Ann. N.Y. Acad. Sci. ISSN 0077-8923

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Issue: *Meditation*

# Transcending as a driver of development

Frederick Travis

Center for Brain, Consciousness, and Cognition, Maharishi University of Management, Fairfield, Iowa

Address for correspondence: Frederick Travis, Ph.D., Center for Brain, Consciousness, and Cognition, Maharishi University of Management, 1000 North 4th Street, MR 683, Fairfield, IA 52557. ftravis@mum.edu

**This paper draws from three different bodies of research to discuss the hypothesis that age-appropriate experiences enhance brain and cognitive development throughout the life span. These age-appropriate experiences could be considered as the drivers of development at each age, including drivers to foster development beyond adult abstract thinking, as described in Piaget's formal operational stage. We explore how a nurturing caregiver is the driver in the first 2 years of life, how language learning is the driver from 3 to 10 years, and how problem solving is the driver in the teenage years. To develop beyond adult rational thinking, we suggest that the driver is transcending thought, which can result when practicing meditations in the automatic self-transcending category, such as Transcendental Meditation.**

**Keywords:** development; meditation; transcending; TM; Transcendental Meditation

## Introduction

This paper discusses the hypothesis that age-appropriate experiences enhance brain and associated cognitive development throughout the life span. Gray matter density and white matter volume dynamically change throughout the first 20 years of life, governed by biological maturation and the effects of ongoing experiences. As brain structure and function change, so would the types of experiences that best support brain and cognitive development. Thus, throughout life, different experiences would serve as optimal drivers to support different stages of development, including drivers to foster development beyond Piaget's formal operations.

## Brain maturation

At birth, children already have most of the neurons that they will have as adults, but these neurons have few connections.[1] During the first two decades of life, a natural process of brain maturation begins with a 3-year burst of connectivity. Gray matter density initially increases 0.4–1.5 mm/year from birth to 3 years and remains high from 3 to 10 years of age.[2,3] Brain connections are sculpted into adult brain patterns through pruning, which occurs at different rates throughout the brain, with the greatest thinning seen in frontal and parietal association cortices.[3–6] While gray matter has a U-shaped trajectory in the first two decades of life, white matter increases throughout childhood and adolescence, as measured by changes in mean diffusivity, radial diffusivity, and fractional anisotropy.[7,8] In early childhood, myelin increases around axons in sensory regions, including ventral visual pathways, and in motor regions, including the internal capsule, basal ganglia, and thalamic pathways. In adolescence, myelin increases in axons that connect sensorimotor regions with frontal and parietal association cortices.[9] White matter density continues to change throughout the life span—a process that is driven by experience and that supports further cognitive development and learning.[10] In general, from childhood to adolescence, local modules develop first, as evidenced by decreasing average path length, increasing node strength, and network clustering.[9] Then, global connections develop with association areas important for attention, cognitive ability, and memory.[11]

These developmental trajectories of gray and white matter are also reported by longitudinal research studies. For example, in a longitudinal neuroimaging study by Giedd *et al.* of 617 subjects aged 5–25 years,[12] white matter steadily increased and gray matter density had an inverted U-shaped

doi: 10.1111/nyas.13071

  

pattern over this age range. In addition, the authors reported different trajectories of gray matter density across the brain and between boys and girls. Gray matter in frontal areas peaked at 9.5 years for girls and 10.5 years for boys, while it peaked in parietal areas at 7.5 years for girls and 9 years for boys.[12]

## Experience shapes brain maturation

These waves of transformation of brain connectivity interact with ongoing experience throughout life. Stimulation shapes the brain and cognitive development, while neglect stunts development. This was evidenced in Romanian orphanages in the late 1980s (filled with 170,000 children at the peak), where a single caregiver attended to 10–15 children, and infants spent most of their time staring at the walls and ceiling rather than interacting with others. It is important to note that these children were not abused. The orphanages had highly structured routines and three shifts of caregivers, and the children were kept safe, warm, fed, and clean. However, the children had limited interactions with adults or other children; this neglect led to low developmental intelligence quotients that were two standard deviations below the norm.[13]

The Bucharest Early Intervention Project investigated whether nurturing experiences can remedy the debilitating effects of neglect in these Romanian children. As part of this project, Windsor *et al.*[14] examined language competency in 174 of the children, who were randomly assigned to remain in the institution or were placed in foster homes. The authors looked at language since it is a key marker of academic and social success. They reported that the age when children were placed in foster homes was highly correlated with language outcomes ($r = 0.7$). If children were placed in foster care before they were 15 months old, they completely regained language skills. If they were placed in foster homes from 15 to 24 months of age, there were dramatic improvements in language abilities, although they did not fully recover. Two years of age seemed to be a critical line, in that children placed in foster homes after 2 years of age had similar language delays at 4 years of age as did children who remained under institutional care.[14]

Poverty, which often includes neglect, also reduces brain and cognitive development. A cross-sectional study reported that the number of years lived in poverty predicted lower working memory and smaller prefrontal cortical and hippocampal volume.[15] As early as 3 years of age, lower socioeconomic status (SES) leads to lower cognitive skills, socioemotional functioning, physical health, and brain connectivity.[16] In a sample of 60 socioeconomically diverse children, SES levels were associated with the size of the hippocampus, amygdala, left superior temporal gyrus, and left inferior frontal gyrus.[17]

The effects of poverty on brain functioning are also seen in longitudinal research. In a longitudinal study by Luby *et al.*[18] that followed 145 preschool-aged children attending day care in the St. Louis area, the authors recorded results from magnetic resonance imaging (MRI), tests of caregiver support observed during the preschool period, and interviews about stressful life events. Poverty levels, disorganized caregiver support, and stressful life events were all associated with smaller white and cortical gray matter volumes and smaller hippocampal and amygdala volumes. The same research group reported that positive maternal support—the opposite of neglect—buffered the effects of poverty and stressful life events on brain structure in the same subject population (92 children from daycare centers in St. Louis). The parents were given three assessments each year for up to 6 years: the Preschool Age Psychiatric Assessment, which measures children's psychiatric symptoms; the Family Interview for Genetic Studies, which assesses maternal history of depression; and the mildly stressful waiting task, which assesses the degree of maternal support of children.[19] In the waiting task, a child is asked to wait 8 min before opening a brightly wrapped present that is within her/his reach. At the same time, the mother is asked to complete the questionnaires. This creates a tension between the mother wanting to fill out the form and the child wanting to open the present. The experimenters coded the strategies that the mother used to help her child deal with impulses to open the gift, even as she focused on completing the questionnaire. MRI scans were taken in the last year of the study. The level of maternal support observed in the real-life waiting task strongly predicted hippocampal volume measured at school age. This effect was seen in children who were diagnosed as clinically depressed, as well as in nondepressed children.[19]

In general, an enriched environment enhances brain development. For example, in animal studies, being in an enriched environmental for 2–6 weeks increased the number of new neurons in the hippocampus and the number of long-distance connections with cortical neurons—this increase in cortical innervation remained even after animals were returned to control conditions.[20] In humans, voluntary exercise also has consistently been reported to increase adult neurogenesis in the hippocampus and improve spatial learning ability. Both voluntary exercise and environmental enrichment increase neurogenesis, in that voluntary exercise increases the number of new cells generated, and environmental enrichment increases the likelihood of the survival of new cells.[21]

## Drivers of development

### *First 2 years of life: a nurturing caregiver is the driver*

The study by Windsor *et al.*[14] in Romanian infants concluded: "The experience of a nurturing caregiver early in life has proven to be one of the most essential prerequisites for healthy development and adaptive functioning in mammals" (p. 2857). As discussed above, the follow-up of these infants reported that living in a foster home reversed the effects of neglect, if the infants moved into the home before they were 2 years old. Thus, a nurturing caregiver appears to be a necessary driver of development in the first few years of life, despite early-life adversity.

The research on mother/child attachment supports this conclusion. The nature of the attachment relationship shapes the orbitofrontal system that governs approach and avoidance.[22] A mother/child attachment that is orderly and secure leads to better regulation of emotions to environmental stress and challenges, optimal hypothalamic–pituitary–adrenal axis regulation, more effective strategies to deal with adversity, and long-term mental and physical health.[23–26]

### *School years: language is the driver*

The 2-year-old child lives in a concrete world. Sensory and motor brain areas are mature and support seeing and manipulating objects. The concrete world completely absorbs their attention—what they see is their reality.[27] With further development, they can begin to think about their experiences. Development during the school years, ages 3–10 years, is driven by language learning. Words are labels for objects and allow the child to think about future possibilities. Language is essential to form concepts, develop logical memory, communicate with others, and exercise critical thinking. Vygotsky viewed language as a mental tool to build problem-solving skills through social interactions. Children interact with adults or older siblings, who model problem-solving skills and/or explain their thinking to the children. Through language, children understand what should be done and then internalize the information, using it to guide their own performance. Through language, they build "tools" in the mind.[28]

Sociocultural interactions facilitated through language allow students to create rules. Internal rule construction rests on perceptual categorization—the ability to group objects by perceptual features—that emerged in the first 3 years of life, as the posterior sensory cortices matured.[29] Perceptual categorization begins to mature around 5 years of age and provides the basis of grouping concepts and applying these concepts to perceptual objects. At this time, children are able to link cause and effect. The diversity of experience becomes manageable with rules, and children at this age seek rules to understand and control their experiences.[30]

### *Preteen and teenage years: problem solving is the driver*

The preteen and teenage years are marked by two major waves of transformation of brain structure and function: the process of neural pruning and the myelination of frontal control circuits. Cortical thickness begins to decrease at the rate of 1–2% each year, beginning around 10 years of age.[4] The connections between the rest of the brain and the prefrontal cortex—the core executive centers—begin to myelinate at 12 years of age and continue throughout this period.[31] By middle to late adolescence, teenagers have fewer connections than they did as children, but these connections are selectively stronger within specific brain networks.

This period is marked by the maturation of two competing systems: the low-road emotional system, including the amygdala and nucleus accumbens, and the high-road executive system, including the prefrontal cortex and bilateral parietofrontal network.[32,33] Longitudinal MRI studies have shown that the emotional system associated with the amygdala and nucleus accumbens matures earlier than the executive system. This imbalanced maturation was correlated with higher self-reported risk-taking and sensation-seeking behaviors.[34,35] Frontal maturation is critical for children to be able to resist habits, control temptations, resist interfering stimuli and distractions, and to adapt to conflicting situations.[36,37]

While frontal maturation begins in most children around 12 years of age, not all adults exercise abstract thinking.[38] We suggest that one needs to exercise frontal circuits in order to develop those circuits, in the same way that children played with language to develop rule-governed behavior, and the sensorimotor child moved her/his rattle in and out of vision to develop sensory and motor systems.[39] Inhibitory control involves the frontal executive system. One study showed that 2 weeks of practice of a go/no-go task improved performance and led to increased gray and white matter volumes in the right inferior frontal gyri of college students.[40] Furthermore, whole-body balance tasks have been shown to significantly increase frontal and parietal gray matter volume and improve the integrity of white matter on the connections between these brain regions.[41] Thus, the driver of development at this age is problem-solving activities.

At 10 years of age, rules are absolute—it is a matter of black and white. At 15 years of age, no rule is sacred—all rules are shades of gray colored by the context.[42] The frequent questioning that teenagers engage in can be supported by adults with discussion of abstract issues. If teenagers are not presented with abstract problems to solve, they may continue to focus on concrete situations, and frontal–parietal circuits associated with formal operations may not fully mature.

### *Adults: transcending is the driver*

According to Piaget, adult abstract reasoning, which he called formal operations, is characterized by hypothetical deductive reasoning. Concepts and categories are real and, in fact, are so real that they become the basis of arguments, social conflicts, and wars.

To go beyond hypothetical deductive reasoning, we suggest that one needs to transcend language. For adults, this is the next driver for development—transcending. Alexander and Langer,[27] when exploring higher human development, suggested, "An intervention to transcend language may be as necessary to cultivate higher states of consciousness beyond ordinary waking, as language learning was to developing adult thinking" (p. 271).

Most formal education develops critical thinking skills, problem solving, and creative thinking; essentially, students are taught how to use their mind. But current education does not teach individuals how to transcend thoughts and explore the source of thoughts. Meditation procedures in the automatic self-transcending category, such as Transcendental Meditation, are designed to transcend thinking and to explore the source of thoughts.[43] Meditation practices that transcend thinking change one's experience of inner self and therefore transform how one experiences the world.[44]

### *Transcending and development*

In addition to our suggestion that transcending enhances development beyond adult critical thinking, research studies report that transcending facilitates development of Piaget's stage of concrete operations. A matched controlled study examined cognitive development in 47 children practicing the children's form of Transcendental Meditation and in 47 matched controls from a top private school in Massachusetts.[45] Cognitive development was operationalized as acquisition of conservation in seven tasks that were ordered from easy to hard: two-dimensional space, number, substance, continuous quantity, weight, discontinuous quantity, and volume. Typically, there is a 5-year lag in mastering all levels of conservation, called horizontal decalage.[46] However, it was found that the children practicing Transcendental Meditation mastered significantly more conservation tasks than the control group, suggesting that the process of transcending may have allowed the child to de-embed from thinking and perception and use higher-order thinking to guide behavior. In a second study that followed 37 students practicing Transcendental Meditation and 29 matched controls for 6 months, the students practicing Transcendental Meditation exhibited greater psychological differentiation, general intelligence, self-concept, analytical ability, and general intellectual performance compared to controls, suggesting that transcending may accelerate the development of higher-order thinking.[47]

Transcending is reported to enhance development in adults as well. A 10-year controlled, longitudinal study reported that subjects practicing Transcendental Meditation showed significant growth in ego development,[48] which is associated with postformal development.[49] Other cross-sectional research in adults reported that Transcendental Meditation practice is associated with higher moral reasoning, more stable sense of self, greater openness to experience, and lower anxiety.[50]

### *Transcending and educational outcomes*

Transcendental Meditation practice has been implemented in the San Francisco middle and upper school system (the Quiet Time program). Longitudinal comparison of students in this program with students in the school not meditating revealed that Transcendental Meditation practice led to significantly lower anxiety and higher resilience,[51] significant improvement on the Standardized Testing and Reporting tests of mathematics and English,[52] and significantly higher graduation rates compared to control subjects as well as to the national average.[53] Three months of Transcendental Meditation practice has also been reported to reduce the severity of attention-deficit hyperactivity disorder, as measured by $\theta/\beta$ ratios, in children aged 10–14 years.[54]

## A model: knowledge is the uniting of the knower, the known, and the process of knowing

How does transcending drive higher development? Experience can be modeled as the interaction of three factors: the knower, the known, and the process of knowing. The known includes facts, spoken rules, and explicit ideas and concepts—the information on formal educational tests. The processes of knowing are how one interacts with the known and include perception, problem-solving skills, critical analysis, empathy, concentration, mindfulness practices, and contemplative practices. The knower is the experiencer, and her/his character, whether tired, stressed, sleepy, clear, or living expanded awareness, determines the quality of the interaction with the known. Transcending leads to the experience of one's innermost self, which is covered by the processes of knowing during waking experiences. Adding this experience to students' lives develops a more stable sense of self, which could provide a new ground for making meaning and supporting continued development.[55]

## Conflicts of interest

The author declares no conflicts of interest.

## References


1. Innocenti, G.M. & D.J. Price. 2005. Exuberance in the development of cortical networks. *Nat. Rev. Neurosci.* **6:** 955–965.
2. Thompson, P.M. *et al.* 2005. Structural MRI and brain development. *Int. Rev. Neurobiol.* **67:** 285–323.
3. Sowell, E.R. *et al.* 2004. Longitudinal mapping of cortical thickness and brain growth in normal children. *J. Neurosci.* **24:** 8223–8231.
4. Marcucci, F. *et al.* 2011. Exuberant growth and synapse formation of olfactory sensory neuron axonal arborizations. *J. Comp. Neurol.* **519:** 3713–3726.
5. Sowell, E.R., P.M. Thompson & A.W. Toga. 2004. Mapping changes in the human cortex throughout the span of life. *Neuroscientist* **10:** 372–392.
6. Sowell, E.R. *et al.* 2003. Mapping cortical change across the human life span. *Nat. Neurosci.* **6:** 309–315.
7. Sowell, E.R. *et al.* 2002. Development of cortical and subcortical brain structures in childhood and adolescence: a structural MRI study. *Dev. Med. Child Neurol.* **44:** 4–16.
8. Barnea-Goraly, N. *et al.* 2005. White matter development during childhood and adolescence: a cross-sectional diffusion tensor imaging study. *Cereb. Cortex* **15:** 1848–1854.
9. Wierenga, L.M. *et al.* 2016. The development of brain network architecture. *Hum. Brain Mapp.* **37:** 717–729.
10. Fields, R.D. 2008. White matter in learning, cognition and psychiatric disorders. *Trends Neurosci.* **31:** 361–370.
11. Schmithorst, V.J. & W. Yuan. 2010. White matter development during adolescence as shown by diffusion MRI. *Brain Cogn.* **72:** 16–25.
12. Giedd, J.N. *et al.* 2015. Child psychiatry branch of the National Institute of Mental Health longitudinal structural magnetic resonance imaging study of human brain development. *Neuropsychopharmacology* **40:** 43–49.
13. Marshall, E. 2014. An experiment in zero parenting. *Science* **345:** 752–754.
14. Windsor, J. *et al.* 2011. Effect of foster care on young children's language learning. *Child Dev.* **82:** 1040–1046.
15. Evans, G.W. & M.A. Schamberg. 2009. Childhood poverty, chronic stress, and adult working memory. *Proc. Natl. Acad. Sci. U.S.A.* **106:** 6545–6549.
16. Doyle, O. *et al.* 2009. Investing in early human development: timing and economic efficiency. *Econ. Hum. Biol.* **7:** 1–6.
17. Noble, K.G. *et al.* 2012. Neural correlates of socioeconomic status in the developing human brain. *Dev. Sci.* **15:** 516–527.
18. Luby, J. *et al.* 2013. The effects of poverty on childhood brain development: the mediating effect of caregiving and stressful life events. *JAMA Pediatr.* **167:** 1135–1142.
19. Luby, J.L. *et al.* 2012. Maternal support in early childhood predicts larger hippocampal volumes at school age. *Proc. Natl. Acad. Sci. U.S.A.* **109:** 2854–2859.
20. Bergami, M. *et al.* 2015. A critical period for experience-dependent remodeling of adult-born neuron connectivity. *Neuron* **85:** 710–717.
21. Olson, A.K. *et al.* 2006. Environmental enrichment and voluntary exercise massively increase neurogenesis in the adult

hippocampus via dissociable pathways. *Hippocampus* **16:** 250–260.
22. Schore, A.N. 2000. Attachment and the regulation of the right brain. *Attach. Hum. Dev.* **2:** 23–47.
23. Oosterman, M. *et al.* 2010. Autonomic reactivity in relation to attachment and early adversity among foster children. *Dev. Psychopathol.* **22:** 109–118.
24. Bowlby, J. 1969. *Attachment.* Vol. I. London: Basic Books.
25. Westrup, B. 2015. Family-centered developmentally supportive care: the Swedish example. *Arch. Pediatr.* **22:** 1086–1091.
26. Levendosky, A.A. *et al.* 2016. Infant adrenocortical reactivity and behavioral functioning: relation to early exposure to maternal intimate partner violence. *Stress* **19:** 37–44.
27. Alexander, C.N. & E. Langer. 1990. *Higher Stages of Human Development: Perspectives on Adult Growth.* New York: Oxford University Press.
28. Vygotsky, L.S. 1978. *Mind in Society: Development of Higher Psychological Processes.* Cambridge, MA: Harvard University Press.
29. Keating, D.B. 2004. "Cognitive and brain development." In *Handbook of Adolescent Psychology*. R.M. Lerner & L. Steinberg, Eds.: 45–84. New York: John Wiley and Sons.
30. Gardner, H. 1982. *Art, Mind and Brain.* Cambridge, MA: Basic Books.
31. Berken, J.A. *et al.* 2015. The timing of language learning shapes brain structure associated with articulation. *Brain Struct. Funct.* DOI: 10.1007/s00429-015-1121-9.
32. Houde, O. *et al.* 2011. Functional magnetic resonance imaging study of Piaget's conservation-of-number task in preschool and school-age children: a neo-Piagetian approach. *J. Exp. Child Psychol.* **110:** 332–346.
33. Leroux, G. *et al.* 2009. Adult brains don't fully overcome biases that lead to incorrect performance during cognitive development: an fMRI study in young adults completing a Piaget-like task. *Dev. Sci.* **12:** 326–338.
34. Mills, K.L. *et al.* 2014. The developmental mismatch in structural brain maturation during adolescence. *Dev. Neurosci.* **36:** 147–160.
35. Qu, Y. *et al.* 2015. Longitudinal changes in prefrontal cortex activation underlie declines in adolescent risk taking. *J. Neurosci.* **35:** 11308–11314.
36. Houde, O. & G. Borst. 2014. Measuring inhibitory control in children and adults: brain imaging and mental chronometry. *Front. Psychol.* **5:** 616.
37. Kuhn, D. 2006. Do cognitive changes accompany developments in the adolescent brain? *Perspect. Psychol. Sci.* **1:** 59–67.
38. Fischer, K.W. *et al.* 1980. A theory of cognitive development: the control and construction of hierarchies of skills. *Psychol. Rev.* **87:** 477–531.
39. Commons, M.L. & T.L. Robinette. 2013. Adult development: predicting learning success. *Train. Ind. Q.* Spring 2013: 31–41.
40. Chavan, C.F. *et al.* 2015. Differential patterns of functional and structural plasticity within and between inferior frontal gyri support training-induced improvements in inhibitory control proficiency. *Hum. Brain Mapp.* **36:** 2527–2543.
41. Taubert, M. *et al.* 2010. Dynamic properties of human brain structure: learning-related changes in cortical areas and associated fiber connections. *J. Neurosci.* **30:** 11670–11677.
42. Nobes, G. & C. Pawson. 2003. Children's understanding of social rules and social status. *Merrill-Palmer Q.* **49:** 77–99.
43. Travis, F. & J. Shear. 2010. Focused attention, open monitoring and automatic self-transcending: categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Conscious Cogn.* **19:** 1110–1118.
44. Travis, F. 2014. Transcendental experiences during meditation practice. *Ann. N.Y. Acad. Sci.* **1307:** 1–8.
45. Alexander, C.N. *et al.* 2003. Effect of practice of the children's transcendental meditation technique on cognitive stage development: acquisition and consolidation of conservation. *J. Soc. Behav. Pers.* **17:** 21–46.
46. Piaget, J. 1965. *Equilibration of Cognitive Structures.* Chicago, IL: Chicago University Press.
47. Dixon, C. *et al.* 2003. Accelerating cognitive and self-development: longitudinal studies with preschool and elementary school children. *J. Soc. Behav. Pers.* **16:** 65–91.
48. Chandler, H.M. *et al.* 2005. Transcendental meditation and postconventional self-development: a 10-year longitudinal study. *J. Soc. Behav. Pers.* **17:** 93–122.
49. Miller, M.E. & S. R. Cook-Greuter. 1994. *Transcendence and Mature Thought in Adulthood: The Further Reaches of Adult Development.* New York: Rowman & Littlefield Publishers.
50. Travis, F., A. Arenander & D. DuBois. 2004. Psychological and physiological characteristics of a proposed object-referral/self-referral continuum of self-awareness. *Conscious Cogn.* **13:** 401–420.
51. Wendt, S. *et al.* 2015. Practicing transcendental meditation in high schools: relationship to well-being and academic achievement among students. *Contemp. Sch. Psychol.* **19:** 312–319.
52. Nidich, S. *et al.* 2011. Academic achievement and transcendental meditation. *Education* **131:** 556–577.
53. Colbert, R. & S. Nidich. 2013. Effects of the transcendental meditation program on graduation, college acceptance, and dropout rates for students attending an urban public high school. *Education* **133:** 495–501.
54. Travis, F., S. Grosswald & W. Stixrud. 2011. ADHD, brain functioning, and transcendental meditation practice. *Mind Brain* **2:** 73–81.
55. Maharishi Mahesh Yogi. 2015. *Maharishi Mahesh Yogi on the Bhagavad-Gita, A New Translation and Commentary, Chapters 1–6.* Fairfield: MUM Press.