ERP study on the effect of distance during the processing of temporal concord

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Introduction. Linear distance can play a pivotal role during online sentence comprehension. For example, during the processing of subject-verb agreement, linear distance could affect the way the subject features are tracked before encountering the verb, the way verb features are matched and integrated with the subject features and the way any subject-verb inconsistency is dealt with [1]. ERP studies testing agreement violations at short or long distance have reported heterogeneous findings so far. Some studies found a reduced P600 for increased distance [2] while others did not [1] and, more recently, an increase in the P600 amplitude has been found for long distance agreement compared to local agreement [3].

In this ERP study, the effect of distance will be further investigated during the processing of a different phenomenon, namely the temporal concord between a deictic temporal adverb and the verb. Similarly to subject-verb violations, adverb-verb tense violations trigger an early negativity followed by a P600 [4,5]. However, differently from subject-verb (number) agreement, the processing of adverb-verb temporal features also involves discourse-related (i.e. deictic) information. High level information is often assumed to require time to be fully processed: the more the distance between two constituents, the more the time for constituents to be semantically interpreted, and the harder the revision processes [6]. It is thus possible that distance can play a more crucial role during the processing of tense. Evidence in this respect has been reported only behaviorally, in an eye-tracking study in Spanish [7] showing that distance affects tense mismatches more than number violations.

Method. In order to qualify the nature of possible extra costs due to distance, (N=23) Italian native speakers were asked to read and judge the grammaticality of 160 sentences as in (1) and (2) and 160 filler items presented word by word, while EEG was recorded (64 ch). Each participant read 40 (20 past, 20 future) items for each of the 4 conditions.

- (1) Il poliziotto *domani/*ieri* testimonierà di fronte al giudice. (*adjacent: control, mismatch*) (The policeman tomorrow/*yesterday will testify in front of the judge)
- (2) *Domani/*Ieri* il poliziotto <u>testimonierà</u> di fronte al giudice. (*distal: control, mismatch*) (Tomorrow/*Yesterday the policeman will testify in front of the judge)

ERPs time-locked to the onset of the verb (Figure 1) were analyzed using a 2(grammaticality) x 2(distance) x 3(longitude) x 2(laterality) repeated measures ANOVA in the lateral sites, and a 2(grammaticality) x 2(distance) x 3(longitude) repeated measures ANOVA in the midline sites (Table 1).

Results. Both local and distal violations elicit a broad (rather frontally) distributed negativity in the 380-480ms interval that does not differ in amplitude or topography as a function of distance. The following P600, which shows a clear posterior topography, is also similar across distance in its first stage (500-800ms). Conversely, an effect of distance emerges in terms of a 4-way interaction with the topographic factors in a later time window (i.e.800-1000ms): a larger positivity is elicited by the distal violations compared to the local ones and this effect is maximal over the right anterior part of the scalp.

Conclusions. Data show that distance affects the processing of adverb-verb tense violation, but this effect appears only during later stages of the online verb processing. The later stage of the P600 has been suggested to correspond to the re-interpretation (or repair) of an agreement mismatch, which can be harder when discourse-related properties are considered [8]. The frontal distribution of the P600 has been related to an increase in discourse complexity [9]. These two accounts taken together thus suggest that in the distal conditions the re-interpretation of the tense mismatch is more demanding because a richer set of (discourse-related) information needs to be examined, thanks to distance. A direct replication of this study is currently in progress in our lab.

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Figure 1. Grand average ERPs of the experimental conditions in anterior-left (AL), frontal (F), anterior-right (AR), central-left (CL), fronto-central (FC), central-right (CR), parietal-left (PL), centro-parietal (CP), parietal-right (PR) sites.



Table 1. Time windows (in milliseconds) after the target stimulus onset, and relative statistically significant main effects or interactions in lateral and midline sites

	Lateral sites	Midline sites
380-480	gram(F(1,22)=4.92, p<0.05)	gram(F(1,22)=4.27, p=0.05)
500-800	gramxlon(F(2,44)=5.68, p<0.05)	gramxlon(F(2,44)=8.33, p[GG]<0.05)
	- lateral-parietal sites:	- centro-parietal sites:
	gram(F(1,22)=4.58, p<0.05)	gram(F(1,22)=5.31, p<0.05)
800-1000	gramxdistxlonxlat(F(2,44)=8.33,p<0.05)	gramxlon(F(2,44)=17, p[GG]<0.05)
	- lateral-anterior sites:	- fronto-central sites:
	gramxdistxlat(F(1,22)=4.22, p=0.05)	gram(F(1,22)=6.03, p<0.05)
	- right-anterior sites:	- centro-parietal sites:
	gramxdist(F(1,22)=4.58, p<0.05)	gram(F(1,22)=25.04, p<0.05)

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