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Developmental origins of recoding and decoding in memory

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ABSTRACT

Working memory is severely limited in both adults and children, but one way that adults can overcome this limit is through the process of recoding. Recoding happens when representations of individual items are chunked together into a higher order representation, and the chunk is assigned a label. That label can then be decoded to retrieve the individual items from long-term memory. Whereas this ability has been extensively studied in adults (as, for example, in classic studies of memory in chess), little is known about recoding's developmental origins. Here we asked whether 2- to 3-year-old children also can recode—that is, can they restructure representations of individual objects into a higher order chunk, assign this new representation a verbal label, and then later decode the label to retrieve the represented individuals from memory. In Experiments 1 and 2, we showed children identical blocks that could be connected to make tools. Children learned a novel name for a tool that could be built from two blocks, and for a tool that could be built from three blocks. Later we told children that one of the tools was hidden in a box, with no visual information provided. Children were allowed to search the box and retrieve varying numbers of blocks. Critically, the retrieved blocks were identical and unconnected, so the only way children could know whether any blocks remained was by using the verbal label to recall how many objects comprised each tool (or chunk). We found that even children who could not yet count adjusted their searching of the box depending on the label they had heard. This suggests that they had recoded representations of individual blocks into higher-order chunks, attached labels to the chunks,

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and then later decoded the labels to infer how many blocks were hidden. In Experiments 3 and 4 we asked whether recoding also can expand the number of individual objects children could remember, as in the classic studies with adults. We found that when no information was provided to support recoding, children showed the standard failure to remember more than three hidden objects at once. But when provided recoding information, children successfully represented up to five individual objects in the box, thereby overcoming typical working memory limits. These results are the first demonstration of recoding by young children; we close by discussing their implications for understanding the structure of memory throughout the lifespan.

1. Introduction

Many years ago, George Miller (1956) made an influential observation about the limits of humans' ability to remember information over short intervals. He noted that the span of immediate memory could not be characterized in terms of a discrete amount of information measurable in, say, number of bits. Rather, immediate memory appears to hold a fixed number of *chunks*, with each chunk holding an effectively limitless amount of information, thanks to the process of *recoding.* Recoding involves taking some input (e.g., a string of numbers such as 070302215911) and dividing the input into meaningful chunks (e.g., my mother's birthday, my university's zip code, the emergency telephone number). If one wants to remember such a string of numbers, and if those numbers have been linked with semantic content, one need only maintain the much shorter list of recoded units in working memory. To retrieve the individual numbers, one *decodes* those units using knowledge stored in long-term memory. The hierarchical organization of recoded information allows for the compression of that information without serious informational degradation or loss (Dirlam, 1972; Shannon, 1948).

The psychological processes of recoding and decoding have been studied in adults in now-classic experiments on memory in the game of chess (Charness, 1976; Chase & Simon, 1973; De Groot, 1965; Frey & Adesman, 1976). For example, Chase and Simon (1973) briefly presented adult observers with chess boards on which the pieces were placed either randomly or in positions that could be part of a playable chess game, and asked them to reconstruct the boards from memory. They found that when observers were shown playable boards, the accuracy with which the pieces were reconstructed was related to the observers' expertise in chess. The more advanced the chess player, the more positions they recalled. Importantly, chess experts' superior performance was not caused by greater overall working memory capacity, because when the chess pieces were placed randomly on the board there was no difference between the recall of experts and that of novices. Rather, chess experts apparently were able to *recode* the positions of the chess pieces into meaningful chunks using a coding scheme derived from their knowledge of chess. Those chunks could then be decoded to retrieve the subordinate information: the pieces and their precise positions.

Research on recoding and decoding suggests that these processes are largely automatic. Chase and Simon (1973) argued that their chess experts "saw" the board differently than did novices, perceiving the higher order relationships between the pieces instantly. Such expertise often results in differential visual processing of a display (e.g., geometric diagrams in Epelboim & Suppes, 2001; see also Chi, Glaser, & Rees, 1982, for a review of evidence from physics experts). However, despite its seeming automaticity, recoding requires at least two key steps (Bower, 1970; Ericsson & Kintsch, 1995; Simon, 1974; Wortman & Greenberg, 1971). First, representations of individual items must be *chunked* together to form a higher order unit. For example, in the case of chess, the observer must initially learn that particular configurations of pieces form a meaningful group. Critically, this new, higher order representation of the group preserves representations of each piece it contains. Second, recoding involves