Explaining Enculturated Cognition

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Abstract

Many of our cognitive capacities are shaped by enculturation. Enculturation is the temporally extended transformative acquisition of cognitive practices such as reading, writing, and mathematics. They are embodied and normatively constrained ways to interact with epistemic resources (e.g., writing systems, number systems). Enculturation is associated with significant changes of the organization and connectivity of the brain and of the functional profiles of embodied actions and motor programs. Furthermore, it has a socio-culturally structured dimension, because it relies on cumulative cultural evolution and on the socially distributed acquisition of cognitive norms governing the engagement with epistemic resources. This paper argues that we need distinct, yet complementary levels of explanation and corresponding temporal scales. This leads to explanatory pluralism about enculturated cognition, which is the view that we need multiple perspectives and explanatory strategies to account for the complexity of enculturation.

Keywords: enculturation; neural plasticity; neural reuse; embodied cognition; cognitive niche construction; cumulative cultural evolution; cultural learning; reading acquisition; explanatory pluralism

Introduction

Many cognitive processes are shaped and facilitated by our successful acquisition of cognitive practices such as reading, writing, or mathematics. Cognitive practices are evolutionarily recent, embodied interactions with writing systems, number systems, and various other epistemic resources in our local environment (Fabry, 2017; Menary, 2015). Given the evolutionary recency of cognitive practices, with reading, writing, and mathematics dating back to approx. 3000 BC (Donald, 1991), the question arises how their acquisition can be explained from an empirically informed perspective. The purpose of the present paper is to sketch an explanatory framework that can help close the current gap in thinking about the phylogenetic and ontogenetic emergence of cognitive practices. The proposal is that competence in the performance of cognitive practices is the result of *enculturation*.

Enculturation is defined as the acquisition of cognitive practices during ontogeny. It is a temporally extended process that augments and transforms our overall cognitive capacities. There are two background assumptions that inform the conceptualization of enculturation. First, it is committed to a robust variant of embodied cognition (Menary, 2015). On this view, the embodied interaction with the local environment plays an indispensable functional role in at least some cognitive processes. In the present context, embodiment is understood as the *bodily manipulation* of epistemic resources (Menary, 2010; Rowlands, 1999), e.g. by initiating and executing eye movements and hand movements. Second, the present account of enculturation rests on on the assumption that cognitive practices are cases of strong embedded cognition (Menary, 2015). This amounts to the idea that at least some cognitive processes are realized by the integration of cerebral, extra-cerebral bodily, and environmental components. We will see in the course of this paper that the theoretical commitments to strong embodied and embedded cognition are supported by empirical research.

Shaping the Brain and the Rest of the Body

Enculturation is associated with significant changes to the organization and connectivity of the brain and to the functional profiles of embodied actions and motor programs. *Learning driven plasticity* (LDP) is a potent principle governing ontogenetic brain development, according to which structural changes of the organization and connectivity of brain areas lead to new neuronal functions (Ansari, 2012; Menary, 2015). LDP is not an open-ended process that leads to the unlimited realization of new neuronal circuits. Rather, it is constrained by the functional biases of certain cortical units that contribute to the development of new neuronal connections. This is suggested by empirical and conceptual work on *neural reuse* (Anderson, 2010, 2015) and *neuronal recycling* (Dehaene, 2005, 2010). The idea is that especially evolutionarily recent cognitive practices need to allocate and re-exploit already existing structural and functional connections of brain areas and integrate them into new neuronal circuitry. The scope of neural reuse in each particular case depends on the functional and structural biases of specific brain areas and on the functional proximity of uses to which these areas can be put (Anderson, 2015).

Neural reuse – and its component process of neuronal recycling that is associated with the acquisition of reading, writing, or mathematics – is a guiding principle of LDP. This is especially important in cases of enculturation. The reason is that it helps explain how cognitive practices can be acquired, given that there was not sufficient evolutionary time for the development of brain circuits unequivocally and exclusively dedicated to them.

The assumption that enculturation is defined as the acquisition of embodied cognitive practices gives rise to the idea that LDP is complemented by a genuinely bodily form of transformation. According to the principle of *learning driven bodily adaptability* (LDBA), new bodily ways to interact with the socio-culturally structured environment emerge in the course of enculturation. LDBA guides the ontogenetic trajectory of skilled motor action. The resulting development of new motor patterns and action routines is constrained by extra-cerebral bodily biases, e.g., by the functional potential of the overall morphology of human bodies and their constitutive parts (Dounskaia, van Gemmert, & Stelmach, 2000; Furuya & Altenmüller, 2015; Phillips, Ogeil, & Best, 2009). The employment and allocation of bodily resources available to the human organism bring about the embodied adaptation to new cognitive practices in close co-ordination with LDP. In this sense, the functional biases of brain areas are complemented by the biases of functional units of the rest of the body. It is important to note that the overall possibility space of cognitive practices is not only defined, but also delimited by the anatomical and physiological properties of the human body.

Interacting with the Cognitive Niche

The present account of enculturated cognition is committed to the view that cognitive practices are distributed across the brain, the rest of the body, and the local environment. This leads to the assumption that our understanding of LDP and LDBA needs to be complemented by considerations of the embodied interaction of cognitive systems with the cognitive niche. The cognitive niche can be defined as the incrementally, trans-generationally structured socio-cultural environment that provides human organisms with epistemic resources for the completion of cognitive tasks (Bertolotti & Magnani, 2016; Clark, 2006, 2008; Kendal, 2011; Sterelny, 2003, 2012; Stotz, 2010). Examples of resources in the cognitive niche include writing systems, number systems, and notational symbol systems. In addition, the cognitive niche is also characterized by socio-cultural institutions like kindergartens, schools, or universities. Cognitive practices are shared by a large number of individuals in the cognitive niche. Therefore, the skilful performance of cognitive practices is constrained by sets of cognitive norms. These norms regulate the interaction with epistemic resources (Menary, 2007, 2016). They need to be learned and automatized in the course of enculturation (Menary, 2013). Since cognitive practices are socio-cultural phenomena, their acquisition is itself a socio-culturally structured process. This process is characterized by *scaffolded learning* (Clark, 1997; Estany & Martínez, 2014; Wood, Bruner, & Ross, 1976). The notion of scaffolded learning refers to the idea that the acquisition of a cognitive practice is a systematic process of novice-expert interaction in the cognitive niche. This interaction is structured by the current developmental stage of the novice and a specific set of skills and knowledge that needs to be acquired in the long run (Vygotsky, 1978).

Socio-Cultural Learning

It is conceivable that scaffolded learning is the result of evolutionary processes that have shaped specific types of socio-culturally transmitted human cognitive capacities (Boyd, Richerson, & Henrich, 2011; Henrich, 2016). According to Kline's (2015) recent framework for the investigation of teaching, *direct active teaching* is of vital importance for human scaffolded learning. It is defined by the "[…] manifestation of relevant information by the teacher to the pupil, as well as the pupil's interpretation of that information as generalizable" (Kline, 2015, p. 12). In contrast to other forms of teaching and learning that are ubiquitous in the animal kingdom, e.g., social tolerance or opportunity provisioning, direct active teaching is specific to humans. It is likely to have co-evolved with genuinely human ways of cognitive niche construction. If correct, cumulative cultural evolution and scaffolded learning, where the latter might be the result of trans-generationally emerged socio-cultural processes (Heyes, 2012), mutually influence and constrain each other.

In sum, enculturation is a complex phenomenon that requires the synthesis of several explanatory components targeting the cerebral, the extra-cerebral bodily, and the socio-cultural dimensions of cognitive practices. This leads the question how we can combine these components in such a way that we will end up with an explanation of enculturation that is both conceptually coherent and empirically plausible without running risk of committing mereological fallacies. The suggestion of the present paper is to analyse enculturation at three levels of explanation and corresponding time scales.

Levels and Time Scales of Explanation

Levels of explanation are defined by the conceptual and/or empirical tools, by the research questions, and by the individuation and operationalization that are employed to account for (a component of) a certain target phenomenon (Dennett, 1969; Drayson, 2012, 2014; Metzinger, 2013). In this sense, levels specify the scope and the epistemic tools of explanation. Following Drayson (2012), it is reasonable to include Kim's distinction of the vertical and the horizontal into our meta-theoretical consideration of explanation: "The term 'vertical' is meant to reflect the usual practice of picturing micro-macro levels of a vertical array, with the micro underpinning the macro. In contrast, we usually represent diachronic causal relations on a horizontal line, from past (left) to future (right) […]" (Kim, 2005, p. 36). This distinction adds a temporal dimension to the individuation of levels of explanation. Accordingly, levels of explanation correspond to specific temporal scales. For the present considerations, we can distinguish three levels of explanation and corresponding time scales.

First, on a sub-personal level of explanation, we can provide an account of the cerebral and extra-cerebral bodily functions that underlie the acquisition of cognitive practices. On this level of explanation, we focus on the corresponding physiological time scale. This temporal scale is defined by time intervals that have a duration of hundreds of milliseconds to several seconds. The time intervals are determined by the full range of electrophysiological, neuroimaging, and eye-tracking paradigms and the resulting statistical analyses. This explanatory component is concerned with the consideration of LDP and LDBA.

Second, on a personal level of explanation, we can investigate the diachronic unfolding of specific changes of the human organism as a whole that characterize the ontogenetic process of enculturation. This level of explanation corresponds to an organismic timescale. First, we can develop an account of the temporal unfolding of the novice's ongoing interaction with experts in a particular domain. This helps specify the various stages of the acquisition of cognitive practices and the ways in which it relies on the scaffolding by other cognitive agents. Second, from this perspective we can provide an account of the properties of epistemic resources in the cognitive niche as they are relevant for the acquisition and on-going realization of cognitive practices. Finally, we can identify the set of cognitive norms that are acquired and applied in the course of the acquisition of a certain cognitive practice.

Third, the supra-personal level of explanation is also relevant for a full-fledged account of enculturation. The reason is that contemporary cases of enculturation are rendered possible by evolved biological principles and the inter-generational transmission of practices, skills, and epistemic resources. On this view, enculturation is constituted by the interdependence of evolved cerebral and extra-cerebral bodily biases and of the on-going large-scale process of cognitive niche construction. Therefore, it seems reasonable to introduce an additional type of diachronic explanation, namely a supra-personal level of explanation that focuses on an evolutionary time scale comprising hundreds to thousands of years.

Reading Acquisition: A Paradigm Case of Enculturation

To illustrate the considerations, conceptual distinctions, and the meta-theoretical assessment of the account of enculturation, I will now consider reading acquisition as a paradigm case of enculturation. At first sight, reading poses a challenge to researchers, because it requires an explanation of how we are able to acquire reading, given that there was not sufficient evolutionary time for dedicated brain areas to develop. Dehaene (2010) refers to this as the "reading paradox."

On a sub-personal level of explanation and at a physiological time scale, this paradox can be solved by considering LDP and its guiding principle, i.e., neural reuse. There is now much empirical evidence suggesting that the brain undergoes significant plastic changes in the course of reading acquisition at times t_1, t_2, and t_3. First, many studies and theoretical evaluations emphasize the crucial importance of the left ventral occipito-temporal (vOT) area (Dehaene, 2005, 2010; McCandliss, Cohen, & Dehaene, 2003; Price & Devlin, 2003, 2004; Vogel, Petersen, & Schlaggar, 2014).[1] Recent studies indicate that its activation level peaks in beginning readers and that its decrease, by way of comparison with the level of neuronal activation at t_1, is associated with reading proficiency (Ben-Shachar, Dougherty, Deutsch, & Wandell, 2011; Brem et al., 2010; Maurer et al., 2006). Second, there is a significant increase of functional connectivity between the left vOT area and left-hemispheric frontal and temporal areas that are reliably associated with language processing and production (Dehaene et al., 2010; Gaillard, Balsamo, Ibrahim, Sachs, & Xu, 2003; Turkeltaub, Gareau, Flowers, Zeffiro, & Eden, 2003). It is in virtue of LDP that new structural and functional connections can be realized as a solution to new and challenging processing needs.

LDP is complemented by LDBA. In the case of reading acquisition, LDBA is mainly realized by the developmental trajectory of eye movements. In general, eye movement patterns in reading are constituted by the alternation between fixations and saccades (Rayner, 2009; Rayner et al., 2001, 2007). Eye movements are necessary because of the acuity limitations of the visual field. The functional biases of the ocular-motor system, e.g., the saccadic latency and the saccadic span, constrain the developmental trajectory of reading. Research paradigms employing eye-tracking methodologies are specifically interested in evaluating the span or amplitude of saccades, the duration of fixations, and the landing positions or locations of fixations with regard to certain target words embedded in syntactically and semantically structured linguistic items. Comparisons of novice and proficient readers reveal that proficient readers display a decrease of fixation durations, refixations (i.e., several fixations targeted at the same word), as well as an increase of saccadic amplitudes (Huestegge et al., 2009; Joseph & Liversedge, 2013; Seasseau et al., 2013). These findings suggest that ocular-motor patterns adapt to the demands and requirements of processing structured linguistic material.

On a personal level of explanation and at an organismic time scale, reading acquisition is characterized by scaffolded learning and structured novice-teacher interactions. In the case of alphabetic writing systems, reading instruction puts a particular emphasis on phonics instruction (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). Phonics instruction conveys the *alphabetic principle*, according to which graphemic units of an alphabetic writing system correspond to phonemic units of the target language (Castles & Coltheart, 2004; Dehaene, 2010; Snowling, 2000; Ziegler & Goswami, 2006). In the vast majority of cases, the alphabetic principle can only be understood and applied if

[1] Intriguingly, recent data from fMRI experiments indicate that the left vOT area is also significantly associated with writing and its acquisition (Ludersdorfer, Kronbichler, & Wimmer, 2015; Purcell, Jiang, & Eden, 2017; Purcell, Napoliello, & Eden, 2011; Rapp & Lipka, 2011). This provides further support for the idea of neural reuse, because it establishes that one particular brain area has a certain bias that makes it suitable to contribute to functionally distinct, yet partly overlapping neural circuits.

novices receive extensive instruction and scaffolded tutorials provided by teachers and other caregivers. These tutorials provide detailed information about the cognitive norms underlying reading, e.g., by progressively increasing the complexity of phoneme-grapheme correspondences in the training materials. In addition, there are other types of meta-linguistic awareness that need to be made explicitly available to novice readers. Beginning readers are already proficient speakers of their native language and are able to apply fluently syntactic, semantic, and pragmatic norms in their everyday conversations. However, they usually lack the explicit insight that utterances are made up of sentences and that sentences are constituted by the combination of words (Frith, 1985; Rayner et al., 2001). To novices, these basic properties have to be made explicitly available in order to put them in the position to apply the knowledge about it automatically and fluently at later stages of reading acquisition. Furthermore, novices need to be acquainted with the norm that alphabetic writing systems are decoded from left to right and from the top to the bottom of a page (Dehaene, 2010). In sum, explicit reading instruction is a good example of scaffolded learning and of the socio-culturally structured transmission of knowledge and skills.

The history of writing systems is a good example of cumulative cultural evolution (Henrich, 2016). This example needs to be approached on a supra-personal level of explanation and at an evolutionary time scale. The first writing system we know of is the cuneiform system. It dates back to approx. 3000 BC and was pictorial in origin. The cuneiform system was cumulatively refined in the service of an accurate representation of abstract ideas and relations that were especially relevant for trade and the organization of social communities. Furthermore, the functional biases of the brain and the rest of the body constrained the properties of symbols, e.g., the arrangement of lines or inter-letter spacing (Dehaene, 2010). Linearity, the grouping of symbols, and grammatical norms were not pre-given properties of early writing systems. Rather, they gradually evolved over hundreds of years. Tracing back the development of alphabetic writing systems, Donald characterizes the evolutionary trajectory as a "[…] progression from a primarily visual medium, inventing completely new representations like lists of numbers, to a medium which, increasingly, tried to map the narrative products of the language system" (Donald, 1991, 289). In sum, then, contemporary writing systems are the direct result of cumulative cultural evolution. They were afforded by the socially structured need of a system that can represent transactions, relations, genealogies, and so forth.

Towards Explanatory Pluralism

The previous considerations suggest that we need at least three levels of explanation and corresponding temporal scales to unveil the complex dynamics that give rise to enculturation. This suggestion is at odds with *explanatory monism*, according to which there will always be one and only one explanation of a certain target phenomenon or a specific set of target phenomena in the long run (Colombo & Wright, 2017; Kellert, Longino, & Waters, 2006). It is informed by unificationism and by reductionism. Unificationism is the idea that there will always be one set of principles that is able to unify previously distinct kinds of explanation targeted at a certain phenomenon. Reductionism about theory formation is the idea that we will gain new knowledge if we discover low-level principles to which previously entertained higher-level explanations can be reduced (Colombo & Wright, 2017). The present analysis of enculturation and the distinction of complementary levels of explanation and corresponding time scales leads to the view that it is at least unlikely, if not impossible, that unificationism and reductionism are meta-theoretical principles that will lead to a complete and exhaustive account of enculturation. This is the reason why the present account of enculturated cognition is an example of *explanatory pluralism* about theory formation in the cognitive sciences. Explanatory pluralism is the view that there will always be more than one and only one explanation of a specific target phenomenon (Van Bouwel, Weber, & de Vreese, 2011; Dale, 2008; de Jong, 2001). This stance towards enculturation promises to arrive at a better understanding of the complexity of the phylogenetic and ontogenetic development of cognitive practices and of the temporal unfolding of enculturated organism-niche interactions. Thus, the positive proposal is that the phylogenetic and ontogenetic components of enculturation on sub-personal, personal, and supra-personal levels of explanation are required for the prospect of a full-fledged and complete account of enculturation. The consideration of reading acquisition as a paradigm case of enculturation can lend support to the idea that we need the pluralistic explanatory stance in order to account for the vast set of empirical results and empirically informed considerations applying to enculturation.

Concluding Remarks

Enculturation is a temporally extended process that transforms our overall cognitive capacities. In this paper, I have argued that enculturation is a complex phenomenon that needs to be approached on at least three levels of explanation and corresponding time scales. The reason is that enculturation spreads across the brain, the rest of the body, and the cognitive niche. Explanatory pluralism allows us to do justice to these dynamics, because it provides us with an explanatory strategy that is able to track the ontogenetic and phylogenetic component processes of enculturation. The application of this strategy to the cases of reading acquisition shows that the present account of enculturation has the conceptual resources to connect initially disparate lines of empirical research. The suggestion is that the present account of enculturation promises to provide us with a better understanding of the ways in which our cognitive processes are shaped and re-shaped by the delicate interaction of the brain, the rest of the body, and the cognitive niche.

References

Anderson, M. L. (2010). Neural reuse: A fundamental organizational principle of the brain. *Behavioral and Brain Sciences*, *33*(4), 245–266.

Anderson, M. L. (2015). *After phrenology: Neural reuse and the interactive brain*. Cambridge, Mass: MIT Press.

Ansari, D. (2012). Culture and education: New frontiers in brain plasticity. *Trends in Cognitive Sciences*, *16*(2), 93–95.

Ben-Shachar, M., Dougherty, R. F., Deutsch, G. K., & Wandell, B. A. (2011). The development of cortical sensitivity to visual word forms. *Journal of Cognitive Neuroscience*, *23*(9), 2387–2399.

Bertolotti, T., & Magnani, L. (2016). Theoretical considerations on cognitive niche construction. *Synthese*, 1–23.

Van Bouwel, J., Weber, E., & de Vreese, L. (2011). Indispensability arguments in favour of reductive explanations. *Journal for General Philosophy of Science*, *42*(1), 33–46.

Boyd, R., Richerson, P. J., & Henrich, J. (2011). The cultural niche: Why social learning is essential for human adaptation. *Proceedings of the National Academy of Sciences*, *108*(Supplement 2), 10918–10925.

Brem, S., Bach, S., Kucian, K., Guttorm, T. K., Martin, E., Lyytinen, H., Brandeis, D., et al. (2010). Brain sensitivity to print emerges when children learn letter-speech sound correspondences. *Proceedings of the National Academy of Sciences*, *107*(17), 7939–7944.

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition*, *91*(1), 77–111.

Clark, A. (1997). *Being there: Putting brain, body, and world together again*. Cambridge, Mass.: MIT Press.

Clark, A. (2006). Language, embodiment, and the cognitive niche. *Trends in Cognitive Sciences*, *10*(8), 370–374.

Clark, A. (2008). *Supersizing the mind: Embodiment, action, and cognitive extension*. New York: Oxford University Press.

Colombo, M., & Wright, C. (2017). Explanatory pluralism: An unrewarding prediction error for free energy theorists. *Brain and Cognition*, *112*, 3–12.

Dale, R. (2008). The possibility of a pluralist cognitive science. *Journal of Experimental & Theoretical Artificial Intelligence*, *20*(3), 155–179.

Dehaene, S. (2005). Evolution of human cortical circuits for reading and arithmetic: The "neuronal recycling" hypothesis. In S. Dehaene, J.-R. Duhamel, M. D. Hauser, & G. Rizzolatti (Eds.), *From monkey brain to human brain: A Fyssen Foundation Symposium* (pp. 133–157). Cambridge, Mass: MIT Press.

Dehaene, S. (2010). *Reading in the brain: The new science of how we read*. New York: Penguin Books.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Filho, G. N., Jobert, A., Dehaene-Lambertz, G., et al. (2010). How learning to read changes the cortical networks for vision and language. *Science*, *330*(6009), 1359–1364.

Dennett, D. C. (1969). *Content and consciousness*. London, New York: Routledge & K. Paul.

Donald, M. (1991). *Origins of the modern mind : Three stages in the evolution of culture and cognition*. Cambridge, Mass: Harvard University Press.

Dounskaia, N., van Gemmert, A. W. A., & Stelmach, G. E. (2000). Interjoint coordination during handwriting-like movements. *Experimental Brain Research*, *135*(1), 127–140.

Drayson, Z. (2012). The uses and abuses of the personal/subpersonal distinction. *Philosophical Perspectives*, *26*(1), 1–18.

Drayson, Z. (2014). The personal/subpersonal distinction. *Philosophy Compass*, *9*(5), 338–346.

Estany, A., & Martínez, S. (2014). "Scaffolding" and "affordance" as integrative concepts in the cognitive sciences. *Philosophical Psychology*, *27*, 98–111.

Fabry, R. E. (2017). Betwixt and between: The enculturated predictive processing approach to cognition. *Synthese*, 1–36.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia.Neuropsychological and cognitive studies of phonological reading* (pp. 301–330). Hillsdale, N.J.: Erlbaum.

Furuya, S., & Altenmüller, E. (2015). Acquisition and reacquisition of motor coordination in musicians. *Annals of the New York Academy of Sciences*, *1337*(1), 118–124.

Gaillard, W. D., Balsamo, L. M., Ibrahim, Z., Sachs, B. C., & Xu, B. (2003). fMRI identifies regional specialization of neural networks for reading in young children. *Neurology*, *60*(1), 94–100.

Henrich, J. P. (2016). *The secret of our success: How culture is driving human evolution, domesticating our species, and making us smarter*. Princeton: Princeton University Press.

Heyes, C. (2012). Grist and mills: On the cultural origins of cultural learning. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1599), 2181–2191.

de Jong, H. L. (2001). Introduction: a symposium on explanatory pluralism. *Theory & Psychology*, *11*(6), 731–735.

Kellert, S. H.; Longino, H. E.; Waters, C. K. (2006). Introduction: the pluralist stance. In C. K. Kellert, S., Longino, H., & Waters (Ed.), *Minnesota studies in philosophy of science, vol. 19: scientific puralism* (pp. vii–xxix). Minneapolis: University of Minnesota Press.

Kendal, J. R. (2011). Cultural niche construction and human learning environments: Investigating sociocultural perspectives. *Biological Theory*, *6*(3), 241–250.

Kim, J. (2005). *Physicalism, or something near enough*. New Jersey: Princeton University Press.

Kline, M. A. (2015). How to learn about teaching: An evolutionary framework for the study of teaching behavior in humans and other animals. *Behavioral and Brain Sciences*, *38*, 1–70.

Ludersdorfer, P., Kronbichler, M., & Wimmer, H. (2015). Accessing orthographic representations from speech: The role of left ventral occipitotemporal cortex in spelling. *Human brain mapping*, *36*(4), 1393–1406.

Maurer, U., Brem, S., Kranz, F., Bucher, K., Benz, R., Halder, P., Steinhausen, H.-C., et al. (2006). Coarse neural tuning for print peaks when children learn to read. *NeuroImage*, *33*(2), 749–758.

McCandliss, B. D., Cohen, L., & Dehaene, S. (2003). The visual word form area: Expertise for reading in the fusiform gyrus. *Trends in Cognitive Sciences*, *7*(7), 293–299.

Menary, R. (2007). *Cognitive integration: Mind and cognition unbounded*. Basingstoke, New York: Palgrave Macmillan.

Menary, R. (2010). Dimensions of mind. *Phenomenology and the Cognitive Sciences*, *9*(4), 561–578.

Menary, R. (2013). The enculturated hand. In Z. Radman (Ed.), *The hand, an organ of the mind: What the manual tells the mental* (pp. 349–367). Cambridge, Mass: MIT Press.

Menary, R. (2015). Mathematical cognition: A case of enculturation. In T. Metzinger & J. M. Windt (Eds.), *Open MIND* (pp. 1–20). Frankfurt am Main: MIND Group.

Menary, R. (2016). Pragmatism and the pragmatic turn in cognitive science. In D. Engel, Andreas K., Friston, K., & Kragic (Ed.), *Where is the action? The pragmatic turn in cognitive science* (pp. 219–237). Cambridge, Mass: MIT Press.

Metzinger, T. (2013). The myth of cognitive agency: Subpersonal thinking as a cyclically recurring loss of mental autonomy. *Frontiers in Psychology*, *4*.

Phillips, J. G., Ogeil, R. P., & Best, C. (2009). Motor constancy and the upsizing of handwriting. *Human Movement Science*, *28*(5), 578–587.

Price, C. J., & Devlin, J. T. (2003). The myth of the visual word form area. *NeuroImage*, *19*(3), 473–481.

Price, C. J., & Devlin, J. T. (2004). The pro and cons of labelling a left occipitotemporal region “the visual word form area.” *NeuroImage*, *22*(1), 477–479.

Purcell, J. J., Jiang, X., & Eden, G. F. (2017). Shared orthographic neuronal representations for spelling and reading. *NeuroImage*, *147*, 554–567.

Purcell, J. J., Napoliello, E. M., & Eden, G. F. (2011). A combined fMRI study of typed spelling and reading. *Neuroimage*, *55*(2), 750–762.

Rapp, B., & Lipka, K. (2011). The literate brain: The relationship between spelling and reading. *Journal of cognitive neuroscience*, *23*(5), 1180–1197.

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest*, *2*(2), 31–74.

Rowlands, M. (1999). *The body in mind: Understanding cognitive processes*. Cambridge: Cambridge University Press.

Snowling, M. J. (2000). *Dyslexia* (2nd ed.). Malden, MA: Blackwell Publishers.

Sterelny, K. (2003). *Thought in a hostile world: The evolution of human cognition*. Malden, Mass: Blackwell.

Sterelny, K. (2012). *The evolved apprentice: How evolution made humans unique* (Vol. 2012). Cambridge, Mass: The MIT Press.

Stotz, K. (2010). Human nature and cognitive–developmental niche construction. *Phenomenology and the Cognitive Sciences*, *9*(4), 483–501.

Turkeltaub, P. E., Gareau, L., Flowers, D. L., Zeffiro, T. A., & Eden, G. F. (2003). Development of neural mechanisms for reading. *Nature Neuroscience*, *6*(7), 767–773.

Vogel, A. C., Petersen, S. E., & Schlaggar, B. L. (2014). The VWFA: It’s not just for words anymore. *Frontiers in Human Neuroscience*, 1–10.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, Mass: Harvard University Press.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, *17*(2), 89–100.

Ziegler, J. C., & Goswami, U. (2006). Becoming literate in different languages: Similar problems, different solutions. *Developmental Science*, *9*(5), 429–436.