A Pupillometric Study of Prosody-Syntax Interaction in Turkish

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Introduction: This study investigated a pupillometric evidence for prosody-syntax interaction in Turkish. Pupil diameter processing is measured when participants listened sentences containing prosodic and syntactic incongruities. Our main objective is to put forth how the pupil dilation elucidates prosody-syntax interaction, and secondly, to address the relation between prosodic and syntactic incongruity with the changes in pupil diameter.

Background: Pupil diameter has been recently used as a reliable psychological measurement for processing of language comprehension. Since pupillometry is a lately used measurement, there are restricted number of studies on online processing of prosody. In this context, Engelhardt, Patsenko & Ferreira (2010) found that visual context has a greater effect on ambiguity resolution than does prosody. Zellin et al. (2011) also found an interaction between focus type and focus prosody in discourse processing.

Two language sources was used in this study: prosody and syntax. Turkish exhibits a free word order and the constituents can occur both pre- and post-verbally. Post-verbal constituents in Turkish are always given information (i.e, discourse entities, which the speaker assumes the hearer already knows), hence these constituents do not bear focus (F) feature (e.g. Erguvanlı, 1984, Göksel, 1998). In this regard, while the prosodic violation is provided by incongruous focus and prosodic boundary in post-verbal position, the syntactic violation is provided in the same position by case marking manipulation provided with a dative case misleadingly being assigned, instead of the accusative case.

Method: 20 participants (14 female, mean= 23.79, SD= 5.28; 6 male, mean= 24.33, SD= 3.77) were native speakers of Turkish, and normal/corrected-to-normal vision. The study was supported by a Tübitak (1001) Project. Stimuli consisted of 50 sentences for each of the following four experimental variables in post-verbal positions: Syntactically and prosodically congruent (CC): *duvar–ı* (pencil–ACC), prosodically incongruent (PC): *DUVAR–I* (pencil–ACC), syntactically incongruent (SC): *duvar–a* (wall–DAT), syntactically and prosodically incongruent (PS): *DUVAR–A* (wall–DAT). Stimuli were programmed using *SMI* software. Eye tracker and a 1900 CRT 22-inch wide screen monitor (refresh rate of 140 Hz) were interfaced with a 3-GHz Pentium 4 PC. The stimuli were presented isolated one after the other on the center of gray screen (R: 106 G: 106 B: 106). Pupil diameter was monitored with an SMI RED 500 eye tracker, which uses infrared pupil tracking to sample eye position data at 500 Hz. A 5-point target display was used for calibration of eye position and then a second 5-point display was used to validate the accuracy of calibration and it was checked after every 50 sentences. We used *lme4* package in R (R Core Team, 2013) by using *lmer()* function for pupillometric data and *glmer()* function for behavioral data to fit linear mixed-effects (LME) models, with Syntax (congruent, incongruent), Prosody (congruent, incongruent) and their interaction as fixed factors. In addition to fixed factors considered in simple linear regressions, LME models account for random variation induced by items and participants. Pupillometric data were analysed in a 1200 ms time window beginning the onset of the post-verbal object (i.e., critical word). The rationale for examining a 1200 ms time window was based on a previous study by Just and Carpenter (1993) who observed peak pupil response 1200 ms following the location in an ambiguous sentence. The mean normalized pupil size was calculated according to equation of Lemercier et. al (2014), the result of this ratio representing the percentage change in pupil dilation. The experiment is done approximately 45 minutes for each participant.

Results: As for the percentage change in pupil dilation, we found no interaction of Syntax and Prosody ($|ts| \leq 1.278$, $p = 0.201$), while main effect of Syntax ($|ts| \leq 4.565$, $p < 0.001$) and

Prosody ($|ts| \leq 3.397$, $p < 0.001$) were significant. The results of percentage change in peak dilation are similar to those seen in percentage change in pupil dilation. Main effect of Syntax ($|ts| \leq 4.092$, $p < 0.001$) and Prosody ($|ts| \leq 3.261$, $p < 0.001$) were significant, and no interaction found for Syntax and Prosody ($|ts| \leq 1.388$, $p = 1.165$). As for peak latency, there was no significant main effects of Syntax ($|ts| \leq 0.699$, $p = 0.485$) and Prosody ($|ts| \leq 1.482$, $p = 0.138$). We also did not find a significant Syntax × Prosody interaction ($|ts| \leq -1.426$, $p = 0.154$). This indicates that when syntactic structure and prosodic structure conflict, pupil diameter reliably increases; whereas when the prosody and syntax align, pupil slope is flat or slightly negative.

Measurements	CC	PC	SC	PS
Baseline (mm)	3.85 (0.02)	3.86 (0.02)	3.87 (0.02)	3.86 (0.02)
Pupil diameter (mm)	3.66 (0.02)	3.67 (0.02)	3.71 (0.02)	3.74 (0.02)
Pupil dilation (%)	−3.85 (0.47)	−3.22 (0.47)	−2.87 (0.46)	−1.49 (0.48)
Peak pupil point (mm)	3.83 (0.02)	3.85 (0.02)	3.87 (0.02)	3.91 (0.02)
Peak dilation (%)	0.73 (0.51)	1.32 (0.50)	1.58 (0.49)	3.05 (0.51)
Peak latency (ms)	1082.80 (39.62)	1142.80 (15.87)	1111.10 (21.87)	1089.50 (35.37)

Table 1. Mean baseline, pupil dilation, peak dilation, and peak latency values for each condition

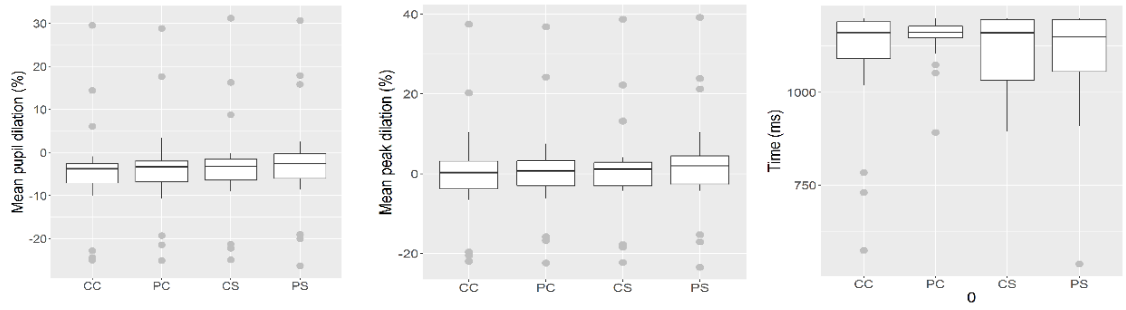

Figure 1. Mean pupil, peak dilation and latency for four conditions

Conclusion: This study is a preliminary step as to provide further insights whether the pupil dilation for prosody-syntax interaction is sensitive to online measurement for spoken language processing. Although the pupil diameter results indicated a large significancy effect on processing for the main effect of prosody and syntax, there were no interaction effect between these linguistic sources. Our findings for pupillometry implicated an independent processing of prosody and syntax rather than an interactive processing.

References

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