Turning the young parser into the adult parser: Working memory matters

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Children exhibit difficulties in processing structural ambiguity due to their failure to revise their initial misinterpretation (Trueswell et al., 1999). This difficulty is often attributed to their non-adult cognitive attributes, one of which is their limited working memory capacity. Our study investigates whether children become more adult-like in processing structural ambiguity when the working memory burden associated with reanalysis is alleviated. The rationale is based on several adult working memory models, such as the one by Lewis et al. (2006), which proposes that when the ambiguous word is adjacent to the disambiguation point, the linear distance between them is minimized, and so is the working memory burden with reanalysis. The present study aims to explore whether the same rationale can be applied to child sentence processing.

Using the visual world paradigm, the eye movement data of 25 Mandarin-speaking four-year-olds, 25 five-year-olds and 30 adults were collected. The participants were presented with 8 target and 8 control items in random order, each containing a spoken sentence and a picture (see Fig.1). The target sentences (see (1)) had the following structure: "NP1 + Modal + V + NP2 + *DE* + NP3". The morpheme *DE* is a possessive marker, so "NP2 +*DE* + NP3" indicated a possessive relation in which NP2 (*xiaogou* "dog") was the possessor and NP3 (*piqiu* "ball") was the possessee. The verb *ti* 'kick' could take either NP2 or NP3 as a plausible complement. If the parser incrementally processed the sentence, it might initially analyze "NP1 + Modal + Verb + NP2", as in (2), as a complete sentence before encountering the disambiguating point *DE* which is adjacent to the ambiguous NP2. Upon hearing *DE*, the parser had to reanalyze NP2 as the modifier of the actual object NP3 (*piqiu* 'ball'). By contrast, the control sentences (see (3)) followed the structure of the target sentences up until the point of disambiguation, but crucially did not involve a garden path. If the participants were able to revise their initial interpretation, when hearing *DE* in the target sentences, they should be expected to: 1) switch their looks from the dog to the dog's ball; 2) exhibit more looks to the dog's ball and fewer looks to the dog than when hearing the adverb *yixia* "once" in the controls.

Fig.2 and Fig.3 show the average fixation proportions on two critical areas: *Target_Mod* (the dog) and *Target_Obj* (the dog's ball). As shown in both figures, all the three age groups showed similar eye gaze patterns. They initially looked more at the dog and then switched their looks to the dog's ball when hearing *DE* (Fig.2). Besides, they exhibited more looks to the dog's ball and fewer looks to the dog when hearing *DE* in the targets than when hearing *yixia* in the controls (Fig.3). However, 4-year-olds showed an overall delay in exhibiting the relevant pattern than the older groups. The observed eye gaze patterns were then confirmed by statistical modelling.

The findings suggest that 4-year-olds could revise their initial representation, though not as effective as 5-year-olds and adults, when the working memory burden associated with reanalysis was reduced to minimum. The findings also provide a good example of how adult processing models can inform us about child sentence processing, as well as calling for a fine-grained model of child sentence processing that specifies how each cognitive component contributes to the development of the young parser.

(1) Xiaomao yaoqu ti xiaogou DE piqiu
Cat will kick dog DE ball
"The cat is going to kick the dog's ball."

(2) Xiaomao yaoqu ti xiaogou
Cat will kick dog
"The cat is going to kick the dog."

(3) Xiaomao yaoqu ti xiaogou yixia
Cat will kick dog once
"The cat is going to kick the dog once."

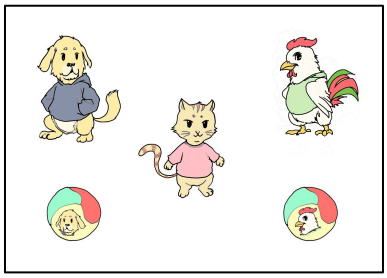

Fig.1 Example visual stimulus

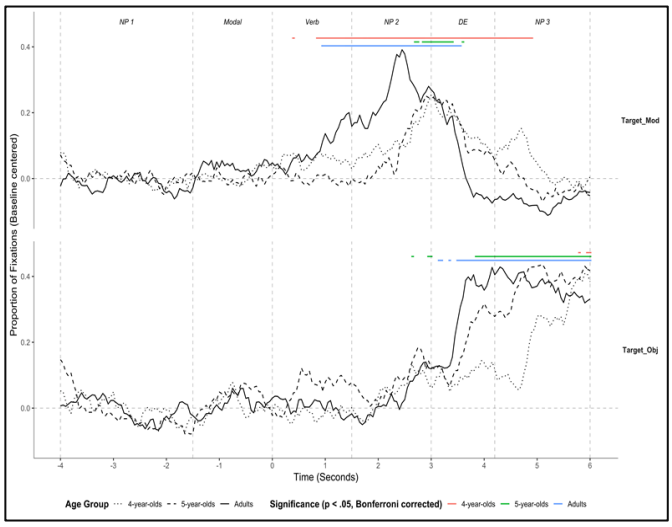

Fig.2 Average fixation proportions in the *Target_Mod* area (upper panel) and in the *Target_Obj* area (lower panel) by the 4-year-olds (dotted line), the 5-year-olds (dashed line) and the adults (solid line). The illustrated proportions are baseline centered (subtracting the mean fixation proportion in that area before the verb). The colored lines indicate a significantly higher fixation proportion than the baseline in this area during this temporal bin; the red line represents the 4-year-olds, the green line the 5-year- olds and the blue line the adults.

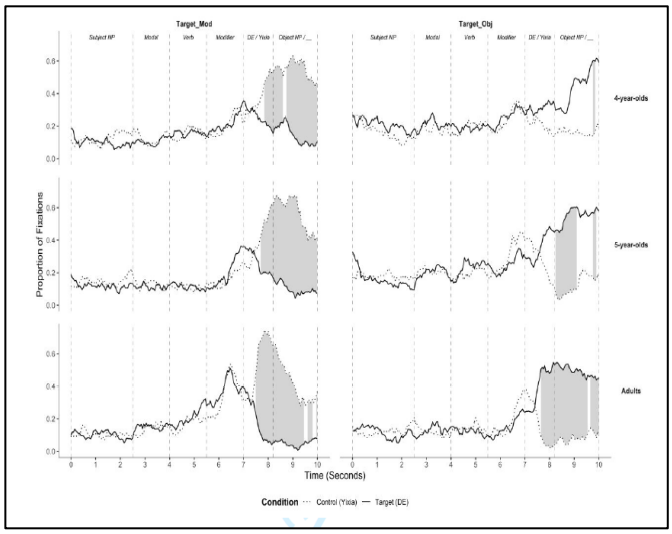

Fig.3 Average fixation proportions in the *Target_Mod* area (e.g. the dog, left column) and in the *Target_Obj* area (e.g. the dog's ball, right column) by the 4-year-olds (upper panel), the 5-year-olds (middle panel), and the adults (lower panel). The gray areas indicate significant differences between the target and control baseline conditions on the basis of the adjusted p values ($p < .05$).

Selected references

Lewis, R. L., Vasishth, S., & van Dyke, J. A. (2006). Computational principles of working memory in sentence comprehension. *Trends in Cognitive Sciences, 10*, 447–454.

Trueswell, J.C., Sekerina, I., Hill, N.M. & Logrip, L. (1999). The kindergarten-path effect: studying on-line sentence processing in young children. *Cognition, 73*, 89-134.