Does childhood hearing loss impede prediction in sentence processing?

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In ideal listening situations, listeners readily predict upcoming language input based on previous context [1]. However, listeners with hearing loss (HL) must process language based on suboptimal auditory input. While hearing devices such as hearing aids (HAs) and cochlear implants (CIs) improve access to sound, they provide input that is mildly, in the case of HAs, or severely, in the case of CIs, distorted relative to normal hearing (NH). Studies investigating prediction in other adverse listening conditions have found that listeners predict less when input is suboptimal [2], however alternative accounts suggest that poor-quality input may *increase* listeners' reliance on prediction in compensation [3]. We therefore investigated sentence-level prediction among primary school children who use HAs and/or CIs to determine whether and to what extent they might use prediction. We hypothesised that children with HL would predict less than children with NH, as they may not be able to spare cognitive resources for prediction due to their atypically slow and effortful language processing [4,5]; may struggle with some domain-general cognitive skills which are necessary for prediction, cf. [6]; or may strategically avoid predicting to 'keep their options open' [7]. We also expected that children with HL may process language slower than children with NH overall [4], though we have found substantial individual variability in related work [8].

Twenty-five children with NH (M_{age} = 9;6) and 25 children with HL (14 HA, 9 CI, 2 bimodal; M_{age} = 10;2) completed an eye-tracking task using the visual world paradigm [9]. Thirty-two sentence pairs were matched with visual arrays of four images. Each pair contained one constraining sentence (the object noun was predictable from the sentence context) and one unconstraining sentence (context did not predict a specific continuation; Table 1). One image always depicted the object of the sentence (the target), while the others represented items with varying semantic relationships to the predictable sentence of the pair, following [10]. If children use prediction during sentence processing, we would expect earlier looks to the target in the predictable vs. the unpredictable condition. If children with HL process language more slowly, we would expect them to look at the target later than the children with NH.

Each participant heard 16 predictable and 16 unpredictable sentences while their looking behaviour was recorded using a Tobii X2-60 portable eye-tracker. Participants clicked on the image that best matched each sentence. As the data were noisy, a jackknifing procedure was employed for analysis [11]. A four-parameter logistic curve was fit to each participant's jackknifed looks to the target and the parameter values extracted [7]. The parameter of interest was the crossover point, which quantifies the shift of the curve in the time dimension, and thus the speed of looks to the target. Crossover point values were entered into an ANOVA with factors Constraint (constraining vs. unconstraining context) and Group (NH vs. HL), and the F-value corrected to compensate for jackknifing [11]. The crossover point occurred significantly earlier for the predictable than the unpredictable sentences ($F_c(1,48)$ = 31.27, p < .001; Fig. 1). However, no significant main effect of Group or Group x Constraint interaction was present (both ps > .05). Furthermore, post-hoc analysis found no significant differences between children with HL who used different types of hearing devices.

These results demonstrate that even children who chronically receive suboptimal auditory input can predict upcoming sentence constituents, and do not predict to a different extent to children with NH. It seems that children with HL are not prevented from predicting by cognitive limitations, nor do they strategically avoid it, contrasting with [6,7]. Furthermore, we do not find evidence that children with HL process language slower than children with NH, in line with a subset of participants in related work [8]. These findings suggest that the use of top-down information for prediction in language processing is not disrupted by hearing loss and highlight the robustness of prediction across populations of listeners.

References
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Table 1 – Sample sentence pairs and corresponding images.

Constraining sentence	**Unconstraining sentence**	**Target image**	**Agent-related image**	**Verb-related image**	**Distractor image**
The surfer visits the beach.	The boy likes the beach.	Beach	Surfboard	Museum	Umbrella
The cyclist rides the bike.	The nephew buys the bike.	Bike	Helmet	Skateboard	Violin
The bird builds the nest.	The uncle finds the nest.	Nest	Feather	House	Shoe

Figure 1 – Mean proportion of looks to the target image across the trial for NH (blue) and HL (red) groups in constraining (solid line) and unconstraining (dashed line) sentence conditions. Shaded areas show 95% confidence interval of the mean. Horizontal dotted line shows chance. Vertical dashed lines show sentence onset and offset.