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Quantitatively assessing the development of adjective ordering preferences using child-directed and child-produced speech corpora

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Adults have robust ordering preferences that determine the relative order of adjectives in multi-adjective strings: this is why “small gray kitten” is preferable to “gray small kitten” in English and many other unrelated languages. These preferences appear to be based on abstract representations, rather than simply reflecting where specific adjectives appear in the input. One hypothesis holds that adjective ordering is determined by abstract syntax, with adjectives grouped into lexical semantic classes that are hierarchically ordered (Dixon, 1982; Cinque, 1994). These lexical classes and their hierarchical ordering are then primitives in the representation of the preferences. Recently, Scontras, Degen, and Goodman (2017) identified adjective subjectivity as a robust predictor of ordering preferences, with less subjective adjectives preferred closer to the modified noun; they advanced the hypothesis that ordering preferences—and the lexical class ordering observed cross-linguistically—derive from the perceived subjectivity of the adjectives. Despite the cross-linguistic robustness of these ordering preferences, little is known about their development in children, other than that these preferences do in fact develop (Bever, 1970; Martin & Molfese, 1972; Hare & Otto, 1978). To assess when more abstract knowledge about adjective ordering emerges and how that knowledge gets represented, we use corpus analysis and quantitative metrics connecting children’s input, underlying representations, and output. We find that a more abstract representation does not emerge until four years old, and this representation appears to be based on ordered lexical classes rather than subjectivity.

To assess children’s input and children’s output, we examined 688,428 child-directed and 1,069,406 child-produced utterances from ages 2 to 4 in CHILDES (MacWhinney, 2000). This dataset yielded 3,066 adjective-adjective-noun (**AdjAdjN**) strings in child-directed speech (6,132 adjective tokens of 383 types) and 975 AdjAdjN strings in child-produced speech (1,986 adjective tokens of 232 types). We compared three underlying representations connecting children’s input to their output: (i) **input frequency** of the adjective’s position in AdjAdjN strings, (ii) hierarchically ordered **lexical semantic** classes, and (iii) **subjectivity**-based ordering. Each adjective from the AdjAdjN datasets was assigned to a lexical semantic class and associated with an adult subjectivity score. We obtained these subjectivity scores from 108 adult participants on MTurk, replicating the methodology of Scontras et al. (2017) for child-register adjectives like *teeny*.

To compare the input frequency vs. lexical semantic class vs. subjectivity hypotheses at ages 2, 3, and 4, we calculated the likelihood of the age-specific child-produced AdjAdjN data under each hypothesis, given the child-directed input (see equations (1) – (4)). Log likelihood scores for each representation at each age appear in Table 1. We find that input frequency—in other words, simply tracking the word-level position statistics—best accounts for the child AdjAdjN productions at ages 2 and 3, while the lexical semantic class hypothesis best accounts for child AdjAdjN productions at age 4. This finding suggests that more abstract knowledge underlies children’s adjective ordering preferences at age 4 (but not earlier), and that this abstract knowledge is lexical-class-based rather than subjectivity-based. We see the emergence of this abstract knowledge by observing the difference between the lexical class and input frequency hypotheses in terms of data coverage: from age 2 to 3, the lexical class score approaches input frequency’s and then overtakes it by age 4. The subjectivity hypotheses has a similar pattern: the difference between it and the best performing hypothesis narrows as children age, though subjectivity never overtakes the winning hypothesis through age 4. Thus, it remains unclear when (or whether) subjectivity replaces lexical class as the underlying representation for adjective ordering preferences—this may depend on children’s development of the conceptual underpinnings of subjectivity, which occurs remarkably late (Foushee & Srinivasan, 2017). Taken together, our results demonstrate that children initially track the word-level statistics of their input when determining adjective ordering preferences. By age 4, they shift to a more abstract and compact representation based on lexical semantic class.

Equations for relating underlying representations to observed adjective position in productions:

$$p_2exp(adj_x) = \frac{f_{input}(< adj_x) + 0.5 * f_{input}(= adj_x)}{N_{input}(adj)} \quad (1)$$

Equation 1: Probability of adj_x appearing two positions away from the noun (**2-away**) when combined with another adjective, given the lexical class or subjectivity hypothesis. $f_{input}(< adj_x)$ is the number of adjective tokens that are from a closer lexical class or are less subjective, depending on the hypothesis. $f_{input}(= adj_x)$ is the number of adjectives in the same lexical class or with equal subjectivity; adj_x will appear 2-away with a 50% chance in this case. $N_{input}(adj)$ is the number of adjective tokens that appeared in AdjAdjN strings in the input.

$$p_2exp(adj_x) = \frac{f_{2input}(adj_x)}{N_{input}(adj_x)} \quad (2)$$

Equation 2: Probability of adj_x appearing 2-away as dictated by its position in the input. $f_{2input}(adj_x)$ is the count of adj_x appearing 2-away; $N_{input}(adj_x)$ is the total number of AdjAdjN strings where adj_x appeared.

$$p(D(adj_x)|H) = \binom{N}{f} (p_2exp(adj_x))^f (1 - p_2exp(adj_x))^{N-f} \quad (3)$$

Equation 3: The likelihood of the data for a given adjective $D(adj_x)$ under a specific representational hypothesis H . This depends on the number of total times that adjective appeared in an AdjAdjN string (N), the number of times that adjective appeared in the 2-away position (f), and the probability of the adjective appearing in the 2-away position ($p_2exp(adj_x)$).

$$p(D|H) = \prod_{adj_x \in A} p(D(adj_x)|H) \quad (4)$$

Equation 4: The total likelihood of the output data D under H is the product of the individual adjective likelihood probabilities.

age	representational hypotheses		
	input freq.	lexical class	subjectivity
2	-202.6	-334.9	-322.4
3	-125.1	-164.0	-187.4
4	-182.9	-165.2	-221.0

Table 1: Log likelihood scores for each hypothesis. Scores range from 0 (best) to -infinity (worst). The best score for each age is **bolded**.

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