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Electrophysiological evidence for the effects of unitization on associative recognition memory in older adults

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ABSTRACT

Normal aging is associated with greater decline in associative memory relative to item memory due to impaired recollection. Familiarity may also contribute to associative recognition when stimuli are perceived as a 'unitized' representation. Given that familiarity is relatively preserved in older adults, we explored whether age-related associative memory deficits could be attenuated when associations were unitized (i.e., compounds) compared with those non-unitized (i.e., unrelated word pairs). Young and older adults performed an associative recognition task while electroencephalogram (EEG) was recorded. Behavioral results showed that age differences were smaller for recognition of compounds than for unrelated word pairs. ERP results indicated that only compounds evoked an early frontal old/new effect in older adults. Moreover, the early frontal old/new effect was positively correlated with associative discrimination accuracy. These findings suggest that reduced age-related associative deficits under unitized condition may be associated with the presence of familiarity-based retrieval of compounds in older adults.

1. Introduction

Dual-process theories propose that recognition memory is supported by two processes: familiarity and recollection (e.g., Mandler, 1980; Yonelinas, 2002). Familiarity is a fast-acting process thought to act without retrieval of the details of the relevant stimulus or event being processed. Recollection refers to a more deliberate process that entails conscious retrieval of the details of the stimulus or event being processed. It has been assumed that familiarity and recollection make differential contributions to item and associative recognition. Whereas both familiarity and recollection can support the item recognition, only recollection can support the associative recognition (Yonelinas, 2002). In a typical associative recognition task, the participants study unrelated word pairs during encoding (e.g., watch-grape, pepper-map, tiger-candle), and make a distinction between the intact pairs (e.g., watch-grape) and the rearranged pairs (e.g., pepper-candle) during retrieval. Performing this task accurately requires recollection because item familiarity is equal for intact pairs and rearranged pairs (Mecklinger & Jäger, 2009), and only recollection can support the retrieval of relational representations (Cohn, Emrich, & Moscovitch, 2008).

It is well established that normal aging is associated with episodic memory decline. The associative deficits hypothesis (ADH) attributes age-related memory impairments to difficulties in creating and retrieving associations between single units of information in older adults (Naveh-Benjamin, 2000). Greater decline in associative memory than item memory in older adults has been demonstrated using a wide range of materials (see Old & Naveh-Benjamin, 2008, for a meta-analysis). From the perspective of dual-process theories, disproportionate decline in associative memory relative to item memory in older adults is due to impaired recollection despite relatively preserved familiarity (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Howard, Bessette-Symons, Zhang, & Hoyer, 2006; Yonelinas, 2002; but see Wang, de Chastelaine, Minton, & Rugg, 2012).

Though a number of studies support the proposal that associative recognition memory is supported solely by recollection

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(Donaldson & Rugg, 1998, 1999; Hockley & Consoli, 1999; Yonelinas, 1997), recent studies have challenged this view by demonstrating that familiarity can also contribute to associative recognition when to-be-remembered stimuli are perceived as a single integrated or "unitized" representation (Bader, Mecklinger, Hoppstadter, & Meyer, 2010; Diana, Van den Boom, Yonelinas, & Ranganath, 2011; Diana, Yonelinas, & Ranganath, 2008; Jäger & Mecklinger, 2009; Jäger, Mecklinger, & Kipp, 2006; Rhodes & Donaldson, 2007; Rhodes & Donaldson, 2008; Tibon, Gronau, Scheuplein, Mecklinger, & Levy, 2014; Yonelinas, Kroll, Dobbins, & Soltani, 1999), which is referred to as "unitization hypothesis" (Quamme, 2004). Here, unitization means a condition in which two or more separate items are integrated into a whole unit (Graf & Schacter, 1989).

Further studies have demonstrated that associative memory performance in amnesic patients with more severe impairment in recollection than in familiarity could benefit from enhanced engagement of familiarity during the retrieval phase due to unitization (Diana, Yonelinas, & Ranganath, 2010; Giovanello, Keane, & Verfaellie, 2006; Quamme, Yonelinas, & Norman, 2007). For instance, Giovanello et al. (2006) first confirmed that the compound words (e.g., traffic-jam), one kind of pre-experimentally unitized association, could induce a more familiarity-based judgment than could the unrelated word pairs (e.g., table-street). Subsequently, they observed that amnesic patients exhibited better associative recognition on compound words relative to unrelated words pairs.

If age-related associative deficits may be attributed to impaired recollection, could older adults' performance be improved when associative recognition is supported by familiarity, as in the amnesic patients? Three recent studies examined this question, and their findings are incompatible. Jäger, Mecklinger, and Kliegel (2010) did not find a facilitation effect of unitization for older adults; in contrast, they found that older adults performed worse in associative recognition of unitized face pairs compared with unrelated face pairs, which was attributed to that unitization processes were impaired in the older adults. In contrast, Ahmad, Fernandes, and Hockley (2014), Bastin et al. (2013) demonstrated that age differences in associative memory were significantly reduced under unitized encoding condition. Unfortunately, two of these studies did not reliably estimate the independent contributions of familiarity and recollection to associative recognition in older adults (e.g., Ahmad et al., 2014; Jäger et al., 2010). Although Bastin et al. (2013) found that the contribution of familiarity was greater in the unitized condition than in the non-unitized condition in older adults in a receiver operating characteristics (ROCs) analysis, their analysis was exploratory as the number of trials was small for a standard ROCs analysis.

The present study was designed to further explore whether age-related associative memory deficits could be alleviated when stimuli could be unitized during a study phase. In addition, it was designed to discern whether improved associative recognition performance was accompanied by enhanced engagement of familiarity-related retrieval processes. To this end, we compared the associative recognition of compound words with unrelated word pairs in young and older adults. The compound words used represent pre-experimental associations, are considered to reflect a single unit (Rhodes & Donaldson, 2007), and hence are well-suited to create a unitized condition (Ahmad et al., 2014; Giovanello et al., 2006).

Event-related potentials (ERPs) provide an effective way to record the time course of processes associated with episodic memory retrieval. ERP studies of young adults have identified several old/new effects characterized by more positive-going deflections for correctly classified old items than correctly rejected new items. The early frontal old/new effect, maximal at bilateral frontal scalp between around 300 and 500 ms, has been thought to reflect familiarity-based recognition (Friedman & Johnson, 2000; Rugg & Curran, 2007; but see Paller, Voss, & Boehm, 2007), and the parietal old/new effect maximal at left parietal regions and occurring between 500 and 800 ms is believed to reflect recollection-based recognition (Rugg & Curran, 2007). Finally, the late right frontal old/new effect that occurs between about 800 and 1600 ms has been associated with post-retrieval monitoring and evaluation processes and is likely linked to executive function of right prefrontal cortex (Friedman, 2013; Hayama, Johnson, & Rugg, 2008).

In a standard associative recognition task, the participants were asked to remember the compound words or unrelated word pairs as associations during an initial study phase. During a subsequent test phase, they were required to judge whether the presented word pairs were intact, rearranged, or new while EEG was recorded. Behaviorally, we predicted that age differences would be smaller for associative recognition of compound words than for unrelated word pairs. For the ERP results, due to the enhanced contribution of familiarity to recognition of unitized word pairs and relatively preserved familiarity in older adults (Friedman, 2013; Koen & Yonelinas, 2014), we expected that the compounds would evoke greater early frontal old/new effect than did unrelated word pairs for both young and older adults. Further, as the older adults showed impaired recollection (Friedman, 2013; Wang et al., 2012; Yonelinas, 2002) and post-retrieval monitoring processes (McDonough, Wong, & Gallo, 2013; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Yonelinas, 2002), we expected that the left parietal and late right frontal old/new effects would be significantly reduced for unrelated word pairs for older adults than for young adults. We also expected that both age groups would show similar left parietal and later right frontal old/new effects under the unitized condition, as the unitized representations might be relatively easy to be formed and retrieved for compounds.

2. Materials and methods

2.1. Participants

Twenty-five right-handed healthy young (age range 19–27 years) and 24 older (age range 61–76 years) adults participated in the study. Years of education were matched between groups. Demographic characteristics of the participants are presented in Table 1. All participants were native Chinese speakers with normal

Table 1
Demographic characteristic and neuropsychological performance of young and old participants (mean and standard deviations).

	Young (n = 25)	Old (n = 24)	p[a]	Cohen's d
Age	21.80 (2.16)	69.54 (4.50)	–	–
Gender (Male/Female)	13/12	15/9	–	–
Education (years)	15.72 (1.67)	15.38 (1.56)	ns	0.21
MMSE	–	28.83 (1.13)	–	–
Block design test	43.4 (4.49)	34.96 (6.42)	<.001	1.54
Digit span forward	8.80 (1.04)	7.54 (1.18)	<.001	1.13
Digit span backward	6.76 (1.54)	5.04 (1.33)	<.001	1.19
Trail making (seconds)	9.59 (8.06)	31.66 (25.80)	<.001	1.16
Logic memory-immediate	12.14 (3.21)	9.52 (2.12)	.002	0.96
Logic memory-delayed	10.88 (2.82)	7.96 (2.11)	<.001	1.17
Paired-association learning	6.06 (1.71)	4.60 (2.17)	.012	0.75
Vocabulary test	56.32 (6.55)	54.29 (5.65)	ns	0.33
Category fluency test	27.96 (6.45)	26.79 (6.05)	ns	0.19
Written fluency test	6.56 (2.20)	6.67 (2.35)	ns	0.04

[a] Independent samples two-tailed t-tests. ns: not significant. MMSE: Mini-Mental Status Examination. Trail making scores were obtained by Trail making B minus Trail making A.

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