The Development of Event Segmentation: An Introduction to the Special Focus

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Abstract

■ Event segmentation—the process by which people parse continuous experience into meaningful units—shapes how we understand and remember the world from early in life. Yet, despite its foundational role in cognition, the developmental trajectory of event segmentation remains poorly understood. This Special Focus brings together new research examining how children and adults segment events, with an emphasis on individual differences. The contributions shed light on how children's memory relates to their segmentation profiles, reveal neural signatures of individual variability in adult segmentation, and introduce methodological advances for tracking how individual brains carve up experience. Together, these papers suggest that variability—often dismissed as noise—may be central to understanding how event segmentation emerges and changes with age. We hope to inspire curiosity about event segmentation idiosyncrasies in childhood, prompting researchers to uncover why children experience the world so distinctively and what this reveals about cognitive development. ■

INTRODUCTION

To deal with the massive amount of input that we experience moment to moment, we carve up our experience into discrete events—a process referred to as *event segmentation* (Zacks & Swallow, 2007; Zacks & Tversky, 2001). Event segmentation influences our cognition in critical ways—shaping what we remember (Clewett, DuBrow, & Davachi, 2019; Ezzyat & Davachi, 2011) and how we make sense of the world around us (Zacks, Kurby, Eisenberg, & Haroutunian, 2011; Swallow, Zacks, & Abrams, 2009). As such, event segmentation can inform a long-standing puzzle about how young humans deal with the massive amount of sensory input they experience, referred to quite famously by William James as a "great blooming, buzzing confusion" (James, 1890). Despite the foundational role that event segmentation plays in cognition and the promise it holds for unraveling this long-standing developmental puzzle, our current understanding of how event segmentation develops is lacking. Here, we call for an expansion of our understanding of how event segmentation develops and outline key areas of need, highlighting how an appreciation of individual differences will be key to filling in knowledge gaps.

What little we know about event segmentation in childhood presents a surprising puzzle. A handful of studies suggest that children segment experience at a coarser timescale than adults, identifying fewer event boundaries (Cohen, Tottenham, & Baldassano, 2022; Zheng, Zacks, & Markson, 2020; Glebkin, Olenina, & Safronov, 2019). This finding stands at odds with event segmentation theory (Zacks, Speer, Swallow, Braver, & Reynolds, 2007), which posits that event boundaries emerge when event models held in working memory fail to predict ongoing experience. Since both schematic knowledge and working memory are less developed in children (Cowan, 2022; Brod & Shing, 2019; Brod, Lindenberger, & Shing, 2017; Gathercole, Pickering, Ambridge, & Wearing, 2004), one would expect children's event models to poorly predict experience, resulting in more frequent event boundaries, not less. Perhaps considering methodological limitations could resolve this apparent conflict between theory and data. Studies relying on children's explicit boundary judgments (Zheng et al., 2020; Glebkin et al., 2019) may have missed experienced boundaries during lapses in attention and cognitive control (Decker, Duncan, & Finn, 2023; Davidson, Amso, Anderson, & Diamond, 2006); those relying on neural decoding (Cohen et al., 2022) may have missed idiosyncratic boundaries. Indeed, children's explicit boundary judgments are less temporally aligned than adults' (Benear et al., 2023; Ren, Wharton-Shukster, Bauer, Duncan, & Finn, 2021; Zheng et al., 2020), echoing other domains in which children are more idiosyncratic (Wojcik & Kandhadai, 2020; Zortea, Menegola, Villavicencio, & de Salles, 2014). As noted in this Special Focus (Wilford, Chen, Wharton-Shukster, Finn, & Duncan, 2025), the integration of misaligned neural signals can obscure idiosyncratic boundaries: If each child segments events frequently but differently, group-level decoding will misrepresent their segmentation as coarser or slower than it really is.

Accordingly, this Special Focus aims to bring individuality to the forefront of understanding the development of

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event segmentation. Benear, Onwukanjo, Olson, and Newcombe (2025) explore whether children whose event segmentation judgments better conform to adult norms also recall events in more adult-like detail. Wilford et al. (2025) validate an fMRI method that holds promise for identifying personalized neural proxies for event segmentation, thereby overcoming the challenges of asking children to explicitly identify event boundaries. Lastly, Rah, Shin, and Lee (2025) demonstrate the neural differences underlying variability in how adults use spatial boundaries to structure their memory of sequential events. After reviewing the contributions, we discuss several possible mechanisms that could underlie children's idiosyncratic segmentation of events, the development of this ability, and insights that burgeoning neuroimaging methods could provide.

CONTRIBUTIONS IN THIS SPECIAL FOCUS

Benear et al. (2025) explore how the development of adult-like event segmentation may support children's ability to freely recall narratives. This contribution builds on prior research (Benear et al., 2023; Zheng et al., 2020), in which children explicitly identified event boundaries in cartoons and then had their memory tested. In both cases, children whose segmentation judgments were more closely aligned with adults' tended to perform better on memory tests—recognizing more scenes and, in the case of Benear et al. (2023), making better temporal order judgments. The current submission turns to free recall, an ability that is still early in its development for the age range that they sampled (4- to 7-year-olds; Selmeczy, Fandakova, Grimm, Bunge, & Ghetti, 2019; Perlmutter, Sophian, Mitchell, & Cavnaugh, 1981). Their findings are more nuanced than prior reports. Although adult-like event segmentation was strongly correlated with later free recall performance, these variables were only marginally related after controlling for age. This raises the possibility that segmentation and recall abilities co-develop rather than directly influence one another. But their findings also raise another possibility. Verbal ability, which showed an even stronger link to free recall, may act as a bottleneck—preventing younger children from expressing memories that were otherwise intact. Indeed, nearly half of 4- to 5-year-olds failed to recall anything. These findings caution researchers that prolonged developmental trajectories in cognitive domains such as language can obscure the relationship between children's event segmentation and their memory.

Likewise, the protracted development of executive control might obscure essential insights into the development of event cognition. Explicit boundary judgments, in which participants note when one related sequence of actions ends and another begins, are the field's current gold standard. Even for children who understand these abstract instructions well, implementing them is akin to a challenging prospective memory task: They must vigilantly monitor the engaging movie for subtle cues, apply consistent decision criteria to determine if a boundary occurred, and inhibit the urge to become engrossed in the movie. Performance on prospective memory tasks develops into adolescence due to their heavy executive demands (Engle, Tuholski, Laughlin, & Conway, 1999). We have every reason to expect that children will likewise forget to report many internally experienced event boundaries. Indeed, prior work has sought to overcome these challenges by indirectly measuring children's event segmentation using fMRI (Benear et al., 2023; Cohen et al., 2022) or dwell time (Zheng et al., 2020); however, reliable segmentation estimates within individuals are still needed.

Addressing this hurdle, Wilford et al.'s (2025) contribution to the Special Focus validates a new method to decode event transitions from individual participants' fMRI data. Building on prior work (Sava-Segal, Richards, Leung, & Finn, 2023), Wilford and colleagues adapt a state segmentation algorithm known as the greedy state boundary search (GSBS) to create a neural proxy for event segmentation (Geerligs, van Gerven, & Güçlü, 2021). GSBS offers advantages over the hidden Markov model (Baldassano et al., 2017) approach used by Sava-Segal et al. (2023) because it can simultaneously estimate the number of boundaries experienced and their timing for individual participants. Promisingly, Wilford et al. (2025) demonstrate that after thorough denoising, personalized GSBS boundary estimates in adults displayed patterns consistent with the canonical cortical hierarchy and occurred during narrative transitions identified as event boundaries by other participants. Notably, individuals with more fine-grained neural segmentation of movies and stronger hippocampal responses at personalized neural boundaries also recall the film in greater detail, highlighting the effectiveness of this approach for examining individual differences. However, excessive motion in the assessed developmental sample emerged as a critical limitation of the technique. This suggests that future applications addressing developmental questions will need to incorporate advanced motion mitigation strategies, such as high-speed prospective motion correction (Frost et al., 2019).

Finally, Rah et al.'s (2025) contribution to the Special Focus brings these findings into the spatial realm by building on their prior work (Rah, Kim, & Lee, 2022), in which it was shown that spatial boundaries can actually improve sequence memory in children as young as 5 years of age. The current work explores the neural basis of these spatial boundaries in adults using virtual reality. Unlike the children in the 2022 paper, Rah et al. (2025) in this Special Focus find that only half of the adults have improved sequence memory when the sequence event does not cross a spatial boundary. In looking more closely at this group, they find that those with superior within-boundary sequence memory have greater neural responsivity to boundaries in predicted regions. This highlights pervasive individual differences in what might count as an event boundary and how these boundaries structure memory in adults. This work also calls for extending these questions about developmental shifts in idiosyncrasy to spatial questions; it could be that space is a more important cue for segmentation, and possibly even used more consistently, in childhood.

OPEN DIRECTIONS

Bringing all this together, there is a great need to understand idiosyncrasies in event segmentation to fully understand how event segmentation changes across development. First, previous research is clear that children's explicit judgments of event boundaries are less aligned in time than adults' (Benear et al., 2023; Ren et al., 2021; Zheng et al., 2020). Indeed, one study showed reduced intersubject correlations in boundary placement in children across five separate cartoons (Ren et al., 2021). Another showed greater variability in boundary placement in a longer form animated show (Benear et al., 2023). A third similarly found reduced agreement in children as compared with adults across five short child-friendly movie clips that used both explicit boundary judgments and more indirect measures of dwell time (Zheng et al., 2020). Here, we note that this greater variability on the part of children is likely meaningful. A pressing question about development therefore pertains to the nature of this idiosyncrasy. We review several possibilities in the next paragraphs, inspired by the papers in this Special Focus.

One explanation for children's greater idiosyncrasy is the slow maturation of cognitive processes needed for adult-like segmentation—working memory, sustained attention, and executive function (Zacks et al., 2007). Immature cognitive systems may lead to greater performance variability, as captured by the "Anna Karenina principle" (Finn et al., 2020): Skilled adults tend to succeed in similar ways, whereas children, due to developmental limitations, falter in unique ways. From this view, adult-like segmentation represents a kind of optimal performance, requiring the orchestration of multiple mature cognitive systems. From this adults-are-optimal perspective, it seems intuitive that adult-like segmentation leads to better memory (Benear et al., 2023; Zheng et al., 2020), and it is even tempting to infer that the segmentation supports memory formation. Still, we need to consider two key alternative explanations. First, correlations between segmentation and memory might reflect the pervasive "positive manifold" phenomenon, in which strength in any one cognitive ability is highly correlated with strength in another (Cattell, 1967). Causal manipulations, such as those performed in adults (Flores, Bailey, Eisenberg, & Zacks, 2017), will be necessary to rule this out. Second, explicit segmentation tasks are cognitively demanding, and children may fail not because their ability to segment is poor but because the task overwhelms their executive capacity. This calls for more indirect or implicit measures. The personalized neural approach developed by Wilford et al. (2025) in this issue could help disentangle true segmentation ability from task-related confounds.

We should not discount the possibility, though, that children's segmentation is not deficient but simply "different." Semantic organization is important for adult event segmentation (Newberry & Bailey, 2019). Adults construct these semantic scaffolds based on decades of life experience, much of which is regimentally similar for those in the same culture, such as shared experiences with media, social norms, and educational and work environments. By contrast, young children will have fewer shared experiences to draw on when constructing their semantic models of events (Ngo, Benear, Popal, Olson, & Newcombe, 2021). Indeed, related research shows that the first associated word to pop into children's minds when given a cue (e.g., cat when given dog) is more likely to be unique compared with those of adults (Wojcik & Kandhadai, 2020; Dubossarsky, De Deyne, & Hills, 2017; Zortea, Menegola, Villavicencio, & de Salles, 2014; Coronges, Stacy, & Valente, 2007). Children's idiosyncratic semantic organization is also seen in their performance on classic false memory paradigms. When given a list of related words, children less often falsely remember a semantically related lure compared with adults (Holliday, Brainerd, & Reyna, 2011; Brainerd, Reyna, & Ceci, 2008). Importantly, this does not mean that children do not falsely remember things; however, their memory intrusions are highly idiosyncratic and less semantically related to the word lists than adults'. Having unique semantic scaffolds could produce more variable—but not necessarily worse—event segmentation. Indeed, even infants display evidence of event segmentation (Hespos, Grossman, & Saylor, 2010; Hespos, Saylor, & Grossman, 2009; Baldwin, Baird, Saylor, & Clark, 2001) with consequences for their memory (Sonne, Kingo, & Krøjgaard, 2016, 2017). This perspective brings an alternative interpretation to the memory–segmentation relations investigated in this Special Focus by Benear et al. (2025). Specifically, children with less-normative models of the world may struggle to recall narratives created by adults because their semantics do not provide sufficient scaffolding for subsequent recall. Future work could test this possibility by using movies of natural actions or narratives created by children.

A related possibility is that children rely on different types of cues than adults to structure their experience. A rich literature demonstrates that children tend to prioritize perceptual over semantic information when learning new concepts and making inductive inferences (Hayes, Fritz, & Heit, 2013; Sloutsky, 2010; Hayes, 2007; Sheya & Smith, 2006; Rodrigo, Javier, & Camacho, 1999). Adults do use perceptual shifts, such as changes in spatial context, to segment events, but they usually disregard superficial disruptions to perceptual flow, such as those introduced by continuity edits in film (Magliano & Zacks, 2011). For example, adults may not register cuts that shift focus between characters during a conversation as event boundaries. With their focus on the perceptual, children might perceive these shifts as boundaries, complicating their understanding of movie stimuli used by papers included in this Special Focus. Future work using first-person, continuous-perspective video may provide a more developmentally appropriate window into how children segment real-world events. Related developmental differences could also involve broader shifts from concrete to abstract signals of boundaries. For example, Rah et al. (2022) found that with age, children rely on increasingly abstract representations of spatial boundaries to organize their sequence memory. However, as shown by Rah et al. (2025) in this Special Focus, adults' variable use of virtual spatial boundaries could be an important source of individual differences in adults.

Another factor to consider in thinking about children's idiosyncratic event segmentation is age-related differences in the potency or strength of event boundaries. According to event segmentation theory, boundaries serve to flush outdated event models and initiate the construction of new ones (Zacks & Swallow, 2007); this shift is thought to manifest in abrupt changes in patterns of neural activity (as in Wilford et al., 2025). Benear et al. (2023) demonstrated such shifts in children at normative event boundaries—although, without an adult comparison group, the relative strength of those shifts remains unknown. They could be more permeable or less coordinated across the cortical hierarchy. Some evidence from Ren and colleagues (2021) supports this view: Although normative event boundaries influenced children's memory accessibility, the effect was weaker than in adults. This could reflect how content from prior events persists through permeable event boundaries. Put another way, children's boundaries may be every bit as potent as adults', just timed differently. The tools developed by Wilford et al. (2025) in this Special Focus will be critical for assessing this possibility.

Lastly, researchers could inform our understanding of children's idiosyncratic event segmentation through a deeper exploration of the neural level of analysis. Event segmentation is hypothesized to occur when the brain detects a prediction error, which is sufficiently large to merit resetting the current event model (Zacks et al., 2007). This chain of events requires sensitivity to the narrative perturbation and sufficient malleability in ensemble dynamics within critical brain regions. Put another way, the brain needs to be sufficiently attuned to and open to change when a potential event boundary occurs. Dynamical systems approaches have revealed that activity in neuromodulatory regions can regulate the brain's sensitivity to change (Taylor et al., 2024; Munn, Müller, Wainstein, & Shine, 2021). These dynamics turn up or down a person's likelihood of undergoing neural state transitions, which are thought to underlie event segmentation (Baldassano et al., 2017). Since neural modulatory systems undergo complex developmental trajectories (Saboory, Ghasemi, & Mehranfard, 2020; Galvin, Arnsten, & Wang, 2018; Abreu-Villaça, Filgueiras, & Manhães, 2011), children's brains may be especially prone—or resistant—to event model resets at different stages of development. Individualized neural modeling approaches, such as the GSBS method validated by Wilford et al. (2025), could identify precursors to these transitions in individual brains. Tracing the developmental prevalence of such antecedents could clarify why children experience events so differently from one another—and from adults.

CONCLUSIONS

Taken together, the papers in this Special Focus highlight a developmental trajectory in which event segmentation becomes more adult-like with age—but also reveal substantial individual variability, especially in early development. We propose that this idiosyncrasy is not random: It likely reflects differences in both the inputs to segmentation (such as attention, experience, and semantic scaffolding) and the mechanisms by which segmentation occurs. The emerging picture is one in which children's experiences are shaped not only by what they bring to a narrative in a cognitive sense but also by how their brains dynamically respond to change. As event models are constructed and reset, neural sensitivity to prediction error and flexibility in ensemble dynamics may influence the likelihood of perceiving a boundary. These dynamics are likely to shift across development, though the precise mechanisms—potentially involving broader changes in neural excitability and control—remain to be fully understood. By showcasing the multifaceted possible mechanisms underlying the development of event segmentation, we hope to highlight the value of combining the diverse approaches included in this Special Focus. Future work linking cognitive interpretations of experience with their neural instantiations can move beyond describing developmental differences to explaining how they arise—and how they shape memory, learning, and the subjective flow of time.

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Diversity in Citation Practices

Retrospective analysis of the citations in every article published in this journal from 2010 to 2021 reveals a persistent pattern of gender imbalance: Although the proportions of authorship teams (categorized by estimated gender identification of first author/last author) publishing in the *Journal of Cognitive Neuroscience* (*JoCN*) during this period were M(an)/M = .407, W(oman)/M = .32, M/W = .115, and W/W = .159, the comparable proportions for the articles that these authorship teams cited were M/M = .549, W/M = .257, M/W = .109, and W/W = .085 (Postle and Fulvio, *JoCN*, 34:1, pp. 1–3). Consequently, *JoCN* encourages all authors to consider gender balance explicitly when selecting which articles to cite and gives them the opportunity to report their article's gender citation balance.

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