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Self-referential processing improves memory for narrative information in healthy aging and amnestic Mild Cognitive Impairment

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ABSTRACT

The *Self-Reference Effect* (SRE), enhanced memory for self-related information, has been established in healthy young and older adults but has had limited study in age-related memory disorders such as amnestic Mild Cognitive Impairment (aMCI). Additionally, the majority of SRE studies have been conducted using trait adjective paradigms, which lack ecological validity; memory for narrative information has real-world importance and has been shown to decline in healthy aging and, to a greater extent, in aMCI. The present study investigated whether self-referential processing promotes memory for narrative information in healthy aging and, for the first time, in aMCI. The promotion of recollection (vivid re-experiencing of an event) through self-referential processing, termed the *Self-Reference Recollection Effect* (SRRE; Conway and Dewhurst, 1995), was also examined, as was the potential impact of material valence on the SRE. Twenty individuals with aMCI and thirty healthy older controls encoded short narratives under self-reference, semantic, and structural conditions. Memory for narrative details was subsequently tested. Results indicated a SRE for narrative information in both aMCI and healthy control groups on a recognition memory test. The SRRE was found in healthy controls and individuals with aMCI. Material valence did not impact the SRE in either group. The SRE appears to be powerful enough to circumvent loss of hippocampal function in aMCI, possibly due to the multimodal nature of narrative information. Findings from this study highlight the potential of the SRE as an effective intervention tool for improving memory for narrative information in aMCI.

The Self-Reference Effect (SRE; Rogers et al., 1977), enhanced memory for self-related information, is well-established in young adults, and has received increased attention in healthy aging due to its potential as an intervention strategy (e.g., Carson et al., 2016; Genon et al., 2014; Glisky and Marquine, 2009; Gutchess et al., 2007a, 2010; Gutchess et al., 2007b; Lalanne et al., 2013; Leblond et al., 2016; Mueller et al., 1986; Rosa et al., 2015; Rosa and Gutchess, 2013). Through self-referential processing of information, individuals are able to capitalize on *personal semantic memory* (self-knowledge) to promote *episodic memory* (memory for details of events tied to a specific time and place).

Evidence of the SRE in healthy older adults who show episodic memory decline indicates that the strategy may be extended to populations known to experience even more significant changes to episodic memory, such as those with amnestic Mild Cognitive Impairment (aMCI).

aMCI is considered an intermediate stage between healthy cognitive aging and dementia of the Alzheimer's type and is characterized by changes in episodic memory that are greater than expected for age and education, but with maintained independence in completing complex activities of daily living (Albert et al., 2011; Petersen et al., 1999, 2001). A diagnosis of aMCI constitutes a high risk factor for the development of Alzheimer's disease (Farias et al., 2009; Mitchell and Shiri-Feshki, 2009; Petersen et al., 1999, 2005; 2009). The few studies that have investigated the SRE in aMCI have employed typical trait adjective paradigms, in which participants incidentally encode trait adjective words self-referentially in addition to other conditions that commonly involve semantic processing of the meaning of the words or

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more superficial structural decisions about the words. These studies have found disparate results, with one showing an advantage for positive trait adjectives encoded self-referentially (Leblond et al., 2016) and others indicating no memory advantage for self-referenced trait adjectives over those encoded semantically (Carson et al., 2018; Rosa et al., 2015).

Findings of the SRE in aMCI using trait adjective paradigms are not only inconclusive, but they do not provide much information about the potential usefulness of the self-referential strategy in aMCI, given that trait adjective words are generally not sought to be remembered in our day-to-day lives. Stimuli that are more ecologically valid, such as narratives, are likely to be more indicative of the potential of self-referential processing to lead to improved memory in aMCI. Memory for narrative information is integral to everyday functioning, as it characterizes communications of our own life experiences and allows us to gather knowledge about others (Kropf and Tandy, 1998). We communicate in everyday life in a manner that resembles storytelling (Miller, 1995). The integration of personal narratives has been thought to influence the overall coherence of self-identity (Mar et al., 2010) and the maintenance of a coherent sense of self through time (Bluck and Habermas, 2000; Tulving, 2002). Further, narrative material engages different and richer processes than single words (Xu et al., 2005). This is supported by neuroimaging studies showing that distinct brain regions are implicated in lab-based tests of episodic memory involving recognition of single words versus real-world tests of autobiographical episodic memory involving recall of personal narratives (e.g., Gilboa, 2004; McDermott et al., 2009).

There is evidence that older adults exhibit impaired memory for narrative information when compared to their younger adult counterparts (Byrd, 1985; Hultsch and Dixon, 1984; Olofsson and Backman, 1993; Surber et al., 1984; Zelinski et al., 1984). These deficits extend to autobiographical narratives, with healthy older adults showing a decline in memory for specific details of past personal events, and episodic memory more generally (Addis et al., 2010; Addis et al., 2008; Levine et al., 2002; Piolino et al., 2006, Piolino et al., 2009; Schacter et al., 2013). The decline in episodic autobiographical memory is even more significant in aMCI (Barnabe et al., 2012; Gamboz et al., 2010; Murphy et al., 2008; cf. Leyhe et al., 2009; Irish et al., 2010). The SRE may provide a unique way to improve memory for the narrative information that is inherent in vividly recalling the unfolding of a past personal event.

There are few studies that have investigated the SRE for narrative information. An early study by Reeder et al. (1987) showed that memory for personality profiles was enhanced in young adults when self-referential processing was emphasized during reading. More recently, Carson et al. (2016) demonstrated that self-referential processing improved memory for short narratives in neurotypical aging. Encouragingly, the few studies using self-referential processing to improve narrative memory in memory-impaired populations (and those at risk of developing memory impairment) have found the strategy to be effective. Grilli and Glisky (2010) showed that imagining sentences self-referentially improved memory in traumatic brain injury. A more recent study by Grilli et al. (2018) showed that cognitively intact older adults at greater risk for developing Alzheimer's disease due to being carriers of the ε4 polymorphism of apolipoprotein E (APOE) benefitted from self-referential processing of narrative information to the same extent as older adults who were not carriers. These studies indicate that self-referential processing of narrative information may be an effective strategy for promoting memory in aMCI.

Studies by Conway and colleagues (Conway and Dewhurst, 1995; Conway et al., 2001) have suggested that self-referential processing promotes the process of *recollection*, the contextualized re-experiencing of encoded information. This is in contrast to the process of *familiarity*, which involves recognition of information without the sense of re-experiencing and context (Tulving, 1985). Recollection is known to be especially vulnerable to changes in healthy aging (Bastin and Van der Linden, 2003; Java, 1996; Light et al., 2000; Mäntylä, 1993), and these changes are even more pronounced in aMCI. In contrast, familiarity appears to remain relatively preserved in aMCI (e.g., Anderson et al., 2008; Hudon et al., 2009; Irish et al., 2010; Serra et al., 2010; Westerberg et al., 2006; cf. Koen and Yonelinas, 2014). The association between self-referenced information and recollection has been termed the *Self-Reference Recollection Effect* (SRRE) by Conway and Dewhurst (1995), and this phenomenon has been demonstrated in research in younger adults (Leshikar and Duarte, 2012; van den Bos et al., 2010) and healthy older adults (Carson et al., 2016; Genon et al., 2014; Leshikar et al., 2015). Studies of the SRRE have primarily used trait adjectives as stimuli. To our knowledge, only one study has investigated the SRRE for trait adjectives in aMCI and found no difference in recollection between self-referenced and semantically encoded words (i.e., no SRRE in aMCI; Carson et al., 2018). Given that narratives are more detailed and context-rich than trait adjective words, they may elicit higher rates of recollection for self-referenced material in this population.

A final area of interest in the present study was the potential influence of material valence on the presence of a SRE and SRRE. Studies of trait adjectives in healthy young and older adults have been variable in terms of valence preferences (e.g., Carson et al., 2016; Glisky and Marquine, 2009; Gutchess et al., 2007b; Leshikar et al., 2015). Examination of memory for narrative details in Carson et al. (2016) showed better cued recall for negative details across the lifespan, but no effect of valence on a test of narrative recognition. The two studies that have investigated the impact of valence on the SRE in aMCI have likewise shown mixed results. Leblond et al. (2016) found that the SRE was limited to positively valenced trait adjective words in aMCI, while Carson et al. (2018) did not find an influence of valence on memory in this population. The effect of valence on the SRE in aMCI may depend on the meaningfulness of the information that is encoded, which will be investigated in the current study.

The present study examined whether the benefits of self-referential encoding of narrative information extends to individuals diagnosed with aMCI. We predicted that a SRE would be found in aMCI, though possibly to a lesser magnitude than that seen in healthy older adults. We additionally predicted that the meaningfulness and structure of narratives would promote recollection in aMCI via a SRRE. Finally, we investigated the potential influence of valence on the SRE and SRRE for narratives.

1. Methods

1.1. Participants

Twenty older adults with aMCI (age: $M = 72.7$, $SD = 5.7$) and 30 controls (age: $M = 70.1$, $SD = 5.5$) participated in the study. The same sample of participants was tested for Carson et al. (2018). Participants were recruited through the Department of Neuropsychology and Cognitive Health at Baycrest Health Sciences and through the Rotman Research Institute and York University research volunteer databases. aMCI was classified according to established diagnostic criteria (Albert et al., 2011; Petersen et al., 1999, 2001). All participants received monetary compensation for their participation. A brief medical history was obtained over the telephone to rule out the presence of neurological, cardiovascular, or psychiatric disorders known to affect cognition. Informed consent was obtained from all participants in accordance with the procedures of the Research Ethics Boards at Baycrest Health Sciences and York University.

1.2. Neuropsychological measures

A brief battery of targeted neuropsychological tests was administered to all participants who had not been assessed within the past 6 months. The neuropsychological battery included measures of verbal and non-verbal learning and memory (Hopkins Verbal Learning Test-Revised; Brandt and Benedict, 1997; Brief Visuospatial Memory Test-Revised, Benedict, 1997), working memory (Digit Span; Wechsler, 1997), processing speed (Digit-Symbol coding; Wechsler, 1997), incidental memory (Digit-Symbol coding incidental learning; Wechsler, 1997), word reading (National Adult Reading Test-Revised; Blair and Spreen, 1989), confrontation naming (Boston Naming Test; Kaplan et al., 1983), speed and attention switching (Trail Making Tests A and B; Reitan and Wolfson, 1993), phonemic fluency (FAS; Spreen and Benton, 1977); semantic fluency (animal naming; Rosen, 1980), and an overall screening measure of cognitive functioning (Montreal Cognitive Assessment; Nasreddine et al., 2005). Mood status was measured using the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983).

1.3. Experimental tests

1.3.1. Materials

Stimuli were three to four sentence narratives (46–53 words) used in a previous study by Carson et al. (2016). Narratives were equated according to the number and type of event details using the Autobiographical Interview scoring method (Levine et al., 2002). They were written from the first-person perspective and described either a positive or negative experience. See Fig. 1 for an example of a narrative and see Carson et al. (2016) for a more detailed description of the generation and piloting of the narratives. Each narrative was presented with a corresponding title. Narratives were randomly assigned to six study lists of six narratives each (three positive and three negative per list) and one distractor list of 36 narratives (half positive, half negative).

1.3.2. Procedure

Participants made yes/no judgments about narratives under three types of blocked study conditions. The self-reference condition emphasized imaging oneself as the protagonist of the narrative and asked participants to decide for each trial: "Can I easily imagine myself experiencing this event?" The semantic condition required participants to decide: "Does this story describe a positive event?" Finally, the structural condition asked participants: "Does the word 'the' appear more than 3 times?" Narratives were presented on a computer screen with E-Prime software (Psychology Tools). Each of the six study lists of narratives was assigned to either the self-reference, semantic, or structural condition blocks (two lists per condition), and the assignment of narrative list to condition was counterbalanced across participants. Blocked conditions were presented in a pseudorandomized order, with no two blocks of the same condition appearing sequentially. Each trial began with a fixation cross presented for 500 ms followed by a narrative presented for 20 s, during which time the participant was prompted to make the yes/no judgment. Each trial ended with the presentation of a fixation cross for 5 s. Presentation order of narratives within a given block was randomized across participants. Practice trials preceded test trials. Reaction time and response type (yes/no) was recorded for each judgment. During a 10-min retention interval, participants were administered the National Adult Reading Test-Revised (NART-R) and a subtraction task devised by the investigators.

Following the retention interval, a cued recall test was administered, during which participants were asked to recall aloud as many details as possible from each narrative, with the narrative's title serving as a cue. A recognition test was subsequently administered, which required participants to distinguish previously studied narrative details from distractor details (old/new button press). Thirty-six studied narratives details and 36 distractor details were presented in random order. Half of the distractor details had a similar theme to studied narrative details and half had novel themes. See Fig. 2 for an example. An equal number of positive and negative distractor details were presented. When a participant indicated that a narrative detail had been previously studied ("old"), he/she was asked to make an additional remember/know decision with a button press. Participants received a thorough explanation of the remember/know distinction before completing the recognition test and were asked to demonstrate to the examiner that they understood this distinction. Participants were also given a cue card with a simplified explanation of the remember/know distinction for use during the recognition test. The recognition test was self-paced, and responses were recorded.

1.3.3. Scoring of narrative cued recall

Narrative cued recall was audio recorded and transcribed for scoring. Cued recall was scored according to a scoring key created for each narrative in order to standardize scoring between raters. Details were accepted if they had the same or equivalent meaning to narrative components. Details were then tallied according to the condition and valence in which they were initially presented. Scoring was performed by two independent raters, blind to the allocation of narratives to the study conditions and to participant group. Inter-rater reliability was calculated using Pearson's correlation coefficient.

1.4. Statistical analyses

Healthy control and aMCI groups were compared on age, years of formal education, and performance on neuropsychological measures using t-tests. Narrative cued recall scores were analyzed in a 2 × 3 × 2 (participant group × encoding condition × valence) mixed ANOVA. Narrative recognition scores were calculated by subtracting the proportion of false alarms from the proportion of hits, resulting in a "corrected recognition" score. An overall false alarm rate was used to calculate the "corrected recognition" score. A 2 × 3 × 2 (participant group × encoding condition × valence) mixed ANOVA was used to analyze narrative recognition scores. Proportion of false alarms (distractor narrative details endorsed as "old") was analyzed in a 2 × 2 mixed ANOVA (participant group × valence). The proportion of details correctly recognized that were judged as easy to imagine in the self-reference encoding condition were compared to details correctly recognized that were indicated as difficult to imagine at encoding in a 2 × 2 (participant group X ease of imagining) mixed ANOVA. Experiences of recollection and familiarity during the recognition test

Dentist Visit

event **time** **perceptual** **perceptual**
I went to the dentist last week. I was lying back in the chair, blinded by the overhead light, when
event **thought/emotion**
he informed me that I needed a root canal. I couldn't believe what I was hearing, and I was
thought/emotion
worried that it would be extremely painful.

Fig. 1. Generation of narratives according to internal detail categories described in the Autobiographical Interview scoring protocol (Levine et al., 2002).

Original Narrative Presented During Study
I went to the dentist last week. I was lying back in the chair, blinded by the overhead light, when he informed me that I needed a root canal. I couldn't believe what I was hearing, and I was worried that it would be extremely painful.

Corresponding Detail Presented During Recognition Test
I needed a root canal.

Distractor Detail Presented During Recognition Test (same theme)
He told me that I had three cavities.

Distractor Detail Presented During Recognition Test (novel theme)
It rained for the entire vacation.

Fig. 2. Examples of a narrative presented during study, the corresponding detail presented at recognition, a distractor detail with the same theme presented at recognition, and a distractor detail with a novel theme presented at recognition.

was measured using a remember (recollection)/know (familiarity) button press. Scores were then calculated with the Independence Remember Know (IRK) method (Jacoby et al., 1997; Yonelinas and Jacoby, 1995). Recollection scores were calculated for each study condition according to corrected recognition [proportion remember hits – proportion remember false alarms] and analyzed using a 2 × 3 × 2 (participant group × encoding condition × valence) mixed ANOVA.

2. Results

Demographic information and performance on neuropsychological measures are presented in Table 1. The aMCI and healthy older adult control groups did not differ significantly in terms of age, t (48) = -1.62, p = .11, or formal years of education, t (48) = -0.16, p = .87.

2.1. Narrative cued recall

Raters showed high inter-rater reliability with a Pearson's correlation coefficient of 0.96 (see Fig. 3 for cued recall scores). Overall cued recall was low in both participant groups, with healthy controls recalling 26% of narrative details and the aMCI group recalling just 13% of details. A main effect of group indicated significantly higher recall in the control group (**M** = .26, **SD** = 0.14) compared to the aMCI group (**M** = 0.13, **SD** = 0.10), F (1,48) = 25.23, $p < .001$, $\eta_p^2 = 0.35$. A main effect of condition was also found, F (2,96) = 38.05, $p < .001$, $\eta_p^2 = 0.44$, with planned contrasts indicating higher cued recall for narrative details encoded in the self-reference condition (**M** = 0.26, **SD** = 0.13) over the semantic condition (**M** = 0.23, **SD** = 0.13), F (1,48) = 4.9, p = .03, $\eta_p^2 = 0.09$, and improved memory for narrative details encoded in the semantic condition over the structural condition (**M** = 0.12, **SD** = 0.11), F (1,48) = 31.57, $p < .001$, $\eta_p^2 = 0.40$. The interaction between participant group and encoding condition was marginally significant, F (2,96) = 2.63, p = .08, $\eta_p^2 = 0.05$, and pairwise comparisons revealed that while there was a significant difference between the self-reference and semantic conditions for healthy controls (p = .02), this difference was not significant for the aMCI group (p = .99). Both groups showed a significant advantage for the semantic condition over the structural condition ($ps < .001$). A main effect of valence was found, indicating better recall for negative details (**M** = 0.23, **SD** = 0.15) over positive details (**M** = 0.18, **SD** = 0.13), F (1,48) = 50.69, $p < .001$, $\eta_p^2 = 0.51$. The interaction between participant group and valence was not significant, F (1,48) = 0.08, p = .78, $\eta_p^2 = 0.002$.

Table 1
Demographic information and performance on neuropsychological measures.

	HC (n = 30)	aMCI (n = 20)	Effect size (*d*)
age	70.1 (5.5)	72.7 (5.7)	0.46
education (years)	15.7 (2.8)	15.8 (2.8)	0.04
% female	60	55	
HVLT-R total	28.1 (3.5)	21.6 (3.1) ***	1.96
HVLT-R delayed recall	10.1 (1.6)	6.0 (2.5) ***	1.95
HVLT-R recog disc.	11.4 (.9)	8.7 (2.2) ***	1.60
BVMT-R total	25.2 (5.4)	14.8 (6.4) ***	1.76
BVMT-R delayed recall	10.0 (1.6)	5.4 (2.5) ***	2.19
BVMT-R recog disc.	5.9 (.3)	5.6 (.6)	0.63
Digit Symbol Coding	62.0 (12.6)	61.2 (10.9)	0.07
Incidental Learning	12.3 (4.6)	6.1 (4.0) ***	1.44
Free Recall	7.6 (1.1)	6.2 (1.9) **	0.90
Digit Span Forward	7.0 (1.2)	6.7 (1.2)	0.25
Digit Span Backward	5.23 (1.6)	5.4 (1.3)	0.12
Phonemic Fluency (FAS)	48.2 (10.5)	44.4 (12.0)	0.35
Semantic Fluency (Animals)	20.1 (5.1)	16.1 (5.5) *	0.75
Boston Naming Test	56.6 (2.8)	52.2 (6.5) **	0.88
TMT A (secs)	34.7 (9.8)	37.3 (9.7)	0.27
TMT B (secs)	77.7 (31.4)	90.1 (28.5)	0.41
HADS-A	4.2 (2.8)	5.1 (3.5)	0.28
HADS-D	2.6 (2.6)	2.5 (2.8)	0.04
MoCA	27.7 (2.1)	25.5 (2.4) ***	0.98
NART-R (FSIQ)	116.4 (6.9)	116.0 (4.4)	0.07

Note. Values represent means (standard deviations). HC = healthy controls; aMCI = amnestic Mild Cognitive Impairment; HVLT-R = Hopkins Verbal Learning Test- Revised; recog disc. = recognition discrimination; BVMT-R = Brief Visuospatial Memory Test- Revised; Incidental Learning and Free Recall = memory subtests associated with WAIS-III Digit Symbol Coding test; TMT = Trail Making Test; HADS = Hospital Anxiety and Depression Scale; HADS-A = Anxiety score; HADS-D = Depression score; MoCA = Montreal Cognitive Assessment; NART-R = National Adult Reading Test- Revised; FSIQ = Full Scale Intelligence Quotient. HC significantly higher score than aMCI ***$p < .001$, **$p < .01$, *$p < .05$. Each aMCI participant was individually classified according to established clinical criteria for single domain aMCI (e.g., Petersen et al., 2001; Albert et al., 2011). Table adapted from Carson et al. (2018).

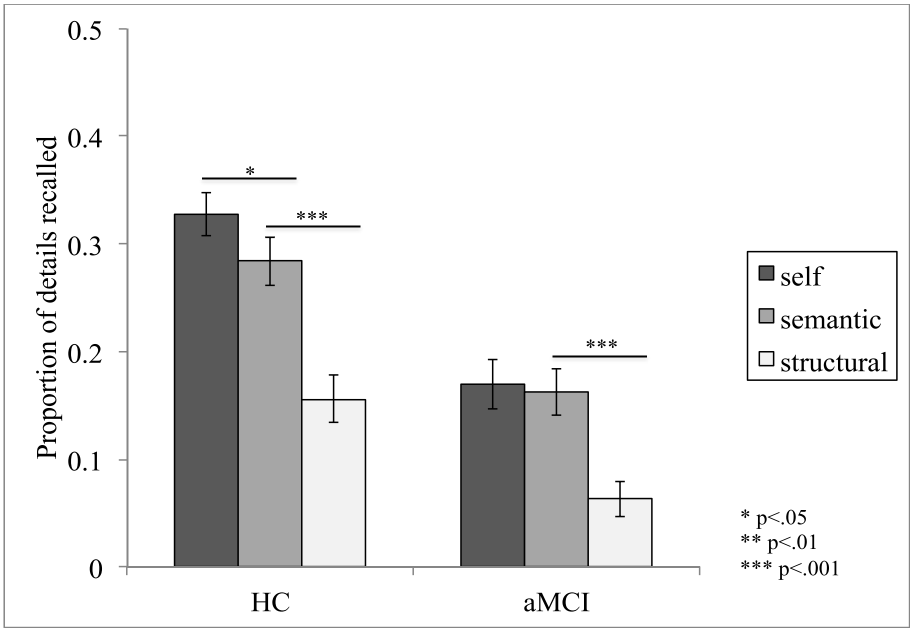

Fig. 3. Narrative cued recall scores, as a function of participant group and encoding. condition. HC = healthy control; aMCI = amnestic Mild Cognitive Impairment. Error bars represent standard error.

2.2. Narrative recognition

Uncorrected scores are presented in Table 2. A main effect of group was found, indicating that the older adult control group showed overall higher corrected recognition than the aMCI group, F (1,48) = 15.03, $p < .001$, $\eta_p^2 = 0.24$. A main effect of condition was also apparent, F (2,96) = 103.04, $p < .001$, $\eta_p^2 = 0.68$, with planned contrasts indicating enhanced memory for narratives encoded in the self-reference condition over the semantic condition, F (1,48) = 9.39, $p = .004$, $\eta_p^2 = 0.16$, and enhanced memory for narratives encoded in the semantic condition over the structural condition, F (1,48) = 108.22, $p < .001$, $\eta_p^2 = 0.69$. There was no significant interaction between participant group and encoding condition, F (2,96) = 49, $p = .62$, $\eta_p^2 = 0.01$. No main effect of valence was revealed, F (1,48) = 0.21, p = .65, $\eta_p^2 = 0.004$ nor a significant valence by group interaction, F (1,48) = 1.51, p = .23, $\eta_p^2 = 0.03$ (see Fig. 4 for corrected recognition performance).

An analysis of whether narratives judged as easy to imagine oneself experiencing led to better memory than those judged as difficult to imagine (self-reference encoding condition), showed a main effect of judgement across group, F (1,38) = 34.99, $p < .001$, $\eta_p^2 = 0.48$, indicating that narratives judged as easy to imagine (M = 0.72, SD = 0.23) were more accurately recognized on the recognitition test than those judged as difficult (M = 0.28, SD = 0.23). The interaction between participant group and judgement was not significant, F (1,38) = 0.03, $p = .87$, $\eta_p^2 = .001$.[1]

2.3. False alarms

Scores are presented in Table 2. A main effect of group was found, F (1,48) = 4.45, p < .04, $\eta_p^2 = 0.09$, indicating that the aMCI group made significantly more false alarms than the healthy older group during the recognition test. Additionally, a main effect of valence, F (1,48) = 4.57, $p = .04$, $\eta_p^2 = 0.09$, showed that across both aMCI and healthy control groups, significantly more false alarms were made for positive versus negative narrative details. No group by valence interaction was revealed, F (1,48) = 0.18, $p = .67$, $\eta_p^2 = 0.004$.

2.4. Narrative recollection (SRRE)

A main effect of condition was found, F (2,96) = 63.63, $p < .001$, $\eta_p^2 = 0.57$, with self-referential encoding enhancing recollection over semantic processing, F (1,48) = 6.52, $p = .01$, $\eta_p^2 = 0.12$ and semantic processing improving recollection over structural encoding, F (1,48) = 59.86, $p < .001$, $\eta_p^2 = 0.56$. There was a marginally significant main effect of participant group, F (1,48) = 3.34, $p = .07$, $\eta_p^2 = 0.07$, with the healthy control group showing higher recollection scores than the aMCI group. The interaction between encoding condition and participant group was non-significant, F (2,96) = 0.32, $p = .73$, $\eta_p^2 = 0.01$. There was no effect of valence F (1,48) = 0.06, $p = .81$, $\eta_p^2 = 0.001$ nor a significant valence by participant group interaction, F (1,48) = 1.5, $p = .23$, $\eta_p^2 = 0.03$. Recollection "remember" scores, calculated according to corrected recognition, are presented in Fig. 5. Also, see Table 2 for uncorrected recollection scores.

There was few familiarity "know" button press responses made across both participant groups and this prevented further analysis of familiarity scores. This absence did not impede the main goal of studying recollection in healthy aging and aMCI.

3. Discussion

To our knowledge, this study is the first to show that self-referential processing effectively improves narrative memory in aMCI. This finding is noteworthy given that memory for narrative information notably declines in aMCI, a deficit that potentially contributes to the decline in autobiographical episodic memory observed in this population (Murphy et al., 2008). Brain structures likely to support improved performance despite known changes to hippocampal volume in aMCI are discussed below.

3.1. Self-reference effect (SRE) for narrative information

The current study found an SRE for narrative information in aMCI on a test of recognition memory. Evidence of the SRE in aMCI is

[1] Due to technical difficulties accessing the data necessary for this analysis, a subset of participants was included (22 healthy controls and 18 aMCI).

Table 2
Narrative recognition and recollection "remember" scores.

	Condition	Valence	Overall Recognition		Recollection "Remember" Scores	
			HC	aMCI	HC	aMCI
Hits	Self-Reference	Pos	.87 (.13)	.81 (.16)	.68 (.27)	.65 (.22)
		Neg	.88 (.14)	.70 (.19)	.72 (.27)	.61 (.25)
	Semantic	Pos	.82 (.16)	.72 (.22)	.63 (.31)	.60 (.29)
		Neg	.83 (.14)	.66 (.20)	.59 (.29)	.52 (.32)
	Structural	Pos	.44 (.27)	.38 (.27)	.24 (.27)	.25 (.23)
		Neg	.49 (.27)	.39 (.26)	.32 (.28)	.28 (.27)
False Alarms		Pos	.10 (.08)	.16 (.17)	.04 (.05)	.09 (.13)
		Neg	.08 (.07)	.13 (.12)	.03 (.04)	.09 (.11)

Note. Values represent means (standard deviations). HC = healthy controls; aMCI = amnestic Mild Cognitive Impairment; Pos = positive; Neg = negative.

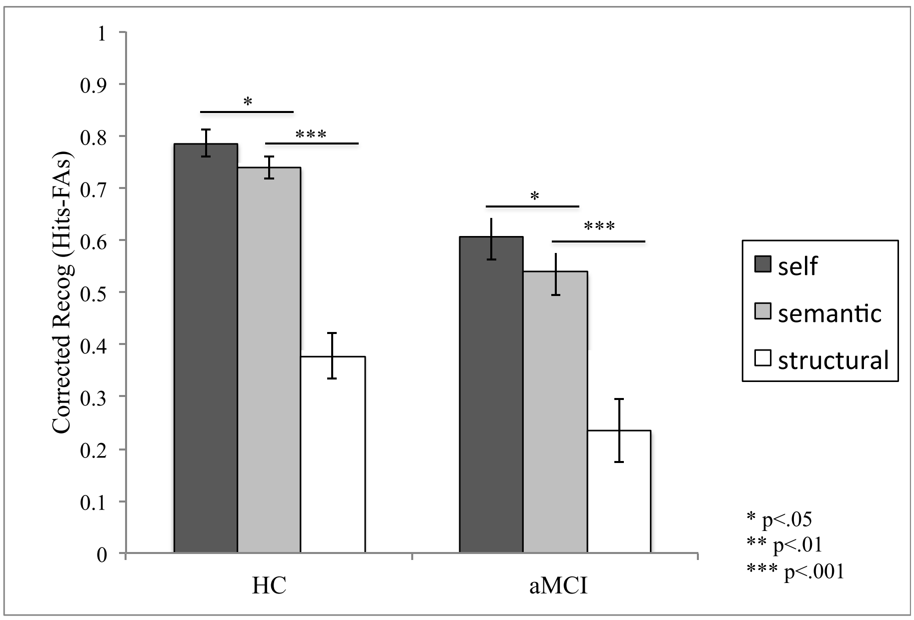

Fig. 4. Narrative corrected recognition scores indicating recognition memory accuracy, as a function of participant group and encoding condition. HC = healthy control; aMCI = amnestic Mild Cognitive Impairment. Error bars represent standard error.

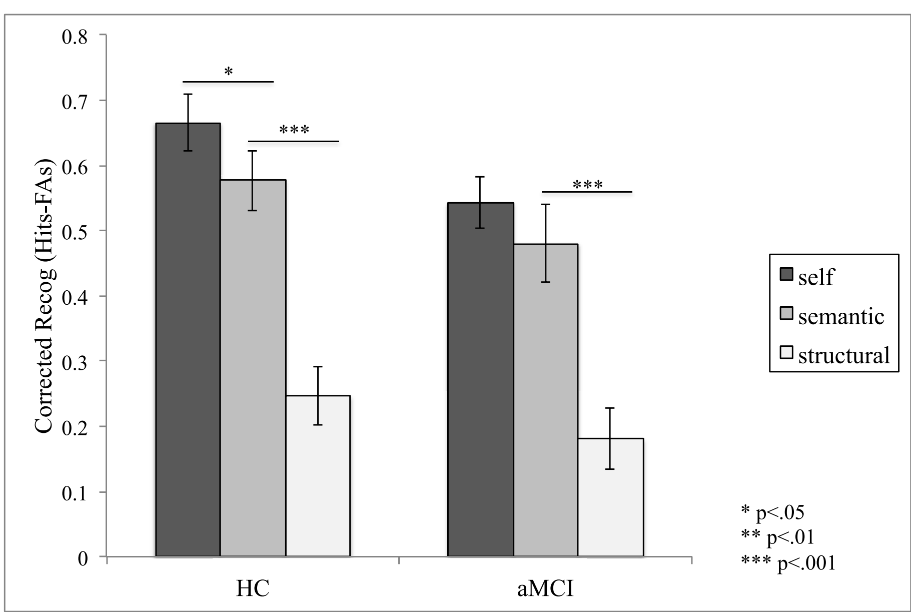

Fig. 5. Narrative corrected recognition, indicating recollection "remember" scores, as a function of participant group and encoding condition. HC = healthy control; aMCI = amnestic Mild Cognitive Impairment. Error bars represent standard error.

inconsistent with two previous studies on memory for trait adjectives that found no preferential benefit to self-referential processing over another form of deep encoding in this population (Carson et al., 2018; Rosa et al., 2015). A third study by Leblond et al. (2016) found the SRE in aMCI specific to positive trait adjective words. These inconsistencies may be due to differences in stimuli across studies, with the use of narratives in the current study and trait adjectives in the other three studies. Narrative material engages different and richer processes than single words (Xu et al., 2005), and older adults have been shown to benefit from the added context available in narratives (Burke and Light, 1981; Johnson, 2003; Stine et al., 1989; Tun and Wingfield, 1993; Wingfield and Stine, 1991). Indeed, a meta-analysis by Johnson (2003) indicated that healthy older adults remember longer narrative passages better than shorter passages, an advantage thought to be due to the availability of additional contextual information in the longer passages. It is likely that the rich context of narratives versus single words was associated with the high recognition accuracy exhibited in both groups. In order to comprehend narratives, it has been shown that we integrate story information, such as characters and their goals, with our own semantic knowledge, creating a mental representation of the overall event (Zwaan and Radvansky, 1998). Access to this constructed mental representation allows for enhanced recognition accuracy of coherent narrative material (Yarkoni et al., 2008).

The use of narrative information as stimuli appeared to promote self-referential processing in aMCI in the current study. Perhaps individuals with aMCI were able to capitalize on self-referential processing of narrative information due to the structure and context inherent in narratives that makes them easier than single words to process and retrieve. Further, in the present study, participants were explicitly instructed to imagine themselves as the protagonist of the narratives, along with any associated thoughts or feelings in the self-reference condition. These explicit instructions may have promoted strategic encoding of the material in aMCI, a population who generally has difficulty with self-initiated encoding strategies but can show improvement with specific encoding instructions (Acevedo and Lowenstein, 2007; Belleville et al., 2006; Hampstead et al., 2008). Though the SRE did not improve narrative memory in aMCI to the extent that it did in their healthy counterparts, it is indeed encouraging that the effect is found in aMCI, as it is in other memory-impaired populations (Grilli and Glisky, 2010).

Both aMCI and healthy control groups showed greater improvement in memory for narratives that were judged at encoding as easy to imagine oneself experiencing (self-reference encoding condition). Perhaps self-consistent information is easier to encode using the self-reference technique. An alternative interpretation is that it is self-congruency and not self-relatedness that leads to improved memory in the self-reference encoding condition. To verify that it was indeed self-referential processing that improved memory for narratives in this paradigm, future research could include narratives that are not written from a first-person perspective and explicitly ask participants to rate the self-congruency of narratives.

Though the aMCI group showed the SRE on a test of recognition memory, a marginal interaction suggests that, unlike healthy controls, there might not have been an advantage for self-referenced details over semantic details on a test of cued recall. The literature indicates that recall declines in healthy aging compared to recognition (Craik and McDowd, 1987; Parker et al., 2004). Perhaps this phenomenon is exacerbated in aMCI and individuals are only able to benefit from elaborative processing strategies in situations with inherent environmental support, such as on a test of recognition memory. Further, it is notable that overall cued recall of details was low in both healthy aging and aMCI groups. Analysis of the cued recall data thus may not be as informative as that of the recognition memory data, which more clearly indicates that in a situation of environmental support individuals with aMCI are able to capitalize on self-referential processing to improve memory for narrative information.

3.2. Self-Reference Recollection Effect (SRRE) for narrative information

The SRRE was found across participant groups in the present study. This indicates that self-referential processing of narratives led to improved recollection in both healthy individuals and those with aMCI. This finding must be validated in future research as, despite a non-significant interaction between participant group and encoding condition, the aMCI data do not appear to show a clear difference between self-reference and semantic conditions. There has been very limited study of the SRRE in aMCI and the one study of which we are aware found no SRRE in aMCI for trait adjective words (Carson et al., 2018). Potentially due to the context-rich nature of narrative information, the aMCI group was able to improve recollection with self-referential processing. This finding is particularly significant, given that recollection is an integral component of episodic memory, known to decline in healthy aging and even more so in aMCI (Anderson et al., 2008; Hudon et al., 2009; Irish et al., 2010; Serra et al., 2010; Westerberg et al., 2006). Due to the low frequency of "know" responses indicating familiarity, the contribution of familiarity to the SRE for narrative information in aMCI could not be analyzed. The low frequency of "know" responses is a further indicator that narrative stimuli are more easily encoded in a fashion that promotes vivid re-experiencing of the material (i.e., recollection) than other less context-bound stimuli.

3.3. Influence of valence

Enhanced memory for negative details of narratives was found across participant groups on the narrative cued recall test, while no influence of valence was apparent when the SRE and SRRE were examined via recognition memory performance. Carson et al. (2016) found a similar pattern in young and healthy older adults when comparing memory for narrative information on cued recall and recognition tests. Indeed, previous research has indicated that SRE tests of recall are more sensitive to effects of valence than those of recognition (D'Argembeau et al., 2005). Furthermore, past research has indicated that negative information is remembered in a detailed fashion in older adulthood, while memory for positive information is more gist-like (Kensinger et al., 2007). It must be noted that we compared positive versus negative valence and did not explore emotionality in general (with comparison to neutral stimuli), which has been shown to enhance memory in healthy and pathological aging (see Gutchess and Kensinger, 2018 for comment on the intersection between the SRE and emotionality in aging). Further research is necessary to explore the interaction between valence and the SRE for narrative information and whether the effect is specific to type of memory retrieval process (recall versus recognition).

3.4. Implications for brain-behaviour relationships

Episodic memory depends on hippocampal integrity, which has been shown to decline in healthy aging and more significantly in aMCI (e.g., Apostolova et al., 2012; Devanand et al., 2007; Jack et al., 2000; Morra et al., 2009; Mueller et al., 2010; Pennanen et al., 2004; Shi et al., 2009; Yushkevich et al., 2015). A boost in memory via the SRE is likely supported by a number of brain regions that are known to remain relatively intact in these populations. In the case of narrative information utilized in the current study, the SRE appears to be powerful enough to circumvent loss of hippocampal function.

Neuroimaging studies examining the SRE in healthy young adults have identified cortical midline structures, particularly the medial prefrontal cortex, as being integral to self-related processing and memory (e.g., Amodio and Frith, 2006; Benoit et al., 2010; Craik et al., 1999; Gutchess et al., 2007a; Kelley et al., 2002; Leshikar and Duarte, 2014; Macrae et al., 2004; Northoff et al., 2006). Despite structural and functional neuroanatomical changes in healthy aging (Cabeza, 2002; Cabeza and Dennis, 2012; Eyler et al., 2011; Park and Gutchess, 2005;

Raz, 2000; Reuter-Lorenz and Lustig, 2005; Turner and Spreng, 2012), the medial prefrontal cortex has been shown to remain relatively preserved (Gutchess et al., 2007a; Hedden and Gabrieli, 2004; Mather, 2003). Neuroimaging studies of the SRE in healthy older adults have likewise found activation of cortical midline structures (Genon et al., 2014; Gutchess et al., 2007a, 2010; 2015; Kalenzaga et al., 2015).

Neuroimaging research investigating the SRE in aMCI is limited but provides additional insight into the brain-behaviour relationships governing the phenomenon in this population. Unlike the case of healthy aging, the SRE in aMCI is variable, and that variability may be associated with the integrity of structures mediating performance on different types of SRE tasks. For example, some studies have indicated that brain areas critical to the SRE are not more significantly impacted in aMCI than in healthy aging. Zamboni et al. (2013) found that individuals with aMCI activated the medial prefrontal cortex to the same extent as controls when required to answer questions about themselves versus other people. Additionally, a study by Gaubert et al. (2017) found that while cortical midline structures showed the same level of activation in patients (combined group of MCI and Alzheimer's disease) and controls when participants engaged in self-referencing, angular gyrus dysfunction in patients was related to deficits in self-related memory. By contrast, Ries et al. (2007) investigated the SRE in healthy aging and MCI and found that cortical midline activity was subtly attenuated for self-appraisal in MCI when compared to healthy controls. Further, this study indicated that activation of cortical midline structures during self-related processing was associated with level of anosagnosia in aMCI.

One possible explanation for the findings of the current study is that residual hippocampal function helps to support the interaction between self-related processing and new learning of narratives. This explanation is consistent with the finding of an SRRE, given that recollective processes have been shown to rely on hippocampal integrity. Indeed, at least one study has shown that using strategies to improve memory in MCI promotes hippocampal activity (Hampstead et al., 2012). The relationship between residual hippocampal function and the SRE in aMCI merits further study. A further and not mutually exclusive explanation is that the additional recruitment of brain regions associated with processing narrative information may have promoted memory in aMCI in the current study. This interpretation is further supported by neuroimaging research demonstrating distinct neural patterns associated with learning as context and complexity increases from single words to single sentences to coherent narratives (Xu et al., 2005). Initially evidenced by Grilli and Glisky's study of the Self-Imagination Effect in a memory-impaired population (2010), the multimodal nature of narrative information encoded from a self-relevant perspective may provide a unique situation in which individuals with aMCI can capitalize on intact cognitive functions to improve mnemonic deficits.

4. Conclusions

The SRE has been primarily studied using trait adjective words as stimuli, which have little ecological validity and relevance to everyday functioning. Memory for narrative information is compromised in healthy aging and more notably in aMCI due to known changes in hippocampal function. This type of information has real-world importance and provides a valuable target for improvement with the SRE. The current study shows that memory for narrative information benefits from self-referential encoding in aMCI. Self-referential processing also enhances recollection of narratives. Cued recall was enhanced for negative details across both healthy controls and aMCI groups; however, there was no influence of valence when the SRE and SRRE were examined via recognition memory. Overall, the present study indicates that the SRE may be a valuable intervention tool for improving memory for narrative information in aMCI.

CRediT authorship contribution statement

Nicole Carson: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing - original draft, Writing - review & editing. **R. Shayna Rosenbaum:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing - original draft, Writing - review & editing. **Morris Moscovitch:** Writing - review & editing. **Kelly J. Murphy:** Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Writing - original draft, Writing - review & editing.

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