

Cognitive effort during the processing of relative clauses with psychological predicates in Spanish: a pupillometric study

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The asymmetry in the processing of subject (S) and object (O) relative clauses (RC) is well documented in literature and seems to be present in a wide range of languages (e.g, in Spanish; in English; in German; and French). However, this asymmetry has mostly been studied in sentences with transitive activity predicates (ACT), while there has been no evidence reported regarding the processing of RCs with psychological predicates (PSY). Memory based accounts of this phenomena predict a general locality preference for shorter filler-gap dependencies (Gibson, 1998; Lewis & Vasishth, 2005). In the case RCs with ACTs, SRCs instantiate a shorter filler-gap dependency than ORCs and this explains why the former are easier to process. However, considering the structural properties of PSYs in Spanish (see note 1), it's in the case of ORCs that a shorter filler-gap dependency is established. Therefore, the processing of ORCs with these predicates should entail less difficulty and lower cognitive effort than SRCs. Task-evoked pupillary responses (TEPR) have been used as a reliable neurophysiological index of cognitive effort in different domains (Beatty, 1982; Beatty & Lucero-Wagoner, 2000). In the sentence comprehension domain, TEPRs have provided a measure of differential processing cost according to the type of structure and its syntactic complexity (e.g, Just and Carpenter, 1993; Scheepers & Crocker, 2004; Schluroff, 1982). **Design:** 33 subjects participated in an auditory sentence comprehension task. They were asked to listen to a sentence; then were showed an image and were prompted to judge whether the image they saw faithfully reflected the content of the sentence heard or not (see Fig. 1). The stimuli (n=20) consisted of RCs with PSYs (1) and with ACTs (2) (see note 2). We manipulated the type of RC with each predicate: SRCs (1.a and 2.a) and ORCs (1.b and 2.b). The images selected were counterbalanced to make the sentences either true or false. Response accuracy and reaction times (RTs), as well as TEPRs, were measured during the task. Pupil diameter was monitored using a desktop-mounted, video-based eye tracker (EyeLink 1000, SR Research Ltd., Ontario, Canada) at a sampling rate of 1000 Hz. **Results:** on average, participants answered 89% ($SE=0.8\%$) of the total stimuli correctly; Figs. 2 and 3 show mean correct answers and standard error, and mean RTs and standard error (only RTs of correct answers were considered) according to condition respectively. Linear mixed-effect models were fitted for data analysis. Results show that RCs with PSYs were harder to comprehend ($p=.02$) and were processed more slowly ($p<.001$) than RCs with ACTs. As it was expected, in the case of RC with ACTs, SRCs were easier to comprehend ($p=.003$) and faster to process than ORCs ($p=.004$). In the case of PSYs, we found that ORCs were easier to comprehend ($p=.007$) but that there were no significant differences between ORCs and SRCs RTs ($p=.58$). **Analysis of TEPRs (in progress):** For each individual trial, mean pupil size during the presentation of the fixation cross will be considered as baseline pupil size. Cognitive effort of sentence processing will be operationalized as the difference between the maximum pupil diameter size achieved during the exploration of the image and the pause after the response and the baseline pupil diameter size ($\Delta TEPR$). Linear mixed-effects models will be fitted for data analysis with $\Delta TEPR$ as dependent variable, predicate type and RC type as fixed factors, log verb frequency as control factor, and item and subject as random factors. **Discussion:** Accuracy measures showed the expected pattern, i.e. opposite asymmetries for SRC/ORC with ACTs and PSYs. However, the asymmetry is not evident for PSYs regarding RTs. We hypothesize that while more time (compared to ACTs) leads to accurate responses in the case of the less demanding ORC, it does not comprise enough time to get the right answer in the more difficult SRC. We will explore this issue using pupil size measures as a proxy of the entailed cognitive demand. **Conclusions:** Our results agree to some extent with the predictions of memory based explanations of the SRC/ORC asymmetry regarding the processing of RCs with PSYs in Spanish. Pupil size data will help understanding the dynamics of the cognitive effort entailed by the processing of these specific structures.

- (1) a. En la imagen aparece la maestra que le gusta a la bruja.
In the image appears the teacher.NOM that CL.DAT likes the witch.DAT.
'In the image appears the teacher that the witch likes'.
- b. En la imagen aparece la bruja a la que le gusta la maestra.
In the image appears the witch.DAT the that CL.DAT likes the teacher.NOM.
'In the image appears the witch that likes the teacher'.
- (2) a. En la imagen aparece la maestra que le grita a la bruja.
In the image appears the teacher.NOM that CL.DAT yells the witch.DAT.
'In the image appears the teacher that yells at the witch'.
- b. En la imagen aparece la bruja a la que le grita la maestra.
In the image appears the witch.DAT the that CL.DAT yells the teacher.NOM.
'In the image appears the witch that the teacher yells at'.

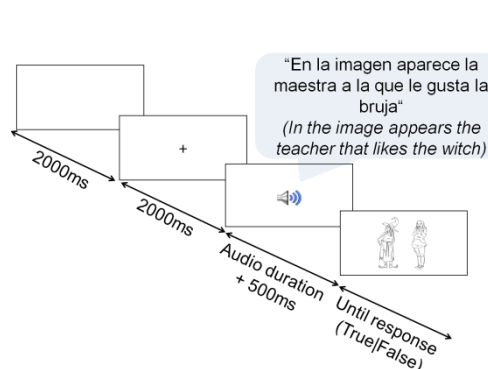


Fig. 1

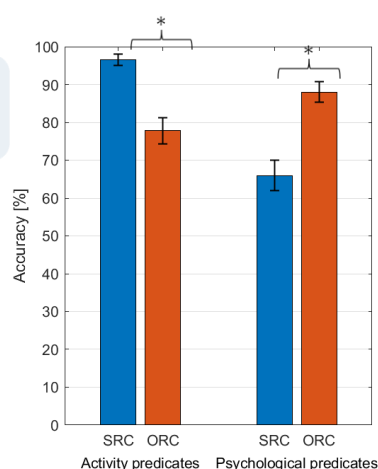


Fig. 2

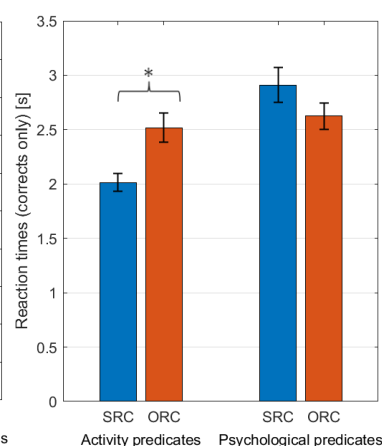


Fig. 3

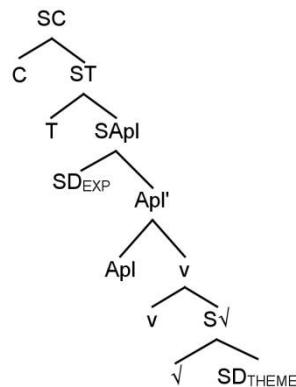
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Note 1

In Spanish, the syntactic structure of sentences with psychological predicates (Belletti & Rizzi, 1988) such as *gustar* ('to like'), also known as third class psychological predicates, differs from the structure of sentences with ACTs. The theme of the event is projected as a subject with nominative case, whereas the experience is projected as an object with dative case. Pujalte (2015) argues that in Spanish, objects of PSYs are generated in a higher syntactic position than subjects, i.e. as high applicative phrases (Pylkkänen, 2008):

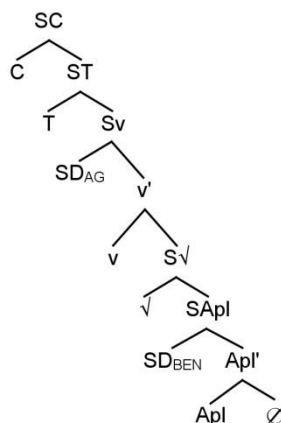
(4)



Note 2

As we have mentioned in the note above, third class psychological predicates project the theme of the event, i.e. the object, with dative case. Therefore we chose ACTs, such as *gritar* 'to yell', that also project the object, the beneficiary argument, with dative case and not accusative as most transitive activity predicates do in Spanish. Cuervo (2003) argues that these dative arguments are introduced and licensed as low applicative phrases:

(5)



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