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The art of self-testing by attempting cryptic crosswords in later life: the effect of cryptic crosswords on memory self-efficacy, metacognition and memory functioning

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Abstract

Background: Previous research has suggested that older adults who are more cognitively active in later life show an attenuation in cognitive decline in healthy aging. Furthermore, cognitive intervention studies have indicated that ecologically valid cognitive interventions can promote cognitive functioning but only in task-specific abilities. Since it has been shown that the art of self-testing can promote metacognitive awareness in older adults, attempting cryptic crosswords may be used as a cognitive intervention for older adults.

Methods: In Experiments 1 and 2, a questionnaire technique was used and demonstrated that older adults became more aware of their episodic memory deficits after attempting cryptic crossword clues. Based on this, Experiment 3 used an intervention technique over a six-week period to investigate whether such awareness enabled older adults to improve cognitive functioning in a number of domains. This experiment used a revolutionary within-subjects technique to control for potential mediating factors.

Results: The results supported previous research in that older adults showed an increase in the monitoring pathway of metacognition but were unable to use this enhanced awareness to change their behaviour when undertaking objective tests of cognitive ability. Post-hoc analysis highlighted subgroups of older adults who showed improvements in certain cognitive abilities, such as episodic memory functioning and judgement of learning abilities.

Conclusions: The standard clinical trial technique might be inappropriate when testing either cognitive interventions or pharmacological tests. The within-subjects approach could be adapted to investigate follow-up effects of different types of interventions including ecologically valid cognitive interventions.

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Introduction

There is a need to provide cognitive interventions that are both cost-effective and easy to access for older adults [1-5]. Older adults show significant deficits in both episodic memory and metacognition [6-10]; therefore, it is important to develop cognitive interventions that target these cognitive functions.

Cognitive interventions that have focused on metacognitive training have provided strong evidence that cognitive decline in healthy aging can be attenuated or reversed [6, 11-14]. Furthermore, the art of self-testing has been used as an intervention technique to promote both metacognition and episodic memory functioning in older adults [6]. In self-testing

participants study items repeatedly and use cognitive introspection to assess whether specific items have been learned sufficiently to facilitate later recall [15]. One drawback of laboratory-based interventions that focus on metacognition or cognitive training is that there is little evidence that such interventions produce observable changes in everyday cognitive functioning [16, 17]. Second, Smith et al. [18] showed there was no significant functional cognitive benefit of a computer-based intervention versus an active lifestyle, with the exception of certain task-specific domains.

Recently, psychologists have developed cognitive interventions based upon more ecologically valid activities, based on the use-it-or-lose-it or use-dependency theory [2, 19-23]. Considerable empirical support indicates that adults who are more cognitively active in later life demonstrate a significant attenuation in the rate of cognitive decline and later onset of dementia [4, 24-32]. Interventions based on the use-dependency theory have shown promise to produce transferable benefits in cognition [19-21]. Furthermore, the benefits of cognitive, physical and social exercises also apply to participants with mild cognitive impairments (MCI) [22].

However, these interventions tend to be relatively uneconomical and require extensive training of staff and participants. In line with Salthouse [2, 3] we propose that it is possible to identify everyday cognitive activities that are related to novel information processing [30] and similar to cognitive training techniques that have shown transfer effects for everyday functioning [17].

Attempting crosswords has been associated with the attenuation of cognitive decline in older adults [30, 33] and rated by older adults as being highly cognitively-demanding [2]. Completion of a cryptic crossword is different than completing a regular crossword and encourages self-testing [34, 35], but recent research has not discriminated the relationship between the type of crossword undertaken and cognitive benefit. A cryptic crossword clue is made up of two components that must both match to produce the solution (e.g. the clue “an antelope, just born we hear (3)” should produce the solution “new” – a gnu is a type of antelope where the ‘g’ is silent and ‘just born’ can mean ‘new’ which is a homophone of gnu). The new solution must fit with intersecting solutions

that have already been solved. Thus, cryptic crosswords promote self-testing in three distinct ways. As cryptic crosswords require little training and are economical, such activities could potentially be used alternatively to economical laboratory-based interventions [6, 27, 36].

We investigated the impact of undertaking cryptic crosswords on MemSE, metacognition and episodic memory. Two experiments used a questionnaire technique to investigate the subjective relationship between undertaking cryptic crosswords and MemSE and explore whether an individual’s ability to complete cryptic crosswords affects their willingness to attempt such crosswords and MemSE. Then, an intervention technique was used to measure objective measures of cognitive activity and both subjective and objective measures of cognitive functioning in metacognition and episodic memory were measured.

Methods

Experiment 1

Participants

The sample population (366 participants, mean age: 38.40, SD:23.44) was heavily skewed towards younger participants, therefore established age groups were used based on previous research [24] and these were 18-38 (N = 199, mean age = 20.26 [SD = 3.93], mean number of years in education = 14.96 [SD = 2.05]), 39-59 (N = 41, mean age = 51.98 [SD = 5.52], mean education = 16.24 [SD = 2.95]), and 60-90 (N = 104, mean age = 70.83 [SD = 7.43], mean education = 14.89 [SD = 3.46]). There was no significant difference in the number of years in education between the younger and older participant groups, $t < 1$. The middle age group was omitted from the analysis, thus the total number of participants was 324.

Cognitive Activity Measures

The questionnaire is available from the corresponding author. Participants were asked to rate how often they undertook attempting three different types of crossword on a 5-point Likert scale ranging from “every day” to “never” and whether they still

attempted, had given up attempting, or never attempted cryptic crosswords. A 5-point Likert scale was used to assess what proportion of participants' lives were spent attempting cryptic crosswords (0-25%, 26-50%, 51-75%, 76-100%, or not applicable).

Self-Reported Memory Self-Efficacy Measures

Participants were asked to report their overall MemSE using a simplified version of Berry, West and Dennehey [37] and two sections focused on episodic memory functions. First, participants estimated their ability to recall fifteen random words compared to when they were in their prime (Episodic Memory Prime Difference [EMPD], the higher the EMPD denotes a MemSE). The second section posed questions relating to episodic memory (Episodic Memory Total [EM Total]). A 4-point Likert scale ranging from 0-25%, 26-50%, 51-75%, 76-100% was used (Cryptic Proportion). Participants had to rate ten cryptic crossword clues in terms of difficulty on a 5-point Likert scale (Total Perceived Cryptic Ability), calculated by summing the ten responses that were coded 0-4 for very easy-very difficult.

Design and Procedure

The specific experimental design and procedure are outlined in Supplemental Data.

Experiment 2

Participants

The sample consisted of 71 participants with a mean age of 70.54 (range = 60 – 86, SD = 6.572) and mean number of years in education of 14.85 (SD = 3.790). Participants who had attempted the cryptic clues before or after the episodic MemSE questions received Version 1 (n=34; mean age: 70.18; SD: 5.992) or 2 (n = 37; mean age: 70.86; SD: 7.130), respectively. There were no significant differences in age, education, Cryptic Crossword Frequency, Cryptic Proportion, Cryptic Solve Total, or Cryptic Effort. The pen and paper method was used because computer use is cognitively demanding [2,3].

Cognitive Activity Measures

The same questions were used as in Experiment 1 for EM Total and EMPD. However, participants wrote the actual percentages to answer each question. A Likert scale was used to calculate the proportion of participant's lives that they had attempted cryptic crosswords and how much effort they used. The Likert scale measures were: 1 = 0 – 25%, 2 = 26 – 50%, 3 = 51 – 75%, 4 = 76 – 100% and 5 = not applicable. The variable of Cryptic Solve Total was calculated by summing the total number of cryptic clues participants solved correctly. For each correct answer, participants received one point with a maximum of 10 points. The questionnaire is available upon request from the corresponding author.

Design and Procedure

The details of the design and procedure can be found in Supplemental Data.

Experiment 3

Participants

Seventeen of 20 volunteers recruited from the local community completed the study. Written consent was obtained. The mean age was 70.4 years (SD = 5.54) and a mean number of years in education of 15.74 (SD = 3.98). All participants undertook a mini-mental state examination [38] and all scores indicated an absence of cognitive impairment. The characteristics of these participants are listed in Table 1. They were separated into two groups based on which intervention activity they completed first. There was no significant difference between participants who undertook the intervention activity or placebo activity for the factors measured (Table 1).

Design and procedure

The cognitive intervention required participants to attempt cryptic crosswords for one hour per day of a six-week period. The specific details of the design and procedure are listed in the Supplemental document.

Table 1. Correlations between three MemSE dependent variables, cryptic solve total and age, number of years in education, cryptic crossword frequency and cryptic proportion

| | MemSE Total | EMPD | EM Total | Cryptic Solve Total |
|-----------------------------|-------------|--------|----------|---------------------|
| Age | -.191** | .441** | -.463** | .322** |
| Education | .056 | -.086 | .031 | .150** |
| Cryptic Crossword Frequency | -.065 | .247** | -.129* | .692** |
| Cryptic Proportion | -.086 | .228 | -.135 | .713** |

** Significant to 0.01 level (2-tailed)

* Significant to 0.05 level (2-tailed)

Data analysis

ANOVA analysis was used to identify changes in cognitive functioning between the two interventions [18]. The details of the ANOVA analysis can be found in Supplemental Data.

Results

Experiment 1

Experiment 1 used a questionnaire technique to investigate whether participation in cognitively stimulating activities were related to memory self-efficacy (MemSE) in younger and older adults and determine the proportion of one’s life spent participating in each type of crossword on a regular basis.

Correlational Analysis

As expected, there was a significant negative correlation between age and both MemSE and EM Total as well as a significant positive correlation between age and EMPD (Table 2). The positive correlation indicates that older adults feel that their episodic memory system is weaker now compared to when they regarded themselves as in their prime. There was also a significant positive correlation between age and Total Perceived Cryptic Ability, however more older adults attempted cryptic crosswords than younger adults as demonstrated by a positive correlation between Age and Cryptic Crossword Frequency, $r(321) = .471, p < .001$, and

the significant positive correlation between Age and Cryptic Proportion, $r(72) = .485, p < .001$.

The sample population was separated on the basis of age and correlation analysis was repeated to investigate the effect of Total Perceived Cryptic Ability on the MemSE factors. In the older sample there was a significant correlation on Total Perceived Cryptic Ability and EM Total, $r(96) = .273, p < .01$, but not in the younger population. This indicates that older adults who felt that the cryptic crosswords were easier to solve had more confidence in their episodic memory ability. The opposite may also be true, that is that older adults who felt that the cryptic clues were more difficult to solve became more aware of their episodic memory deficits.

Table 2. Demographic and cognitive assessment means scores (standard deviations) separated by order of intervention activity

| Mean Demographic and Cognitive Assessment scores | First Intervention Activity | |
|--|-----------------------------|----------------|
| | Crosswords | Colouring |
| Age | 73.13 (5.72) | 68.00(4.33) |
| Education | 15.75(3.37) | 15.72(4.66) |
| Mini-Mental State Examination | 29.63(0.52) | 29.67(0.50) |
| Socialisation | 9.13(4.49) | 5.78(4.02) |
| Total Crossword Frequency | 3.5 (3.02) | 2.56 (2.13) |
| Total Cognitive Activity | 11.75(4.43) | 10.89(4.51) |
| Final Crossword Completion Score | 862.54(772.79) | 742.67(609.61) |
| JOL correct proportion | 5.22(1.10) | 4.17(0.97) |
| JOL incorrect proportion | 4.27(0.93) | 3.52(0.74) |
| JOL Gamma correlations | 0.44(0.57) | 0.55(0.29) |
| Episodic MemSE | 46.88(9.25)* | 55.11(6.62)* |
| Total MemSE | 44.25(18.10) | 49.11(4.29) |
| Memory strategy | 42.63(9.94) | 37.22(13.48) |
| Cognitive strength | 47.63(8.80) | 50.33(10.56) |
| Intertrial recall trial 1 | 7.00(2.00) | 8.44(1.81) |
| Intertrial recall trial 2 | 9.38(1.92) | 10.11(1.45) |
| Intertrial recall trial 3 | 10.88(2.75) | 11.22(1.72) |
| Intertrial recall trial 4 | 12.13(2.36) | 12.11(2.15) |
| Intertrial recall trial 5 | 13.50(3.12) | 12.89(2.03) |
| Intertrial consolidation 1 | 79.68(15.23) | 69.95(16.71) |
| Intertrial consolidation 2 | 64.72(21.00) | 66.73(13.62) |
| Intertrial consolidation 3 | 74.27(18.94) | 68.77(13.62) |
| Intertrial consolidation 4 | 76.26(14.71) | 73.56(7.19) |
| Intertrial encoding 1 | 35.00 (10.00) | 42.22(9.05) |
| Intertrial encoding 2 | 29.95(8.54) | 37.27(5.10) |
| Intertrial encoding 3 | 44.06(16.73) | 45.17(10.01) |
| Intertrial encoding 4 | 40.77(11.48) | 49.71(14.82) |
| Intertrial encoding 5 | 53.17(17.88) | 50.31(24.19) |

* Significant to 0.05 level (2-tailed)

ANOVA Analysis

A 2 X 3 (Age Group vs. Cryptic Status) was conducted for each dependent variable of MemSE. Covariates of Cryptic Proportion and Total Perceived Cryptic Ability were included in the analysis. Only relevant results are reported below.

Regarding the dependent variable of MemSE, there was no significant main effect of Cryptic Status and no significant two-way interaction between Age group and Cryptic Status, $F = 1.59$, $F < 1$, respectively. There was a borderline significant main effect of Age Group on MemSE, $F(1, 239) = 3.44$, $p = .06$, $\eta^2 = .014$. The marginal means confirm that younger adults reported a 13.84% higher MemSE than older adults. The covariates of Cryptic Proportion and Total Perceived Cryptic Ability were included separately to produce two ANCOVAs. When Cryptic Proportion was included there was a significant two-way interaction between Age Group and Cryptic Status, $F(2, 56) = 5.12$, $p < .01$, $\eta^2 = .155$ (in this ANCOVA the factor of Age Group did not produce a significant main effect, $F = 2.03$).

As illustrated in Fig. 1, older adults who still attempted cryptic crosswords had the highest MemSE score compared to the other five subsamples. Furthermore, older adults who had given up attempting such crosswords also reported the lowest MemSE score for the older sample population. This supports the theory that older adults continue attempting cryptic crosswords when they feel capable.

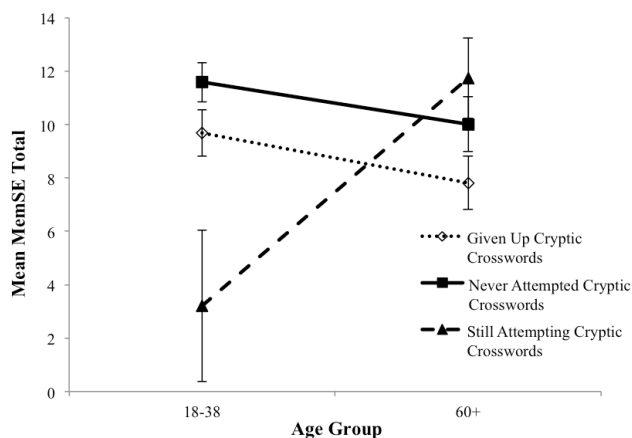


Figure 1. Two-way interaction between age group and cryptic status on MemSE total when controlling for cryptic proportion

When controlling for the proportion of one’s life for attempting such crosswords there is a clear indication that older adults continue attempting cryptic crosswords if they have a high MemSE, however they appear to give up cryptic crosswords if their MemSE drops.

The analysis was repeated for the dependent variable of EM. The results confirmed the correlational analysis with a main effect of Age Group on EM Total, $F(1,240) = 41.22$, $p < .001$, $\eta^2 = .147$. The marginal means showed that younger adults had a 40.13% higher EM Total than older adults.

The covariate of Total Perceived Cryptic Ability was included in an ANCOVA and the significant main effect of Age Group was maintained. There was no significant main effect of Cryptic Status on EM Total. However, there was a significant two-way interaction between Age Group and Cryptic Status on EM Total, $F(2, 225) = 2.97$, $p = .05$, $\eta^2 = .026$. The marginal means showed that younger adults who had given up attempting cryptic crosswords had a 5.62% higher EM Total than those who still attempt such crosswords. Conversely, older adults who had given up attempting such crosswords had a 23.56% lower EM Total than older adults who still attempted such crosswords.

The significance for the interaction was increased when cryptic proportion was included in the ANCOVA. Once again the main effect of Age Group on EM Total was significant, but there was also a significant interaction between Age Group and Cryptic Status, $F(2, 55) = 3.81$, $p < .05$, $\eta^2 = .122$. Older adults who still attempt cryptic crosswords had the highest EM Total of the older subsample, while older adults who gave up cryptic crosswords had the lowest EM Total score of the six subsamples (Fig. 2). This relationship was reversed in the younger sample.

The original ANOVA was repeated for the EMPD dependent variable. Notably, a higher EMPD score denotes a lower confidence in episodic MemSE. There was a significant main effect of Age Group on EMPD, $F(1,241) = 24.54$, $p < .001$, $\eta^2 = .092$. Older adults reported a 67.39% higher EMPD than younger adults. There was a significant main effect of Cryptic Status on EMPD, $F(2,241) = 7.20$, $p < .001$, $\eta^2 = .056$.

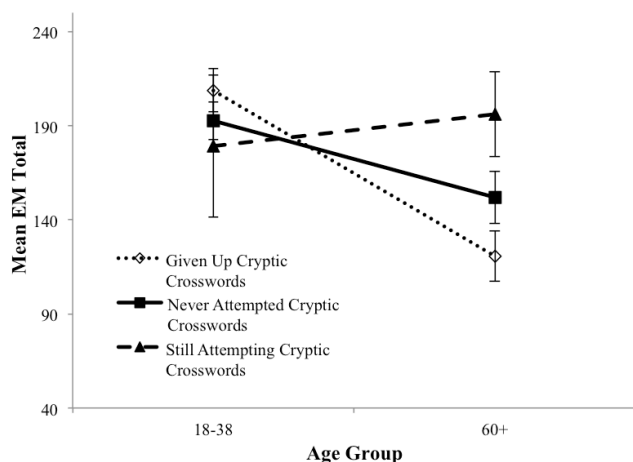


Figure 2. Two-way interaction between age group and cryptic status on EM total when controlling for cryptic proportion

The marginal means indicate that participants who had given up cryptic crosswords had a 59.07% higher EMPD than those who still attempted such crosswords. There was also a significant interaction between Age Group and Cryptic Status on EMPD, $F(2,241) = 3.68, p < .05, \eta^2 = .030$. Including the covariates of Cryptic Proportion and Cryptic Solve did not change the main effects of the two factors and interaction.

Older adults who have given up cryptic crosswords reported the highest EMPD score of all subgroups of participants (Fig. 3).

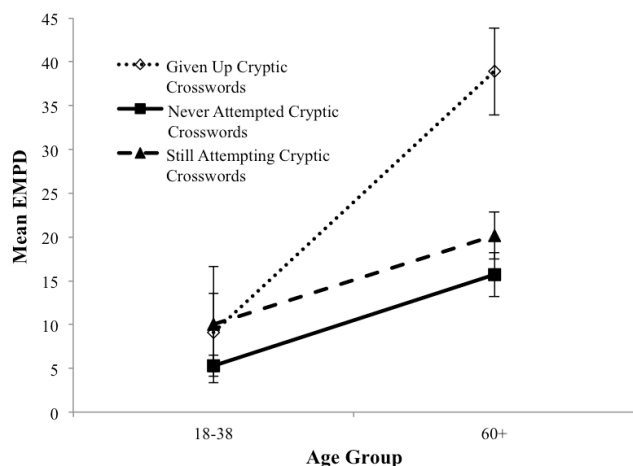


Figure 3. Two-way interaction between age group and cryptic status on EMPD

Furthermore, within the younger population there appears to be a relatively low difference between the three groups based on cryptic status. Further analysis used t tests to compare younger and older adults who have either given up cryptic crosswords or who were still attempting or never attempting such crosswords. Within the younger sample population there was no significant difference between these two groups, $t < 1$, however in the older sample population there was a significant difference between those who had given up cryptic crosswords compared to a combined group of those who still attempt or have never attempted such crosswords, $t(73) = 3.22, p < .05$.

Experiment 2

Correlational Analysis

For the overall sample population the only significant correlation was between age and EMPD, $r(71) = .276, p < .05$. This indicates that although all the sample population was aged over 60, older participants felt that there was a greater difference in their episodic memory ability at the current point in time compared to when they regarded themselves as in their prime. No other significant correlations were found for the overall sample population, therefore the correlational analysis was repeated for the two separate groups of participants who either attempted Version 1 or Version 2 of the questionnaire.

Table 3 shows the correlation coefficients for EMPD and EM Total for the variables of Age, Education, and the three cryptic crossword variables. Of note is that while there were no significant correlations between the factors for participants who undertook Version 1 of the questionnaire there are two significant correlations between EMPD and Age, and EMPD and Cryptic Solve Total. These results suggest that participants who attempted the cryptic crossword clues before undertaking the EMPD test became more aware of the difference between their current episodic memory function compared to when they regarded it in its prime. Furthermore, and perhaps more critically, participants taking Version 2 of the questionnaire who were more able to solve the crossword clues reported a significantly lower EMPD suggesting that the ability to solve the crosswords enhanced their episodic MemSE.

Table 3. Illustration of Cryptic Crossword Intervention period

| Testing period | Rest | Testing period | Rest | Testing period |
|--------------------------------|-----------|---|------------|---|
| Baseline . One testing session | Two weeks | Intervention period one. Three testing sessions totalling six-weeks | Four weeks | Intervention period two. Three testing sessions totalling six-weeks |

The opposite may also be the case, that is, the participants who struggled to solve the cryptic crossword clues became more aware of their cognitive deficits. There were no results of note from the EM Total variable.

ANOVA Analysis

A fixed factor termed Version was included in all ANOVA analysis; this had two levels (either Version 1 or 2 of the questionnaire). Further factors were created by using a median split for Cryptic Crossword Frequency, Cryptic Proportion, Cryptic Effort and Cryptic Solve Total, these were all termed Median Cryptic Frequency, Median Cryptic Proportion, Median Cryptic Effort and Median Cryptic Solve Total. Thus 2 X 2 ANOVAs were conducted and covariates of the original cryptic measures were included where appropriate for the two dependent variables of EMPD and EM Total. Only results of note pertaining to Experiments 1 and 3 are presented here.

Regarding the dependent variable of EMPD a 2 X 2 ANOVA (Version X High or Low Median Cryptic Solve Total) was conducted. There was no significant main effect of Version or Median Cryptic Solve Total on EMPD, $F < 1$ and $F = 2.84$, respectively. However, there was a significant interaction between the two factors on EMPD. Fig. 4 illustrates the interaction of the two factors on EMPD. For participants who undertook Version 1 of the questionnaire there is relatively no difference in terms of EMPD. However, the results show that participants who were more adept at solving the cryptic crossword clues showed a lower EMPD when undertaking Version 2 of the questionnaire compared to participants who were less able to solve the cryptic crossword clues.

When the covariates of Cryptic Frequency and Cryptic Proportion were included in the analysis the interaction was maintained at significance and there was no change in the significance of the two main effects of EMPD. However, when the covariate of Cryptic Effort was included in the analysis there was a borderline significant main effect of Median Cryptic Solve Total, $F(1, 66) = 3.76, p < .06, \eta^2 = .05$ and the two-way significant interaction was maintained. No other noteworthy results were found when Median Cryptic Crossword Frequency, Median Cryptic Effort or Median Cryptic Proportion was substituted for Median Cryptic Solve Total.

With regards to the dependent variable of EM Total, there was no significant main effect of Version or Median Cryptic Solve Total, $F < 1$ and $F = 3.49$, respectively. There was also no significant interaction between the two factors on EM Total, $F < 1$. When the covariate of Cryptic Crossword Frequency was included in the analysis there was a borderline main effect of Median Cryptic Solve Total, $F(1, 66) = 3.63, p = .06, \eta^2 = .05$. The marginal means show that participants who were better at solving the cryptic crosswords clues had a 14.72% higher EM Total than those who were less able to solve the cryptic crossword clues. The covariate did not affect the significance of the main effect of Version or the two-way interaction.

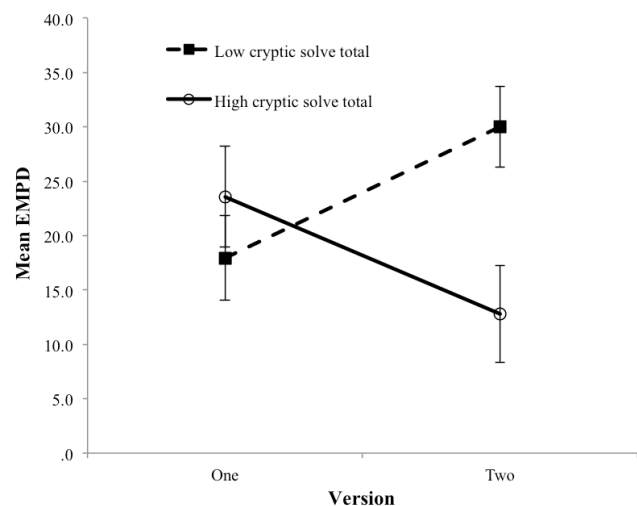


Figure 4. Two-way interaction between version and cryptic solve total on EMPD

When the covariate of Cryptic Effort or Cryptic Proportion was included separately as covariates in the ANOVA the main effect of Median Cryptic Solve was maintained. No other results of note were found when including other median factors for this dependent variable.

Experiment 3

As previously discussed, cognitive interventions have been shown to promote cognitive functioning in older adults [4, 6, 11, 12, 14-22, 27, 28, 33, 36, 39, 40, 41, 42]. Thus, if cryptic crosswords promote memory self-testing then it is possible that older adults who attempt such crosswords on a regular basis may show an increase in metacognitive awareness, which may in turn transfer to episodic memory functioning. Conversely, if older adults show a deficit in the control pathway of metacognition then self-testing will not enhance episodic memory functioning. Experiment 3 investigated this directly by using an intervention study over a six-week period. A counterbalanced within-subjects technique was used as post-hoc analysis can separate the overall sample population into smaller subsamples based on factors such as education or social engagement.

Within-subjects analysis

Subjective measures

Cognitive strength results

There was no significant main effect of either intervention activity, $F < 1$, or visit, $F = 2.661$, on the Cognitive Strength dependent variable. The baseline results did not show a significant difference in terms of Cognitive Strength between those who undertook either crosswords or colouring first. The intervention period showed that those who completed the colouring intervention first had a significantly higher Cognitive Strength throughout the whole intervention period compared to those who attempted the crossword intervention first, $F(1, 15) = 4.830$, $p < 0.05$, $\eta^2 = 0.244$. There were no significant two-way or three-way interactions between the factors on Cognitive Strength.

Memory Strategy results

The results showed no significant main effects of Memory Strategies for intervention activity, $F < 1$, visit, $F < 1$, or first intervention activity, $F < 1$. The two-way interactions between intervention activity and first intervention activity, $F < 1$, intervention activity and visit, $F < 1$, and visit and first intervention activity, $F < 1$, on memory strategies were all non-significant. The three-way interaction between all three factors on Memory Strategies was also non-significant, $F < 1$.

Total MemSE results

Statistical analysis was repeated for this dependent variable. The results showed no significant main effect of intervention activity, $F < 1$, visit, $F < 1$, or first intervention activity, $F = 3.224$, on total MemSE. Furthermore, there were no significant two-way or three-way interactions between any of the factors.

Episodic MemSE results

There were no significant main effects of either visit, $F = 1.590$, or first intervention activity, $F < 1$, on Episodic MemSE. There was a significant main effect of intervention activity on Episodic MemSE, $F(1, 15) = 5.465$, $p < 0.05$, $\eta^2 = 0.267$. The marginal means indicate that when participants undertook the colouring intervention activity they had a mean Episodic MemSE which was 5.06% higher than when they were attempting the crossword intervention. None of the three factors produced a significant two-way or three-way interaction with one another. These results suggest that participants became more aware of their episodic memory deficits when attempting the cryptic crossword intervention compared the placebo task.

Objective measures

Episodic memory intertrial results

With regards to intertrial recall (ITR), the within-subjects factor of trial was included in the analysis to produce a $2 \times 3 \times 5 \times 2$ ANOVA. The results showed a significant main effect of trial on ITR, $F(4, 60) =$

99.126, $p < 0.001$, $\eta^2 = 0.869$. The marginal means confirmed that recall was on average 59.29% higher on the fifth trial compared to the first trial. None of the other factors produced significant main effects on ITR. There were two significant two-way interactions; first, between trial and visit, $F(8, 120) = 2.435$, $p < 0.05$, $\eta^2 = 0.140$, and second, between first intervention activity and intervention activity, $F(1, 15) = 33.863$, $p < 0.001$, $\eta^2 = 0.693$. The first interaction does not shed any light on the impact of either activity on ITR and the second interaction simply indicates that participants, on average, recall 12.25% more words during their second intervention period compared to their first, regardless of specific activity.

The analysis was repeated for the dependent variable of gained access (GA) thus a $2 \times 3 \times 5 \times 2$ ANOVA included the within-subjects factor of trial to analyse the GA results. There was a significant main effect of trial on ITE, $F(4, 52) = 10.062$, $p < 0.001$, $\eta^2 = 0.436$. The marginal means show mean GA was 17.58% higher on the last trial compared to the first trial. The only significant two-way interaction on GA was between the factors of intervention activity and first intervention activity, $F(1, 13) = 6.664$, $p < 0.05$, $\eta^2 = 0.339$. On average GA was 9.48% higher during the second intervention period compared to the first. For the lost access (LA) dependent variable the analysis was repeated, however LA was not calculated for the final trial. As mentioned earlier, MA is considered an inverse measure of consolidation, therefore the lower MA, the higher the consolidation. Therefore a $2 \times 3 \times 4 \times 2$ ANOVA was used. There were no significant main effects of either intervention activity, $F < 1$, visit, $F = 1.574$, or first intervention activity, $F < 1$, on LA. There was, however, a significant main effect of trial on LA, $F(3, 45) = 7.336$, $p < 0.001$, $\eta^2 = 0.328$. LA was 10.44% lower on the last trial compared to the first trial. Once again there was a significant two-way interaction between first intervention activity and intervention activity, $F(1, 15) = 10.192$, $p < 0.01$, $\eta^2 = 0.405$. Mean LA was 6.93% lower during the second intervention activity.

JOL gamma correlations

For the whole sample population, there was no evidence that attempting cryptic crosswords on a

regular basis promoted metacognition (See below for further discussion).

Post-hoc between-subjects analysis

Subjective results

Post-hoc showed that the mediating factor of Total Previous Crossword activity had a significant impact on the effectiveness of the cognitive intervention. There was a significant two-way interaction between previous Total Crossword Activity and Intervention Activity on Total MemSE, $F(1, 13) = 5.088$, $p < 0.05$, $\eta^2 = 0.281$.

The marginal means show that individuals who regularly completed crosswords in the past did not show a great deal of variation on memory self-efficacy ratings while undertaking either cryptic crosswords or colouring. Conversely, participants who reported a lower past total crossword frequency score had a lower memory self-efficacy rating while undertaking crosswords compared to when completing colouring (see Fig. 5). These results suggest that individuals who regularly attempt crosswords have a relatively fixed memory self-efficacy. However, for those who do not complete crosswords on a regular basis it is possible that the crossword intervention enables them to gain more insight into their cognitive functioning and specifically those cognitive abilities that decline with age.

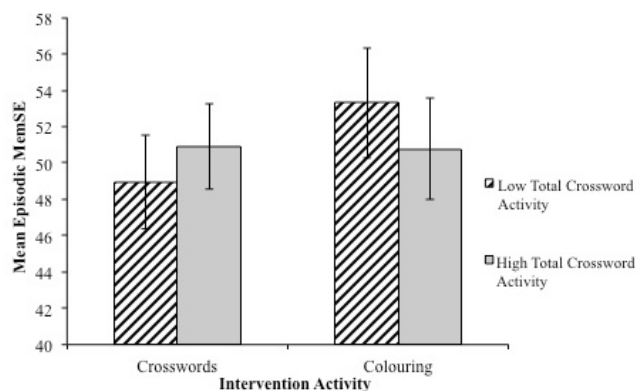


Figure 5. Two-way interaction between intervention activity and previous total crossword activity on episodic MemSE

Objective measures

Episodic memory intertrial results

The results showed that there was a significant two-way interaction between Intervention Activity and Total Cognitive Activity, $F(1, 11) = 7.429, p < 0.05, \eta^2 = 0.403$. The marginal means showed that for individuals classed as having a high previous Total Cognitive Activity, mean GA during the crossword intervention was 24.29% higher than individuals classed as having a low previous Total Cognitive Activity. Whereas during the placebo intervention individuals with lower previous Total Cognitive Activity encoded on average 2.42% more during the placebo intervention than those in the high Total Cognitive Activity group.

There was also a significant three-way interaction between Intervention Activity, Trial and Total Cognitive Activity on GA, $F(4, 44) = 3.275, p < 0.05, \eta^2 = 0.229$ (Fig. 6). The marginal means indicate that individuals who are classed as having a high Total Cognitive Activity have a higher mean GA across all trials for both intervention activities. However, the results also indicate that participants who have a lower Total Cognitive Activity show a greater GA while undertaking the placebo intervention compared to the crossword intervention. This pattern is reversed for individuals with a higher Total Cognitive Activity; GA, on average, is higher when they are attempting the crossword intervention activity as opposed to the placebo activity.

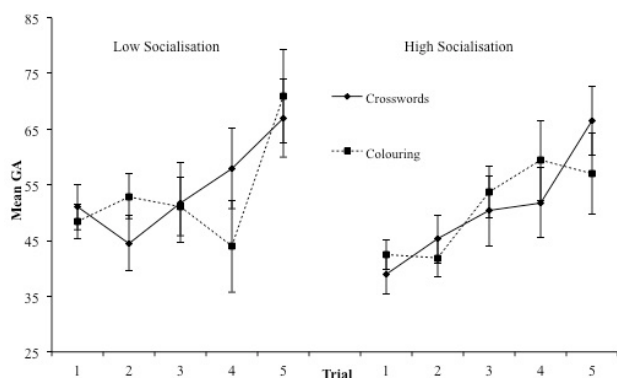


Figure 6. Three-way interaction between cognitive intervention, trial and median socialisation score on gained access

Finally, there was evidence that the amount of socialisation a participant was exposed to mediated the effectiveness of the intervention activity. GA increased at a greater rate across trials for individuals with a higher Socialisation Score when they were attempting the crossword intervention activity compared to the placebo activity. For individuals with a low Socialisation Score the pattern was reversed but to a lesser degree; encoding across trials was slightly greater when these participants were undertaking the placebo intervention activity compared to the crossword intervention activity.

JOL gamma correlation results

Following correlational analysis and ANCOVA results the between-subjects factor based on median number of years in education was added to the original ANOVA described above. The results showed a significant main effect of intervention activity on JOL gamma correlations, $F(1, 14) = 6.92, p < 0.05, \eta^2 = 0.331$. The marginal means show that on average participants had a JOL gamma correlation that was 9.81% higher when they were completing crosswords compared to when they were completing the placebo intervention activity.

The results also showed a significant two-way interaction between intervention activity and education group, $F(1, 13) = 11.308, p < 0.01, \eta^2 = 0.465$. The marginal means showed that participants who were classed as having a higher number of years in education had a mean gamma correlation that was 21.29% higher when they were attempting the placebo intervention activity compare to the crossword activity. However, individuals who were classed as having a lower number of years in education had a mean gamma correlation that was 128.1% higher when they were doing the cryptic crossword intervention activity compared to the placebo activity. This indicates that cryptic crosswords promote metacognition in individuals who have a relatively low number of years in education.

Post-hoc between-subjects results summary

The post-hoc analysis indicated that metacognitive awareness for episodic memory functioning was

promoted in individuals, who could be regarded as at risk of early cognitive decline [43], when undertaking the crossword intervention compared to the placebo. This was demonstrated in both subjective and objective measures of episodic memory awareness. Conversely, the objective measures of episodic memory showed that the crossword intervention benefitted participants who were both more cognitively and socially active to a greater degree than the placebo. Thus, there is no evidence that participants who showed a greater awareness of their episodic memory functioning used this to promote their actual episodic memory functioning.

Discussion

Experiment 1

The results supported previous research [40,44] in that older adults report significant deficits in both overall cognitive functioning and episodic memory cognitive abilities. Older adults attempted more cryptic crosswords than younger adults, which became of interest when taking into account whether participants had given up cryptic crosswords or were still attempting them. There was strong evidence that older adults who had given up attempting cryptic crosswords had a significantly lower MemSE than those who were still attempting such crosswords. This was less apparent in younger adults and specifically when focusing on episodic MemSE.

The relationship between MemSE and Cryptic Status became more apparent when the factor of perceived difficulty was taken into account. Our results suggest that older, but not younger, adults who perceive the cryptic clues to be more difficult reported a lower episodic MemSE.

The proportion of participant's lives spent attempting cryptic crosswords also had an impact on the relationship between Cryptic Status and MemSE, specifically regarding episodic memory. Our correlational analysis also supported the view that older participants who attempted cryptic crosswords for more of their lives reported a higher episodic MemSE, which again was not the case in younger adults. Unfortunately, due to the relatively small sample size, it was not possible to explore these described relationships further.

Taken together the results support the theory that cryptic crosswords promote self-testing. In self-testing experiments older adults have shown to become more aware of their cognitive abilities after repeatedly self-testing [6]. The results of Experiment 1 support Bandura's [39] theory of MemSE, in that individuals will withdraw from undertaking certain activities if they find them too difficult in order to preserve their confidence in their cognitive abilities [45].

According to a classic metacognition model [46], the monitoring pathway feeds back information concerning one's actual ability of completing a task (object-level; completing cryptic crosswords) to the meta-level (MemSE). If the individual cannot adjust his/her performance at the object-level, through the control pathway, their meta-level will readjust (drop in MemSE). Older adults have a deficit in the control pathway and thus struggle to adjust their behaviour to complete a cognitive task more effectively [6, 14, 36].

Experiment 2

Overall, the results confirm that of others [39, 40] in that older adults who were less able to solve the cryptic crossword clues reported a lower episodic MemSE score.

As in Experiment 1, the results suggest that older adults who struggle with completing cognitive tasks such as cryptic crosswords show a drop in their MemSE. Individuals are aware of their cognitive abilities and through the monitoring pathway will adjust their meta-level in accordance to their cognitive ability (object-level) [46]. This is supportive of Dunlosky et al. [6, 14], who showed that older adults had an intact monitoring pathway and are aware of a drop in cognitive functioning. This was confirmed when older adults undertook Version 1 of the questionnaire there was no significant difference in the episodic MemSE depending on their ability to solve the cryptic crossword clues. If Dunlosky et al. [6, 14] are correct then older adults who do not regularly attempt cryptic crosswords should show a drop in episodic MemSE and an increase in awareness of their cognitive deficits; however, due to the fact that their control pathway does not function as efficiently as younger adults this increase in awareness should not affect older adults ability to

complete objective episodic memory tasks. This theory was tested in Experiment 3.

Experiment 3

The within-subjects results support others [40, 47] in that the cognitive intervention had a significant effect on subjective measures of cognitive functioning and not objective measures of cognitive functioning as suggested by Floyd and Scogin [48]. Participants became less confident in their episodic memory ability while undertaking the crossword intervention compared to the placebo task.

Episodic memory and semantic memory are key components in the ability to solve cryptic crosswords and are used repeatedly. Due to the heavy involvement of episodic memory, it is possible that our results did not show a significant effect of the crossword intervention on the two dependent variables of cognitive strength and total MemSE as the questionnaires focused on a number of different constructs of memory.

Therefore, it is likely that cryptic crosswords do not have a significant impact on all constructs of memory (or other cognitive constructs) and thus there was no effect on global everyday cognitive functioning, as shown by others who suggested that strategic cognitive training does not have a significant effect on subjective measures of everyday functioning [16]. However, due to the lack of a follow-up test it is possible that the crossword intervention may promote subjective measures of everyday cognitive functioning [16,17]

There was no evidence that attempting cryptic crosswords on a regular basis promoted objective measures of verbal learning, metacognition or episodic memory performance, converse to previous studies [11, 18, 19, 21, 48]. Notably, subjective measures of episodic memory awareness indicated that participants show an improvement in the monitoring pathway of metacognition, but the JOL gamma correlation results did not show an objective improvement in episodic memory awareness, in support of others [49] who have suggested that subjective measures of cognitive performance can be unreliable.

Even if older adults became more aware of their episodic memory deficits, there is no evidence that the participants used this awareness to adapt their performance on the episodic memory task. This was true for the verbal learning task and the episodic memory intertrial learning task. Two explanations can be proposed: first, older adults appear to be unable to choose the appropriate strategy to complete a specific task [7, 27, 36, 50]; second, it is possible that participants did not adjust their control over their cognitive abilities due to the fact that the memory trials were experimenter-paced. Self-testing can promote objective measures of metacognition and episodic memory performance on self-paced memory trials [6]. However, the results are drastically curtailed when the experimenter paces the memory test. This finding is more evident in older adults and suggests that healthy aging has a significantly larger effect on the control rather than the monitoring pathway of metacognition [11, 36, 51]. This may explain why older adults appear to show significantly less transfer effects from cognitive training to everyday functioning or non-specific cognitive tasks [11, 16, 17].

Within-subjects analysis overview

The results suggested that the cognitive intervention had a greater effect on subjective rather than objective measures of functioning, which is supportive of Rapp et al. [47]. However, it is possible that the subjective measures of functioning are unreliable [49]. The lack of main effects of the crossword intervention on both subjective measures of global cognitive functioning and objective measures of metacognition, verbal learning and episodic memory suggest that previous research which had found a relationship between undertaking similar activities and cognitive functioning in later life may have done so due to the design used [4, 28, 30, 33]. There are a wide range of mediating factors that cannot be controlled for, which can mediate the effectiveness of a cognitive intervention [1].

Between-subjects post-hoc analysis

Previous research has suggested that individuals who can be regarded as at risk of early cognitive decline in

healthy aging may show a greater benefit of cognitive interventions [19, 52, 53]. However, it has been demonstrated that cognitive interventions appear to be more effective for individuals who display higher levels of cognitive functioning [11,12]. Post-hoc analysis allowed the whole sample population to be split on the basis of potential mediating factors based on a median split of measures taken at baseline or post-hoc in the circumstance of the ability to successfully complete the crossword intervention.

With regards to the subjective measures of cognitive functioning, the results showed that participants who regularly completed crosswords before taking part in the study did not show a large benefit of the crossword intervention on the basis of episodic MemSE. Conversely, participants who did not regularly attempt crosswords prior to the intervention demonstrated a significant decrease in their MemSE when attempting the crossword intervention. This supports the hypothesis that attempting cryptic crosswords promotes self-testing, which in turn enhances the monitoring pathway of metacognition as demonstrated in laboratory studies [6] and in Experiment 2. It is possible that undertaking crosswords for these individuals has a greater impact on their metacognition due to the fact that the crosswords were a novel task. This supports Park et al. [42] who suggested that novel intervention activities will have a greater impact on cognitive functioning and potentially neurogenesis than well-practised activities [30, 54].

An alternative possibility is the fact that participants who do not regularly attempt crosswords have the hallmark of a relatively low cognitive reserve [55, 56, 57]. This theory was supported with the results from JOL gamma correlations which demonstrated that individuals with fewer number of years in education, indicative of low cognitive reserve and a risk factor of early cognitive decline or dementia [4, 31, 43], showed significant improvements in JOL when undertaking the crossword intervention compared to the placebo.

The results also support the fact that older adults appear unable to use this increase in metacognitive awareness to adapt their episodic memory functioning [6, 36]. This supports the view that older adults show

a deficit in the control pathway of metacognition [6, 36, 50].

With regards to the objective measures of episodic memory functioning, these results support the view of others [11, 12] who have suggested that participants with a greater cognitive ability at baseline show a larger response to a cognitive intervention.

Our results also show evidence that participants who report a greater degree of socialisation respond better, in terms of GA performance, when attempting the crossword intervention compared to their counterparts. If these participants respond more positively to cognitive interventions then it is likely that previous research that has used the standard clinical trial results may have found positive benefits of cognitive interventions due to the mediating factor of socialisation. It is important that future research considers the impact of mediating factors of socialisation when recruiting participants. Bosma et al. [58] highlighted the fact that participants who take part in more social activities show an attenuated level of decline in cognitive functioning.

Overall, the post-hoc analysis highlights the need to consider multiple potential mediating factors when undertaking a cognitive intervention. It is not always possible to include all mediating factors into the analysis to identify the direct effect of a cognitive intervention on specific cognitive functions [1-3]. The within-subjects approach and post-hoc between-subjects analysis emphasizes the fact that there are a number of factors which are essential to provide a positive outcome of any intervention [43]. The results from the subjective measures of cognitive functioning are, on the whole, contrary to those when measuring memory performance objectively. However, there is strong support for the fact that participants show an increase in cognitive awareness when attempting tasks that encourage self-testing. However, unfortunately there is no evidence that participants can use these skills to enhance their actual cognitive functioning. The post-hoc analysis highlights the fact that individuals with certain characteristics may benefit from self-testing interventions, but more fortunate individuals appear to be able to use this type of intervention to promote their actual cognitive functioning.

Our results suggest that there is support for the use-dependency theory when using subjective assessments of cognitive functioning; however, there is a lack of support for the theory when taking into account objective measures of a wide range of cognitive functions. Finally, the results of Experiment 3 suggest that cognitive interventions are only beneficial for a select group of older adults who already show high levels of cognitive functioning.

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