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Research article

Unitization facilitates familiarity-based cross-language associative recognition

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ABSTRACT

The unitization effect means a phenomenon in which familiarity can contribute to associative recognition judgments when pairs of items are treated as a single entity rather than two separate items. Cumulative evidences suggested that the unitization effect was not influenced by the type of language, and this effect could be generalized to bilinguals when they performed an associative recognition in their second language. In the present study, the influence of familiarity on cross-language associative retrieval under unitization and the underlying neurophysiological mechanism behind this effect were investigated. Participants completed two "study-test" tasks presented in intralinguistic (from Uygur to Uygur) or interlinguistic assignment (from Chinese to Uygur) respectively. The study showed that: (1) during intralinguistic assignments, both FN400 and LPC were found under unitization for balanced and unbalanced bilinguals, while an LPC but not FN400 was found under non-unitization. (2) During interlinguistic assignments, both FN400 and LPC were found under unitization for balanced bilinguals. However, an LPC but not FN400 was found under unitization for unbalanced bilinguals. Collectively, these results indicated that unitization facilitated familiarity to support cross-language retrieval. In particular, the effects of familiarity on cross-language retrieval were mediated by the second language proficiency.

1. Introduction

Dual-process theory posits that recognition memory is supported by both recollection and familiarity. Recollection provides access to detailed information about events previously encountered, whereas, familiarity refers to recognition without retrieving episodic details [1]. Traditionally, researchers suggest that recollection is necessary in associative recognition [2]. Different from item recognition, associative recognition emphasizes the importance of the distinctive information (*i. e.*, the link between items) because of the equal familiarity of all items [3]. The link between items is often hard to retrieve owing to the weak trace, which makes familiarity work ineffective. Recently, more and more evidences suggest that familiarity can also support associative recognition when two or more separate items are unitized as a new single entity [4–10]. For example, two words "monkey'' (a kind of animal) and "foot'' (a part of body) have respective separate meaning. They were lack of preexisting relations because they come from different semantic categories and rarely occur together in a free association task. However, they can create a new single meaning when they are combined into a word pair "monkey-foot'' (*i.e.*, naughty child). The well-unitized whole becomes more familiar than its constituents, and then this whole familiarity can help participants recognize the association like item recognition. This is designated as unitization effect which describes that familiarity can play roles in associative recognition when pairs of items are treated as a single entity rather than two separate ones [11].

Previous researches showed that the unitization effect was present in various languages (*e.g.*, English, Chinese, Uyghur, French, German) [5–8,12,13], which were limited to intra-language retrieval (*i.e.*, study

Abbreviations: TAP, The transfer appropriate processing; FN400, an early (300∼500 ms) frontal old/new effect; LPC, a later (500∼800 ms) left parietal old/new effect.

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and test in same language). As cross-language associative retrieval for bilinguals is very common in daily life, whether the unitization effect exists in cross-language retrieval (*i.e.*, study and test in different language) is worth investigating. We were interested in when bilinguals encoded word pairs in one language and retrieved word pairs in another language, would the unitization still work? That was, when Uygur-Chinese bilinguals unitized word pairs "monkey-foot" as a single unit in Chinese, could familiarity contribute to retrieve "monkey-foot" in Uygur?

When it comes to cross-language retrieval, although the surface characteristics (*e.g.*, perceptual features) of two languages are different, there are overlapping of the deep characteristics (*e.g.*, semantic attributes) between them. For instance, "black" (the English word) and "黑'' (the Chinese word) are translation equivalents. The English word "black" means one sense COLOR, depressed, a type of humor, and so on, while the Chinese word "黑'' means one sense COLOR, evil-minded. Among them, the most essential semantic "One sense COLOR" is an overlapping semantic attribute of two words. According to TAP (the transfer appropriate processing), cross-language retrieval mainly relies on the cross-language transfer effect, which mainly depends on overlapping semantic attributes between two languages [14,15]. The more the semantic attributes overlapped, the better the transfer effect. Several researches indicated that associative recognition of words was a conceptual-driven process, relied mainly on processing of semantic attributes [2,3]. There are overlapping of semantic attributes between two languages, and that can elicit the cross-language transfer effects. Thus, we assumed that the unitization effect might be observed in cross-language associative retrieval. That was, once bilinguals had integrated different items into a single entity in one language, he (or she) could discriminate intact and rearranged pairs in another language.

In addition, the unitization effect in cross-language associative retrieval may be mediated by L2 (*i.e.*, the second language) proficiency. According to RHM (the Revised Hierarchical Model), balanced bilinguals (*i.e.*, completely proficient in the two languages) can access the concept of the L2 words directly, while unbalanced bilinguals (*i.e.*, more proficient in L1) may have to access the concept of the L2 words through the L1 (*i.e.*, the first language) translation equivalents [16]. The process difference between balanced and unbalanced bilinguals is embodied in two aspects: one is the number of activated languages. Only target language is activated for balanced bilinguals regardless of encoding or retrieval, while both L2 and L1 are activated for unbalanced bilinguals in both encoding and retrieval. The simultaneous activation of both languages mean it is necessary to inhibit the non-target language. The other one is that an extra translation process is only needed by unbalanced bilingual. The two added process for unbalanced bilingual may consume a lot of cognitive resources.

The cross-language transfer concerning conceptual processing in an explicit memory task occurs frequently. It is worth noting that cognitive resources influences this process heavily. As is known to all, divided attention is a common way to compete for cognitive resources. Researchers found that divided attention could interrupt encoding or retrieval by consuming cognitive resources [17]. During encoding, memory and concurrent tasks competed for general resources, which might interrupt encoding [18,19]. During retrieval, they competed for the same representations when memory and concurrent tasks required the same type of materials, which might also interrupt retrieval [20]. Only target language words are activated for balanced bilinguals, while both L2 and L1 words are activated for unbalanced bilinguals in cross-language memory. As a result, unbalanced bilinguals may have to complete two divided attention tasks (*i.e.*, translating words from one language to another and inhibiting activation of non-target language). In a cross-language memory (*e.g.*, from L2 to L1), for example, it is necessary for unbalanced bilinguals to translate L2 to L1 firstly. And then, they have to inhibit L2 during L1 encoding because of the simultaneous activation of both languages. These process compete for general resources and interrupt encoding. During L1 retrieval, unbalanced bilinguals may also have to inhibit L2 because of the simultaneous activation of both L2 and L1. On account of retrieving L1 and inhibiting L2 require the same type of materials (words) and compete for the same representations, these process perhaps increase overall involvement of cognitive control mechanisms, and employ more cognitive resources [21]. Thus, we assumed that the unitization effect might be influenced by L2 proficiency.

Both top-down (definition framework or interactive image) and bottom-top processes (compound word or semantically related word pairs) could achieve unitization [6,8]. In this paper, we employed compound word pairs to examine whether the unitization effect could emerge in a cross-language context, and whether it was mediated by L2 proficiency. If the unitization effect worked as effectively as intra-language retrieval, it could greatly promote the cross-language memory of bilinguals. In the current study, participants completed two associative recognition tests presented in intralinguistic or interlinguistic assignment respectively.

Two temporally and topographically distinct ERP components are related to familiarity and recollection. Familiarity has been associated with a component named FN400, which is a negative-ongoing activity electrical activity recorded over bilateral frontal regions at 300~500 ms; whereas recollection has been linked to a component named LPC, which is a positive component over posterior regions at 500~800 ms [22,23]. If unitization facilitated familiarity to support cross-language associative retrieval, this unitization effect was indicated by FN400. If not, an LPC but not FN400 would be found. In view of L2 proficiency contributing to cross-language retrieval. We had the following predictions: (1) under unitization condition, both assignments wound be supported by familiarity indicated by FN400 for balanced bilinguals, while an LPC but not FN400 would be found in cross-language retrieval for unbalanced bilinguals. (2) Under non-unitization condition, both assignments wound be supported by recollection indicated by LPC.

2. Methods

2.1. Participants

Participants in the present study were 34 healthy Uygur undergraduate students (17 balanced and 17 unbalanced bilinguals) from Xinjiang Normal University. They received remuneration after experiment. Their language background were rated by LEAP-Q (the language experience and proficiency questionnaire) [24]. The results indicated that there was no difference in L1 (Uygur) proficiency, $t(32) = 0.59$, $p > 0.05$. However, L2 (Chinese) proficiency [$t(32) = 2.12$, $p < 0.05$, $Cohen'd = 0.73$], the frequency of L2 usage [$t(32) = 6.48$, $p < 0.001$, $Cohen'd = 2.22$], and language switching ability [$t(32) = 2.43$, $p < 0.05$, $Cohen'd = 0.83$] were significantly different. The Ethics Committee of Xinjiang Normal University approved this study.

2.2. Materials

240 compound and 240 unrelated word pairs (Table 1) were drawn from Liu et al. (2019) [13]. A separate group of 21 Uygur undergraduate students (10 balanced bilinguals and 11 unbalanced bilinguals) participated in a pretest to determine familiarity of word pairs and the degree to which word-pairs could be unitized as a single unit in two languages. Familiarity of word pairs were rated by a scale ranging from 1 (hardly familiar) to 7 (completely familiar). The results showed all word pairs were familiar for bilinguals. There was no difference between the familiarity of compound word pairs and unrelated word pairs ($Fs < 1$, $Ps > 0.5$; Table 2). Levels of unitization of word pairs were rated by a scale ranging from 1 (hardly unitized) to 7 (completely unitized). The results showed all compound word pairs could be unitized as a single unit in two languages. However, compound word-pairs were rated as being more unitized than unrelated word-pairs in both Chinese [intralinguistic materials: $t(20) = 44.20$, $p < 0.001$, $Cohen'd = 14.53$; interlinguistic

Table 1
Illustration of word pairs in Experiment.

	Study		Test		
Type	compound word (translation)	unrelated word pair	old (translation)	rearranged (translation)	new (translation)
L2-L1	监狱 小鸟	日期 人民	تۇرمە قۇش	ئۆلۈم ھەرپ	بالىلار چۆچىكى
	(jail bird)	(date people)	(jail bird)	(dead letter)	(fairy tale)
	死亡 线条	阳台 字母	چىسلا خەلق	بالكون سىزىق	بىلىم ياز
	(dead line)	(balcony letter)	(date people)	(balcony line)	(knowledge summer)
L1-L1	مايمۇن پۇت	ئىستاكان پەلەي	مايمۇن پۇت	تېرە رەسىم	سودا بانكىسى
	(monkey foot)	(cup glove)	(monkey foot)	(skin picture)	(business bank)
	تېرە باش	ئاياغ رەسىم	ئىستاكان پەلەي	ئاياغ باش	ئۈگرە ئېلان
	(skin head)	(shoe picture)	(cup glove)	(shoe head)	(noodle advertisement)

Table 2
Description of materials [*M (SD)*].

	Type	Language	Familiarity	Levels of unitization
L2-L1	compound word-pairs	Chinese	6.22(0.33)	6.15(0.32)
		Uygur	6.43(0.31)	6.28(0.26)
	unrelated word-pairs	Chinese	6.07(0.37)	1.80(0.27)
		Uygur	6.27(0.32)	1.77(0.34)
L1-L1	compound word-pairs	Chinese	6.18(0.31)	6.20(0.28)
		Uygur	6.33(0.32)	6.32(0.31)
	unrelated word-pairs	Chinese	6.03(0.42)	1.78(0.26)
		Uygur	6.21(0.35)	1.62(0.29)

materials, $t(20) = 58.19$, $p < 0.001$, $Cohen'd = 16.26$] and Uygur [intralinguistic materials: $t(20) = 59.98$, $p < 0.001$, $Cohen'd = 17.40$; interlinguistic materials, $t(20) = 63.35$, $p < 0.001$, $Cohen'd = 19.04$]. 480 word pairs were divided into two groups, which were presented in intralinguistic or interlinguistic assignment respectively. For each group, 160 pairs were presented in the encoding phase, and the remaining 80 pairs served as new pairs (half related and half unrelated) during retrieval. Each group was distributed into 5 blocks, so that each block contained 16 compound, 16 unrelated, and 16 new word pairs.

2.3. Procedure

Participants completed two “study-test” tasks presented in intralinguistic or interlinguistic assignment (Figs. 1). At study, participants remembered word pairs (compound or unrelated) presented on the center of the screen. Each trial began with a “+” for 700 ~ 1100 ms, followed by either compound or unrelated word pairs displayed for 5000 ms. The order of word pairs was pseudo-randomized to ensure stimuli of the same condition presented in no more than three consecutive trials. At test, participants were presented with word pairs appeared in one of three retrieval conditions: intact, rearranged, or new word pairs. After a “+” for 700 ~ 1100 ms, word pairs were presented for 3000 ms, and participants were instructed to discriminate intact pairs (studied items in studied association), rearranged pairs (studied

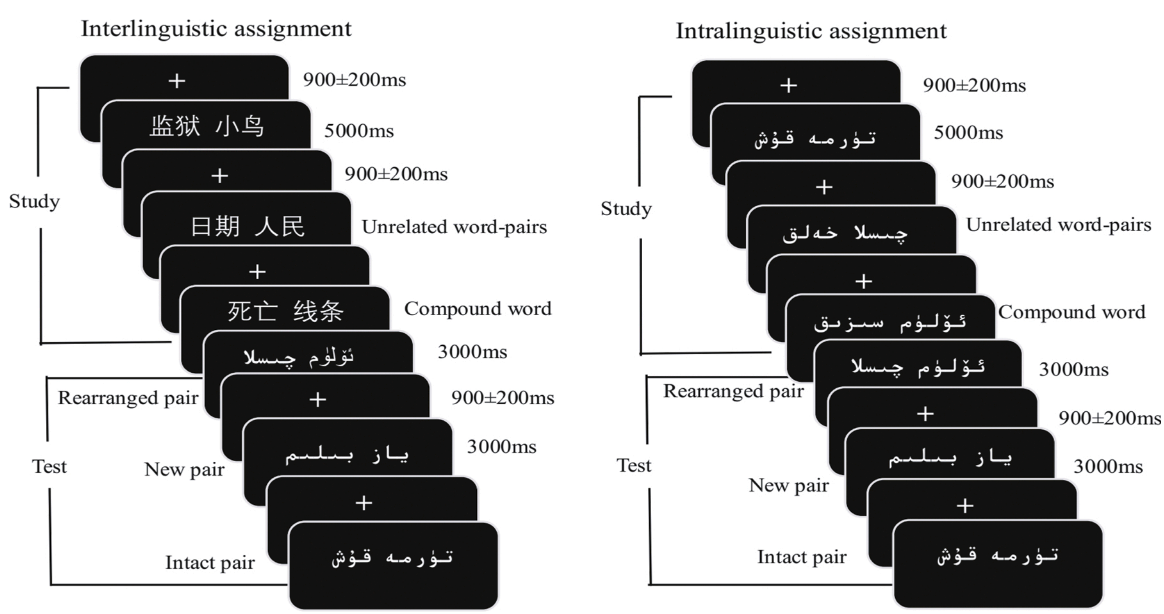

Fig. 1. Stimuli and experimental design. During the study phase, the examples of. word pairs ‘监狱 小鸟’,‘日期 人民’,‘死亡 线条’means ‘jail bird’, ‘date people’, and ‘dead line’, respectively; during the test phase, the examples of word pairs ‘ئۆلۈم چىسلا’, ‘ياز بىلىم’, and ‘تۇرمە قۇش’ mean ‘dead people’, ‘knowledge summer’, and “jail bird’, respectively. Word pairs are the same in interlinguistic and intralinguistic assignment.

items in unstudied association), or new word pairs (unstudied items).

2.4. EEG recording

EEG data of test phase were recorded through 62 Ag/AgCl electrodes by the NeuroScan SynAmps system. EEG signals were sampled at a rate of 1000 Hz, with a band-pass of 0.05~100 Hz, and impedances were kept no more than 5kΩ. All channels were re-referenced offline to averaged mastoids. Recordings were digitally filtered with a band-pass of 0.05 ~ 40hz. EEG data of test phase were divided into 1200 ms epochs, in which waveforms were corrected relative to the 200 ms pre-stimulus baseline. Epochs' amplitude exceeding ±75μV were rejected. A linear regression estimate was used to correct electrooculography blink artefacts.

ERP data of correct test trials were analyzed. For the FN400 effect, left (F1, F3, F5) and right frontal (F2, F4, F6) electrodes from 300 to 500 ms were analyzed, and for the LPC effect, left parietal (P1, P3, P5) electrodes were analyzed based on prior researches [7,13]. The presence of rearranged pairs forced participants to make recognition judgments based on the specific relationship between the words instead of pure words. Rearranged items were excluded from statistics analysis as processing of rearranged items could suffer from interference by intact words in the test phase [5,25]. This contaminated the comparability of rearranged and intact pairs. Additionally, as accuracy for rearranged items was lower than for another two item types, the signal-to-noise ratio for the ERPs to rearranged items was relatively low [5]. We conducted repeated-measures ANOVA with a between-subjects factor of L2 proficiency and four within-subjects factors: language, encoding, location and response. SPSS 21.0 was used for statistical analysis (alpha level: 0.05).

3. Results

3.1. Behavioral results

Pr, an index of discrimination measure of old/new effect, is equal to hit rates for intact pairs minus false alarm rates for new pairs [26]. A 2 L2 proficiency (balanced *vs* unbalanced) × 2 language (intralinguistic *vs* interlinguistic) × 2 encoding (compound *vs* unrelated) × 2 response (intact *vs* new) repeated-measures ANOVA revealed main effects of language [$F(1, 32) = 35.90$, $p < 0.001$, $\eta^2_p = 0.53$; Table 3], encoding [$F(1, 32) = 52.79$, $p < 0.001$, $\eta^2_p = 0.62$], and a two-way interaction of language-by-encoding [$F(1, 32) = 8.71$, $p < 0.01$, $\eta^2_p = 0.21$]. A follow-up ANOVA revealed a greater *Pr* for compound than unrelated word-pairs in intralinguistic assignment for both balanced [$F(1, 16) = 29.30$, $p < 0.01$] and unbalanced bilinguals [$F(1, 16) = 30.30$, $p < 0.01$]. However, there was only a greater *Pr* for balanced bilinguals [$F(1, 16) = 13.51$, $p < 0.01$], but not for unbalanced bilinguals [$F(1, 16) = 4.22$, $p > 0.05$] in interlinguistic assignment. A similar ANOVA on response bias (Br = FAs/[1 - *Pr*]) showed neither a main nor interaction effect [$Ps > 0.5$]. The results indicated the difference of *Pr* between unbalanced and balanced bilinguals in interlinguistic assignment was not because of their response bias.

Response times (RTs) were extracted from correct trials only. A similar repeated-measures ANOVA revealed that all main effects were significant [$Ps < 0.001$]. There were two-way interactions of language-by-encoding [$F(1, 32) = 6.84$, $p < 0.05$, $\eta^2_p = 0.18$], language-by-L2 proficiency [$F(1, 32) = 5.96$, $p < 0.001$, $\eta^2_p = 0.16$], and language-by-response [$F(1, 32) = 27.10$, $p < 0.001$, $\eta^2_p = 0.46$]. A follow-up ANOVA revealed that RTs were significantly faster for the compound than for unrelated word-pairs in interlinguistic assignment for both balanced and unbalanced bilinguals. However, there was no significant difference in intralinguistic assignment among them.

4. ERP results

4.1. FN400: early frontal old/new effect (300~500 ms)

A 2 L2 proficiency (balanced *vs* unbalanced) × 2 language (intralinguistic *vs* interlinguistic) × 2 encoding (compound *vs* unrelated) × 2 location (left anterior *vs* right anterior) × 2 response (intact *vs* new) repeated-measures ANOVA revealed no main effect of response [$F(2, 64) = 1.65$, $p > 0.05$], but a three-way interaction of language-by-L2 proficiency-by-encoding [$F(1, 32) = 3.06$, $p < 0.001$, $\eta^2_p = 0.09$; Fig. 2]. A follow-up ANOVA was executed for both balanced and unbalanced bilinguals respectively.

4.1.1. Unbalanced bilinguals

A language × encoding × location × response repeated-measures ANOVA revealed main effects of response [$F(1, 16) = 11.22$ $p < 0.005$, $\eta^2_p = 0.41$], encoding [$F(1, 16) = 5.42$, $p < 0.005$, $\eta^2_p = 0.25$], and a two-way interaction of language-by-response [$F(1, 16) = 5.42$, $p < 0.005$, $\eta^2_p = 0.25$]. A follow-up ANOVA showed that neither compound [$F(1, 16) = 1.20$, $p > 0.05$] nor unrelated word-pairs [$F(1, 16) = 0.21$, $p > 0.05$] could elicit FN400 in interlinguistic assignment. However, an FN400 for the compound [$F(1, 16) = 33.20$, $p < 0.001$] but not for the unrelated word-pairs [$F(1, 16) = 3.04$, $p > 0.05$] was observed in intralinguistic assignment.

4.1.2. Balanced bilinguals

A similar ANOVA revealed main effects of response [$F(1, 16) = 14.46$, $p < 0.005$, $\eta^2_p = 0.48$], and encoding [$F(1, 16) = 14.35$, $p < 0.005$, $\eta^2_p = 0.47$]. However, no interaction was found [$Ps > 0.5$]. Results indicated that FN400 could be observed in intralinguistic and interlinguistic assignment under the compound word-pairs, while two assignments could not elicit FN400 under the unrelated word-pairs.

4.2. LPC: later left parietal old/new effect (500~800 ms)

A 2 L2 proficiency (balanced *vs* unbalanced) × 2 language (intralinguistic *vs* interlinguistic) × 2 encoding (compound *vs* unrelated) × 2 location (left central *vs* right central) × 2 response (intact *vs* new) repeated-measures ANOVA revealed a main effect of location [$F(2, 64) = 5.02$ $p < 0.001$, $\eta^2_p = 0.14$], and a four-way interaction of language-by-location-by-response-by- encoding [$F(2, 64) = 6.89$, $p < 0.001$, $\eta^2_p = 0.18$; Fig. 3].

Table 3
Description of behavioral results [*M* (*SD*)].

		compound word-pairs				unrelated word-pairs			
Type	Proficiency	intact	rearranged	new	Pr	intact	rearranged	new	Pr
Hits	unbalanced	0.75(0.13)	0.74(0.12)	0.53(0.18)	0.68(0.12)	0.74(0.12)	0.69(0.14)	0.57(0.15)	0.50(0.17)
L2-L1	balanced	0.78(0.16)	0.74(0.16)	0.60(0.18)	0.72(0.20)	0.72(0.18)	0.69(0.18)	0.60(0.17)	0.57(0.19)
L1-L1	unbalanced	0.86(0.08)	0.83(0.11)	0.77(0.11)	0.76(0.14)	0.90(0.08)	0.74(0.12)	0.57(0.17)	0.70(0.17)
	balanced	0.85(0.12)	0.85(0.13)	0.76(0.14)	0.84(0.12)	0.93(0.08)	0.79(0.13)	0.69(0.13)	0.74(0.14)
RTs (ms)	unbalanced	1824(259)	2270(245)	2015(267)	–	2105(293)	2091(262)	2278(327)	–
L2-L1	balanced	1904(325)	2191(207)	2024(176)	–	2034(294)	2088(229)	2199(320)	–
L1-L1	unbalanced	1544(236)	2183(214)	1638(241)	–	1745(286)	1976(205)	1729(247)	–
	balanced	1654(256)	2186(202)	1774(278)	–	1813(360)	1997(226)	1789(317)	–

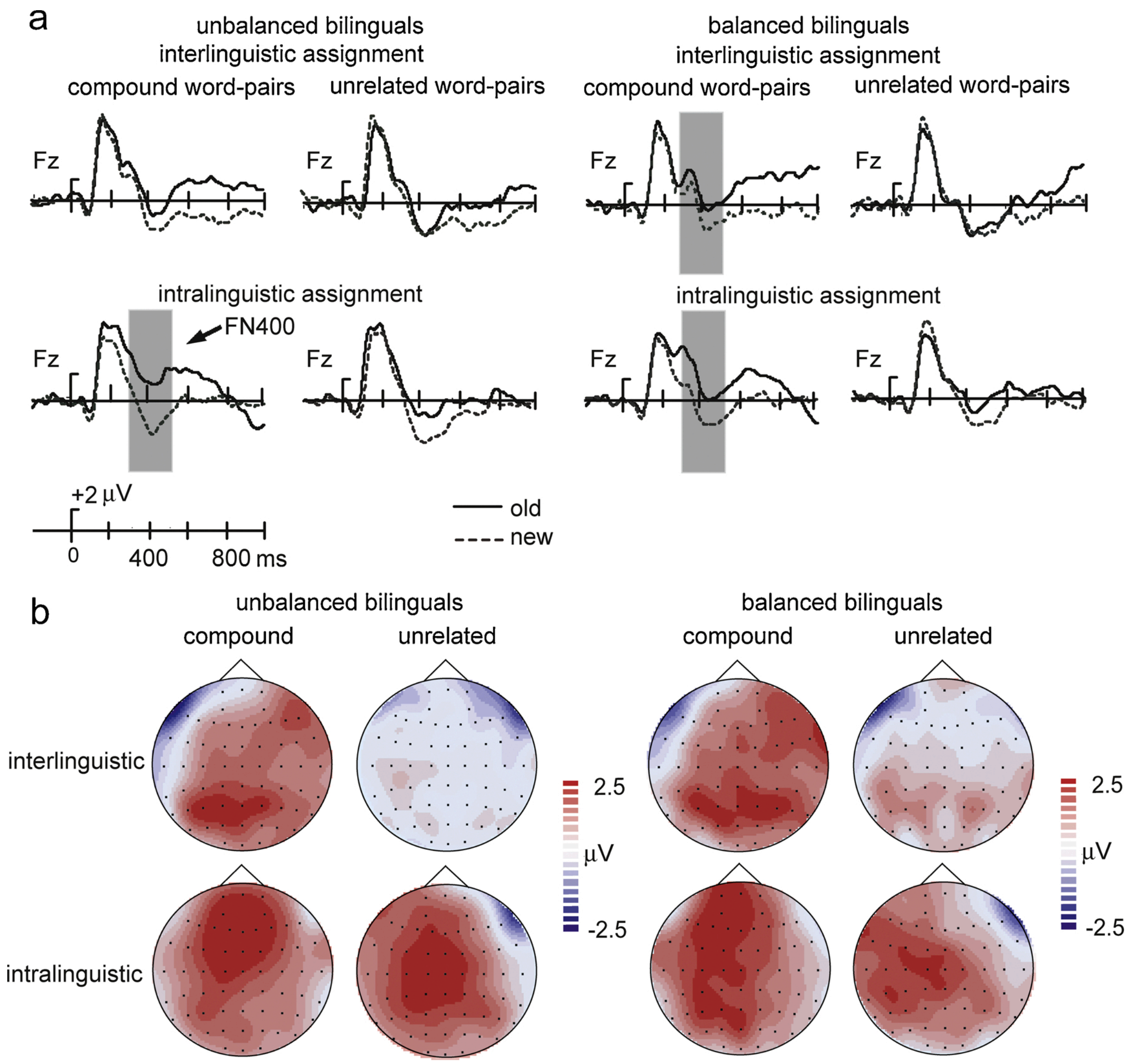

Fig. 2. ERP results for interlinguistic or intralinguistic assignment at 300~500 ms. (a) Grand average ERP waveforms recorded at Fz for unbalanced (Left) and balanced bilinguals (Right). (b) Topographical maps (intact minus new) for unbalanced (Left) and balanced bilinguals (Right).

4.2.1. *Unbalanced bilinguals*

A language × encoding × location × response repeated-measures ANOVA revealed main effects of response [$F(1, 16) = 13.16$ $p < 0.005$, $\eta^2_p = 0.48$], and encoding [$F(1, 16) = 37.66$, $p < 0.001$, $\eta^2_p = 0.70$]. However, no interaction was found [$Ps > 0.5$]. The results indicated that there was an LPC in both intralinguistic and interlinguistic assignments regardless of the encoding strategy.

4.2.2. *Balanced bilinguals*

A similar ANOVA revealed main effects of response [$F(1, 16) = 54.87$, $p < 0.001$, $\eta^2_p = 0.77$], and encoding [$F(1, 16) = 11.54$, $p < 0.005$, $\eta^2_p = 0.42$]. Same as the unbalanced bilinguals, intralinguistic and interlinguistic assignments could elicit LPC among balanced bilinguals regardless of the encoding strategy.

4.3. *Topographic analysis*

Vector-scaled data for the 300~500 ms and the 500~800 ms time window was used to analyze the topographical differences of intact and new.

A 2 L2 proficiency (balanced *vs* unbalanced) × 2 language (intralinguistic *vs* interlinguistic) × 2 time (300~500 ms *vs* 500~800 ms) × 4 location (left anterior, right anterior, left central *vs* right central) × 2 response (intact *vs* new) repeated-measures ANOVA revealed a significant interaction between time and location [$F(61, 1952) = 1.38$, $p < 0.05$, $\eta^2_p = 0.04$], indicating different topographic distributions between the FN400 and the LPC effect. The FN400 effect was distributed more anteriorly while the LPC effect were distributed in the left central site.

5. Discussion

The important findings of the present study were twofold. Firstly, the unitization effect emerged in a cross-language context. This effect was indicated by an FN400 component in a cross-language context under unitization for balanced bilinguals. The results indicated that unitization facilitated familiarity to supported cross-language associative retrieval. Secondly, in the interlinguistic assignment, an FN400 component was found under unitization for balanced bilinguals but not for unbalanced bilinguals. The results showed that the unitization effect in a cross-language context was mediated by L2 proficiency.

Consistent with previous literatures [4–8], we found that familiarity supported associative recognition under unitized encoding conditions. The current study further extended the unitization effect to cross-language associative retrieval. According to the TAP theory, cross-language transfer existed in tasks emphasizing semantic

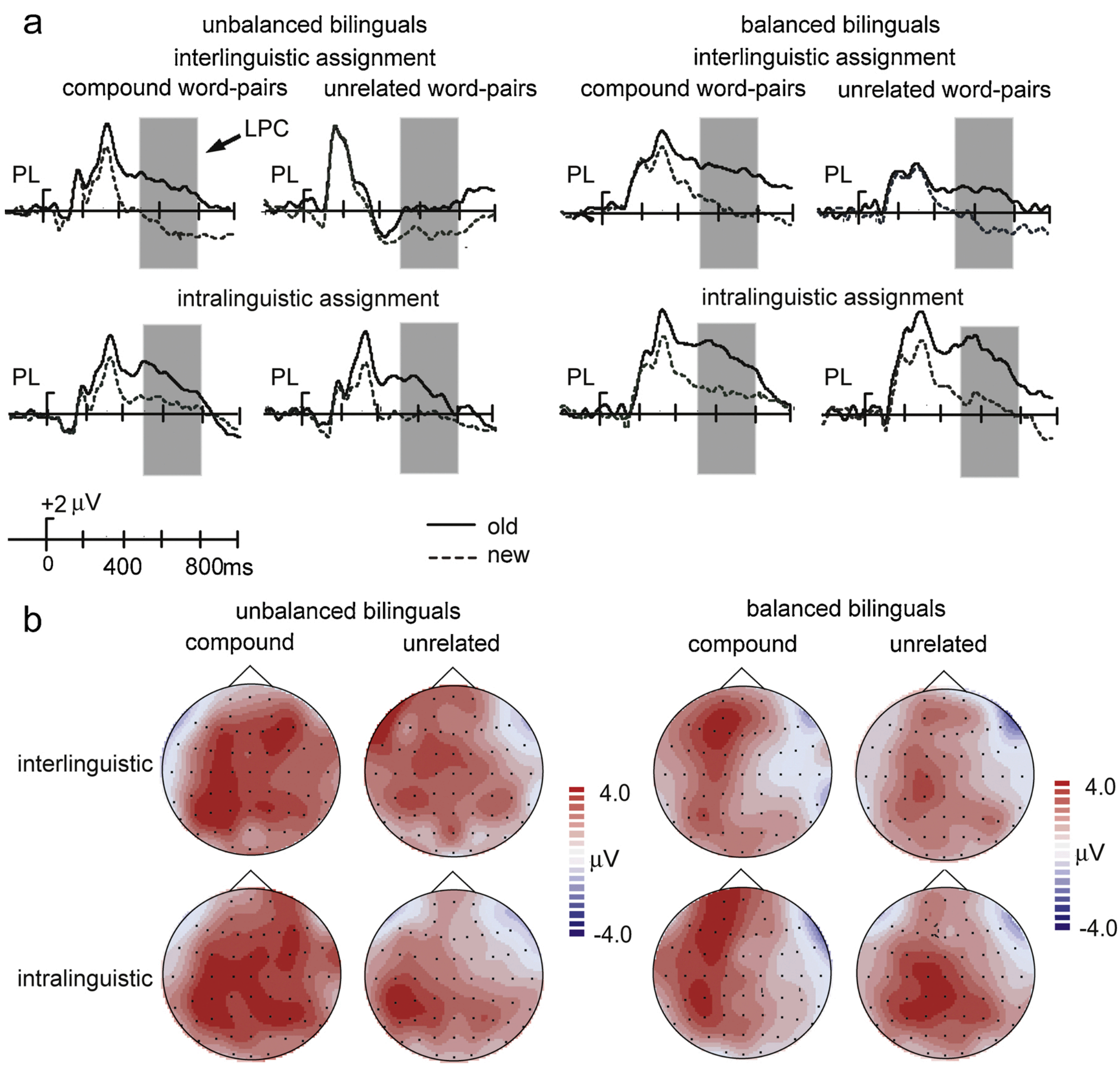

Fig. 3. ERP results for interlinguistic or intralinguistic assignment at 500~800 ms. (a) Grand average ERP waveforms recorded at P1 and P3 (PL) for unbalanced (Left) and balanced bilinguals (Right). (b) Topographical maps (intact minus new) for balanced (Left) and unbalanced bilinguals (Right).

processing [27,28]. In the interlinguistic assignment, the surface characteristics were changed, but they were overlapped in semantic attributes between two languages. Thus, unitization could support familiarity-based cross-language associative retrieval when they integrated different items into a single entity. Combined with previous studies, we posited that unitization occurred provided semantic relatedness exceeded some certain level according to the level of unitization framework. Both the type of language and retrieval language congruence did not influence unitization effect as long as the unitization congruence kept constant between study and test [29].

In addition, the current study had shed some light on the unitization effect, especially the unitization effect in cross-language associative retrieval was mediated by L2 proficiency. In the current study, balanced bilinguals accessed the concept of Chinese words (L2) directly without activation of Uygur words (L1). Subjects employed similar cognitive resources in Uygur and Chinese, could integrate different Chinese items

ent in semantic representation

tive recognition. This was the reason why unitization could still work.

In contrast, unbalanced bilinguals had to access the concept of Chinese words through Uygur translation equivalents. During encoding, translating Chinese words to Uygur translation equivalents might compete for general resources. Moreover, although Chinese words had been translated to Uygur translation equivalents, Chinese words were still activated. This would in turn compete for general resources. The overused general resources might interrupt unitized encoding of Uygur words, resulting weak unitized representation. During retrieval, unbalanced bilinguals might have to inhibit activation of Chinese words when they retrieved Uygur words. Because retrieving Uygur words and inhibiting activation of Chinese words required the same type of materials (words), they competed for the same representations, perhaps increasing overall involvement of cognitive control mechanisms, and occupying more cognitive resources. Together, the implementation of unitization and the switch between languages competed for common available processing resources, and inhibiting activation of non-target language required processing resources during encoding [30]. Unbalanced bilinguals consumed lots of cognitive resources to inhibit activation of Chinese words in both encoding and retrieval, resulting in eliminating unitization effect, which lacked an FN400 effect in

val.

ompound word pairs which was bottom-top processes to examine whether the unitization effect could achieve in a cross-language context. Whether the result of the present study would generalize to a top-down approach was unknown. Future research can investigate top-down processes of the unitization to examine the unitization effect of cross-language associative retrieval.

6. Conclusion

To conclude, unitization facilitated familiarity to support cross-language associative retrieval, and the unitization effect was mediated by L2 proficiency. However, researches on the underlying mechanisms of cross-language associative retrieval, as well as the dynamic interaction with L2 proficiency still needed to be further explored.

Author contributions

Guixiong Liu, Yujuan Wang and Chunyan Guo bore the responsibility for the study design and analysis of the data. Guixiong Liu wrote the original draft of the article. Yujuan Wang revised the article. Yongping Jia participated in the study design and acquired the data. All authors contributed substantially to this work and approved the final manuscript.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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