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Commentary: The ontogeny of human memory: Where are we going?

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In their review, Jabès and Nelson provide an update of Nelson's 1995 cognitive neuroscience model of human memory development. Here, we highlight the major changes in perspective after 20 years of advances in our understanding of the neural basis of memory, and advocate the need for more systematic investigations of memory processes across the lifespan, which combine different models and levels of analysis: from genes, to brain to behavior.

Original theoretical framework

In 1995, Nelson explored the relation between early memory development and corresponding changes in brain development, and conceptualized this knowledge in a coherent theoretical framework (Nelson, 1995). With great foresight, Nelson proposed that the development of different types of memory depends on the development of different brain structures. Although the original model lacked substantial corroborative data, this is no longer the case. Today, beyond the hypothetical, we have concrete examples illustrating the relation between the emergence and development of memory and the development of specific brain structures. A major part of Nelson's original model focused on the role of the hippocampal formation in explicit (declarative) memory processes, and it is therefore no surprise that the updated model (Jabès & Nelson, 2015) is also heavily focused on this brain region and its functions. The hippocampus is the central part of a larger brain network supporting memory processes (Lavenex & Amaral, 2000). It thus makes sense to start investigations of the neurobiological basis of memory with the central piece of the puzzle. However, the contribution of other brain regions to human memory development is clearly an area that will require systematic investigations at the behavioural and neurobiological levels. This was true then, is true today and will remain true in the future.

Hippocampus

In 1995, Nelson considered the existing information regarding hippocampal development and concluded that the human and nonhuman primate hippocampus and surrounding structures (excluding the dentate gyrus) matured early in life. Since then, however, there has been a fundamental change in perspective (Jabès & Nelson, 2015). Indeed, it is now well established that the hippocampal formation is not a single structure, but comprises a number of distinct regions and circuits (Amaral & Lavenex, 2007; Lavenex & Amaral, 2000) that subserve different computational processes and memory functions (Copara et al., 2014; Kesner, Lee, & Gilbert, 2004; Lavenex & Banta Lavenex, 2013; Nakashiba et al., 2012). Our recent work at the genetic and neuroanatomical levels revealed that different hippocampal regions mature at different times during development (Favre, Banta Lavenex, & Lavenex, 2012a, 2012b; Jabès, Banta Lavenex, Amaral, & Lavenex, 2010, 2011; Lavenex, Banta Lavenex, & Amaral, 2007; Lavenex, Sugden, Davis, Gregg, & Banta Lavenex, 2011). These findings, together with our studies of the development of human spatial memory (Ribordy, Jabès, Banta Lavenex, & Lavenex, 2013; Ribordy Lambert, Lavenex & Banta Lavenex, 2015), support the hypothesis that the differential maturation of distinct hippocampal circuits might underlie the differential emergence of specific "hippocampus-dependent" memory processes, culminating in the emergence of adult-like episodic memory concomitant with the maturation of all hippocampal circuits (Lavenex & Banta Lavenex, 2013). This is a view shared by Jabès and Nelson (2015).

Behaviour

In 1995, Nelson described a number of behavioural tasks that human infants and children begin to master at different ages during early postnatal life. What was missing then, and has been somewhat improved now, is our understanding of the representational demands of these tasks, and thus our characterization of the basic cognitive processes under study. For example, by focusing on spatial learning and memory processes, our laboratory has benefited from the abundance of studies performed in various species, including mice, rats, monkeys and humans, which provide a coherent theoretical framework to comprehend the functional role of distinct hippocampal regions and circuits across the lifespan. In contrast, as described by Nelson, considerable energy has been spent trying to understand and explain the seemingly discrepant behavioural findings between studies using the delayed-nonmatching-to-sample and visual-paired comparison tasks, which both supposedly test visual recognition memory. Since the ability to perform these tasks emerges at different ages (Overman, Bachevalier, Turner, & Peuster, 1992; Pascalis & de Schonen, 1994), and different brain lesions affect task performance differentially in individuals of different ages (Pascalis, Hunkin, Holdstock, Isaac, & Mayes, 2004; Zeamer, Heuer, & Bachevalier, 2010; Zola et al., 2000), it is likely that these tasks do not evaluate the same cognitive processes, or

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do so only very superficially. Although differing methodological details of these tasks might lead to discrepant results, we argue that it is fundamental to understand the basic representational demands of the task (as it is actually performed) in order to identify and define the cognitive processes under study. This was true then, is true today and will remain true in the future.

Future

We have undoubtedly learned a great deal regarding the neurobiological basis of human memory development over the past 20 years. However, there is still much work ahead and we hope to learn as much if not more in the next 20 years. In order to do so, it will be necessary to carry out systematic studies of memory development across the lifespan (including during aging), using different models and at different levels of analysis. The benefits of such systematic studies will be multi-faceted: First, systematic studies of brain development in humans and other animals will help us to understand how specific genes contribute to the normal and abnormal development of functional circuits, such as in Down and Williams syndromes. Second, electrophysiological studies performed in different species will provide evidence of the functional maturation of specific memory circuits in order to derive a coherent theoretical framework concerning memory development. Third, studies utilizing tasks with well understood representational demands will continue to advance our understanding of the functional role of specific brain areas across the lifespan. Finally, advances in non-invasive imaging technologies will also enable us to establish direct links between different models and analysis levels. Such diverse approaches to memory development will be key to unravelling the mysteries of the ontogeny of human memory development.

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Conflict of interest

The authors have no conflicts of interest to declare.

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