Probing an Integrated Mental Lexicon with the Trilingual Cognate Priming Advantage: From Behavioral Evidence to Computational Architecture

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Introduction

Previous studies have shown that trilinguals respond faster to triple cognates, which share form and meaning across three languages, than to double cognates, which share them across only two [1,2]. This triple cognate advantage has been interpreted as evidence that language-nonselective lexical access extends to trilinguals. However, it remains unclear whether this advantage can be observed in the absence of cross-language orthographic overlap, whether it emerges during the early, automatic processing probed by masked priming [3], and whether it is jointly modulated by L2 and L3 proficiency.

Accounting for trilingual co-activation and its joint modulation by L2 and L3 proficiency poses a challenge for computational accounts of multilingual lexical processing. Existing accounts, including BIA+ [4] and Multilink [5], posit an integrated lexicon but do not fully specify how three languages interact or how proficiency in multiple languages jointly influences lexical processing [6,7]. We examined these issues in Chinese–English–Japanese (CEJ) trilinguals, whose languages are written in distinct scripts, using a behavioral experiment followed by a computational implementation of an integrated mental lexicon.

Behavioral Experiment

Fifty-two CEJ trilinguals (L1 Chinese, L2 English, L3 Japanese, all JLPT N1) completed a masked translation priming naming task. Targets comprised 120 Japanese katakana words (Figure 4): 60 CEJ triple cognates (e.g., ギター, Chinese translation prime 吉他, *guitar*) and 60 EJ double cognates (e.g., スカート, Chinese translation prime 裙子, *skirt*). English proficiency (LexTALE) and Japanese proficiency (SPOT90) were tested after the naming task and entered as continuous predictors.

Results (Figure 1): Related primes produced larger priming for triple cognate pairs (139 ms) than for double cognate pairs (83 ms), yielding a 56-ms *triple cognate priming advantage* (b = 0.064, p < .001). Critically, the Prime Type × Cognate Status × L2 Proficiency × L3 Proficiency interaction was significant (b = 0.033, p = .002) and robust (permutation p = .009; BF = 11.7). This priming advantage was absent only when a trilingual's Japanese proficiency was relatively higher and English proficiency relatively lower (14 ms, p = .483; simple effects at ±1 *SD*), presumably because the efficiently retrieved Japanese target would leave little room for additional facilitation while the weakly co-activated English word would add little support or competition. These findings suggest that all three languages are co-activated early, even in the absence of orthographic overlap, and that the efficiency of co-activation is jointly modulated by L2 and L3 proficiency.

Computational Modeling

We next tested whether the observed behavioral effects could emerge from the computational implementation of the integrated mental lexicon (Figure 2). Orthographic, phonological, and semantic representations were constructed using vectors from a 17,490-word trilingual lexicon. Three sequentially trained Self-Organizing Maps (SOMs) visualized the topological organization of each layer (Figure 3) [8,9]. Deep Discriminative Learning (DDL) learned the mappings through which activation propagated between layers [10]. Interactive Activation and Competition (IAC) dynamics were used to simulate response times [11]. Following BIA+ and Multilink, proficiency was implemented as word-level resting-level activation (RLA).

Results: The model reproduced the triple cognate priming advantage (simulated b = 0.070, p < .001), demonstrating that this effect can emerge from an integrated mental lexicon without a cognate-specific mechanism. However, it did not reproduce the four-way interaction observed in the behavioral data. This model–data discrepancy identifies a specific limitation of the current implementation, suggesting that multilingual proficiency cannot be captured solely through modulation of RLA.

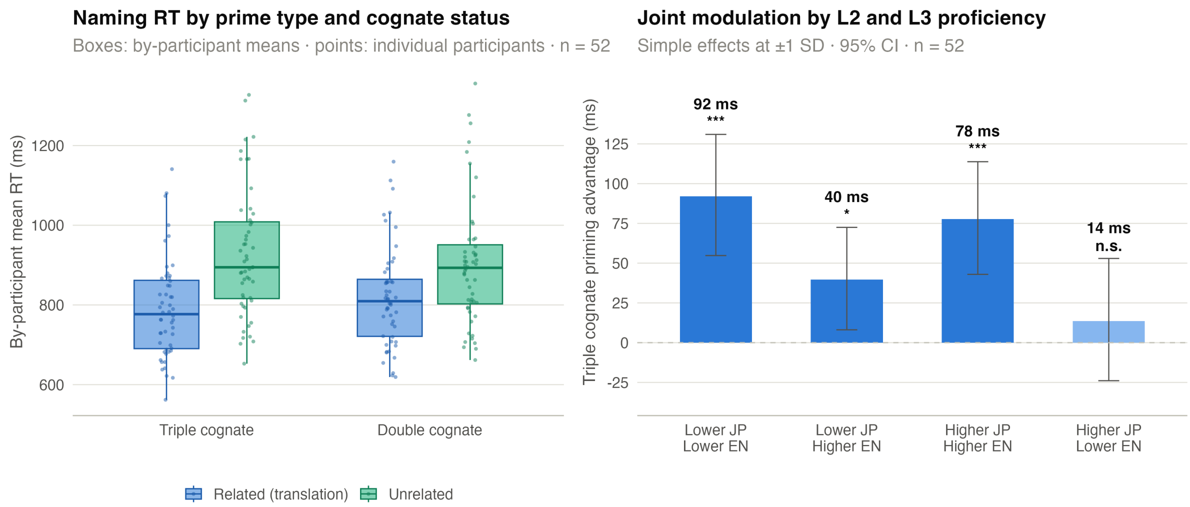

Figure 1: Behavioral results. Left: by-participant mean RT distribution by Prime Type × Cognate Status, showing both translation priming (related vs. unrelated) and the triple cognate priming advantage (triple vs. double cognates). Right: the triple cognate priming advantage across four proficiency configurations (simple effects at LexTALE × SPOT90 ±1 *SD*).

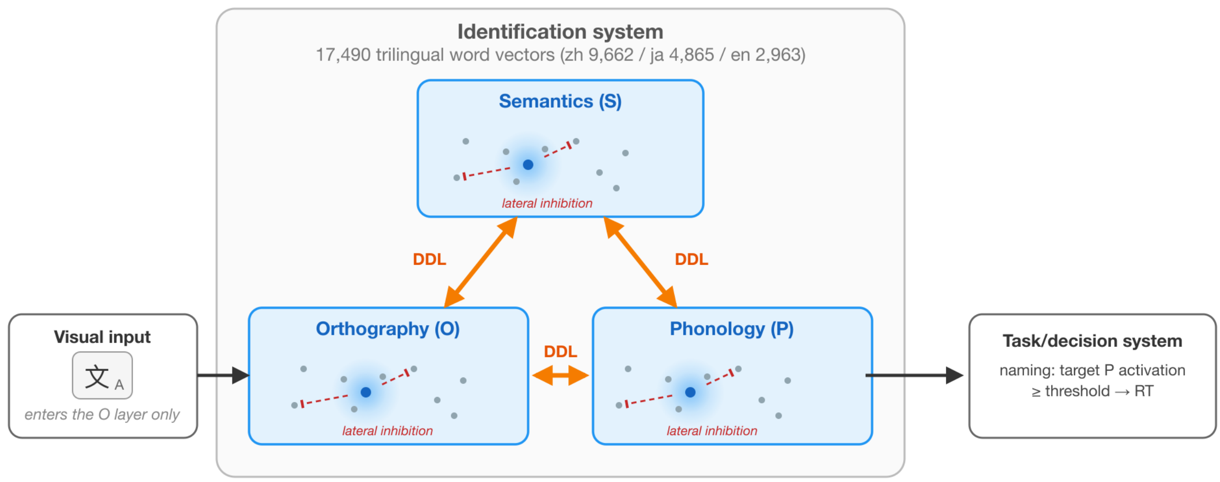

Figure 2: Computational implementation of the integrated mental lexicon. The three-layer lexicon serves as the identification system and the naming readout as the task/decision system, a division adopted from BIA+ [4]. Input enters at the orthographic layer, activation propagates across the layers through the DDL mappings under IAC dynamics, and the naming response is read out from the phonological layer.

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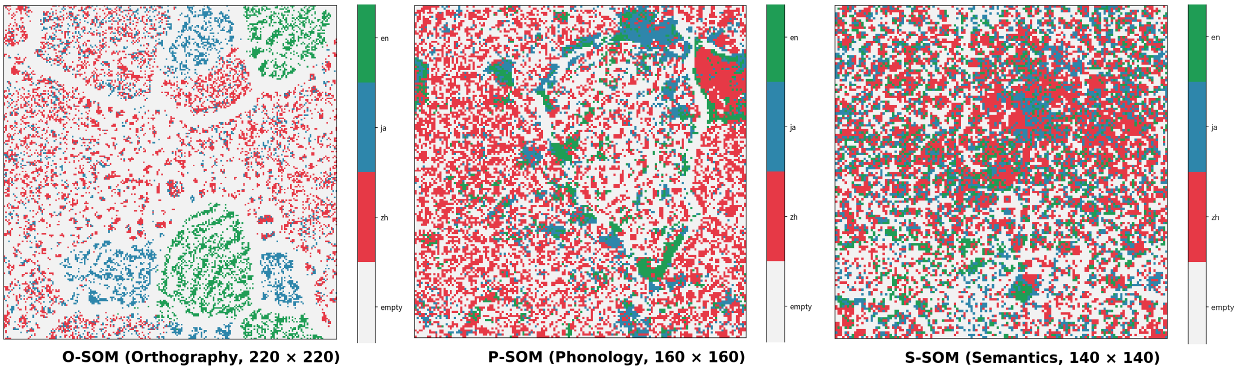

Figure 3: Organization of the three layers, visualized by the three SOMs. Each map was trained sequentially in the order of acquisition (L1 Chinese, then L2 English, then L3 Japanese), following DevLex-II [9]. Each node is colored by the dominant language of the words mapped onto it (red = Chinese, blue = Japanese, green = English, white = empty). The orthographic map is largely language-distinct, with Chinese and Japanese kanji partially integrated. The semantic map is highly cross-linguistically integrated, with translation equivalents occupying nearby locations. The phonological map falls between, with cognates and cross-linguistically similar phonological items locally clustered. These organizational patterns emerge from the geometry of the input vectors.

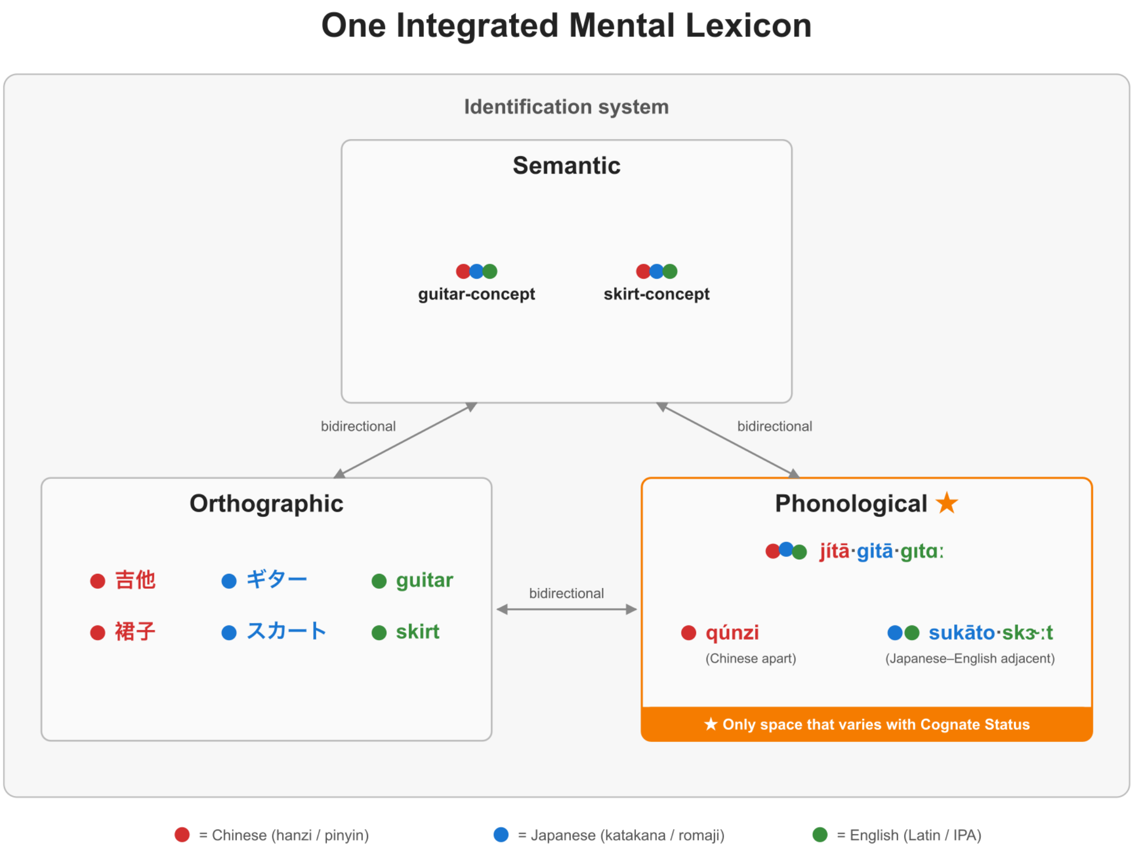

Figure 4: The integrated mental lexicon, serving as the model's identification system [4], illustrated with one triple cognate and one double cognate. Each item comprises its Chinese, Japanese, and English words. The two cognate types have comparable semantic and orthographic organization. Translation equivalents are located near one another in the semantic layer, while their orthographic forms remain separated by script across hanzi, katakana, and the Latin alphabet. The critical difference lies in the phonological layer. For the triple cognate, the Chinese, Japanese, and English forms occupy neighboring positions, whereas the double cognate contains an adjacent English–Japanese pair with the Chinese form located farther away. Because activation spreads bidirectionally and resonates over time across the interconnected semantic, orthographic, and phonological layers [5], this difference in cross-language phonological similarity would influence processing throughout the lexicon.