

How do visual modality and linguistic structure affect temporal processing of sign language?

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The temporal processing of an incoming perceptual signal depends on the sensory modality of presentation and the temporal structure of the signal. We investigated the visual domain by comparing the processing of a purely visual language with that of non-linguistic temporally structured information. Twenty-three hearing highly proficient users of Spanish Sign Language (LSE), all of whom use LSE professionally on a daily basis, took part in this experiment. The experiment included two tasks: in the linguistic task participants saw sentences in LSE, which they had to repeat; in the non-linguistic task they saw videos of a dot tracing combinations of four consecutive symbols (two letters and two digits), which they had to identify. All stimuli were distorted using local time-reversal: each video was divided into windows of a set duration, and each window was temporally reversed while maintaining the windows' relative order (Hwang, 2011; see Figure 1). The duration of the window varied across stimuli (0–399 ms); longer reversal windows create greater distortion and lower accuracy in perception. In order to characterize how the size of reversal window modulates the level of accuracy in perception, we run a linear mixed model analysis. The results show that locally time-reversed distortion similarly affects both conditions (see Figure 2). The visual modality is characterized by a gradual and constant decrease in intelligibility, in contrast with the pattern normally displayed in the acoustic modality by spoken languages, for which a sharp drop in intelligibility reveals a temporal integration window for the signal (Ueda et al., 2017). However, compared to the non-linguistic task, LSE is more resilient to temporal manipulation: intelligibility never drops below 50% even in the most severe distortion (reversal-window of 399 ms) but reaches 20% in the non-linguistic condition. This study shows that temporal processing in the visual domain is conditioned by the modality. Sign language though displays an advantage: its spatial and temporal structure allows for redundancy of the linguistic information in the visual signal, which might compensate for the loss of information due to the temporal distortion.

Bibliography:

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- Hwang, S. O. K. (2011). *Windows into sensory integration and rates in language processing: insights from signed and spoken languages* (Doctoral dissertation).

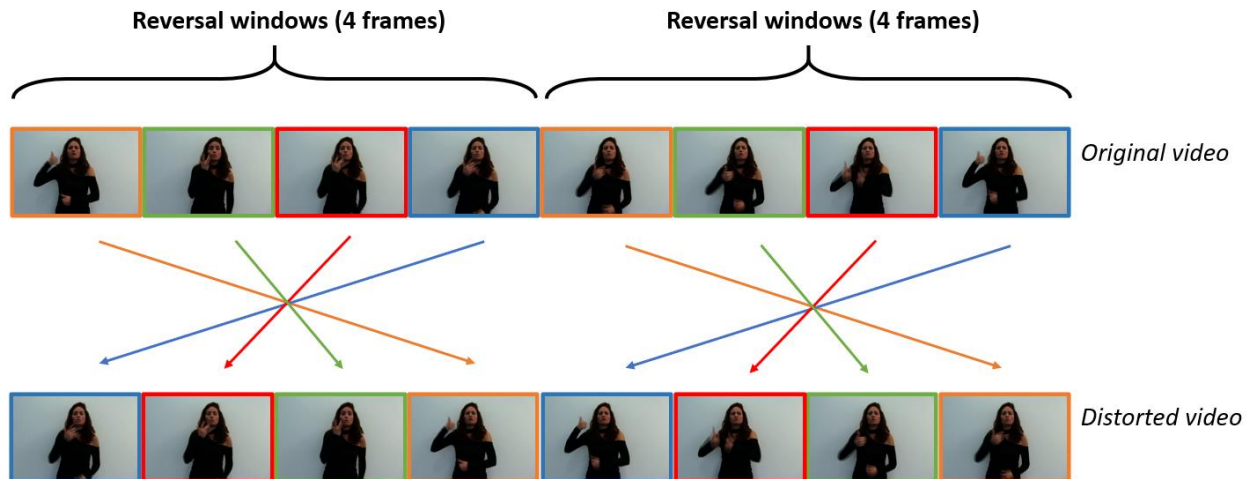


Figure 1: Demonstration of how locally time-reversal distortion is applied to videos in LSE. In the example the reversal window is 4 frames long.

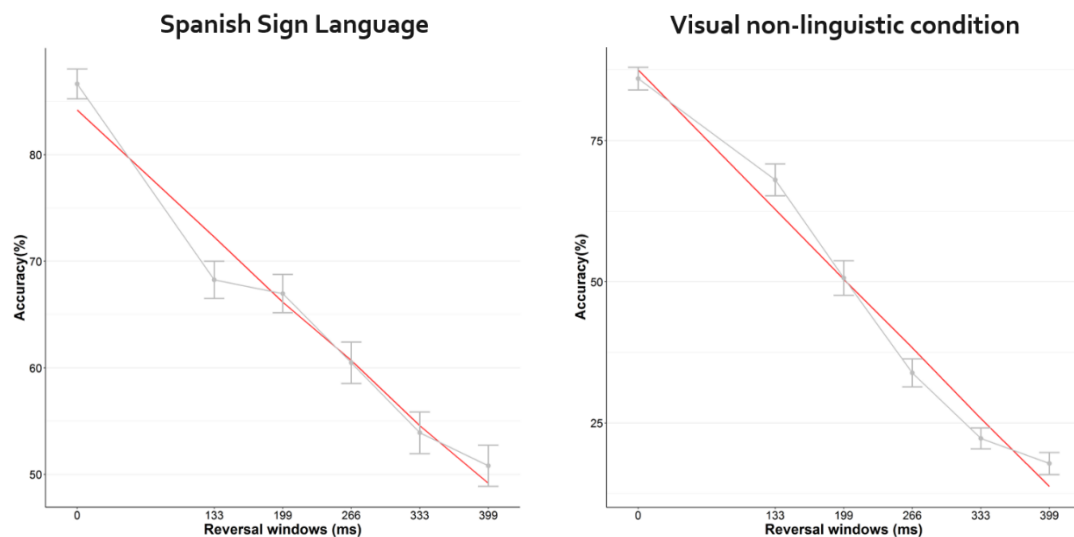


Figure 2: Plots show the accuracy curve as a function of reversal window size for Sign Language condition (left) and visual non-linguistic condition (right). The grey line represents mean accuracy across participants, while the red line shows the predicted values. The models used are:
 LSE: $\text{Accuracy} \sim \text{Reversal Window} * \text{Number of Repetition} + (1/\text{Participant}) + (0 + \text{Reversal Window}/\text{Participant}) + (1/\text{Item})$
 Visual non-linguistic: $\text{Accuracy} \sim \text{Reversal Window} + (1/\text{Participant}) + (0 + \text{Reversal Window}/\text{Participant}) + (1/\text{Item})$

Spanish Sign Language

Spanish Sign Language (LSE – *lengua de signos española*) is the most widely used signed language of Spain. (Another sign language, LSC – *llengua de signes catalana*, is used in the region of Catalonia.)

Like other sign languages, LSE is a fully-developed, natural language with rich syntactic and semantic features, comparable to those of spoken languages. Communication in sign language is visuo-spatial and employs different body articulators such as the hands, upper body, head and facial features (including the mouth, eyes, and eyebrows). There are various models for the phonological structure of sign languages but all agree that the parameters of handshape (the form the hands adopt), location (on the signer's body or in the signing space before the body) and movement (which may be internal to the hand and thus involve a change of handshape, or comprise a translational movement through space) are the fundamental sub-lexical units of the sign. These parameters are combined in a largely simultaneous manner, and this marks an important distinction between spoken and signed languages: in spoken languages, due to the constraint of the acoustic modality, information is delivered in a sequential way. The visuo-spatial nature of signed languages allows parallel processing through the combination of different 'phonological' parameters and the simultaneous use of the articulators, and this impacts the temporal organization of the linguistic information.