Postprint of the Second Language Memory Advantage Effect in Associative Recognition in Bilinguals

Authors: Liu Guixiong, Jia Yongping, Wang Yujuan, Maihefuleaiti Kanji, Guo Chunyan

Date: 2018-09-13T00:00:00+00:00

Abstract

Using ERPs technology, this study examined whether bilinguals exhibit a second language memory advantage effect in associative recognition. Participants completed two types of "study-test" tasks in Uyghur (L1) and Chinese (L2). In the study phase, participants learned compound words and unrelated words presented in a mixed format, while in the test phase, they were required to discriminate between "intact", "rearranged", or "new" word pairs. Behavioral results revealed that: (1) For compound words, L2 accuracy was higher than L1, and L2 reaction times were faster than L1; for unrelated words, L2 accuracy showed no significant difference from L1, but L2 reaction times were faster than L1. (2) In both L2 and L1, accuracy for compound words was higher than for unrelated words, and reaction times were faster than for unrelated words. ERPs results revealed that: (1) Under high-integration conditions, L2 only elicited the FN400 effect, whereas L1 elicited both the FN400 effect and the LPC effect; under low-integration conditions, both L2 and L1 only elicited the LPC effect. (2) In terms of temporal dynamics, L2 and L1 completed the retrieval of associative information at 650 ms and 900 ms, respectively. These results indicate that under high-integration conditions, bilinguals exhibit an L2 memory advantage in associative recognition. Furthermore, the experimental results also demonstrate from a bilingual perspective that integrative encoding can facilitate the role of familiarity in Uyghur associative recognition. The practical significance of this study's findings lies in providing cognitive neuroscience evidence for minority students in our country to acquire the national common language and script.

Full Text

The Bilingual L2 Advantage in Associative Recognition

LIU Guixiong[1,2], JIA Yongping[1], WANG Yujuan[3], MAIHEFULAITI· Kanji[1], GUO Chunyan[2]

[1] Department of Psychology, Xinjiang Normal University; Xinjiang Normal University Key Laboratory of Mental Development and Learning Science, Urumqi 830017, China
[2] School of Psychology, Capital Normal University; Beijing Key Laboratory of "Learning & Cognition" , Beijing 100048, China
[3] School of Intellectual Property, Chongqing University of Technology, Chongqing 400054, China

Abstract

This study employed ERPs technology to investigate whether bilinguals exhibit a second language memory advantage effect in associative recognition. Participants completed two "study-test"tasks in Uyghur (L1) and Chinese (L2). During the study phase, they learned compound and unrelated word pairs presented in a mixed format; during the test phase, they distinguished between "intact," "rearranged," or "new" word pairs. Behavioral results revealed: (1) For compound words, L2 accuracy was higher than L1 and L2 reaction times were faster than L1; for unrelated words, L2 accuracy did not differ significantly from L1, but L2 reaction times were faster than L1. (2) In both L2 and L1, accuracy for compound words was higher than for unrelated words, and reaction times were faster for compound words than for unrelated words. ERP results showed: (1) Under high unitization conditions, L2 elicited only the FN400 effect, whereas L1 elicited both FN400 and LPC effects; under low unitization conditions, both L2 and L1 elicited only the LPC effect. (2) In terms of temporal course, L2 and L1 completed associative relationship retrieval at 650 ms and 900 ms, respectively. These results indicate that bilinguals exhibit an L2 memory advantage in associative recognition under high unitization conditions. Furthermore, the findings provide bilingual evidence that unitized encoding can facilitate the role of familiarity in Uyghur associative recognition. The practical significance of this study lies in providing cognitive neuroscientific evidence for minority students in China to acquire the national common language.

Keywords: associative recognition; bilingualism; unitization; familiarity; recollection

Introduction

In recent years, researchers have begun investigating the second language memory advantage effect in bilinguals. Some studies have found that in item recognition, bilinguals show higher hit rates and lower false alarm rates for their second language (L2) compared to their first language (L1), demonstrating an L2 memory advantage effect (Francis & Strobach, 2013). However, it remains unclear whether an L2 memory advantage exists in associative recognition. Item and associative recognition represent distinct cognitive processes. In item recognition, people rely on intrinsic information to differentiate old from new items, whereas in associative recognition, they depend on associative information between items to distinguish intact pairs from rearranged ones. Word frequency differentially affects these processes: low-frequency words show better item recognition but poorer associative recognition compared to high-frequency words (Clark, 1992), suggesting a memory disadvantage for low-frequency words in associative recognition. Some researchers argue that L2 vocabulary functions similarly to low-frequency words in bilinguals' L1 (Gollan, Montoya, Cera, & Sandoval, 2008), leading to the hypothesis that bilinguals' L2 associative recognition performance might be lower than L1, showing an L2 memory disadvantage.

The Source of Activation Confusion (SAC) model can explain differential L2 memory effects in item versus associative recognition. The SAC model posits that information is stored in a network structure comprising concept nodes and episode nodes, with successful retrieval depending on the activation level of episode nodes (see Figure 1 [Figure 1: see original paper]). During testing, cue words activate their concept nodes, which spread activation to corresponding episode nodes. The activation level of an episode node is influenced by both the activation level of the concept node and the number of episode nodes connected to that concept node—more connected episode nodes create greater interference, reducing activation (Dinan, Reder, Arndt, & Park, 2006). In item recognition, L2 concept nodes connect to fewer episode nodes, resulting in less interference and greater episode node activation, yielding higher hit rates. Additionally, L2 concept nodes have lower baseline activation levels, leading to lower false alarm rates. This combination produces the L2 memory advantage in item recognition (Francis & Strobach, 2013).

In associative recognition, retrieval is influenced not only by concept node activation and the number of connected episode nodes but also by the activation level of inter-item relationships. The formation of inter-item relationships is resource-demanding, and lower concept node activation requires more cognitive resources (Reder, Paynter, Diana, Ngiam, & Dickison, 2007). With limited cognitive resources, the lower activation levels of two L2 concept nodes make it difficult to form adequate inter-item relationships (Buchler & Reder, 2007; Kuperman & Van Dyke, 2013). Thus, the key to improving L2 associative recognition lies in promoting relationship encoding between items. Unitization encoding can compensate for this deficiency in L2 inter-item relationship encoding to some extent. Unitization refers to the process of integrating two or more items into a unified concept (Graf & Schacter, 1989), which reduces cognitive resource demands during encoding. After unitized encoding, associative retrieval no longer involves extracting two separate items but rather retrieving a holistic concept—a process similar to item retrieval. With fewer interfering episode nodes in L2, hit rates are higher, while lower concept node activation in L2 yields lower false alarm rates. Consequently, under high unitization conditions, L2 associative recognition performance may exceed that of L1, demonstrating an L2 memory advantage. However, under low unitization conditions, the low activation level of L2 concept nodes makes inter-item relationship formation difficult, resulting in lower associative recognition performance.

Recognition comprises two distinct processes: familiarity and recollection. Familiarity represents a general sense of recognition without conscious extraction of specific details, whereas recollection involves conscious retrieval of detailed information (Mao, Xu, & Guo, 2015; Yonelinas, 2002). ERP research has identified two old/new effects as indices of these processes: an early (300–500 ms) frontal old/new effect (FN400) associated with familiarity-based retrieval, and a later (500–800 ms) left parietal old/new effect (LPC) indicating recollection (Rugg & Curran, 2007; Vilberg, Moosavi, & Rugg, 2006). Recent studies suggest that old/rearranged effects better reflect associative retrieval than old/new effects because old/new effects are confounded by item and relational information—participants can distinguish old from new items based solely on familiarity. In contrast, because familiarity is equivalent for intact and rearranged pairs, effective discrimination requires retrieval of inter-item relational information (Kamp, Bader, & Mecklinger, 2016; Zheng, Xiao, Broster, & Jiang, 2015a). Therefore, this study adopted bilateral frontal old/rearranged effects and left parietal old/rearranged effects as electrophysiological indices of familiarity and recollection, respectively.

In summary, bilinguals demonstrate an L2 memory advantage in item recognition, but whether this advantage extends to associative recognition remains unclear. If bilinguals show an L2 memory advantage in associative recognition under high unitization conditions, it would suggest that the L2 advantage in recognition memory is generalizable under certain conditions. Moreover, if unitized encoding is the key factor underlying this advantage, bilinguals could employ unitization strategies to compensate for relational encoding deficits in L2, thereby facilitating L2 associative recognition. Such findings would provide important scientific evidence for effective acquisition of the national common language among minority students in China. To address these questions, the present study used ERPs to examine whether bilinguals exhibit an L2 memory advantage in associative recognition across different levels of semantic integration (Ahmad & Hockley, 2014; Zheng et al., 2015a). Bilingual participants completed L1 and L2 study-test tasks. In the L1 task, both study and test phases used Uyghur words; in the L2 task, both phases used Chinese words. During study, participants learned mixed presentations of compound and unrelated word pairs; during test, they distinguished "intact," "rearranged," or "new" pairs. In compound words, semantic association between the two words facilitates processing into a unified concept, making inter-item relationships easier to form. Additionally, L2 associative retrieval experiences less interference from irrelevant episode nodes. We therefore hypothesized that under high unitization conditions (compound words), familiarity would support associative recognition and an L2 memory advantage would emerge. In unrelated words, where items are difficult to integrate into a unified concept and inter-item relationships are hard to form, familiarity would not support associative recognition.

Method

Participants Twenty bilingual students (5 male) from Xinjiang Normal University participated for monetary compensation. Two students failed to complete the experiment and were excluded, leaving 18 participants (mean age = 20.78 years, SD = 1.48) with normal or corrected-to-normal vision. Prior to the experiment, participants completed a language background and proficiency questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007). Participants reported 40.37% Chinese exposure (SD = 7.99%), Chinese proficiency of 5.46 (SD = 0.80), Uyghur proficiency of 5.93 (SD = 0.82), and language switching ability of 5.25 (SD = 0.69) on a 7-point scale.

Materials Eight hundred noun pairs were initially selected from the Modern Chinese Dictionary, comprising 400 compound word pairs (e.g., "labor-model") and 400 unrelated word pairs (e.g., "date-people"). Twenty-six students who did not participate in the formal experiment rated the materials for familiarity (1 = very unfamiliar, 7 = very familiar) and unitization level (1 = very low unitization, 7 = very high unitization). Pairs scoring below 5 on familiarity were eliminated. For unitization, compound word pairs scoring below 5 and unrelated word pairs scoring above 3 were eliminated.

The final stimulus set consisted of 642 word pairs. Eighteen pairs were used for practice, and the remaining 624 pairs were randomly divided into two sets of 312 pairs each for L2 and L1 study-test tasks. The L1 materials were translated into Uyghur. After balancing for familiarity and unitization, materials in each language were divided into 13 groups, with each group containing 12 compound and 12 unrelated word pairs. Eight compound and eight unrelated pairs served as study materials, while the remaining four pairs of each type served as "new" test items. Table 1 presents the ratings for both language conditions. Paired-sample t-tests showed that unitization ratings were higher for compound than unrelated words in both L1 [$t(25) = 93.26$, $p < 0.001$] and L2 [$t(25) = 89.64$, $p < 0.001$]. No significant differences emerged between languages in word frequency [$t(25) = 1.29$, $p = 0.208$] or familiarity [$t(25) = 0.64$, $p = 0.412$].

Design The experiment used a 2 (Language: L1, L2) × 2 (Relation: compound, unrelated) × 2 (Response: intact, rearranged) within-subjects design. New stimuli served as filler items and were not included in analyses.

Procedure Stimuli were presented as black-background, white 36-point SimSun font word pairs using Presentation software. Participants completed the experiment in a sound-attenuated, electrically shielded room on a computer with 1024×768 pixel resolution. Participants completed both L1 and L2 tasks, with task order counterbalanced across participants.

The study-test procedure is illustrated in Figure 2 [Figure 2: see original paper]. Practice phase: Participants completed one practice block to familiarize themselves with the task. Study phase: Eight compound and eight unrelated word pairs were randomly presented at the center of the screen for 5000 ms, with an inter-stimulus interval (ISI) of 700–1100 ms. Participants were instructed to remember the words. After the study phase, participants performed a 20-second distractor task (counting backward by threes from a three-digit number). Test phase: Intact, rearranged, and new word pairs were randomly presented at the center of the screen for 3000 ms (ISI = 700–1100 ms). Participants made "intact," "rearranged," or "new" judgments: press "F" if both words were studied and paired as originally presented (intact), press "H" if both words were studied but the pairing was changed (rearranged), or press "J" if neither word was studied (new). The study, distractor, and test phases occurred without intervals. The entire experiment lasted approximately 2 hours and 40 minutes.

ERP Recording and Analysis EEG was recorded from 62 scalp locations using a Neuroscan ESI-64 system with a 64-channel Ag/AgCl electrode cap according to the international 10-20 system. The ground electrode was placed between FPz and Fz, with the reference at the left mastoid (offline analysis used the average of left and right mastoids). Vertical and horizontal electrooculograms were recorded from electrodes above and below the left eye and at the outer canthi of both eyes. The sampling rate was 1000 Hz with a bandpass of 0.05–100 Hz during recording; impedance was maintained below 5 kΩ. Offline analysis excluded trials with eye-movement artifacts or amplitudes exceeding ±75 V, applied a 0.05–40 Hz bandpass filter, and used a −100 to 1000 ms analysis window.

Following Kriukova, Bridger, and Mecklinger (2013), we analyzed old/rearranged effects at frontal (F3, F1, Fz, F2, F4) and parietal (P3, P1, Pz, P2, P4) regions. Grand-averaged waveforms showed divergence between response types beginning at 250 ms post-stimulus. The L2 old/rearranged effect disappeared during 450–650 ms, whereas the L1 effect persisted through 650–900 ms. Based on these patterns, we selected three time windows: 250–450 ms (indexing familiarity), and 450–650 ms and 650–900 ms (indexing recollection) for further analysis of L1 and L2 differences.

ERPs for correct "intact" and "rearranged" responses were obtained through segmented averaging using Neuroscan software. Behavioral and ERP data were analyzed with SPSS 22.0. Mean amplitudes across the three time windows were submitted to Language × Relation × Response × Hemisphere repeated-measures ANOVAs. Follow-up analyses focused on significant main effects and interactions involving Response. Scalp distribution comparisons of old/rearranged effects were conducted by first computing difference wave vectors across 10 electrodes, then performing repeated-measures ANOVAs; significant interactions indicated different scalp distributions (McCarthy & Wood, 1985).

Results

Behavioral Data Behavioral results are presented in Table 2 . We conducted 2 (Language: L1, L2) × 2 (Relation: compound, unrelated) × 2 (Response: intact, rearranged) repeated-measures ANOVAs on accuracy and reaction times. To further examine participants' ability to discriminate intact from rearranged pairs, we analyzed Pr (associative discrimination index; Snodgrass & Corwin, 1988) using Language × Relation ANOVAs.

Accuracy The main effect of Language was marginally significant, $F(1, 17) = 3.59$, $p = 0.075$, $^2p = 0.17$, indicating higher recognition accuracy in L2 than L1. The main effect of Relation was significant, $F(1, 17) = 8.22$, $p = 0.011$, $^2p = 0.33$, with higher accuracy for compound than unrelated words. The main effect of Response was significant, $F(1, 17) = 4.83$, $p = 0.042$, $^2p = 0.21$, with higher accuracy for intact than rearranged pairs. The three-way interaction was not significant, $F(1, 17) = 0.01$, $p = 0.961$. Language did not interact with Response [$F(1, 17) = 0.02$, $p = 0.903$] or Relation [$F(1, 17) = 0.26$, $p = 0.614$], but Response × Relation was significant, $F(1, 17) = 33.67$, $p < 0.001$, $^2p = 0.66$. Simple effects analysis revealed that for compound words, intact pairs showed higher accuracy than rearranged pairs, $F(1, 17) = 17.55$, $p < 0.001$, whereas for unrelated words, this difference was not significant, $F(1, 17) = 2.01$, $p = 0.314$.

Reaction Times The main effect of Language was significant, $F(1, 17) = 8.41$, $p = 0.010$, $^2p = 0.33$, with faster responses in L2 than L1. The main effect of Response was significant, $F(1, 17) = 122.88$, $p < 0.001$, $^2p = 0.88$, with faster responses for intact than rearranged pairs. The main effect of Relation was significant, $F(1, 17) = 5.81$, $p = 0.028$, $^2p = 0.26$, with faster responses for compound than unrelated words. The three-way interaction was not significant, $F(1, 17) = 1.34$, $p = 0.264$. Language did not interact with Response [$F(1, 17) = 0.21$, $p = 0.651$], but Response × Relation was significant, $F(1, 17) = 20.58$, $p < 0.001$, $^2p = 0.55$. Simple effects showed that rearranged pairs were slower than intact pairs for both compound [$F(1, 17) = 25.25$, $p < 0.001$] and unrelated words [$F(1, 17) = 98.51$, $p < 0.001$]. The Language × Relation interaction was significant, $F(1, 17) = 5.09$, $p = 0.038$, $^2p = 0.23$, with simple effects showing faster L2 responses for both compound [$F(1, 17) = 7.66$, $p = 0.013$] and unrelated words [$F(1, 17) = 8.92$, $p = 0.011$].

Associative Discrimination Index (Pr) Pr values represent participants' ability to discriminate intact from rearranged pairs, with higher values indicating better discrimination. The Language × Relation ANOVA showed no significant main effect of Language, $F(1, 17) = 0.21$, $p = 0.651$, but a significant main effect of Relation, $F(1, 17) = 12.88$, $p = 0.002$, $^2p = 0.43$, indicating better discrimination for compound than unrelated words. The Language × Relation interaction was marginally significant, $F(1, 17) = 3.77$, $p = 0.069$, $^2p = 0.18$. Simple effects revealed better discrimination in L2 than L1 for compound words, $F(1, 17) = 2.61$, $p = 0.031$, but no difference for unrelated words, $F(1, 17) = 0.30$, $p = 0.578$.

ERP Results The two response types diverged beginning at 250 ms post-stimulus. During 250–450 ms, old/rearranged effects were present in both L1 and L2. During 450–650 ms, only L1 showed an old/rearranged effect, which persisted through 650–900 ms (see Figure 3 [Figure 3: see original paper]). To verify the statistical validity of these divergences, we conducted simple effects analyses on significant interactions involving Language across the three time windows, with planned comparisons when interactions were not significant (Keppel, 1991).

250–450 ms Time Window The 2 (Language: L1, L2) × 2 (Relation: compound, unrelated) × 2 (Response: intact, rearranged) × 2 (Hemisphere: left, right) ANOVA revealed a significant main effect of Response, $F(1, 17) = 4.51$, $p = 0.049$, $^2p = 0.21$, and a significant Response × Relation interaction, $F(1, 17) = 13.04$, $p = 0.002$, $^2p = 0.43$. The four-way interaction was significant, $F(1, 17) = 7.60$, $p = 0.013$, $^2p = 0.31$. Consistent with the typical scalp distribution of bilateral frontal old/rearranged effects, we further examined effects using mean amplitudes at F3, F1, F2, and F4.

For L2, the main effect of Response was significant, $F(1, 17) = 10.48$, $p = 0.005$, $^2p = 0.38$, and the Response × Relation interaction was significant, $F(1, 17) = 18.86$, $p < 0.001$, $^2p = 0.53$. Follow-up analyses revealed an old/rearranged effect for compound words, $F(1, 17) = 7.18$, $p = 0.016$, $^2p = 0.30$, but not for unrelated words, $F(1, 17) = 4.04$, $p = 0.061$.

For L1, the main effect of Response was not significant, $F(1, 17) = 1.07$, $p = 0.315$, but the Response × Relation interaction was significant, $F(1, 17) = 16.46$, $p = 0.001$, $^2p = 0.49$. Simple effects showed an old/rearranged effect for compound words, $F(1, 17) = 4.78$, $p = 0.041$, but not for unrelated words, $F(1, 17) = 0.01$, $p = 0.914$.

Independent samples t-tests comparing L2 and L1 old/rearranged effects across time windows revealed that both languages showed FN400 effects for compound words, but the difference was not significant, $t(17) = -0.09$, $p = 0.931$. Neither language showed FN400 effects for unrelated words.

450–650 ms Time Window The ANOVA showed a significant main effect of Response, $F(1, 17) = 5.73$, $p = 0.029$, $^2p = 0.25$, and a significant Language × Response interaction, $F(1, 17) = 6.58$, $p = 0.020$, $^2p = 0.28$. The Response × Relation interaction was significant, $F(1, 17) = 18.35$, $p < 0.001$, $^2p = 0.52$, and the four-way interaction was marginally significant, $F(1, 17) = 4.13$, $p = 0.048$, $^2p = 0.20$. Consistent with left parietal old/rearranged effects, we examined mean amplitudes at P3 and P1.

For L2, neither the main effect of Response nor its interaction with Relation was significant ($Fs < 1$), indicating no old/rearranged effect in either compound or unrelated words.

For L1, the main effect of Response was significant, $F(1, 17) = 26.33$, $p < 0.001$, $^2p = 0.61$, and the Response × Relation interaction was significant, $F(1, 17) = 9.65$, $p = 0.007$, $^2p = 0.36$. Simple effects revealed old/rearranged effects for both compound [$F(1, 17) = 13.03$, $p < 0.001$] and unrelated words [$F(1, 17) = 9.97$, $p = 0.006$].

Independent samples t-tests showed that in the 450–650 ms window (Figure 4B [Figure 4: see original paper]), L1 exhibited an LPC effect for compound words whereas L2 did not; for unrelated words, neither language showed an LPC effect. In the 650–900 ms window (Figure 4C [Figure 4: see original paper]), L1 showed an LPC effect for compound words while L2 did not, with L1' s LPC effect significantly larger than L2' s, $t(17) = -2.67$, $p = 0.016$, $d = 2.20$. For unrelated words, L1 showed an LPC effect while L2 did not, though the difference was not significant, $t(17) = -1.61$, $p = 0.126$.

Topographic Analysis We computed difference wave vectors across 10 electrodes (F3, F1, Fz, F2, F4, P3, P1, Pz, P2, P4) for each time window and submitted them to a 2 (Language: L1, L2) × 10 (Electrode) × 3 (Time Window) repeated-measures ANOVA. The Language × Electrode × Time Window interaction was marginally significant, $F(18, 306) = 1.61$, $p = 0.057$, $^2p = 0.09$. Follow-up analyses examined scalp distribution differences between L2 and L1 in each time window. During 250–450 ms, the Language × Electrode interaction was significant, $F(9, 153) = 1.83$, $p = 0.041$, $^2p = 0.13$, but not significant in the other windows ($Fs < 1$). These results indicate different spatial distributions of old/rearranged effects between L2 and L1 (see Figures 5A and 5B [Figure 5: see original paper]).

Discussion

4.1 The Bilingual L2 Advantage in Associative Recognition Under high unitization conditions, bilinguals demonstrated an L2 memory advantage in associative recognition. Behaviorally, L2 showed superior intact/rearranged discrimination and faster reaction times compared to L1. Under low unitization conditions, no significant differences emerged between languages in discrimination ability. ERP results revealed that L2 associative recognition relied solely on familiarity and proceeded more rapidly than L1, which required both familiarity and recollection. Specifically, L2 completed associative retrieval by 650 ms, whereas L1 required until 900 ms.

Francis and Strobach (2013) previously demonstrated an L2 advantage in item recognition. Our study extends this finding to associative recognition under high unitization conditions, suggesting that the L2 memory advantage generalizes across recognition tasks when conditions permit. The SAC model provides a theoretical framework: associative retrieval is influenced by concept node activation, the number of connected episode nodes, and the quality of inter-item relationship encoding. Because L2 concept nodes have lower baseline activation, forming inter-item relationships is challenging. Unitization addresses this by reducing cognitive resource demands, allowing L2 inter-item relationships to be adequately encoded. After unitized encoding, retrieval involves accessing a holistic concept rather than separate items. With fewer interfering episode nodes in L2, hit rates increase, while lower L2 concept node activation reduces false alarms. Consequently, L2 associative recognition surpasses L1 under high unitization.

Previous research found that low-frequency words show poorer associative recognition than high-frequency words (Clark, 1992). However, our low unitization condition revealed no significant L1/L2 differences. Clark's study did not employ unitization strategies, and low-frequency words, like L2 vocabulary in our study, suffer from insufficient inter-item relationship encoding due to low concept node activation. Our results also reflect an L2 memory advantage in associative recognition.

4.2 Unitization Facilitates Familiarity-Based Associative Recognition
Our findings provide bilingual evidence that semantic unitization facilitates familiarity-based associative recognition. As noted, FN400 effects reflect familiarity-based retrieval, whereas LPC effects reflect recollection (Zheng et al., 2015a; Kamp et al., 2016). In compound words, both L2 and L1 elicited FN400 effects, indicating that familiarity supported associative recognition in both languages. In unrelated words, only LPC effects emerged, suggesting that associative recognition relied primarily on recollection. Because compound words have stronger semantic integration than unrelated words, the presence of FN400 effects for compound words but not unrelated words demonstrates that semantic integration induces familiarity-based associative recognition.

Uyghur and Chinese scripts differ substantially in orthographic transparency. Uyghur is a transparent script with regular grapheme-phoneme correspondence, whereas Chinese is an opaque script where one syllable can represent multiple characters (Liu & Cao, 2016). Despite these differences, both languages elicited FN400 effects under high unitization, indicating that familiarity supports associative recognition not only in monolinguals but also across bilinguals' two languages.

Furthermore, L2 compound words elicited only FN400 effects, while L1 compound words elicited both FN400 and LPC effects, suggesting that unitization differentially affected L2 versus L1 associative recognition. As Chinese is a second language for minority students, it influences event encoding and retrieval top-down as a form of experience (Schroeder & Marian, 2012). Uyghur students possess two conceptual encoding systems, and both languages are activated in parallel during L2 comprehension. Consequently, L2 retrieval involves both L2 and L1 cues. However, L1 retrieval receives relatively less contribution from L2 lexical cues because L2 activation is weaker (Schroeder & Marian, 2012). This interaction between language and encoding may constitute an important factor underlying L1/L2 differences in associative recognition, warranting future investigation.

Traditionally, researchers have assumed that bilinguals' L2 relational processing suffers from insufficient encoding (Buchler & Reder, 2007). Our study demonstrates that unitization can compensate for this deficit and promote L2 associative recognition, yielding an L2 memory advantage. This provides crucial cognitive neuroscientific evidence for effective acquisition of the national common language among minority students. Common unitization strategies—including interactive imagery (Diana, Yonelinas, & Ranganath, 2008), perceptual features (Yonelinas, Kroll, Dobbins, & Soltani, 1999), and semantic association (Ahmad & Hockley, 2014)—can be applied to help minority students learn and master the national common language.

Conclusion

1. Under semantic unitization conditions, bilinguals exhibit a second language memory advantage in associative recognition. Bilinguals can successfully retrieve associative relations based solely on familiarity, and this retrieval is faster than in their first language.
2. Unitization not only facilitates familiarity-based associative recognition in bilinguals' first language but also elicits familiarity processing in second language associative recognition. These results demonstrate that the facilitative effect of unitization on familiarity-based associative recognition extends beyond monolingual contexts to bilingual memory, providing important cognitive neuroscientific support for minority language education policies.

References

Ahmad, F. N. & Hockley, W. E. (2014). The role of familiarity in associative recognition of unitized compound word pairs. *Quarterly Journal of Experimental Psychology, 67*(12), 2309–2322.

Buchler, N. E. G., & Reder, L. M. (2007). Modeling age-related memory deficits: A two-parameter solution. *Psychology and Aging, 22*(1), 104–121.

Clark, S. E. (1992). Word frequency effects in associative and item recognition. *Memory and Cognition, 20*(3), 231–243.

Diana, R. A., Reder, L. M., Arndt, J., & Park, H. (2006). Models of recognition: A review of arguments in favor of a dual-process account. *Psychonomic Bulletin and Review, 13*(1), 1-21.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2008). The effects of unitization on familiarity-based source memory: Testing a behavioral prediction derived from neuroimaging data. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(4), 730–740.

Francis, W. S., & Strobach, E. N., (2013). The bilingual L2 advantage in recognition memory. *Psychonomic Bulletin and Review, 20*(6), 1296–1303.

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism and the weaker links hypothesis. *Journal of Memory and Language, 58*(3), 787–814.

Graf, P., & Schacter, D. L. (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(5), 930–940.

Kamp, S., Bader, R., & Mecklinger, A. (2016). The Effect of Unitizing Word Pairs on Recollection Versus Familiarity-Based Retrieval-Further Evidence from ERPs. *Advances in Cognitive Psychology, 12*(4), 168–177.

Keppel, G. (1991). *Design and analysis: A researcher' s handbook*. New Jersey: Prentice-Hall, Inc.

Kriukova, O., Bridger, E., & Mecklinger, A. (2013). Semantic relations differentially impact associative memory: Electrophysiological evidence. *Brain and Cognition, 83*(1), 93–103.

Kuperman, V., & Van Dyke, J. A. (2013). Reassessing word frequency as a determinant of word recognition for skilled and unskilled readers. *Journal of Experimental Psychology, 39*(3), 802–823.

Liu, H. S., Cao, F. (2016). L1 and L2 processing in bilingual brain: A meta-analysis of neuroimaging studies. *Brain and Language, 159*, 60–73.

MacLeod, C. M., & Kampe, K. E. (1996). Word frequency effects on recall, recognition, and word fragment completion tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(1), 132–142.

Mao, X. R., Xu, H. F., & Guo, C. Y. (2015). The emotional memory enhancement effect in dual-process recognition retrieval. *Acta Psychologica Sinica, 47*(9), 1111–1123.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87*(3), 252–271.

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The language experience and proficiency questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech Language and Hearing Research, 50*(4), 940–967.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology/Evoked Potentials Section, 62*(3), 203–208.

Reder, L. M., Paynter, C., Diana, R. A., Ngiam, J., & Dickison, D. (2007). Experience is a double-edged sword: A computational model of the encoding/retrieval trade-off with familiarity. *Psychology of Learning and Motivation, 48*, 271-312.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11*(6), 251-257.

Schroeder S, Marian V. (2012). A bilingual advantage for episodic memory in older adults. *Journal of Cognitive Psychology, 24*(5), 591-601.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*(1), 34-50.

Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. *Brain Research, 1122*(1), 161-170.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*(3), 441-517.

Yonelinas, A. P., Kroll, N. E. A., Dobbins, I. G., & Soltani, M. (1999). Recognition memory for faces: When familiarity supports associative recognition judgments. *Psychonomic Bulletin & Review, 6*(4), 654-661.

Zheng, Z. W., Li, J., Xiao, F. Q., Broster, L. S., & Jiang, Y. (2015a). Electrophysiological evidence for the effects of unitization on associative recognition memory in older adults. *Neurobiology of Learning and Memory, 121*, 59-71.

Note: Figure translations are in progress. See original paper for figures.