

How the Environment Affects the Adolescent Brain

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Submitted: 29. October 2022
Published: 21. November 2022
Volume: 9
Issue: 6
Affiliation: PernilleBülow (Private Enterprise), Boston, United States of America
Languages: English
Keywords: Adolescence, Mental Health, Brain and Behaviour, Trauma, Pathology, Psychological Triggers, Epigenetics, Nature, Nurture
Categories: News and Views, Life Sciences, Medicine
DOI: 10.17160/josha.9.6.856

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Abstract

This article is the second of a two-part series on adolescent brain development and function. While the first article discussed the neuroscience of how the adolescent brain changes as it matures, this article will focus on how the environment can interfere with the adolescent brain and make them more likely to develop mental health disorders. Two major environmental influences are discussed in depth: substance abuse (cigarette smoking, marijuana use and alcohol) and chronic stress (bullying and caregiver maltreatment, e.g. sexual/physical abuse, emotional/psychological abuse, neglect). The results of the studies are discussed in the context of individual differences and long-term consequences on mental and physical health. The main takeaway is that the adolescent brain is particularly susceptible to environmental influences with long-term effects for mental health, and it emphasizes the importance of providing proper emotional support for this age group. This article was first published in Subkit on April 05, 2022 (<https://www.subkit.com/ernillebuelow/posts/part-2-how-the-environment-affects-the-adolescent-brain>).



In the last blog, we focused on the various ways in which the adolescent brain changes. Around the onset of puberty, the brain starts a growth spurt that changes the anatomy and function of certain brain areas, ultimately affecting adolescent behavior. The main take away is that adolescents can have a difficult time with emotional regulation and are swayed easily by peers (but not so much by their caregivers, e.g. parents...). However, we also emphasized how these ongoing changes in brain function and anatomy endow their brain with an exquisite amount of potential for learning and thinking. This heightened potential, also referred to as a critical or sensitive period, can indeed be a period of opportunity, but it also renders them more vulnerable to environmental “insults” and traumatic experiences. In fact, researchers are finding that experiences during adolescence can have long-lasting effects on their mental health in adulthood.

In this blog, we will explore research investigating how experiences affect the adolescent brain and the long-term mental health consequences. We will focus on two types of experiences: substance abuse and chronic stress.

In the next blog of this series, we will turn our focus on what we can all do to help create the groundwork for mental well-being throughout life for our adolescent friends.

Are you on the run and not able to read the full article? (Or just a bit daunted by the length of the blog...I may have gone a bit overboard with all of the writing!). **Then check out the figures throughout the blog** – they each sum up the most important take-aways and is a great **foundation to start a safe conversation with children, colleagues, and family members.**

Here’s a note of observation before we start: In general, we **tend to be better at placing blame than helping adolescents.** Why? Perhaps because adolescents inhabit a body that looks more like an adult, making it challenging for us “seasoned adults” to remember that their brains (and bodies!) are still maturing. **While they may have physical characteristics of adulthood, adolescents still reside in a sphere that is their own.** Right in between childhood and adulthood. Adolescence is a period of exploration and learning, as well as adapting to their new body and associated responsibilities. This blog focuses on **how we can better understand what it is like to move through adolescence, what happens in their brains and bodies, and how we can support them during this process.**



The effects of substance abuse on the adolescent brain

It is a popular, and somewhat controversial, topic whether and how substance usage during adolescence is harmful. Before I start this section, it is important to emphasize that substance usage has unhealthy effects at all ages. Being above 18 or 21 does not suddenly render you immune to the deleterious effects of smoking or alcohol. The question we are entertaining here is whether substance usage and abuse are even more harmful during adolescence. The short answer is that substance use during adolescence likely makes a person more likely to develop long-term addictions, which can have grave consequences for their physical and mental health. For example, adolescents that use nicotine (by smoking cigarettes) are more likely to be dependent on nicotine throughout adulthood as well ([Arain et al., 2013](#)). That is obviously terrible for your lungs and increases your chances of developing cancer. Studies have found the increased dependence on nicotine is not just a function of time (i.e. the more you do something the more habitual it becomes), but is a function of biology. As we learned in the last blog, the adolescent brain is going through a growth spurt that leaves some brain regions more mature than others.

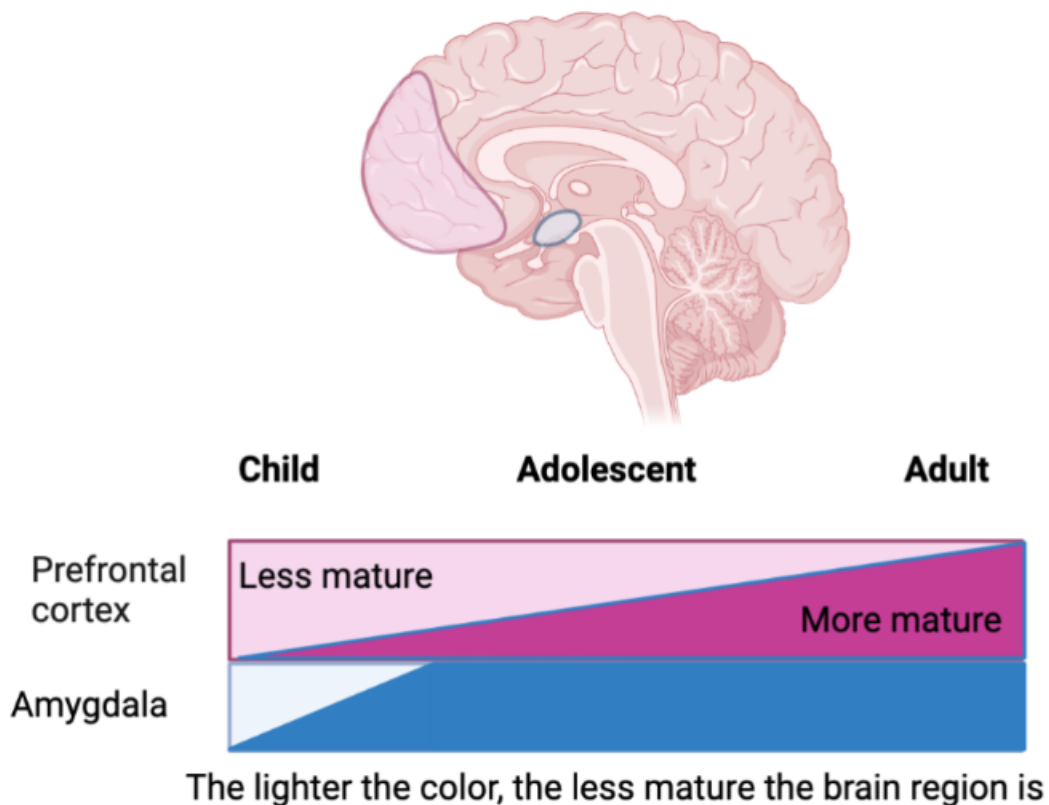




Figure 1: The brain is made up of many different brain regions and these have different "maturation periods". The prefrontal cortex takes many years to mature - in fact, data is showing that the prefrontal cortex is not fully mature until age 25! In contrast, the amygdala, and other brain areas involved in emotion processing, mature much faster. This means that during adolescence the brain areas associated with emotion processing tend to be more active and "ready" to respond, while the prefrontal cortex and other brain regions involved with "rational" decision-making are a bit slower and not as powerful.

The brain regions involved with detecting and processing rewards are well developed, but within these regions there is still an imbalance of the neurotransmitters that are active. In adulthood, reward areas in the brain release dopamine when they experience something rewarding (e.g. smoking a cigarette) while it releases the neurotransmitter GABA during withdrawal from cigarettes. GABA release leads to a reduction in the activity of the reward areas and it leaves one feeling unsatisfied, depressed, and frustrated – in short, it leads to the emotional feelings of withdrawal. In adolescence, the GABA neurotransmitter system is not fully up to speed yet in these reward regions in the brain, which means that an adolescent does not experience the same negative intensity of emotional withdrawal symptoms. It is hypothesized that experiencing withdrawal can help reinforce an aversion to cigarettes (or other drugs) because your brain associates the drug with the negative feelings. The absence of these negative feelings in adolescence leaves them in a blissful relationship with the drug, only remembering the positive feelings the dopamine surges provided them.

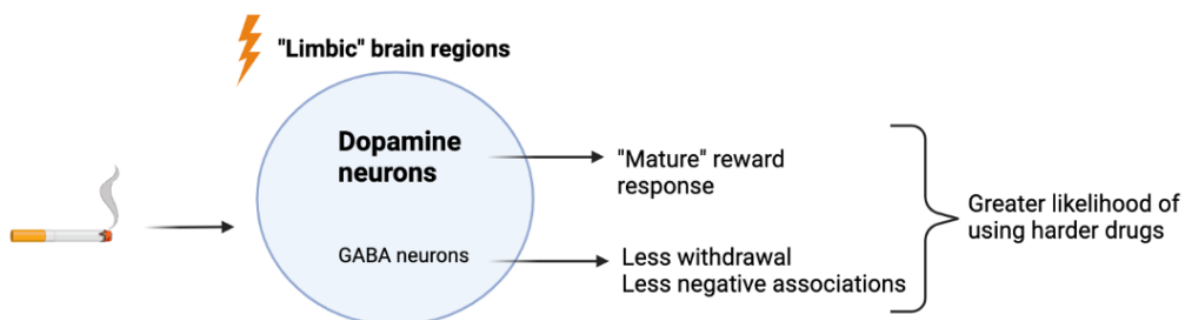


Figure 2: While limbic brain regions, such as the amygdala, mature faster, the composition of neurons in these regions still continue to develop throughout adolescence. The number and type of neurons within the limbic brain regions can actually be modified by genes and experiences as well! Dopamine neurons activate reward responses - that's what makes you



feel the rush of delight when you eat/feel/drink/see something you really like (like chocolate!). There are plenty of Dopamine neurons in the adolescent limbic brain regions, making adolescents experts on feeling these rushes of delight. GABA neurons activate the brain regions that make you feel uncomfortable if you don't get what you want when you are used to it. In my case, if I don't have my after-dinner chocolate, I will get a bit (ok, maybe a lot) grumpy. This feeling is more intense with addictive drugs, and can make you really sick physically. This is referred to as "withdrawal", and while it can motivate you to keep taking the drug (or eating chocolate), it also makes your brain connect the drug to a negative reaction (i.e. your withdrawal), which can actually help you to stop taking the drug. The GABA neurons are less numerous in adolescent limbic brain regions, which results in less withdrawal and less negative memories of how the drug affects you. This can make it easier for adolescents to continue using drugs on/off and, importantly, when they may be offered "hard" drugs, they do not recall any negative effects of abstaining from previous drugs, such as cigarettes. It's a bit like the brain thinking "well, cigarettes were great, and all of those bad things other people say can happen from cigarettes never happened to me, so cocaine is probably not that terrible either". Pair that with adolescents being more easily swayed by their peers ([see Part 1 of this blog series](#)), and you quickly have a recipe for regular drug usage.

Alcohol and cannabis usage in adolescence also appears to have long-term consequences for mental and physical health in adulthood ([Arain et al., 2013](#)). When adolescent rats receive high levels of ethanol (like a night of binge-drinking), it has long-term effects on their brain that resemble the aging brain. Binge-drinking in adolescence might actually speed up your brain's aging process. In adolescent mice and rats, cannabis exposure has long-term negative effects on learning and memory and the rodents express more depressive-like behaviors. Similar to nicotine, cannabis usage in adolescence is associated with a greater risk of substance usage and addiction in adulthood, and these people are also at greater risk of developing cognitive abnormalities, mood disorders, and other challenges. When reading this literature, it is important to consider how much the adolescent has been exposed, whether different drugs were used, and the overall lifestyle of the person. We still do not fully understand what drives the risk of developing long-term addictions or severe psychotic illnesses, but we do know that substance abuse during adolescents is associated with these debilitating outcomes.

An interesting phenomenon is that using one type of drug in adolescence can render you more sensitive to other drugs as well, both in adolescence and in adulthood ([Linker et al., 2020](#); [Sherma et al., 2020](#)). This is likely because all of the drugs activate similar reward regions of the brain, and may activate the same positive memories of the associated effects (even if you have never used the drug before). For example, nicotine usage increases cocaine self-administration in



adolescent mice and cannabis exposure renders adolescent mice more sensitive to the rewarding effects of cocaine. These intersectional effects across drugs may provide a biological explanation of why “milder” drugs like nicotine and cannabis, are gateway drugs to “harder” substances like cocaine and heroin.

The effects of chronic stress on the adolescent brain

Chronic stress happens at every life stage and is detrimental to one’s brain and body regardless of age. However, chronic stress has even greater implications when it happens during “critical periods” such as adolescence. What defines something as chronic stress is ultimately determined by each individual (i.e. some experiences can be extremely stressful to one person while not to another), but there are certain experiences that we know are highly likely to cause chronic stress to all people. Two of these are bullying and parental maltreatment. We will focus on these two in the next section as we discuss how stress during adolescence increases the likelihood of long-term mental health problems.

Many research studies have identified that people that were bullied in their teens are more likely to experience mental and physical health problems in adulthood. A recent study reported that the brains of 14 years olds that have experienced long-term bullying are structurally different from non-bullied 14 year olds (Quinlan et al., 2014). These structural changes correlated with a higher risk of generalized anxiety at age 19, even when the researchers adjusted for other types of stressful life experiences (for example parental abuse). One of the brain regions affected by bullying is the putamen. The putamen is a part of a network of brain regions referred to as the striatum, and they are important in emotional and behavioral regulation, and it plays an important role in driving “reward” related behaviors (remember that the reward system is triggered by drugs such as alcohol and nicotine). In people that are bullied, the putamen is larger at age 14 – this may reflect a stalled maturation. Remember how adolescent brains undergo synaptic pruning? This synaptic pruning actually leads to a reduction in the size of most brain regions, but at the same time, the neuronal connections in these regions also become more efficient. A larger putamen could be the result of a “brake” on the normal maturation and/or it could reflect increased neurogenesis triggered by bullying (to learn more about neurogenesis check the last blog). By age 19, the larger putamen has rapidly reduced in size and is almost similar to a non-bullied’s putamen. One could interpret such a rapid reduction as a “normalization” and recovery of the brain, but scientists worry that the opposite may be the case: such a rapid reduction in size could be the result of cell death (chronic stress is known to



trigger cell death, also known as “apoptosis”) or it could reflect a sudden and fast maturation of the putamen but with a “wiring” that makes it more alert and anxious – a fast maturation during chronic stress could push the putamen into a state of constant alert. This may explain why chronic stress during adolescence leads to higher likelihood of adult psychopathology that is more difficult to treat. It is likely (but not scientifically proven yet) that the longer you have been bullied the more severe the effects are on brain development and the risk of mental health challenges.

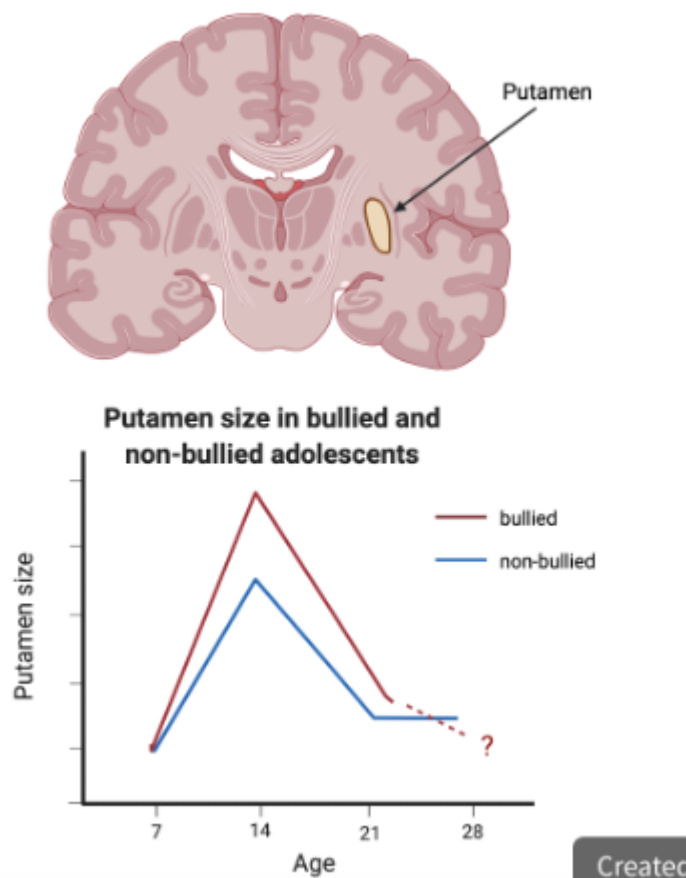


Figure 3: Bullying is associated with changes in the size of several brain regions, including one region called the putamen. If you are bullied, the putamen has a larger size compared to non-bullied peers at age 14. Over time, the putamen reduces back to a size that is similar to non-bullied peers but we don't know how the "wiring" (i.e. how the neurons inside the putamen talk to each other) is affected by the bullying. The putamen in people that were bullied may connect more with other brain regions that make them more anxious in social situations and perhaps making them more prone to mental health challenges like depression.



Another form of chronic stress takes place at home. Parental (or caregiver) maltreatment comes in many shapes: it can be physical (hitting), sexual (molesting), verbal (being called curse words), emotional (being pushed away, gaslighted, unpredictable care), and neglect (simply not being taken care of). Each of these types of maltreatment changes the brain in multiple ways and given the important role of a parent/caregiver these effects are serious and often long-lasting. Studies of maltreated children have identified abnormalities in several brain regions, in particular the ones associated with emotional processing. However, even if the maltreatment does not start until adolescence, it can leave long-lasting imprints on their brain and body. In fact, results from some studies suggest that maltreatment in adolescence (compared to childhood) has stronger and more persistent consequences for mental health in adulthood ([Thornberry et al., 2002](#)). **Clearly, parental maltreatment is terrible at any age, but our society tends to focus more on helping children rather than adolescents that are experiencing parental maltreatment – based on the studies mentioned here, it's worth reconsidering this approach.**

Studies using rats and mice have found that chronic adolescent stress leads to long-term changes in brain function, immune system, and behavior. One of the reasons that adolescents are more sensitive to stress is that one system in our bodies, called the hypothalamic-pituitary-adrenal (HPA) axis, is not fully developed yet. This axis regulates release of the stress hormone cortisol and adrenaline, and adolescent stress has been associated with both reduced and increased levels of circulating cortisol and adrenaline, which generally makes people feel like they are in a state of constant alert and often times that they are extra sensitive situations other people may not find stressful. We will continue to return to the HPA axis in future blog posts as we talk more about mental health challenges.

Another interesting effect of chronic stress in adolescence is that it “primes” your immune system, so that you become more likely to activate inflammatory responses when you are exposed to, for example, a virus. It can also lead to a constant low-grade inflammation in your body which eventually can manifest as a chronic inflammatory disease. In fact, early life adversity accounts for 10% of all adults with low-grade inflammation ([Bekhbat et al., 2019](#)).

Of course, not everyone who has experienced chronic stress during adolescence develops abnormal cortisol or inflammatory responses. What determines whether and how adolescents are affected by chronic stress? Longer duration and greater severity of the chronic stress typically correlate with the intensity of one's



symptoms. Other factors include your support system outside of where the chronic stress resides. For example, do you have a supportive peer-group, a teacher you trust or maybe a hobby that connects you with other people? The more support you have, the better you will get through long, stressful periods. Lastly, your unique genetics can render you more or less susceptible to stress. For example, one study found that adolescent girls who experienced interpersonal stress (that is, they encountered a stressful situation between another person and themselves, e.g. an argument), were more likely to develop depression but only if they also experienced an increased inflammatory response (i.e. their body reacted to the interpersonal stress as if it were a virus) ([Blavich et al., 2020](#)). The girls that had an inflammatory response all had a unique genetic make-up, underscoring the importance of gene X environment interactions when it comes to stress, immune system, and mental health.

One study found that adolescents that were raised by caregivers that displayed “parental warmth” were less likely to experience anxiety and depression ([Butterfield et al., 2020](#)), suggesting that caregivers can directly protect their children from developing mental health disorders. We will touch more on this topic in the next and final blog post discussing what and how we can prevent mental health challenges in our adolescents.

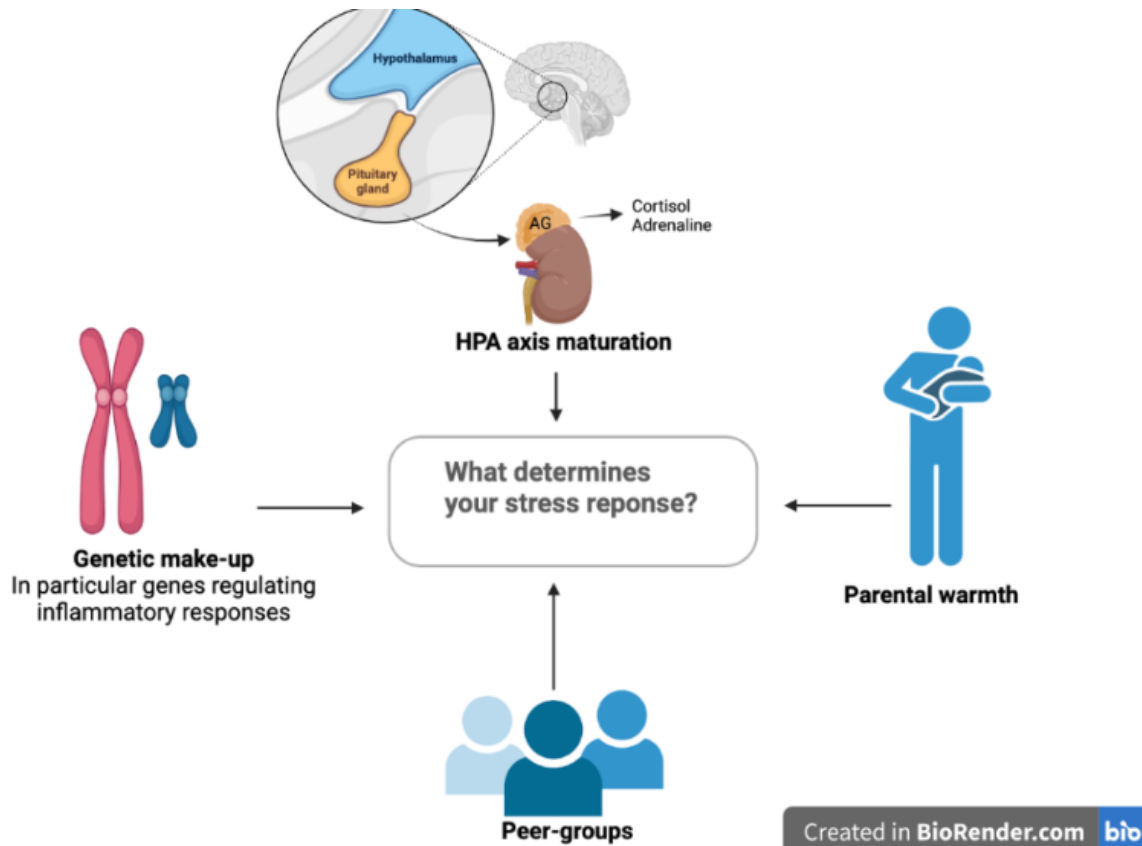


Figure 4: As we will talk more about in the next blog of this three-part series, many factors affect your stress responses. Research is showing that our stress responses throughout life are highly affected by the experiences that we have during adolescence. Bullying, parental maltreatment and drug abuse can affect the body and brain of adolescents in ways that make them more likely to develop depression, anxiety and other mental health challenges later in life. These effects on your body can even make

Disclaimer: eventually, the truth lies in the body and mind of the actor – not the beholder

I cannot proceed without making a quick note of caution. Many – as in very many – people have strong opinions on what is best for the adolescent brain. Is it ok for them to engage in romantic and/or sexual interactions? Is it ok for them to try out alcohol, cannabis, or cigarettes occasionally? Is it okay for them to read books on topics such as genocide, racism, and sexual development? Is homeschooling the better choice? The scientific studies we have discussed above point out the various ways in which the adolescent brain is impacted by environmental factors, such as consistent drug usage, bullying and maltreatment in the home. These are severe stressors that are studied by researchers because they are more likely to



trigger severe and consistent effects on the mind and body. What is most important, which we will cover in the next blog, is that parental warmth and peer groups can prevent the onset of mental health disorders. The content of this blog therefore only applies to these more intense experiences, and do not generalize to other experiences. Are you particularly interested in learning the effects of one type of experience/situation on adolescent (or childhood) development? Send me message and I will get right to it!



About the Author



Pernille Bülow is a science writer, research consultant, and mentor. Originally from Denmark, she moved to the U.S. to finish her B.S. in psychology at UC Berkeley, followed by a PhD at Emory University and a subsequent Post-doctoral fellowship at Harvard Medical School/Massachusetts General Hospital (MGH). Pernille is an expert on brain development and mental health research, topics on which she consults and writes. She currently lives in Boston with her two cats and guinea pig. Pernille has a monthly newsletter on neuroscience research and mental health (<https://www.subkit.com/pernillebuelow>), and offers scientific writing, mentoring and research consultation. Contact Pernille via her website: www.pernillebuelow.com.