Time in the mind of a child: Perspectives on the development of temporal cognition

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Introduction

The ways in which we experience and reason about time are fundamental aspects of human cognition. In the industrialized world, keeping track of time is vital to successful functioning in society. Ideas about the nature of time underlie many aspects of adult life: how we communicate with others, how we schedule our days, how we plan for the future, how we interpret and react to autobiographical events, and how we reason about cause and effect. Both philosophers and cognitive scientists have struggled to explain the nature and origins of this rich, multifaceted, and highly abstract concept of time. One means of exploring the nature of time in the adult mind is by asking how the ability to mentally represent and reason about time develops in children. Although some aspects of temporal cognition, like low-level duration perception, are present at birth, others, like using a clock, take children up to a decade to learn. By tracking how different time-related cognitive phenomena emerge and change across development, we may gain a fuller picture of how the many facets of time interrelate, including the biological and cultural factors that underlie them. To this end, this symposium brings together researchers from around the world to discuss five different aspects of children's temporal cognition, each of which change dramatically during the preschool years.

Each case study presented in the symposium investigates time in the context of a different cognitive system, including motor planning, spatial cognition, language, emotion, event representation, and prospective reasoning. First, **Monier** will discuss children's developing capacity to synchronize their movements to external temporal rhythm. Next, **Tillman** will examine the development of culture-specific spatial representations of time, such as the left-to-right "mental timeline." **Zhang** will explore how children learn time-related language, including the words "yesterday" and "tomorrow." **Redshaw** will investigate how children become able to hold two alternative possible futures in mind. Finally, **McCormack** will discuss her work on the development of emotional and value judgments about past and future events. A leader in the field of temporal cognitive development, **McCormack** will also serve as symposium moderator.

The role of motor and cognitive capacities in developmental differences in rhythmic synchronization

Florie Monier *& Sylvie Droit-Volet*

Rhythmic synchronization is the ability to synchronize a movement to an external rhythm. Prior studies have shown that, relative to older children and adults, younger children have a faster and more variable spontaneous motor tempo, and they have more difficulty slowing down their motor tempo to synchronize it with a slow external tempo. Rhythmic synchronization involves both motor and cognitive capacities. Here, we ask which of these factors drives developmental change. In a series of studies, 3- to 8-year-old children were given a spontaneous motor tempo (finger tapping) task, a synchronization task involving differing inter-stimulus-intervals (ISI), and a continuation task, in which they were asked to maintain the tempo initiated in synchronization. Neuropsychological tests were used to assess their motor and cognitive capacities. Our results showed that the variability of children's inter-tap-intervals (ITI) decreased with increasing age, and that 8-year-olds were better able to slow down their motor tempo with an external tempo than 3- or 5-year-olds. Both motor and cognitive abilities predicted individual differences in the length of ITI on the synchronization and continuation tasks. However, only cognitive capacities (i.e., short-term memory, attention-concentration) accounted for children's variability on the continuation task. These results reveal that improvement in synchronization capacities is related to the development of both motor and cognitive capacities, but that the continuation task is more cognitively demanding.

The development of the mental timeline

Katharine Tillman*, Nestor Tulagan, Eren Fukuda, & David Barner*

When reasoning about time, English-speaking adults often invoke a "mental timeline" stretching from left to right. Although the direction of the timeline varies across cultures, linear representations of time have been argued to be

ubiquitous and primitive. On this hypothesis, we might predict that children also spontaneously invoke a spatial timeline when reasoning about time. However, little is known about how and when the mental timeline develops, or to what extent it is variable and malleable in childhood. We used a sticker placement task to test whether preschoolers spontaneously produce linear representations of temporal events (breakfast, lunch, and dinner) and deictic time words (*yesterday*, *today*, *tomorrow*), and to what degree those representations are adult-like. At age 4, children were able to make linear mappings between time and space with minimal spatial priming. However, unlike older children and adults, most preschoolers did not adopt linear representations spontaneously. Lines produced by children were also more variable in orientation and children could be easily primed to adopt an unconventional vertical timeline. Our findings suggest that preschoolers can readily form linear mappings between time and space to represent temporal sequences and past/future relationships when prompted to do so, but most do not yet do so automatically. These representations are initially flexible, and become increasingly automatic and conventionalized in the early school years.

Children's understanding of 'tomorrow' and 'yesterday'

Meng Zhang *and Judith Hudson*

Children's use of temporal language is often taken as an indication of their understanding of time. This study used a picture-sentence matching paradigm to test children's understanding of the temporal adverbs *yesterday* and *tomorrow*. Children viewed two pictures of an object, e.g., a carved pumpkin and an intact pumpkin, while listening to a sentence, e.g., "I carved the pumpkin yesterday" or "I'm gonna carve the pumpkin tomorrow". They were asked to select one picture to match the sentence. Experiment 1 showed that 3-, 4-, and 5-year-olds all performed better when sentences were in the past tense than in the future tense. In Experiments 2 and 3, the sentences contained conflicting cues from tense and temporal adverbs, e.g., "I carved the pumpkin tomorrow". While adults selected pictures based on the temporal adverbs they heard, 4- and 5-year-olds tended to select pictures showing the outcome of actions, regardless of both tense and temporal adverb. In Experiment 4, children completed two additional tasks involving temporal reasoning. The Before & After Task served as a baseline measure of temporal sequencing and the Yesterday & Tomorrow Task tested children's understanding of *yesterday* in backward reasoning and *tomorrow* in forward reasoning. Results indicated that forward temporal reasoning is easier for children than backward temporal reasoning, and linguistically, they understand the term *yesterday* better than *tomorrow*.

Young children's capacity to envision and prepare for mutually exclusive future possibilities

Jonathan Redshaw**,** *Talia Leamy, Phoebe Pincus, Jessica Crimston, & Thomas Suddendorf*

Because future events can be difficult to predict, adults often envision and prepare for multiple, even mutually exclusive alternatives. To investigate the emergence of this capacity in children, we developed a minimalist paradigm in which participants were given the opportunity to catch a ball dropped into a forked tube with two possible exits. The initial study showed that 2- and 3-year-olds often covered only one exit when preparing to catch the ball, whereas most 4-year-olds spontaneously covered both exits from the first trial onwards. A follow-up study revealed a similar developmental pattern when the mechanism controlling the uncertain outcome was visible, rather than hidden within the tube. Additional follow-up studies, however, showed that 2- and 3-year-olds were much more likely to cover two exits when two balls were certain to drop from separate locations. These findings suggest that young children are not generally limited in reasoning about multiple future events, but rather they are specifically limited in reasoning about mutually exclusive possibilities. One potential explanation is that older children, unlike younger children, possess a meta-representational understanding that their representations of future events can be incorrect, and so they take the opportunity to prepare for alternative versions.

Temporal asymmetries in children's past and future thinking

Teresa McCormack*, Agnieszka Jaroslawska, Patrick Burns, Aine Fitzpatrick, Jemma McGourty, & Eugene Caruso*

There are striking asymmetries in the way adults think about the past versus the future: adults typically (i) report stronger emotion when thinking about the future than the past (ii) place greater value on a future event than a past event and (iii) judge that a future event feels closer than a past event at an equivalent distance. These *future biases* suggest that adults are more oriented toward the future than the past. In this talk, I will describe the first developmental studies to examine whether these biases exist in children. We have found that the tendency to judge future events as feeling closer in time than equivalent past events is very robust, and can be demonstrated in children as young as 4-5 years. Children from around 6-7 years, like adolescents and adults, also report stronger emotions when thinking about the future versus the past. We also found that children from 9-10 years place greater value on future than past events. We will discuss what these findings suggest about children's thinking about the past and future, and their implications for theoretical accounts of temporal asymmetries.