

Stimulus timing during word form learning modulates later processing dynamics: Evidence from pupillometry

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The context in which novel words are learned may have a powerful influence on the nature and quality of linguistic representations. Research on associative learning suggests that *temporal relations* between events are encoded into mental representations of the novel stimuli and influence their later retrieval dynamics [1]. Recent evidence further indicates that presentational timing affects language learning [2, 3], such as the acquisition of written and spoken word form pairs that were either presented asynchronously (spoken-first or written-first) or simultaneously [3]. While *recognizing* novel words in this study was not affected by timing condition, *recall* performance was generally better when words were learned asynchronously. These results are consistent with the notion that timing influences the stability of representation but remain open regarding potential effects of timing on later processing dynamics.

In the present study, we addressed this question using pupillometry. Thirty-nine native German speakers first learned Mandarin Chinese word forms across three weeks. Written (Pinyin) and spoken forms were presented synchronously or asynchronously. In week four, participants completed a match/mismatch task in which spoken words were followed by matching or mismatching written forms. Untrained items were used as distractors (Figure 1 for an overview). Pupil dilation was measured in two TWs, starting with the onset of the spoken (TW1) and the onset of the written word form (TW2).

While accuracy for trained was higher than for untrained items, timing condition did not affect recognition accuracy within the trained items. Critically, effects of timing were seen in participants' pupillary dilations (Figure 2): Growth Curve Analyses revealed that items learned in the written-first condition showed a steeper increase and more sustained dilation than audio-first and synchronous items in TW1, consistent with higher processing demands and sustained effort. In TW2, mismatching items elicited stronger dilation increases, particularly in the written-first condition, suggesting high costs in resolving mismatches of written-first learned items.

Our results demonstrate that contextual factors during learning (i.e., *timing*) modulate processing dynamics during later recognition. These findings are consistent with the notion that timing is integrated into the words' mental representations.

References

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Figures and Tables

Figure 1: Experimental Scheme.



Figure 2: Pupil diameter (arbitrary units) over time for the different training conditions (audio-first, audio-last, sync, untrained) for TW1 (A; spoken word) and TW2 (B; written word).

