

# The Development of Size Sequencing Skills: An Empirical and Computational Analysis

Maggie McGonigle-Chalmers & Iain Kusel



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# **The Development of Size Sequencing Skills: An Empirical and Computational Analysis**

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# The Development of Size Sequencing Skills: An Empirical and Computational Analysis

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## The Development of Size Sequencing Skills: An Empirical and Computational Analysis

*Maggie McGonigle-Chalmers<sup>1</sup> and Iain Kusel<sup>2</sup>*

**Abstract** We explore a long-observed phenomenon in children’s cognitive development known as size seriation. It is not until children are around 7 years of age that they spontaneously use a strict ascending or descending order of magnitude to organize sets of objects differing in size. Incomplete and inaccurate ordering shown by younger children has been thought to be related to their incomplete grasp of the mathematical concept of a unit. Piaget first brought attention to children’s difficulties in solving ordering and size-matching tests, but his tasks and explanations have been progressively neglected due to major theoretical shifts in scholarship on developmental cognition. A cogent alternative to his account has never emerged, leaving size seriation and related abilities as an unexplained case of discontinuity in mental growth. In this monograph, we use a new training methodology, together with computational modeling of the data to offer a new explanation of size seriation development and the emergence of related skills.

We describe a connected set of touchscreen tasks that measure the abilities of 5- and 7-year-old children to (a) learn a linear size sequence of five or seven items and (b) identify unique (unit) values within those same sets, such as second biggest and middle-sized. Older children required little or no training to succeed in the sequencing tasks, whereas younger children evinced trial-and-error performance. Marked age differences were found on ordinal identification tasks using matching-to-sample and other methods. Confirming Piaget’s findings, these tasks generated learning data with which to develop a computational model of the change.

Using variables to represent working and long-term memory (WM and LTM), the computational model represents the information processing of the

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younger child in terms of a perception-action feedback loop, resulting in a heuristic for achieving a correct sequence. To explain why older children do not require training on the size task, it was hypothesized that an increase in WM to a certain threshold level provides the information-processing capacity to allow the participant to start to detect a minimum interval between each item in the selection. The probabilistic heuristic is thus thought to be replaced during a transitional stage by a serial algorithm that guarantees success. The minimum interval discovery has the effect of controlling search for the next item in a principled monotonic direction. Through a minor additional processing step, this algorithm permits relatively easy identification of ordinal values.

The model was tested by simulating the perceptual learning and action selection processes thought to be taking place during trial-and-error sequencing. Error distributions were generated across each item in the sequence and these were found to correspond to the error patterns shown by 5-year-olds. The algorithm that is thought to emerge from successful learning was also tested. It simulated high levels of success on seriation and also on ordinal identification tasks, as shown by 7-year-olds.

An unexpected finding from the empirical studies was that, unlike adults, the 7-year-old children showed marked difficulty when they had to compute ordinal size values in tasks that did not permit the use of the serial algorithm. For example, when required to learn a non-monotonic sequence where the ordinal values were in a fixed random order such as “second biggest, middle-sized, smallest, second smallest, biggest,” each item has to be found without reference to the “smallest difference” rule used by the algorithm. The difficulty evinced by 7-year-olds was consistent with the idea that the information in LTM is integrally tied to the search procedure itself as a search-and-stop based on a cumulative tally, as distinct from being accessed from a more permanent and atemporal store of stand-alone ordinal values in LTM. The implications of this possible constraint in understanding are discussed in terms of further developmental changes.

We conclude that the seriation behavior shown by children at around 7 years represents a qualitative shift in their understanding but not in the sense that Piaget first proposed. We see the emergent algorithm as an information-reducing device, representing a default strategy for how humans come to deal with potentially complex sets of relations. We argue this with regard to counting behaviors in children and also with regard to how linear monotonic devices for resolving certain logical tasks endure into adulthood.

Insofar as the monograph reprises any aspect of the Piagetian account, it is in his highlighting of an important cognitive discontinuity in logicomathematical understanding at around the age of 7, and his quest for understanding the transactions with the physical world that lead to it.

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## The Development of Size Sequencing Skills: An Empirical and Computational Analysis

In this monograph, Maggie McGonigle-Chalmers and Iain Kusel report an investigation into a phenomenon called size seriation. At around the age of seven years children suddenly become capable of systematically organizing objects in order of size. Using touchscreen tasks, they explore the differences between children of five and seven years when learning seriation tasks and when trying to identify size relations such as middle-sized. A computer model simulates the findings and shows how the act of size sequencing itself, together with an increase in memory capacity, creates a new solution for the older child that is not available to the younger child. Taken together, the findings and model reveal changes in mental functioning that explain spontaneous seriation and how the concept of a “unit” emerges during development.

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