2021). However, it remains unresolved as to whether dual-modality input would produce a further benefit (over and above silent demonstration) in young and older groups. Yang et al. (2015) found no performance change when spoken presentation was added to silent demonstration in young adults. This finding not only requires replication; it is useful to establish whether older adults show the same pattern.

Experiment 2

Experiment 2 was focused on exploring different forms of presentation format in more detail. There were two aims in this experiment. First, we aimed to replicate the demonstration advantage (over spoken presentation) in older adults observed in Experiment 1. Second, the potential benefit of dual modalities (i.e., visual and verbal/spoken and demonstration) presentation above demonstration alone in older adults was explored. We expected to replicate the findings from Experiment 1, including worse overall performance in older relative to young adults, and the demonstration advantage in verbal recall in both young and older adults. We also expected to find a dual-modality advantage over spoken-only but not demonstration-only, in line with previous findings involving young adults (Yang et al., 2015). Finally, given that both age groups showed a similar demonstration advantage in Experiment 1, we expected that older adults would show similar single- vs. dual-modality effects as young adults.

Method

Design

The experiment used a 3 (Presentation form: spoken, silent demonstration, dual modalities) × 2 (Recall modality: verbal vs enacted recall) × 2 (Age group: young vs older) mixed design. Presentation form was a within-subject variable, and recall modality and age group were between-subject variables. The dependent variables were same as those in Experiment 1.

Participants

Twenty-four young adults (13 females and 11 males) with a mean age of 19.13 years (*SD*=0.95, range: 17-22) and mean education of 12.88 years (*SD*=0.45), and 24 older adults (13 females and 11 males) with a mean age of 65.96 years (*SD*=2.87, range: 60-70) and education of 13.21 years (*SD*=2.41) took part in the experiment. The young adults were recruited from local universities, and older participants were recruited from the local community. The inclusion and exclusion criteria were same as Experiment 1, and none of the participants took part in Experiment 1. The two age groups were matched in years of education ($t(24.59)=-0.67$, $p=.512$) and gender ratio ($\chi^2=0.08$, $p=.773$).

Measures

The IQ test and MoCA-B were same as those in Experiment 1.

The following instruction span task. The materials were the same as those in Experiment 1, and three instruction lists (List A, B, C) were used for this experiment. The materials for the dual modality condition were same as that in Yang et al. (2015), i.e., videos of demonstrated actions with simultaneous spoken instructions. The procedure of trials was the same as those in Experiment 1. However, unlike Experiment 1, participants in this experiment started from Span 3 and completed all six trials in each span (i.e., Span 3, 4, 5 and 6). The total score range of actions in each condition/list was 0 to 108.

Procedure

The procedure was similar to that in Experiment 1 except that the IQ and MoCA tests (only for older adults) were carried out before the following instruction tasks. The order of the three conditions in the following instruction task was counterbalanced using a Latin square design.

Results

General cognitive functions

The mean IQ score was 122.92 (*SD*=12.73) for the young group and 119.54 (*SD*=10.88) for the older group, ($t_{(46)}$=-.99, *p*=.328). The mean MoCA score for the older group was 27.42 (*SD*=1.41). All the elderly participants had MoCA-B scores higher than 26, and therefore no participant was excluded from the analysis.

Following instruction task

Descriptive results are displayed in Figure 2. A 2 × 3 × 2 (Age group × Presentation form × Recall modality) mixed ANOVA indicated a significant main effect of age group, with superior performance in young adults than older adults, *F*(1,40)=58.40, *MSE*=90.61, *p*<.001, η_p^2=0.57. The main effect of presentation form was significant, *F*(2,88)=8.27, *MSE*=52.09, *p*<.001, η_p^2=0.16. The main effect of recall modality was also significant, with better performance in enacted recall than verbal recall conditions (i.e., enacted-recall advantage, *F*(1,44)=30.57, *MSE*=90.61, *p*<.001, η_p^2=0.41).

The interaction between presentation form and recall modality was significant, $F(2,88)=4.57$, $MSE=52.09$, $p=.013$, $\eta_p^2=0.09$. This interaction was driven by the significant effect of presentation form on verbal recall ($ps<.05$), in contrast to the absence of such effect in enacted recall ($ps>.05$). Simple effect analyses indicated that verbal recall in spoken instruction conditions was worse compared with silent demonstration ($t(23)=4.31$, $p<.001$, $d=0.86$) and dual modality presentation ($t(23)=3.33$, $p=.002$, $d=0.64$), whereas the silent demonstration and dual conditions led to similar performance ($t(23)=1.27$, $p=.210$, $d=0.22$). There was no significant interaction between presentation form and age group, $F(2,88)=0.22$, $MSE=52.09$, $p=.804$, $\eta_p^2<.01$.

The enacted-recall advantage was significant in all three presentation conditions (spoken instruction: $t(46)=5.72$, $p<.001$, $d=1.24$; silent demonstration: $t(46)=3.40$, $p=.001$, $d=0.71$, dual modality: $t(46)=4.90$, $p<.001$, $d=1.07$, respectively). The interaction between recall modality and age group was not significant ($F(1,44)=0.27$, $MSE=90.61$, $p=.609$, $\eta_p^2=0.01$), nor was the three-way interaction ($F(2,88)=0.68$, $MSE=52.09$, $p=.509$, $\eta_p^2=0.02$).

The older adults had worse performance than younger adults in all six conditions (spoken instruction-verbal recall: $t(22)=4.80$, $p<.001$, $d=2.05$; silent demonstration-verbal recall: $t(22)=6.10$, $p<.001$, $d=2.60$; dual modalities-verbal recall, $t(22)=5.39$, $p<.001$, $d=2.30$; spoken instruction-enacted recall: $t(22)=4.18$, $p<.001$, $d=1.78$, silent demonstration-enacted recall: $t(22)=4.27$, $p<.001$, $d=1.82$; dual modalities-enacted recall: $t(22)=3.65$, $p=.001$, $d=1.56$).

Finally, the effect sizes for each of the action-based advantages for young and older groups are shown in Table 1.

Discussion

Three key findings in Experiment 1 were replicated. First, older adults had worse performance in their ability to remember and follow instructions than young adults. Second, there was a demonstration advantage, and encoding modality interacted with recall modality, such that a demonstration advantage emerged on verbal but not enacted recall. Third, the enacted-recall advantage was larger when instructions were spoken than when demonstrated. The one discrepant result from Experiment 1 was that the two age groups showed equivalent enacted-recall effects in this experiment. However, given that the first experiment replicated the previous finding from Jaroslawska et al. (2021) of a smaller enacted-recall benefit in older adults than young adults, Experiment 2 was designed to instead focus primarily on presentation format. Thus, recall format was implemented as a between-subject factor to avoid participant fatigue and this may have rendered the interactive effect less detectable.

The novel findings in this experiment mainly involve the dual modality conditions (spoken instructions with simultaneous demonstrations). Older adults had worse performance in the dual modality conditions than young adults, to a similar extent as the single modality conditions (i.e., spoken instruction or silent demonstration). In addition, in both age groups, performance in the dual-modality conditions was superior to the spoken presentation but similar to demonstration, replicating findings with young adults (Yang et al., 2015) and extending these for the first time to older adults. These findings suggest that, like young adults, older adults also fail to obtain extra benefit from spoken instructions provided alongside visual demonstration. Finally, in both young and older adults, the advantage of dual-modality instructions relative to spoken instructions showed only with verbal recall but not with enacted recall, a finding that mirrors the pattern seen with the two single-modality conditions here and in Experiment 1.

General Discussion

The two experiments in the current study replicate several findings from the recent literature on remembering and following instructions in working memory and extend these to an examination of healthy ageing in a number of novel ways.

Firstly, an ageing effect on following instructions was observed in both experiments. The two studies in the area to date (Coats et al., 2021; Jaroslawska et al., 2021) reported overall age group differences, but these were not apparent in all experimental conditions. More precisely, they failed to find an age effect with verbal recall of spoken instructions. Thus, the ageing effect was less consistent in conditions dominated with verbal processing than the conditions involving action-based processing. This is largely consistent with the observation of a larger age-related decline in the visuospatial than the verbal working memory domain (Bopp & Verhaeghen, 2007; Jenkins et al., 2000). The current study however found age effects in all experimental conditions, including the condition involving verbal recall of spoken instructions, suggesting that an explicit action component is not necessary for ageing effects in following instructions to emerge.

In the present study, both Experiment 1 and 2 found that observing silent demonstration of the instruction sequence led to superior verbal recall compared to spoken presentation. This replicates a range of previous findings with children (Yang et al., 2017) and young adults (e.g., Allen et al., 2020; Lui et al., 2018; Yang et al., 2015). Experiment 2 also showed that adding demonstration to spoken presentation also facilitates performance (e.g., Allen et al., 2020; Waterman et al., 2017; Yang et al., 2015), whereas the reverse was not true (thus replicating Yang et al., 2015).

It is broadly assumed that demonstration facilitates following instructions by offering visual and spatial information regarding actions, objects (and their spatial locations), and the associations between these. Observing actions may also activate motor representations (Hardwick et al., 2018) and thus provide an additional dimension of motoric coding. One possibility then is that, relative to spoken presentation, visual demonstration provides an inherently superior presentation format to support memory for instructions. There may also be a modality asymmetry at play; in preparation for verbal recall, participants might generate a verbal representation either automatically from spoken presentation or through verbal recoding when being presented via demonstration, but a visuo-spatial-motoric representation is not necessarily spontaneously generated by the participant with spoken presentation for verbal recall unless it is provided by the experimenter via demonstration.

The above findings from our young adult participants provide important replications of previous findings (Yang et al., 2015). The present study goes further by also examining these patterns with older adult participants, with the take-home message that single- (Experiments 1 and 2) and dual-modality (Experiment 2) demonstration benefits emerged to the same extent in both age groups. These findings add to a growing body of work suggesting that different forms of demonstration can be effective in boosting the ability to follow instructions in populations that might otherwise show working memory deficits, for example typical children (Waterman et al., 2017; Yang et al., 2017), children with ASD (Wojcik et al., 2011) or ADHD (Yang et al., 2017), and adults with schizophrenia (Lui et al., 2018), and older adults (Coats et al., 2021). Thus, demonstration might offer a relatively efficient and cost-free method of enhancing instruction following at least in certain task contexts (Allen et al., 2020; Waterman et al., 2017). Previous work has suggested that older adults might show a somewhat faster decline in visuospatial working memory (Jenkins et al., 2000; Johnson et al., 2010). This might lead us to predict that demonstration benefits would decrease with age, and indeed this was found by Coats et al. (2021) when comparing spoken vs. spoken plus demonstration. However, no such pattern emerged in the present study; older adults benefited from demonstration just as much as the young adults. Instead, this finding fits with work by Calia et al. (2015) on visuospatial bootstrapping in working memory (see Darling et al., 2017). Calia et al. (2015) found that both young and older adults were able to show improved digit recall when the digits were presented in a familiar, predictable visuospatial array. In that work and the present study, older adults' immediate verbal recall improved just as much as that of young adults when helpful visuospatial information was provided alongside verbal information.

The same improvements were not seen in enacted recall for either age group. The advantage for enacted over spoken recall previously found in children (Gathercole et al., 2008; Jaroslawska et al., 2016; Waterman et al., 2017; Yang et al., 2017), young adults (Allen & Waterman, 2015; Jaroslawska et al., 2021; Makri & Jarrold, 2021; Yang et al., 2016; Yang et al., 2014), and older adults (Jaroslawska et al., 2021) was again found (Allen et al., 2022). Planning for enactment may serve to strengthen the binding between action and object (Makri & Jarrold, 2021; Yang et al., 2016). Evidence from dual task studies suggests that it also appears to elicit motor coding (Jaroslawska et al., 2018; Li et al., in press), that may then feed into and enrich the multidimensional representation of the anticipated action sequence.

However, demonstration did not further improve performance for enacted recall. Thus, in line with previous work using either self-enactment (Allen & Waterman, 2015; Jaroslawska et al., 2021; Jaroslawska et al., 2016) or demonstration (Lui et al., 2018; Yang et al., 2017), incorporating action-based components at either encoding or recall helps, but such effects do not appear to be additive. This growing body of evidence would suggest commonalities underlying the performance gains provided by anticipated enactment, and either self- or observed enactment during encoding.

The present study shows that these outcomes extend to an older adult group. These findings indicate that older adults can plan to enact with resultant improvements in performance, and this seems to involve the same mechanisms as young adults. Broadly in line with Jaroslawska et al. (2021), there was some evidence that the efficiency or effectiveness of this declines with age, as indicated by the smaller enacted-recall advantage in older than young adults (at least in Experiment 1, where a within-subject manipulation was applied). This may reflect age-related difficulties with movement, motor skills, coordination, and action planning (e.g., Berchicci et al., 2012; Contreras-Vidal et al., 1998; Gabbard et al., 2011; Raw et al., 2019; Seidler et al., 2002) that possibly impinge both during planning, and at the point of physical performance. These problems might also in turn place greater demands on executive and cognitive control resources (e.g., Baltes & Lindenberger, 1997; Verhaeghen et al., 2002; Wingfield et al., 2005), which are already declining in older adults (Salthouse et al., 2003). Further work is required before developing a more comprehensive understanding of action planning in working memory.

The present study has shown that introducing action-based components, either through visual demonstration or the requirement to plan for enactment at recall, can improve older adults' ability to follow instructions in a working memory context. This seems to be particularly effective and consistent for demonstration. While it is important to note that these manipulations did not eliminate the age deficit, these manipulations nevertheless have useful and practical benefits, given that working memory declines with age, and the importance of instruction following in everyday life. Efforts should be made to explore how visual demonstration can be employed in real-world contexts.

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Tables

Table 1

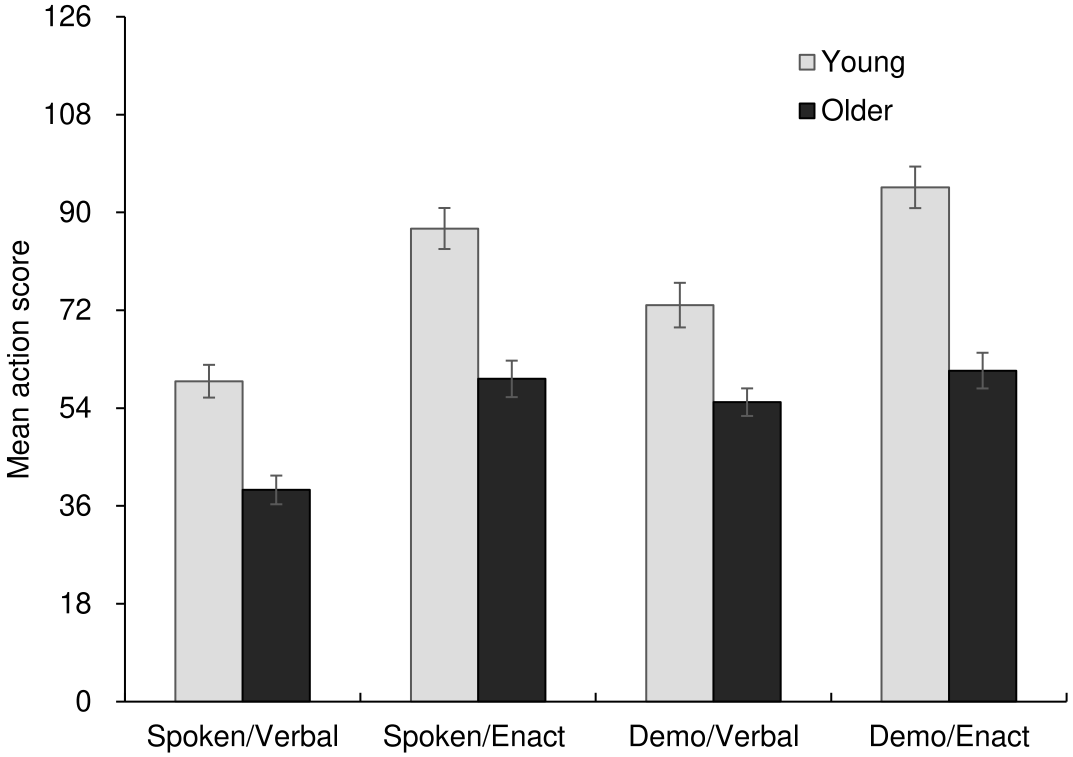
Effect sizes (Cohen's d) of action-based effects

	All	Young	Older
Experiment 1			
Demonstration advantage in verbal recall	1.06	0.87	1.39
Demonstration advantage in enacted recall	0.28	0.45	0.10
Enacted-recall advantage in spoken instruction	1.66	1.84	1.51
Enacted-recall advantage in silent demonstrated instruction	0.87	1.22	0.44
Experiment 2			
Demonstration advantage in verbal recall	0.62	0.69	1.26
Demonstration advantage in enacted recall	0.04	0.26	0.08
Dual advantage (relative to spoken instruction) in verbal recall	0.45	0.47	0.95
Dual advantage (relative to spoken instruction) in enacted recall	0.23	0.32	0.30
Enacted-recall advantage in spoken instruction	1.24	1.39	2.11
Enacted-recall advantage in silent demonstrated instruction	0.71	1.33	0.84
Enacted-recall advantage in dual instruction	1.07	1.36	1.59

Figures

Figure 1

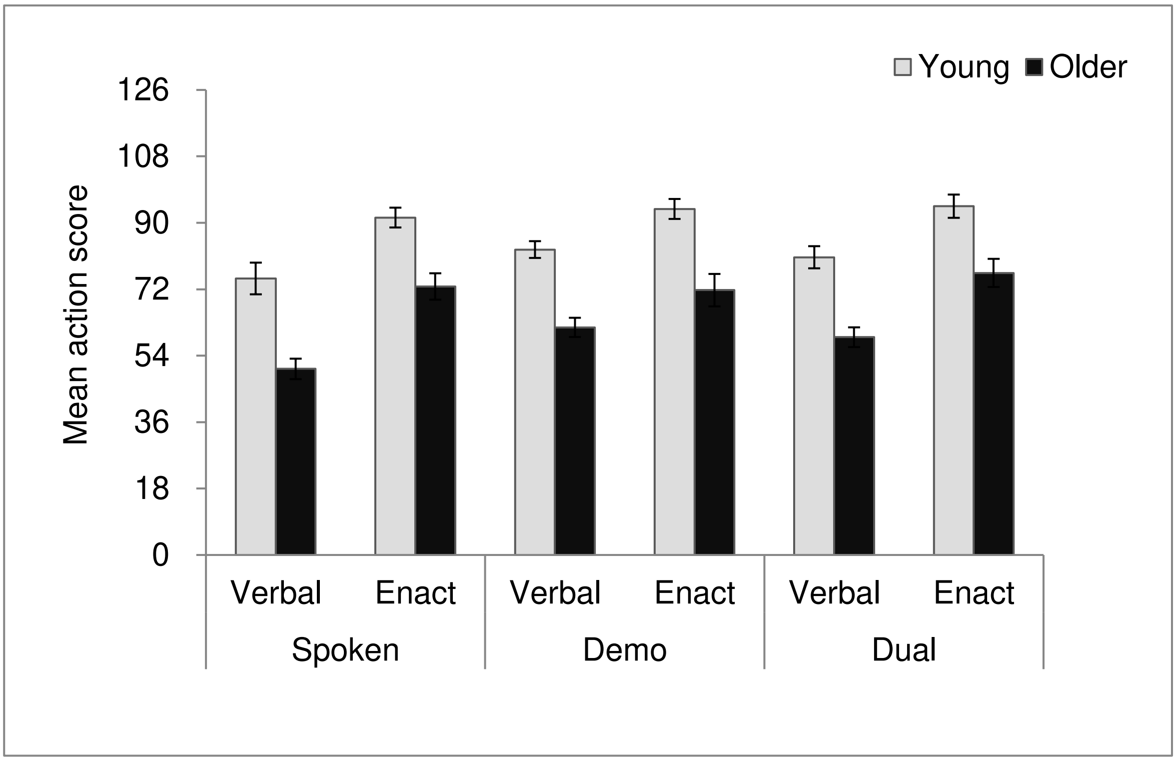
Mean correct action scores as functions of presentation form, recall modality and age group in Experiment 1



Note. Error bars represent standard error. The conditions from left to right were: spoken instruction-verbal recall, spoken instruction-enacted recall, silent demonstration-verbal recall and silent demonstration-enacted recall.

Figure 2

Mean correct action scores as functions of presentation form, recall modality and age group in Experiment 2



Note. Error bars represent standard error. Spoken = spoken instructions, Demo = silent demonstrations, Dual = spoken instructions with simultaneous demonstrations, verbal = verbal recall, enact = enacted recall.