The effect of age and type of training material on the ability to learn an artificial morphological rule

Sara Ferman(1), Avi Karni(2)
(1) Department of Communication Disorders, Faculty of Medicine, Tel Aviv University, Israel
(2) Brain-Behavior Research Center, Faculties of Science and Education, University of Haifa, Mt Carmel, Haifa, Israel

A widely accepted notion is that children acquire both first and second languages rapidly and effortlessly and that this language learning ability decreases with age. A key notion in this view is of a critical window of increased neurological plasticity. This 'childhood superiority' view however, has recently been challenged by some types of behavioral and neurological evidence. A growing body of evidence suggests that adults may not be inferior to children in attaining language proficiency and may even outperform them. Also, it has recently been shown that maturation dependent brain changes occur during childhood and adolescence and that robust cortical reorganization can take place in adulthood as function of training and experience. Some non-linguistic learning abilities improve with maturity.
Therefore, there is an ongoing controversy regarding the effect of age on language learning competence and the memory mechanisms underlying this effect. Here, controlling for the amount and duration of experience with an artificial morphological rule (AMR) we compared the gains attained by 8-year-olds, 12-year-olds and young adults and probed, using behavioral measures the child-adult language learning ability differences.

Experiment 1

Eight 8-year-olds and eight 12-year-olds were trained in the application of an artificial morphological rule (AMR) to repeated items (item-specific learning) and new items (generalization), using judgment and speech production tasks without explicit instruction on the nature of the AMR. The data obtained from the children in the current study was compared with the data obtained in our previous study wherein eight young adults were trained and tested using the same study design (Ferman et al., in revision). Use of an AMR rather than a natural linguistic 'rule' afford the advantages of artificial language learning methodologies: ensuring that the exposure to input, instructions and tasks are equal for all learners. Also, this approach allows for a fine-grained data collection that cannot be achieved in real life language learning situations. The AMR was designed to be analogous to morphological rules of Hebrew grammar and constituted a specific phonological transformation of verbs depending on a semantic distinction of whether the preceding noun (the subject) was animate or inanimate. Each participant took part in 10-15 daily learning sessions and a retention session two months after the termination of the training. We followed response accuracy (% correct), the speed of response (RT [ms]) and the speech production error types and elicited (explicit) verbal reports concerning the participants' insights on the required transformation to try to assess the contribution of the implicit and explicit processes in the learning of the AMR in each age group.
The results for the participants in all three age groups showed that learning to apply the AMR to repeated items demonstrated key characteristics of procedural learning: 1) The group average learning curves of each age group fitted well to a power function model; 2) There was a considerable contribution of the time between sessions to the performance gains in all participants from each of the three age groups. Thus, a single

training session induced not only within-session performance gains but also delayed (between-session) gains in terms of accuracy and speed. 3) The results showed robust retention of the gains on re-testing after an interval of two months.

The results for the participants in all the three age groups suggest that learning to generalize morphological knowledge was subserved by both procedural and declarative memory. The phonological knowledge, i.e., accurate production of the required verb modification was rapidly generalized by all participants, in a manner characteristic of procedural learning. The results obtained from adults and 12-year-olds further suggest that the declarative memory might govern the explicit discovery of the semantic aspect of the AMR which was critical for accurate generalization of the AMR to new items. There were three indications for the discovery of the semantic aspect, which often co-occurred: 1) An explicit verbal report that was made on the role of the semantic distinction in the artificial rule; 2) An abrupt increase in accuracy scores for new items that occurred in all cases within a single session, in both the judgment and production tasks, with scores going from near chance level performance up to 80-100% correct; and 3) A temporary, abrupt, often very large, slowing in RTs in the performance on new items. The later however was measurable only in 7/14 individuals.

Finally, in both adults and 12-year-olds, additional training resulted in highly fluent and accurate performance, indicating a further proceduralization phase.

The comparison of the three age groups showed a positive effect of maturity on the ability to use (i.e., judge and produce) accurately (% correct) and rapidly (RT) specific (repeated) items of an AMR with adults showing the most robust gains and 8-year-olds the lowest gains from the beginning to the end of the learning period. Furthermore, our results show that while 7/8 adults and 7/8 12-year-olds succeeded in fully generalizing the AMR to new items, none of the 8-year-olds were able to correctly generalize. All participants in all three age groups learned to generalize the phonological aspect of the AMR to new items, with adults showing the most robust gains and 8-year-olds the lowest gains throughout the training period. However, the results further showed that 7/8 12-year-olds and 7/8 young adults succeeded in explicitly discovering the semantic aspect of the AMR and subsequently these participants were able to fully generalize the AMR to new items. On the other hand, none of the 8-year-olds were able to explicitly discover the semantic knowledge and therefore none of the younger participants were able to fully generalize the AMR to novel items i.e., none of them performed beyond chance level in judging and producing new items.

Experiment 2

In the second experiment we tested whether a specific modification of the repeated items training list would affect the ability of 8-year-olds to explicitly discover the semantic aspect and subsequently to fully generalize the AMR to new items. In our first experiment most (12/16) repeated trained items where single-paired items i.e., each verb was paired with one specific noun and only 4/16 repeated items were double-paired items i.e., the same verb was paired with two different nouns – one animate and the other inanimate. The explicit verbal reports elicited in experiment 1, revealed that coping with the 4 double-paired repeated items attracted the participant's attention and induced them to look for a 'rule'. This semantic (animate-inanimate) discovery however occurred only in adults and 12-year-olds. Experiment 2 was designed to explore whether training with (only) double-paired items would help 8-year-olds to discover the semantic aspect. Thus, in experiment 2 a second group of

eight 8-year-olds were trained in judging and producing the AMR in conditions identical to the conditions of the first experiment, except that in experiment 2 participants were trained using only double-paired items.
The results showed that in training with only the double-paired items 4/8 participants (2 boys and 2 girls) succeeded in discovering the semantic aspect of the AMR and subsequently these four participants succeeded in fully generalizing the AMR to new items.

Discussion

Altogether, the results of the current study challenge the notion that children are better than adults in learning a language skill. The results suggest that the ability to learn a new linguistic skill, specifically, an AMR, increases with maturity and that the maturation of both procedural and especially the declarative memory may underlie this age-related improvement in language-learning ability. The ability to draw on the procedural memory in learning to use specific items of the AMR, and to apply the phonological aspect of the 'rule', increased between the ages 8 and 12 and continued to improve until young adulthood. There was a similar improvement in the ability to draw on declarative memory for discovering the semantic aspect of the AMR between the ages of 8 and 12. Even under conditions that increased the saliency of the semantic aspect of the AMR, and made its' explicit discovery easier, only 50% of the 8-year-olds were able to fully generalize the AMR.
Our findings support the view that the procedural memory system evolves early in life and develops throughout childhood and that the declarative memory system emerges later and continues to mature until adulthood (DiGiulio et al., 1994). The notion of better skill, specifically language skill learning in children may reflect the emergence of more selective procedural memory consolidation during puberty (Dorfberger et al., 2007) but not better skill learning abilities per se. Thus in line with the tenet of parsimony, the differences in learning an AMR in children and adults, given the same training experience, can be well explained by the interplay of the two memory systems and their age-related contributions.