Children's Developing Ability to Create External Representations: Separating *What* Information is Included From *How* the Information is Represented

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Many areas of education focus on teaching children how to produce specific kinds of external notations. Although most children appreciate the usefulness of creating such representations by their eighth year, their ability to actually *create* useful external representations is highly variable and task specific until adolescence (Cohen, 1985; Karmiloff-Smith, 1979; Lee & Karmiloff-Smith, 1996; Eskritt & Lee, 2001). This variability could result from children's failure to realize *what* information needs to be included in a good representation, or it could result from their inability to figure out *how* to create such a representation, even if they know what to include in it. It is likely that these two difficulties interact such that, when children are deciding on their method of representation, they fail to verify that less salient pieces of information will be included. The current study is a first step in evaluating the contingencies between (1) *what* information is included, (2) *how* the information is represented, and (3) children's ability to create useful external representations.

We asked first and second grade children to create external representations that could be used by others to replicate a complex sequence of actions in a simple puzzle (Klahr, 1985). Children generated the sequence of moves themselves within a well-defined problem to assure they had sufficient understanding of the action sequence to be represented. The closed structure of the problem made it possible to define what specific information needed to be included in the external representation. In addition, we categorized the method of representation both for the overall organization of the notation and specific for each piece of information. In our analysis, we examined how the adequacy of the external representation (i.e., can another person use the notation to replicate the sequence of actions) relates to *what* information is included and *how* the information is represented.

Our analysis of children's external representations distinguishes among (a) references to the object to be moved, (b) the location to move the object, and (c) information about order of the moves. In order to categorize the overall organization of children's notations, we coded their notations as either linguistic or figural. The adequacy of representations was evaluated on a seven-point scale, with 1 denoting no relation between the notation and the task and 7 indicating that all information that was required to replicate the sequence was explicitly represented.

Of the three types of information included, children were more likely to refer to the objects and locations than to sequential order, $F (1, 25) = 21.8$, $p < .001$. This result is consistent with prior findings that suggested children had difficulty including explicit sequence information (Bolger & Karmiloff-Smith, 1991; Lee & Karmiloff-Smith, 1996). Because information about move order was necessary for the notation to be rated as very adequate, the inclusion of sequential information in the notation was related to adequacy, $r = .82$, $p < .001$.

Similar to Lee & Karmiloff-Smith (1996), notational adequacy was associated with the overall organization of the notations, $F (1, 23) = 21.4$, $p < .001$, such that linguistic notations were more adequate than figural notations. The differential inclusion of information about sequence was highly related to notation type, $X^2(N = 24) = 12.2$, $p < .001$; all of the linguistic notations included information about sequence while a majority of the figural notations omitted this information. By categorizing the sequential information included as either explicit (i.e., words or numbers) or implicit (i.e., position on page such as top to bottom), we found that sequential information included in the linguistic notations was more likely to be implicit than in figural notations, $X^2(N= 13) = 5.3$, $p = .02$. However, we found an interaction between overall organization and method used to represent sequential information for notational adequacy, $F (1, 9) = 10.91$, $p = .01$, showing that figural notations with explicit sequential information did not have as high of an adequacy as linguistic notations.

The current study revealed a complex relationship between *what* information is included, *how* that information is represented, and notational adequacy. Future research should address why figural notations with explicit sequential information were not as adequate as linguistic notations.

References

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