Children’s sensitivity to degrees of mispronunciation:
Enriching the preferential looking paradigm with pupillometry

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Introduction
Recent findings indicate that infants can detect sub-segmental changes in words, suggesting the encoding of sub-segmental detail. However, the degree of granularity of this sensitivity remains unclear: Evidence is inconclusive on whether infants give differential responses to small versus large degrees of mismatch (Swingley and Aslin, 2000; Tamási et al., 2016; White and Morgan, 2008). The current study extends previous literature by combining the traditional preferential looking paradigm with a measure automatically collected in studies using such a paradigm: pupil dilation. Given that the magnitude of pupil dilation reflects cognitive effort, pupillometry is an ideal method to study sensitivity to differing degrees of mispronunciation.

Method
We used pupil dilation in conjunction with looking preference, testing 52 30-month-old German-speaking children. In each trial, two pictures were simultaneously presented, the target depicting a familiar item (e.g., a baby) and the distractor an unfamiliar item (e.g., a yak). After a center fixation phase, the same pair of pictures was shown accompanied by an auditory label. By manipulating the degree of mispronunciation (0-3 feature changes to the correct label and a phonologically unrelated label, e.g., \([b]aby\), correct / \([d]aby\), \(\Delta 1F\) / \([f]aby\), \(\Delta 2F\) / \([S]aby\), \(\Delta 3F\) / \(yak\), novel), we tested whether featural distance was negatively correlated with target looking time and positively correlated with pupil dilation.

Results
The predictions were supported by our data. In linear mixed effects models, we observed a downward linear trend in target looking time (\(\beta = -0.15, SE = 0.04, t = -4.19\)) and an upward linear trend in pupil dilation (\(\beta = 0.05, SE = 0.02, t = 1.85\)) in response to the degree of mispronunciation (c.f., Figures 1–2). Time-course analyses were used to explore the evolution of looking preference and pupil dilation in response to differing degrees of mispronunciation (c.f., Figures 3–4). Steady target preference was observed for correct (\(\beta = 0.13, SE = 0.03, t = 4.52\)) and less robust but still significant target preference for \(\Delta 1F\) items (\(\beta = 0.82, SE = 0.04, t = 2.17\)) throughout the trial, preferences flipped from distractor to target for \(\Delta 2F\) and \(\Delta 3F\) items (1500–3000 ms: \(\beta = 0.06, SE = 0.04, t = 1.74\) and \(\beta = 0.06, SE = 0.03, t = 2.04\), respectively), and distractor preference was observed for novel items (200–2300 ms: \(\beta = -0.06, SE = 0.03, t = -1.82\)). In the pupil measure, late differentiation of the \(\Delta 3F\) (1500 ms) and early differentiation of the novel from the correct items (1100 ms) was observed.

Discussion
The results indicate differential sensitivity to small and large degrees of mispronunciation and, as such, the present study corroborates previous work that found children’s word recognition modulated by degree of mismatch (Tamási et al., 2016; White and Morgan, 2008). Moreover, time-course analyses revealed a reliable, albeit weaker target preference in response to \(\Delta 1F\) labels than to correct labels, whereas larger distance (\(\Delta 2F\) / \(\Delta 3F\)) delayed the emergence of target preference, suggesting inhibited reconciliation of the heard label with the correct label. The distractor preference upon hearing the novel label suggests that children are unlikely to associate the target object with a label not resembling the correct label. Apart from positively predicting the magnitude of observed pupillary response, featural distance also predicted latency of differentiation from the correct condition, indicating a late increase in cognitive effort with \(\Delta 3F\) items, and an early increase with novel items. We thus establish that pupillometry can be used in combination with preferential looking paradigms (along with respective time-course analyses) to provide an additional – dynamic and gradient – method to study children’s cognitive processing, hence contributing to our understanding of lexical development.
Figure 1: Mean proportion of looking time towards the target in response to differing degrees of mispronunciation (error bars = SE).

Figure 2: Mean pupil size change in response to differing degrees of mispronunciation (error bars = SE).

Figure 3: Proportion of looking time towards the target over time in response to differing degrees of mispronunciation (error bars = SE).

Figure 4: Pupil size change over time in response to differing degrees of mispronunciation (error bars = SE).

References

