Nonverbal declarative memory in older adults: effects of age, sex, and education

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Introduction

Declarative Memory (DM):

= key learning system rooted in the medial temporal lobe (MTL), including the hippocampus[1-5]
- underlies host of diverse tasks involving the learning of various types of information about events (episodic knowledge) and facts (semantic knowledge)
- declines in healthy aging in various tasks[6-18], beginning as early as one's 20s[19-21] (longitudinally: starting in middle adulthood[22])

Gaps & Weaknesses in previous research on DM in aging:

(1) Different types of information
- very few studies on DM in aging tested with non-verbal material (and tested *without* verbal responses)[23-25]
- different types of nonverbal information might yield different patterns for DM in aging: information linked to established knowledge may yield better performance[26-34]

(2) Role of sex
- Female advantage in verbal DM tasks across lifespan[(35-42)]; but unclear whether and how advantage changes in aging[25,31,36,38,43]
- Unclear whether there are sex differences for nonverbal DM tasks, and how it changes in aging[23,25]

(3) Role of education
- Education associated with better DM performance
- Unclear whether role of education changes with **age**[44,45] or is different for the two **sexes**[39] or dependent on **types of information**

(4) Task-related gaps and confounds
- Explicit vs. incidental encoding: most studies have assessed DM after explicit encoding; but incidental encoding is *more natural* and may yield smaller aging declines[46-48] and smaller sex differences[49]
- Working memory confounds: DM most commonly tested in list-learning, which depends heavily on working memory[50], which itself is affected by age, sex, and education[51,52]
- Focus on Western societies: almost no studies on DM in aging in non-Western samples, although cognitive abilities may show dramatic inter-population variability[53-55]

Present study

- Study of **nonverbal DM** in representative sample of older Taiwanese participants (**balanced sex** ratio, **wide range of education**: 0 to 17+ years)
- DM assessed with a **recognition memory** task following **incidental encoding**
- Design: Age (continuous) x Sex (female/male) x Education (continuous) x Object type (real/novel)

Methods

Participants

704 cognitively and neurologically healthy older adults, assessed in the 2011 wave of the Social Environment and Biomarkers of Aging Study (SEBAS)[56]:

Demographic information [means (SDs)]:

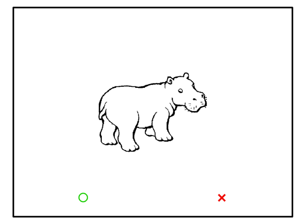
	N	Age (in years)	Education (in years)
Female	327	66.99 (8.38)	6.22 (4.61)
Male	377	68.82 (8.99)	8.84 (4.31)
Total	704	67.99 (8.72)	7.62 (4.64)

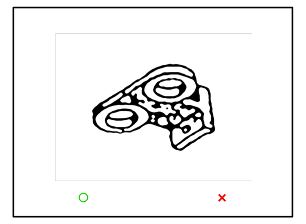
Tasks and Materials[57,58]

1) Incidental Encoding

64 black and white line drawings:
- 32 images depicting real objects ('real')
- 32 images depicting made-up objects ('novel')

Task: Decide if depicted object is real or not.

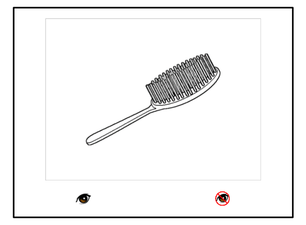


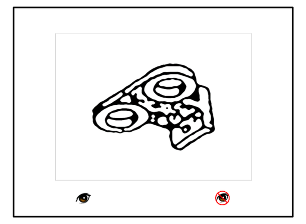


2) Recognition

128 drawings:
- 64 images presented during encoding
- 64 foils not presented during encoding (50% real objects, 50% novel objects)

Task: Decide if image was presented during encoding.





Results

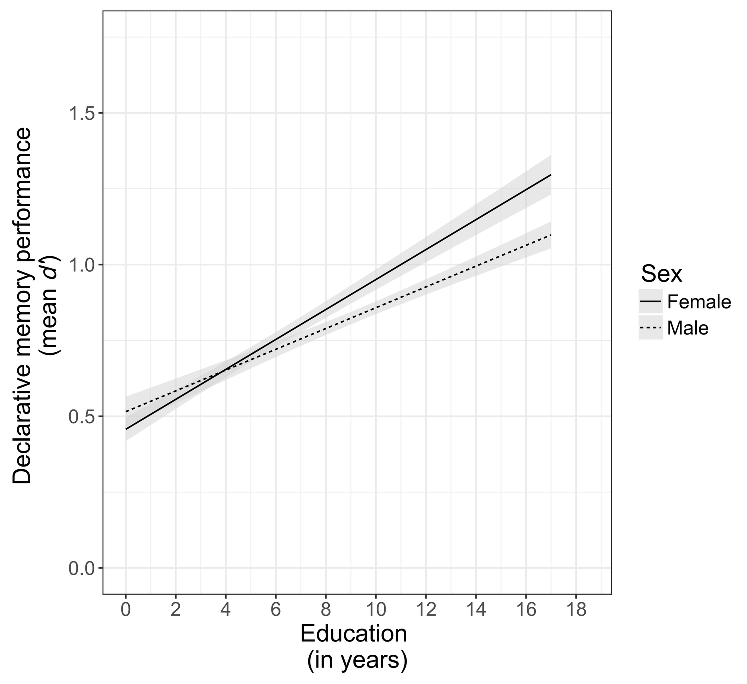
Performance in recognition task [*d'* means (SDs)]:

	Females	Males	All participants
Real objects	1.03 (0.70)	1.13 (0.72)	1.08 (0.71)
Novel objects	0.50 (0.41)	0.49 (0.38)	0.50 (0.39)
All objects	0.76 (0.76)	0.81 (0.66)	0.79 (0.65)

Main effects:

- Age: decreasing performance with increasing age (b = -0.014, SE = 0.002, t = -6.87, p < .001)
- Sex: marginally better performance in women than men (b = 0.057, SE = 0.034, t = 1.65, p = .099)
- Education: increasing performance with increasing education (b = 0.042, SE = 0.004, t = 11.46, p < .001)
- Object type: better performance with real objects than novel objects (b = -0.584, SE = 0.026, t = -22.75, p < .001)

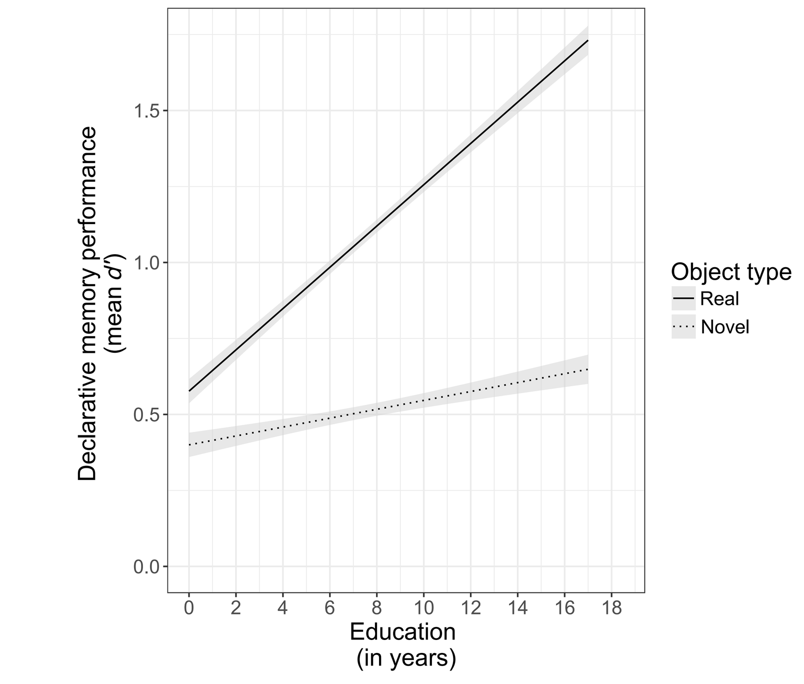
Sex x Education:



Greater positive effect of education for males than females (b = 0.015, SE = 0.007, t = 2.07, p = .039).
- females: b = 0.049, SE = 0.005, t = 9.21, p < .001
- males: b = 0.034, SE = 0.005, t = 6.92, p < .001

Significant female advantage emerging after 9 years of schooling.

Education x Object type:



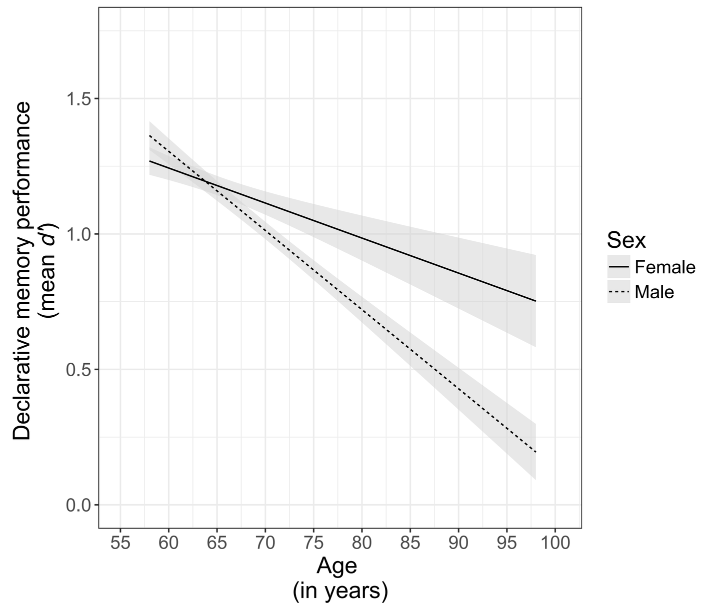
Greater positive effect of education for real objects than novel objects (b = -0.053, SE = 0.005, t = -9.74, p < .001).
- real: b = 0.068, SE = 0.005, t = 15.01, p < .0001
- novel: b = 0.015, SE = 0.005, t = 3.37, p < .0001

Significant advantage for real objects at all levels of schooling.

Age x Sex x Object type:

(b = 0.016, SE = 0.005, t = 3.12, p = .002)

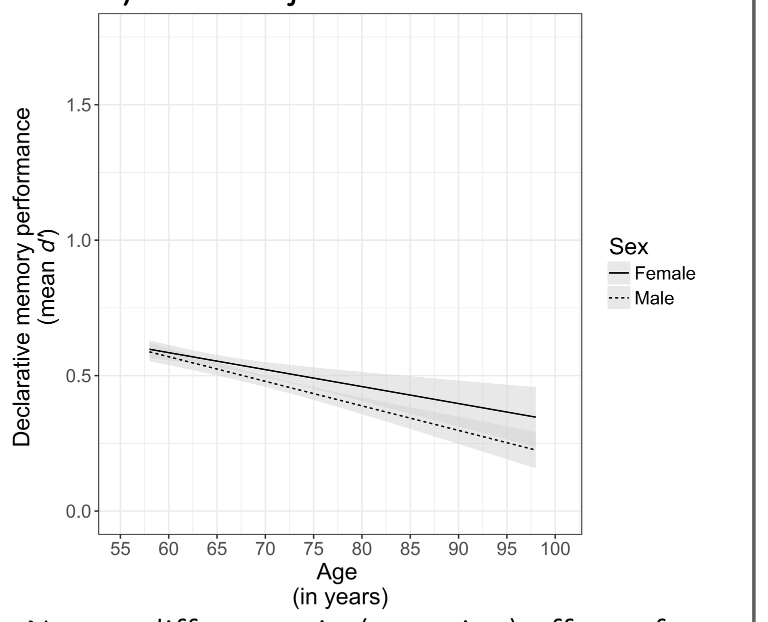
A) Real objects:



Greater negative effect of age for males than females (b = 0.016, SE = 0.005, t = 3.12, p = .002)
- females: b = -0.013, SE = 0.004, t = -3.02, p = .003
- males: b = -0.029, SE = 0.003, t = -9.80, p < .001

Significant female advantage from 70 years.

B) Novel objects:



No sex difference in (negative) effect of age for males vs. females (b = 0.003, SE = 0.005, t = 0.54, p = .589), but main effect of age across both sexes (b = -0.008, SE = 0.003, t = -2.94, p = .003)

Discussion

Main effects:

- Age: in line with previous studies
  - Likely related to age-related declines in hippocampal/MTL structures[59-70]
- Education: in line with previous studies
  - Education -> DM: cognitive stimulation may promote development of neural substrates underlying cognitive abilities[71]
  - DM -> Education: better DM abilities may yield greater educational outcomes
- Object type: in line with previous studies
  - Real objects' existing semantic associations may benefit creation of new episodic memories[72,73]

Sex x Education:

- Female advantage in line with previous studies on nonverbal DM (especially in countries with high levels of female education and employment[55])
- All else being equal, females show advantage at DM, but at low education female advantage may be countered by factors that elevate males' but not females' performance (e.g., participation in workforce outside the home[74,75])

→ Less cognitive and social stimulation for women than men at lower levels of education

Education x Object type:

1) More education = more knowledge (incl. labels for objects) and richer semantic networks, which real objects are more dependent on

2) More education = hippocampal volume increases[71]
- hippocampus more engaged in the recognition memory of known than novel stimuli[76-78]

→ education-moderated hippocampal increases may benefit real more than novel objects

Age x Sex x Object type:

- Hippocampal volumes decrease during aging more in males than females[36,79-83] (especially after age 60[36])
- Hippocampus particularly important for memory of known stimuli (vs. novel stimuli)[76,84,85]
  - But: exact relationship between hippocampal volumes and DM unclear (correlations exist[59,62,65,67,86-88], but young and middle-aged females do not seem to have larger hippocampi than males, despite their DM advantages)
- Novel objects less likely to depend on hippocampus
- Perhaps novel objects retrieved via perirhinal-based 'familiarity' (cf. 'recollection')[2,89-91]
  - Age-related declines in perirhinal volume less reliable than for hippocampus[63,88,92]
  - No steeper perirhinal volume declines for males than females[83,93]

Implications & Conclusions

- Nonverbal **declarative memory weakens with age**, even when tested following **incidental encoding**.
- **Early education** is crucial for later cognitive functioning, perhaps particularly for girls.
  - Males: each additional year of education = 2 years of aging
  - Females: each additional year of education = 5 years of aging
- The greater one's **existing knowledge**, the better one's declarative memory (cf. *Matthew Principle*).
- Studying **non-Western populations** helps advance our understanding of cognition by including heterogeneous samples.

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