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Intelligence moderates the benefits of strategy instructions on memory performance: an adult-lifespan examination

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ABSTRACT

Whether older adults can compensate for their associative memory deficit by using memory strategies efficiently might depend on their general cognitive abilities. This study examined the moderating role of an IQ estimate on the beneficial effects of strategy instructions. A total of 142 participants (aged 18–85 years) received either intentional learning or strategy ("sentence generation") instructions during encoding of word pairs. Whereas young adults with a lower IQ benefited from strategy instructions, those with a higher IQ did not, presumably because they already use strategies spontaneously. Older adults showed the opposite effect: following strategy instructions, older adults with a higher IQ showed a strong increase in memory performance (approximately achieving the level of younger adults), whereas older adults with a lower IQ did not, suggesting that they have difficulties implementing the provided strategies. These results highlight the importance of the role of IQ in compensating for the aging-related memory decline.

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Introduction

Older adults often report having difficulties remembering names of people they meet. They tend to recognize the name or the face independently, but find it difficult to integrate the name and the face into a cohesive representation. This is in line with the associative deficit hypothesis (Naveh-Benjamin, 2000), which states that older adults are specifically impaired in associative memory, whereas they have less problems with remembering single items (Chalfonte & Johnson, 1996; Old & Naveh-Benjamin, 2008). Some studies suggest that this may in part be due to deficient strategy use in aging (for a review, see Shing et al., 2010), and that providing strategy instructions may remove major part of the aging-related deficit in associative memory (Naveh-Benjamin, Brav, & Levy, 2007). In contrast, other studies fail to support these

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findings (Dunlosky, Hertzog, & Powell-Moman, 2005; Shing, Werkle-Bergner, Li, & Lindenberger, 2008). We propose that these inconsistent findings are in important part due to differences in intelligence, which is crucial for efficient strategy use (Barulli, Rakitin, Lemaire, & Stern, 2013). The goal of the current study was therefore to provide an in-depth examination of the potentially moderating role of intelligence on the beneficial effects of strategy instructions on associative memory across the adult lifespan.

Of main interest to the clinical field is the extent to which compensatory strategies can be employed in order to reduce the aging-related decline in associative memory performance. The use of memory strategies (e.g., visualization, sentence generation) relies on cognitive control processes that regulate memory functions by selecting, monitoring, and organizing the content during encoding in order to improve memory formation (Blumenfeld & Ranganath, 2007). These cognitive control operations decline in aging (Craik & Bialystok, 2006) and negatively influence episodic memory performance in older adults (Bouazzaoui et al., 2014). As a result, older adults use less internal memory strategies in daily life (Bouazzaoui et al., 2010) and use less efficient strategies during memory tasks than young adults (Rogers, Hertzog, & Fisk, 2000). According to the environmental support hypothesis (Craik, 1990) older adults have a deficiency in producing efficient strategies spontaneously, but are able to implement them when environmental support (e.g., concrete strategy instructions) is available (Froger, Bouazzaoui, Isingrini, & Taconnat, 2012). Therefore, previous studies have examined whether strategy instructions can facilitate compensation for the aging-related decline in associative memory performance. Naveh-Benjamin et al. (2007) found that older adults were able to fully compensate for the decline in associative memory when strategy instructions were provided during both encoding and retrieval phases of a word-pair task, whereas the same instructions had almost no effect in young adults. These findings indicate that the associative memory deficit in older adults is at least partially mediated by a lack of spontaneous strategy use, which they can compensate for when strategy instructions are provided. In contrast, Shing et al. (2008) revealed an almost equal improvement for both young and older adults after strategy instructions in a German word-pair learning paradigm, despite the finding that young adults used more strategies spontaneously. When using a more difficult German–Malay word-pair paradigm, older adults showed less improvement than young adults after strategy instructions and practice, indicating that either the older adults had difficulties with applying the strategy efficiently or that applying a strategy was insufficient to diminish the associative deficit. A follow-up study of Fandakova, Shing, and Lindenberger (2012) showed that high-performing older adults, who performed better on strategic and associative memory tasks, showed a greater improvement after practice sessions in the difficult word-pair paradigm than low-performing older adults. This is in line with previous research, where children with better short-term memory performance benefited more from strategy instructions than children with a reduced short-term memory capacity (Cariglia-Bull & Pressley, 1990). These findings suggest that individual differences play an important role in the ability to apply strategies efficiently. Hence, to date it is still unclear whether the associative deficit in adults can be explained by deficient strategy use and which mechanisms contribute to successful strategy application.

One crucial variable that has not been considered in these previous studies is the potentially moderating role of general cognitive abilities. Previous studies in adults with mental retardation have shown that memory impairments in individuals with a low IQ can in part be explained by deficient strategy use (Belmont & Butterfield, 1977; Campione & Brown, 1978; Detterman, 1979). Moreover, also in adults with a normal intelligence, a higher IQ estimate contributes to efficient strategy use (Barulli et al., 2013) and enable individuals to compensate in memory tasks (Speer & Soldan, 2015). In the study of Naveh-Benjamin et al. (2007), intelligence levels were presumably high, as the younger participants were all university students, and older adults were matched for education. Therefore, it is possible that in the study of Naveh-Benjamin et al. (2007) the younger adults showed almost no beneficial effect of strategy instructions, because they already used efficient strategies spontaneously, whereas the older adults were able to profit strongly due to their high level of cognitive abilities. In contrast, the participants in the study of Shing et al. (2008) were not explicitly matched on education level or intelligence. The question therefore arises how intelligence interacts with age regarding the beneficial effect of strategy instructions on memory performance.

The goal of the present study was therefore to examine how an intelligence estimate moderates the effect of strategy instructions on associative memory across the adult lifespan. Participants received either intentional learning instructions or additional strategy instructions ("sentence generation") during encoding of a word-pair task. One of the shortcomings of previous research (Naveh-Benjamin et al., 2007; Shing et al., 2008) is the use of extreme age groups. Most studies selectively compared older adults (± ages >65 years) to young adults (± ages 18–30 years), while ignoring middle age groups. However, it is known that cognitive control shows a gradual decline from the age of 50 (De Luca et al., 2003) or even very mild decrements from the age of approximately 30 (Craik & Bialystok, 2006; Park et al., 2002), suggesting that already in these middle-age groups mild declines in spontaneous strategy use can be anticipated. Furthermore, associative memory performance gradually decreases with age (Bender, Naveh-Benjamin, & Raz, 2010). The present study addresses this limitation by including participants across the entire adult lifespan (18–85 years) and examining age as a continuous variable rather than discrete age groups. Based on previous studies, we expect an associative memory deficit in older adults. Therefore, we expect a negative effect of age on associative memory, and not on item memory. Because of the aging-related decline in spontaneous strategy use, we expect older participants to show greater improvement following strategy instructions than younger adults, resulting in an interaction effect between age and strategy instructions (Naveh-Benjamin et al., 2007).

Regarding the role of intelligence, we expect that it moderates the effect of strategy instructions on memory performance in aging. At a younger age, higher levels of intelligence are likely associated with more spontaneous strategy use. Consequently, we expect that younger adults with a high IQ benefit less from external strategy instructions than younger adults with a lower IQ (Linke, Vicente-Grabovetsky, Mitchell, & Cusack, 2011). Moreover, when memory performance declines with aging, participants with a higher IQ may be able to incorporate strategies more efficiently, resulting in a larger benefit from strategy instructions than those with a lower IQ.

Finally, studies to date commonly examined the effects of strategy instructions on immediate memory only. It is clinically relevant to examine whether the beneficial effects of strategy instructions persist after a period of time. Therefore, we tested both immediately after encoding and after a 20-min delay period. When a recognition test is used after a 20-min delay, only small effects of age are found on the rate of forgetting (Davis et al., 2003; Rybarczyk, Hart, & Harkins, 1987). Therefore, we expect the associative deficit pattern and the effects of strategy use and intelligence to remain unchanged when a delay is added between the encoding and recollection phase.

To summarize, the goal of this study was to examine how strategy use supports associative memory across the adult lifespan, to test how intelligence moderates the beneficial effect of strategy-use, and examine whether these effects persist over a 20-min delay period.

Method

Participants

A total of 142 participants were included in the present study. Participants were residents of the Netherlands, lived independently in the community and were fluent in Dutch. They voluntarily participated in this study. Participants were recruited through (oral) advertisement. Prior to the study, participants completed a brief screening questionnaire to check for exclusion criteria: severe psychiatric problems, neurological disorders (e.g., stroke, dementia), substance abuse and uncorrected visual deficits or hearing loss. The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was administered in all participants aged 50 years and older to screen for potentially severe cognitive impairment (cut-off score: 24). One participant was excluded due to a MMSE score of 22.

Care was taken to assure that participants across the total adult lifespan were included with an equal distribution of education level and sex. The mean age of the sample was 49.0 years (range = 18–85; SD = 20.0), with a gender distribution of 39.7% male and 60.3% female participants. Education level was rated according to the classification of the Central Office for Statistics of the Netherlands (CBS, 2011), consisting of three levels: low, average, and high. This classification is based on the International Standard Classification of Education (ISCED: United Nations Educational, Scientific and Cultural Organisation Institute for Statistics [UNESCO-UIS], 2011). The low level of education consists of early childhood, primary, and lower secondary education; the average level consists of secondary, post-secondary non-tertiary, and short cycle tertiary education; and the high level consists of bachelor, master, and doctoral degrees. Within this study sample 22.0% had a low level, 33.3% had an average level, and 44.7% had a high level of education. To estimate the IQ of the participants, two subtests of the *Dutch Wechsler Adult Intelligent Scale – Third Edition* (WAIS-III; Wechsler, 1997) were administered: block design (BD) and vocabulary (V). The subtests BD and V were included because of their high independent correlations with full scale IQ (FSIQ) of the WAIS-III (Wechsler, 1997). Moreover, previous studies have shown that the combination of BD and V is a reliable and valid dyadic short form, which is often used to estimate

Wechsler's FSIQ (Cyr & Brooker, 1984; Ringe, Saine, Lacritz, Hynan, & Cullum, 2002). The mean IQ estimation was 109.0 (range = 73–155; SD = 16.6).

Correlations between all demographical variables were assessed using Spearman correlations. The correlation matrix (Table 1) confirms the equal distribution of sex, education level, and IQ estimate across the adult lifespan. No significant correlations were found between age and gender, education level, or IQ estimation. As one could expect, education level and IQ estimation were strongly correlated.

Materials

The word-pair memory task was modeled after the task used by Naveh-Benjamin et al. (2007). During the study phase 50 word pairs were presented sequentially in black font on a white background on a laptop screen. The words were selected from the CELEX database. All words were high-frequency one- or two-syllable Dutch nouns. The two words in each pair were semantically unrelated and were not strongly related to words in other pairs. The order of the word pairs was randomized for each participant. The presentation duration of the pairs was 8 s with an interstimulus interval of 500 ms between subsequent pairs. The study phase was followed by an immediate and a 20-min delayed item and associative recognition test.

For the immediate recognition test, item and associative memory were measured as follows: for item recognition, 20 single words were used, 10 of which were target words and 10 were distracter words. The target and distracter words were presented in a randomized order for each participant. The associative recognition tests consisted of 20 word pairs. Ten word pairs were shown as they appeared in the study phase. The other 10 pairs consisted of rearranged pairs: all individual words were part of the word pairs in the study phase, but now rearranged into new word-pair combinations.

The delayed recognition test was almost equivalent, except for the stimuli. For the delayed recognition test, item memory was tested with 10 target and 10 distracter words, none of which were used in the immediate recognition test. Also, 10 new target and 10 new rearranged word pairs were used for the delayed associative recognition test, with none of the words being used in the immediate recognition phase.

To rule out possible order effects, two versions of the word-pair task were created with different stimuli for the immediate and delayed tests. The items and word pairs that were used for the immediate tests in version 1 were used for the delayed tests in version 2 and vice versa.

Regarding the performance scores of the word pair task, Hit and False alarm rates were calculated for each participant. Hit rates were calculated by dividing the number of correct target responses by the total number of targets presented in each condition (i.e., 10). False alarm (FA) rates were calculated by dividing the number of incorrect nontarget

Table 1. Spearman correlation matrix among age, gender, education level, and IQ estimation.

	Age	Gender	Education level
Gender	−.15		
Education level	−.14	−.15	
IQ estimate	−.10	−.18	.66***

* $p < .05$; ** $p < .01$; *** $p < .001$.

responses by the total number of nontargets (i.e., 10). For each participant Hit minus FA rates (Pr-values; Snodgrass & Corwin, 1988) were computed for each memory test: immediate item recognition, immediate associative recognition, delayed item recognition, and delayed associative recognition. Hit–FA rates range from −1.0 to 1.0, with 0.0 representing chance level and 1.0 a perfect score. Hit–FA rates were used in the main analyses. Additionally, analyses were performed on Hit rates and FA rates separately.

Procedure

This study was approved by the Ethics Committee Faculty of Social Sciences (ECSS) at Radboud University. Participants were tested individually at home in a quiet room. Participants received information about the study at the beginning of the test session, signed an informed consent form and were asked for demographical information. Each test session had a duration of approximately 60 min. The two versions of the word-pair task were counterbalanced across the sample and within each age group.

Participants were randomly assigned to either the intentional learning or the associative strategy condition. Participants in both conditions were given the intentional learning instructions in which the participants were told to memorize both the words and the pairs for the upcoming item and associative recognition tests. The nature of the recognition tests was thoroughly explained. The participants in the associative strategy condition received an additional instruction, namely that memory performance can be improved by creating a sentence that links the two words of each pair into a meaningful representation. Participants in the associative strategy condition practiced creating meaningful sentences in five word-pair examples and were strongly encouraged to use this sentence strategy during the study phase of the task. To assure that participants used the sentence strategy on each word pair, they were asked to produce the sentences out loud.

Following the task instructions, participants were able to ask questions for clarification. After answering the questions the experimenter initiated the study phase, in which participants were asked to memorize the 50 word pairs. After the study phase, two immediate recognition tests were administered on the laptop, one for item recognition and one for associative recognition. Approximately 20 min after the study phase the delayed recognition tests were administered. The presentation of the stimuli in all recognition tests was self-paced and response to one item was required before the next item was presented.

The 20-min delay was filled with the administration of the BD test. To prevent rehearsal of the stimuli, the participants were not informed about the delayed recognition tests. After completing the delayed recognition tests, the V subtest was administered.

Results

For the statistical analyses IBM SPSS 20.0 was used. Alpha was set at .05 for all analyses and two-tailed tests were used. Multiple regression analyses were performed with Hit–FA rates as dependent variable. Strategy (no strategy instructions versus strategy instructions), Age and estimated IQ were entered as predictors, as well as their 2-way and 3-way interactions. For the main research questions regarding the associative deficit in older adults, the effect of strategy instructions and the moderating role of IQ, multiple regression analyses were performed for the immediate item and immediate associative recognition Hit–FA rates. To examine the effect of delay, similar regression analyses were performed for the delayed item and delayed associative recognition Hit–FA rates. Furthermore, to examine whether the predictors specifically affect the Hit rates, the FA rates, or both, similar regression analyses were performed for Hit rates and FA rates separately. Finally, similar regression analyses for Hit–FA rates were executed with the subtests V and BD as separate measures of crystallized and fluid intelligence respectively, thereby replacing the total IQ estimate. This latter type of analyses was conducted in order to explore whether a more crystallized estimate of intelligence (V) or a more fluid estimate of intelligence (BD), or both, was more important in moderating the effect of intelligence on the beneficial effects of strategy instructions.

Immediate item and associative recognition (Hit–FA rates)

The overall models for the regression predicting immediate item and immediate associative recognition performance were significant, respectively $F(7, 132) = 5.60$, $p < .001$, adjusted $R^2 = .19$ and $F(7, 132) = 11.86$, $p < .001$, adjusted $R^2 = .35$. Table 2 shows the unstandardized and the standardized beta-coefficients for the regression analyses. Strategy and IQ were significant independent predictors for both item (respectively, $p < .001$ and $p = .004$) and associative (respectively, $p < .001$ and $p < .001$) recognition, suggesting that strategy instructions improved item and associate memory performance, and that an increase in IQ-estimate was associated with an increase in item and associative memory performance. Age was a significant predictor for associative recognition ($p = .014$), but not for item recognition. These results show that associative recognition decreases with age, whereas item recognition does not. Furthermore, the interaction between age and IQ was a significant predictor for both item ($p = .021$) and associative ($p < .001$) recognition. Further inspection of these results shows that the positive effect of IQ on memory performance was larger in younger adults than in older adults. The interaction between age and strategy was not significant for item ($p = .847$) or associative ($p = .958$) recognition. The interaction between IQ and strategy was also not significant (respectively, $p = .578$ and $p = .198$).

Table 2. Main and interaction effects of age, strategy, and IQ on Hit–FA rates of immediate item and associative recognition tests.

	Immediate item recognition			Immediate associative recognition		
Predictors	B	SE B	β	B	SE B	β
Age	−.001	.001	−.112	−.004	.002	−.266**
Strategy	.158	.033	.363***	.270	.045	.413***
IQ	.004	.001	.307**	.008	.002	.419***
Age × strategy	.000	.002	−.021	.000	.002	.005
Age × IQ	.000	.000	−.260*	.000	.000	−.370***
Strategy × IQ	−.001	.002	−.059	−.004	.003	−.122
Age × strategy × IQ	.000	.000	.094	.000	.000	.257*

*$p < .05$; **$p < .01$; ***$p < .001$.

A significant 3-way interaction between age, strategy and IQ was observed for associative recognition (p = .013), not for item recognition. To interpret the interaction, we plotted the effect of strategy at older and younger age and higher and lower IQ levels (Figure 1). Slope difference tests showed that in adults with a lower IQ, older adults benefited less from strategy instructions than younger adults, t = −2.64, p = .009. In adults with a higher IQ we found the opposite effect: older adults benefited more from strategy instructions than younger adults, t = 2.76, p = .007. Furthermore, younger adults with a lower IQ benefited more from strategy instructions than younger adults with a higher IQ, t = −3.82, p < .001. Older adults with a higher and a lower IQ did not significantly differ, t = 1.30, p = .195.

Delayed item and associative recognition (Hit–FA rates)

The overall models for the regression predicting the delayed item and the delayed associative recognition performance levels were significant, respectively $F(7, 133) = 4.42$, $p < .001$, adjusted $R^2 = .15$ and $F(7, 133) = 14.21$, $p < .001$, adjusted $R^2 = .40$. Table 3 shows the unstandardized and the standardized beta-coefficients for the regression

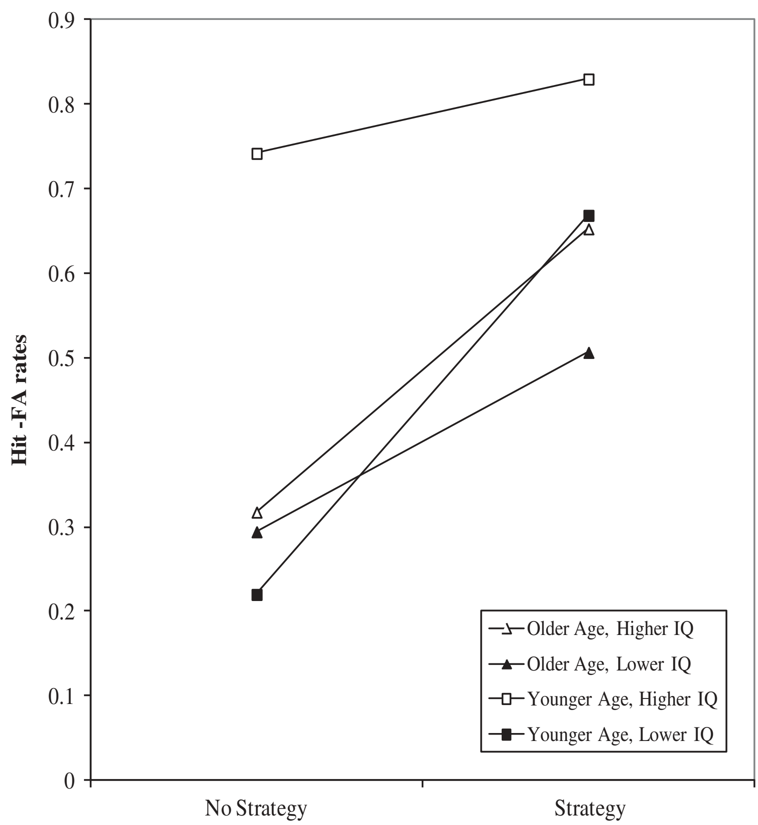

Figure 1. Age × Strategy × IQ effects on immediate associative recognition [Hit–False alarm (FA) rates]. Strategy is a dichotomous measure, consisting of two groups (No strategy, strategy). Age and IQ are continuous measures. Graphical points represent −1 SD and + 1 SD of the mean.

Table 3. Main and interaction effects of age, strategy, and IQ on Hit–FA rates of delayed item and associative recognition tests.

	Delayed item recognition			Delayed associative recognition		
Predictors	B	SE B	β	B	SE B	β
Age	−.003	.001	−.236*	−.006	.002	−.334***
Strategy	.124	.035	.279***	.294	.043	.447***
IQ	.003	.001	.243*	.008	.002	.382***
Age × strategy	.003	.002	.169	.002	.002	.104
Age × IQ	.000	.000	−.257*	.000	.000	−.388***
Strategy × IQ	−.003	.002	−.152	−.002	.003	−.070
Age × strategy × IQ	.000	.000	.388**	.000	.000	.345***

*$p < .05$; **$p < .01$; ***$p < .001$.

analyses. Results of the delayed recognition tests were similar to those of the immediate recognition tests for almost all predictors. Therefore, only additional results will be discussed here. Age was a significant independent predictor for delayed item recognition ($p = .036$), whereas it was not for immediate item recognition. These results indicate that there is no age effect on item recognition directly after encoding, but that performance decreases with age when a delay is added between encoding and recollection.

The 3-way interaction between age, strategy, and IQ was significant for delayed associative recognition ($p = .001$). Slope difference tests were comparable to those of the immediate associative recognition. In adults with a lower IQ, older adults benefited less from strategy instructions than younger adults, $t = -2.58$, $p = .011$. In adults with a higher IQ, older adults benefited more from strategy instructions than younger adults, $t = 4.76$, $p < .001$. Younger adults with a lower IQ benefited more from strategy instructions than younger adults with a higher IQ, $t = -4.53$, $p < .001$. In addition to results of the immediate associative recognition, we found that older adults with a higher IQ benefited more from strategy instructions than older adults with a lower IQ, $t = 2.94$, $p = .004$ (Figure 2).

Furthermore, a significant 3-way interaction between age, strategy, and IQ was found for delayed item recognition ($p = .001$), whereas this interaction was not significant for immediate item recognition. The pattern of slope differences was similar to that of the delayed associative recognition.

Hit rates and FA rates

Additional regression analyses were performed for Hit rates (Table 4) and FA rates (Table 5) separately. Results showed that strategy instruction significantly improves both hits and false alarms. Furthermore, an effect of IQ was observed for Hit rates in all recognition tests. For FA rates, IQ was a significant predictor for associative recognition, whereas it had no effect on item recognition. Age was a significant predictor for Hit rates in delayed recognition tests, whereas it had no effect on immediate recognition. For FA rates, we found that age had a significant effect on associative recognition and not on item recognition.

The 3-way interaction between age, strategy, and IQ was significant for the immediate associative and delayed associative Hit rates. The pattern of slope differences was similar to those of the Hit–FA rates. Furthermore, this 3-way interaction was significant

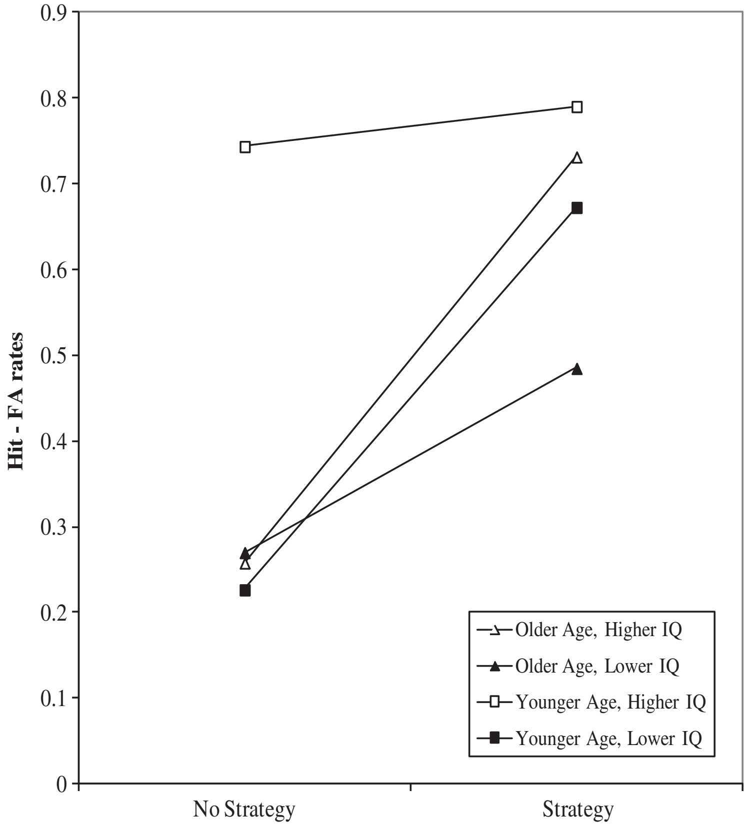

Figure 2. Age × Strategy × IQ effect on delayed associative recognition [Hit–False alarm (FA) rates]. Strategy is a dichotomous measure, consisting of two groups (no strategy, strategy). Age and IQ are continuous measures. Graphical points represent −1 SD and + 1 SD of the mean.

Table 4. Main and interaction effects of age, strategy, and IQ on Hit rates of immediate and delayed item and associative recognition tests.

	Immediate item recognition			Immediate associative recognition			Delayed item recognition			Delayed associative recognition		
Predictors	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Age	−.001	.001	−.106	−.001	.001	−.135	−.002	.001	−.253*	−.002	.001	−.209*
Strategy	.073	.025	.235**	.132	.031	.319***	.063	.030	.172*	.133	.028	.350***
IQ	.003	.001	.293**	.004	.001	.314**	.003	.001	.259*	.003	.001	.296***
Age × strategy	.000	.001	−.009	−.001	.002	−.086	.003	.002	.203	.001	.001	.057
Age × IQ	.000	.000	−.211	.000	.000	−.346**	−.000	.000	−.080	.000	.000	−.328**
Strategy × IQ	−.001	.002	−.061	−.001	.002	−.054	−.003	.002	−.199	.000	.002	−.007
Age × strategy × IQ	.000	.000	.120	.000	.000	.260*	.000	.000	.143	.000	.000	.331**

Immediate item recognition: $F(7, 132) = 3.02$, $p = .006$, adjusted $R^2 = .09$; Immediate associative recognition: $F(7, 132) = 6.35$, $p < .001$, adjusted $R^2 = .21$.
Delayed item recognition: $F(7, 133) = 2.27$, $p = .032$, adjusted $R^2 = .06$; Delayed associative recognition: $F(7, 133) = 7.33$, $p < .001$, adjusted $R^2 = .24$.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5. Main and interaction effects of age, strategy, and IQ on FA rates of immediate and delayed item and associative recognition tests.

	Immediate item recognition			Immediate associative recognition			Delayed item recognition			Delayed associative recognition		
Predictors	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Age	.000	.001	.049	.003	.001	.295**	.000	.001	.038	.004	.001	.318**
Strategy	−.085	.027	−.261**	−.139	.030	−.347***	−.061	.027	−.185*	−.161	.033	−.365***
IQ	−.001	.001	−.131	−.004	.001	−.361**	.000	.001	−.041	−.004	.001	−.314**
Age × strategy	.000	.001	.020	−.001	.002	−.097	−.000	.001	−.003	−.002	.002	−.106
Age × IQ	.000	.000	.146	.000	.000	.247*	.000	.000	.257*	.000	.000	.295**
Strategy × IQ	.000	.002	.020	.003	.002	.143	.000	.002	−.015	.002	.001	.099
Age × strategy × IQ	−.006	.000	−.010	.000	.000	−.151	.000	.000	−.363**	.000	.000	−.229*

Immediate item recognition: $F(7, 132) = 1.95$, $p = .067$, adjusted $R^2 = .05$; Immediate associative recognition: $F(7, 132) = 6.85$, $p < .001$, adjusted $R^2 = .23$.
Delayed item recognition: $F(7, 133) = 2.08$, $p = .050$, adjusted $R^2 = .05$; Delayed associative recognition: $F(7, 133) = 7.42$, $p < .001$, adjusted $R^2 = .24$.
*$p < .05$; **$p < .01$; ***$p < .001$.

for the delayed item and associative FA rates. For the delayed item FA rates, slope difference tests showed similar results to those of the Hit–FA rates. For the delayed associative FA rates, results showed that only younger adults with a higher IQ did not benefit from strategy instructions, whereas all others did.

Vocabulary (V) and block design (BD)

Finally, similar regression analyses were performed for Hit–FA rates with the subtests V and BD as independent IQ measures. Both V and BD had similar main and interaction effects on immediate and delayed item and associative recognition compared to the IQ estimate used in previous analyses. No meaningful differences were found between the effect of V and the effect of BD on Hit–FA rates, or their interaction with strategy instructions and age (Table S1).

Discussion

This study examined the effect of strategy instructions on memory performance across the adult lifespan, with specific interest in the role of IQ. The present study extended previous findings through some methodological improvements, such as including participants across the adult life span, adding a delay condition to the word-pair task and including an IQ estimate as moderator. Consistent with the associative deficit hypothesis, associative recognition decreased with age, whereas item recognition did not (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). When analyzing hits and false alarms separately, we found that age had an effect on false alarms in the associative recognition tests, whereas it had no effect on item recognition. For Hit rates, age was related to both item and associative recognition, but only at delayed testing. We thereby confirmed that the associative deficit in older adults is mainly caused by an aging-related increase in false alarms, rather than a decrease in hits (Bender et al., 2010; Castel & Craik, 2003; Shing, Werkle-Bergner, Li, & Lindenberger, 2009). Furthermore, a strong effect of strategy instructions was present in all conditions, indicating that both item and associative recognition increase when the sentence generation strategy is used.

Moreover, strategy instructions affect both the identification of targets (hits) and the rejection of lures (false alarm) in an equal manner (Shing et al., 2009). With respect to the delayed recognition tests we found the same pattern of results as for the immediate recognition tests. However, an additional effect of age was found for the delayed item recognition, indicating that item recognition decreases with age when a delay is added between encoding and recollection (Davis et al., 2003). Nonetheless, the effect of age remained stronger for associative recognition.

Regarding the main focus of this study, we found that IQ moderates the effect of strategy instructions on associative memory performance in aging. In younger adults, those with a lower IQ benefited more from strategy instructions than those with a higher IQ, who did not improve at all. In older adults this pattern was reversed: here, those with a higher IQ benefited more from strategy instructions than older adults with a lower IQ. At delayed testing older adults with a higher IQ benefited to such extent that they reached the performance level of younger adults with a higher IQ.

By taking IQ into account, this study extends previous findings regarding strategy use in aging. When focusing on adults with a higher estimated IQ we find that the beneficial effects of strategy instructions are absent at a younger age, but increase with advancing age, which is in agreement with the findings of Naveh-Benjamin et al. (2007), who only included participants with a relatively high level of general cognitive ability. However, when the results of older adults with different IQ levels are taken together we find similar beneficial effects of strategy instructions for younger and older adults, in line with the results of Shing et al. (2008). Therefore, IQ appears to underlie these seemingly contradicting results.

Several explanations have been put forward with respect to the workings of IQ on the effect of strategy instructions. One notion suggests that a higher IQ is associated with more spontaneous and efficient strategy use (Barulli et al., 2013). In the present study, younger adults with a higher IQ estimate presumably used efficient strategies spontaneously, and therefore did not benefit from additional strategy instructions (Dirette, 2015). In contrast, younger adults with a lower IQ estimate might have used fewer strategies spontaneously and therefore did benefit from strategy instructions. Furthermore, in adults with a higher IQ estimate the beneficial effects of strategy instructions increased with age. This finding could be explained by the production deficiency hypothesis, which states that spontaneous strategy use decreases with age (Dunlosky et al., 2005; Glisky, Rubin, & Davidson, 2001) and the environmental support hypothesis, which declares that with sufficient environmental support, older adults are able to implement the provided strategies (Froger et al., 2012). However, these theoretical models do not explain the finding that in adults with a lower IQ this pattern is reversed: the beneficial effects of strategy instructions decrease with age.

Another explanation, that could account for the fact that older adults with a lower IQ estimate only showed a small benefit from strategy instructions, focuses on the ability to process the provided strategies efficiently. The older adults with a higher IQ estimate in our study were able to apply the provided strategies and compensate for their memory decrements to such extent that their memory performance almost reached the performance level of younger adults, which was also demonstrated by Naveh-Benjamin and colleagues (2007). In adults with a lower IQ the beneficial effects of strategy instructions decreased with age, which can be explained by an aging-related decline in cognitive resources that are needed to implement the proposed strategy efficiently. According to the processing deficiency hypothesis older adults have difficulties incorporating strategies efficiently, even when associative strategies are provided (Dunlosky & Hertzog, 1998; Hertzog, Price, & Dunlosky, 2012). However, the present study suggests that it is highly dependent on IQ whether or not older adults are able to process and apply these strategies efficiently.

These findings are consistent with the study of Nyberg et al. (2003), which suggests that cognitive reserve (CR) capacity may influence both the production efficiency (e.g., spontaneous strategy use) and the processing efficiency (e.g., efficient use of provided strategies) in older adults. Previous studies have used an IQ estimate as proxy for CR (Alexander et al., 1997; Farinpour et al., 2003; Galioto, Alosco, Spitznagel, Stanek, & Gunstad, 2013), however often a combination with education level, occupational attainment, and engagement in cognitively stimulating leisure activities is used (Opdebeeck, Martyr, & Clare, 2016). As such, also in our study a higher IQ estimate may be indicative of higher levels of CR. CR is known to play an important role in compensating for the consequences of aging-related brain changes by using compensatory cognitive processes (Stern, 2002, 2009). With respect to memory problems, individuals with a higher CR are more likely to compensate for deficits in memory networks by using other cognitive resources, such as memory strategies. Moreover, previous studies have shown that individuals with a higher CR have a lower risk of developing a dementia at older age, as efficient compensatory mechanisms may enable them to function independently for a longer period of time (Dekhtyar et al., 2015; Stern, 2012). Developing effective interventions targeting compensatory mechanisms for aging-related memory decline is therefore important. In a literature review, Metternich, Kosch, Kriston, Harter, and Hull (2010) concluded that compensatory cognitive training, aimed at acquiring and applying memory strategies, is effective in older adults. Whether this type of strategy training is particularly effective for older adults with a higher or lower CR should be investigated in further research. Presumably, more practice sessions are needed for older adults with a lower CR to incorporate these strategies efficiently. Furthermore, older adults with a lower CR might benefit more from the use of external memory aids (e.g., alarm, calendar) than from using internal memory strategies (e.g., associations), as the use of memory aids is cognitively less demanding (Bouazzaoui et al., 2010). One could argue that the sentence generation strategy that was used in this study might be unsuitable for older adults with a lower IQ, since the efficacy of the strategy depends on the meaningfulness and complexity of the sentence that is generated (Richardson, 1998). In the present study the generated sentences were not recorded, therefore no further analyses on the effect of sentence complexity could be performed. Future research should confirm whether older adults with a lower CR are less able to generate meaningful and complex sentences than those with a higher CR, and whether such potential difference could account for the finding that older adults with a lower IQ estimate profited to a lesser extent from the strategy instructions. Nonetheless, when using strategy interventions to compensate for the aging-related decline in memory it is important to adjust the interventions to the CR levels of the participants.

Some limitations of our study should be noted. Since we did not measure spontaneous strategy use directly we cannot confirm whether our participants with a lower IQ estimate used fewer strategies spontaneously. Future studies that explicitly observe spontaneous strategy use in adults with different levels of IQ or other measures of CR are needed.

Furthermore, our interpretations are restricted to the associative strategy used in this study (sentence generation) and may not necessarily extend to other memory strategies (e.g., visual imagery). Also, the word pairs used in this study consisted of familiar, simple words that were relatively easy to associate. The study of Shing et al. (2008) has shown that the associative deficit of older adults may be more pronounced under associatively demanding conditions, with smaller effects of strategy instructions and practice. Future studies should examine whether older adults with a higher CR still benefit from strategy instructions in more demanding conditions. Another limitation is the use of an IQ estimate, which was based on a dyadic short form of the WAIS-III, rather than the use of a full intelligence test battery. Although this dyadic short form is known to have strong correlations with Wechsler's FSIQ and appears to be reliable to estimate gross overall intelligence, it is recommended to be cautious when interpreting exact levels of intelligence (Ringe et al., 2002). Moreover, it would be of interest to examine potential differences between measures of crystallized and fluid intelligence, given their separate abilities and potential effects on strategy use. Whereas crystallized intelligence relies on acquired declarative and procedural knowledge, fluid intelligence is based on controlling mental operations and problem-solving abilities (Carroll, 1993) and has been associated with creativity (Nusbaum & Silvia, 2011). Previous studies have related either measures of fluid intelligence (Ariel, Price, & Hertzog, 2015) or measures of crystallized intelligence (Barulli et al., 2013) to efficient memory strategy use, however, their effects have never been compared directly. A first attempt in this study, by distinguishing between V and BD subtests in relation to the effect of strategy use, did not show meaningful differences in the effect of these two diverse intelligence subtests. A more thorough study, including multiple measures of crystallized and fluid intelligence, is required to elucidate this question.

To summarize, this study is the first to demonstrate that IQ plays a crucial role in the proficient effects of strategy instructions on memory across the adult lifespan. Specifically, older adults with a higher IQ estimate profited substantially from strategy-instructions, whereas those with a lower IQ estimate profited to a lesser extent. Moreover, the present study demonstrated an aging-related decline in associative memory. When adding a delay between encoding and recollection, this aging-related decline is also present for item memory. This study highlights the importance of the role of IQ in compensating for the aging-related decline in associative memory. Future studies are needed to examine the extent to which IQ or other CR measures influence the strategy production deficiency and the strategy processing deficiency in older adults.

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