Neurotypological considerations of temporal concord processing

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Humans are able to represent events in time with several cognitive processes: (a) localizing them on the timeline according to oneself (LOCALIZATION), (b) reasoning about the temporal order between events and sub-events (SEQUENCING), and (c) assessing the belief/truth-value of the existence of the event (EXISTENTIAL), among others [1-3]. The timing of the events can be expressed with language, especially with the grammatical categories of *tense*, *aspect* and *modality* [4-5]. Several ERP experiments have been conducted to understand how the expression of time is processed in the brain, including languages such as Akan [6], Dutch [7-8], German [9], Italian [10], (Taiwan) Mandarin [11-13] and Thai [14]. These studies used the same experimental paradigm, the 'temporal concord paradigm' [10], which consists of placing the grammatical markers of time reference (e.g., English past tense *-ed*) after a deictic time adverb which is coherent or not (e.g., *yesterday*, or **tomorrow*).

This paper proposes to map the cognitive mechanisms linked with the notion of time, their linguistic expressions at the grammatical level and their neurophysiological signatures in order to establish the premises of a neurotypological model of temporal concord processing.

ERP experiments on tense marking focused on two usages: (a) tense used to express deictic localization [6, 8-10], including past, present and future tense, and (b) present tense used for narrative purposes [7]. The first kind is linked with the LOCALIZATION process, and its temporal concord violation elicited a P600 effect regardless of the time frame. The second kind is related to the SEQUENCING process, as tense is used to express the advancement of the temporal perspective (reflected in the experimental design by comparing the temporally incoherent present tense verb with a temporally coherent past tense verb). In this case, this violation is indicated by a short-lived LAN at the 300–500 ms time window.

Experiments on the temporal concord violation of aspect focused on three subtypes, (a) perfective aspect [12], (b) phasal aspect [12, 13], and (c) experiential aspect [13, 14], which are associated with different neurophysiological signatures. The violation of the Mandarin perfective *le*$_1$ (expression of the temporal sequence between the time of the event and its results [15-16]) elicited an LAN, interpreted as reflecting the violation of the temporal SEQUENCE 'event-result'. The violation of the Mandarin phasal aspect *guo*$_2$ elicited a P600, which is associated with its meaning of asserting at least one instance of the event in the past [15, 17], and linked with the LOCALIZATION process. The temporal violation of experiential aspect markers was indicated by a biphasic N400-P600 response in both Mandarin and Thai. Experiential aspect is understood as exhibiting two elements: the *assertion-localization* in the past of the *existence* of an event [17]. These two ERP components can be mapped with these elements: P600 as reflecting the temporal LOCALIZATION, and the N400 temporal EXISTENCE.

As for modality, one experiment was conducted on the '*you* (to have) + VP' construction in Taiwan Mandarin [11], which is analyzed as expressing the existence of an event in time [18]. Its temporal concord violation elicited an N400 effect, taken as indicating the violation in terms of belief/truth-value of the temporal EXISTENCE of the event.

The results of these experiments, which include insights from different typological languages and semantic categories, can be generalized as an attempt to construct a neurotypological model of temporal concord processing [19-20] (see Figure 1). Languages exhibit grammatical markers to express temporal LOCALIZATION, SEQUENCING and EXISTENCE, whose violations are reflected by qualitatively different brain signatures. This suggests a shared cognitive-temporal system across languages but modulated by the specific use of these markers.

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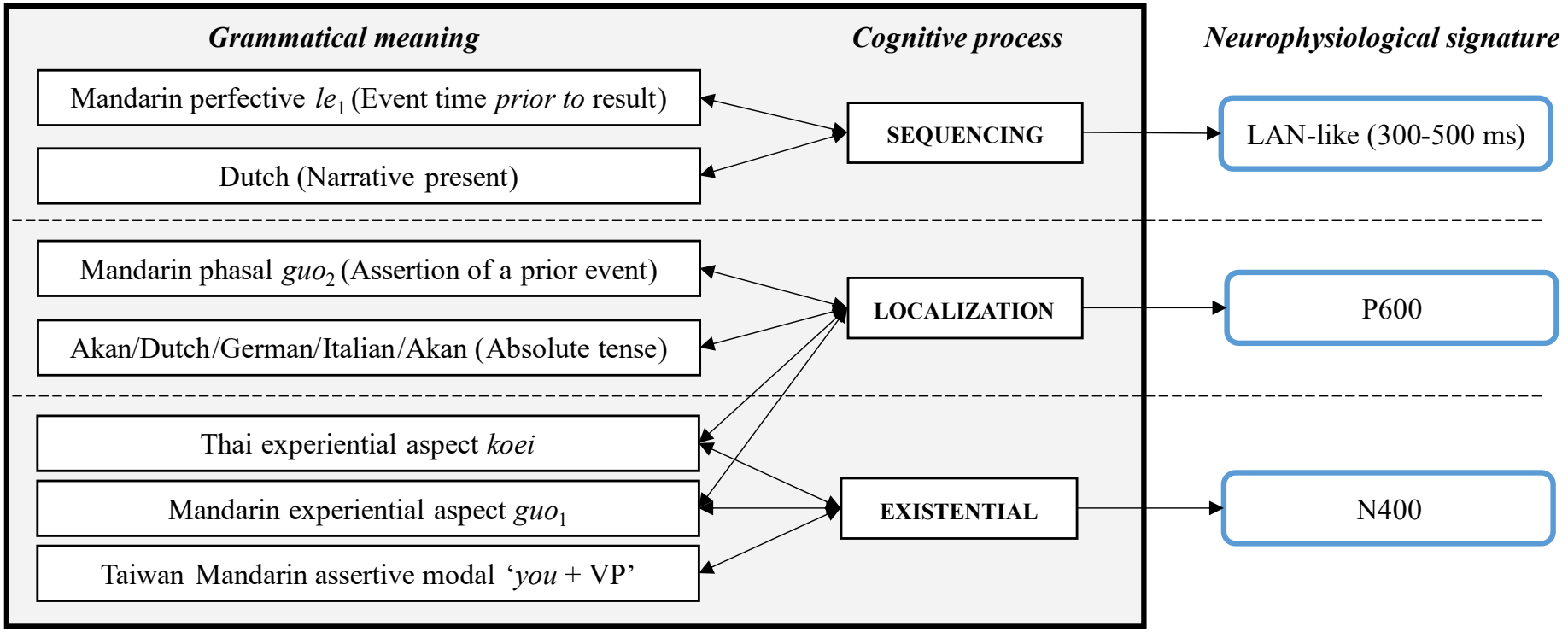

Figure 1. Mapping between (a) the grammatical meaning of the expression of time reference used in the temporal concord experiments, (b) their associated cognitive functions and (c) their neurophysiological signatures