Engagement for learning

Children must engage with the learning opportunities offered by education if they are to learn. So how does our brain become oriented towards a potential learning experience—and how can this scientific understanding of engagement provide insight into effective classroom teaching?

Author/s:

Paul Howard-Jones
Professor, Graduate School of Education, University of Bristol, United Kingdom

Theme/s:

Learning how to learn / Early childhood development / Effective lifelong learning

This report arises from Science of Learning Fellowships funded by the International Brain Research Organization (IBRO) in partnership with the International Bureau of Education (IBE) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The IBRO/IBE-UNESCO Science of Learning Fellowship aims to support and translate key neuroscience research on learning and the brain to educators, policy makers, and governments.

Executive summary

- **Every learner's brain is different.** Students will vary in what most engages their attention and the extent to which they can control their attention. This makes it important for teachers to **monitor engagement and vary their approach**.
- Teachers employ a variety of tactics that are known to **stimulate an "approach" response in the brain**. These include rewards such as **praise and tokens acknowledging achievement, novelty, and shared attention**. These can release neuromodulators capable of improving attention and memory.
- In contrast, **fearfulness can avert attention**, and anxiety can diminish a student's learning by reducing the brain's ability to process information.
- Engagement and student resilience can benefit from greater awareness that **there is no well-defined biological limit to what a student's brain can achieve**. The brain is plastic, and both teacher and student have an important role in constructing its function, connectivity, and even its structure.

Learning begins with the engagement of the student's attention

Effective teaching and learning can be considered to involve:

- *engagement* of the learner's attention
- teacher-guided *building* of knowledge and understanding
- *consolidation* of learning through application, practice, and reflection

Engagement of a student's attention is a necessary first step for all learning and continues to be important throughout the process.

Avoiding anxiety

Effective teachers tend to use management techniques that positively maintain cooperation and engagement in interesting activities rather than over-emphasise their role as disciplinarians. Unduly harsh or inconsistent approaches to maintaining order can create anxiety, which can diminish our capacity to learn. Learning requires us to keep a number of different pieces of information in our conscious attention at the same time, and our ability to do this (our so-called *working memory*) is limited. One brain region that is very important for working memory is the dorso-lateral-prefrontal-cortex (or DLPFC). When students become anxious, studies have shown they become less able to sustain activity in this region of the brain, suggesting less control over their working memory and a struggle to maintain their attentional focus[2].

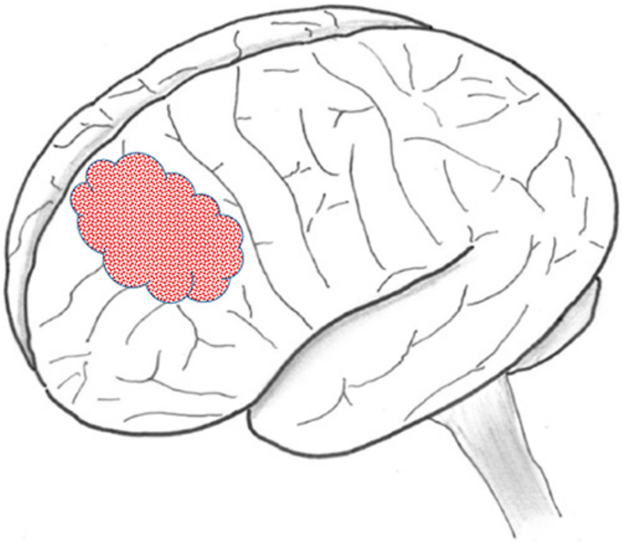

Figure 1. The phrase "dorso-lateral-prefrontal-cortex" (or DLPFC) refers generally to a region at the top of the frontal part of the cortex and extending over both hemispheres. It is an important region for working memory.

Providing positive rewarding environments and interesting contexts

Positive techniques for engaging and managing the class include rewards, as well as novel and engaging tasks and contexts. Most classroom rewards are social (e.g., praise, gold stars, points) and contribute to self-esteem and social standing. These types of social rewards influence the brain's reward system in a similar way to out-of-school rewards and experiences such as receiving money[3,4], food [5], money[6], playing video games[7], and answering educational questions set in a game-like context (see Figure 2). Similar regions of the reward system are activated in anticipation of both social and material rewards[3]. What is meant by the term "reward," therefore, can be very broad.

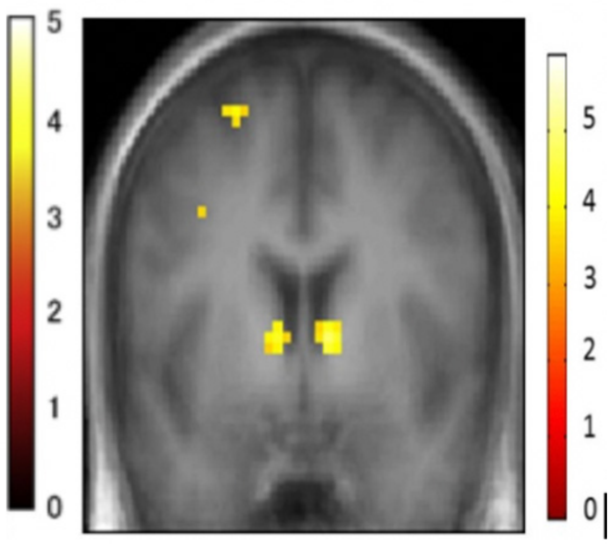

Figure 2. Activation in regions below the cortex is important for our motivation to approach, and subcortical reward centres have been found to activate when we are confronted by a diverse range of experiences such as food and video games. These reward centres have recently been shown to activate when answering educational questions in return for points. (Howard-Jones et al., 2016).

Students can learn by having their attention drawn to what they did correctly (positive feedback) and/or what they did incorrectly (negative feedback), but younger children's brains appear to place greater emphasis on the positive, compared with the negative feedback they receive. In a brain imaging study (see Figure 2), scientists found negative feedback resulted in greater deterioration in the performance of children (8-9 years) than in the performance of adults[8]. Unlike the adults, important regions for reasoning and learning in the brains of the children were more activated by positive feedback than negative, and the improving effect of positive feedback on children's performance was much greater too. Clearly, younger children tend to focus more on the positives in order to learn.

A large number of factors influence how the brain responds to reward and many of these vary from one individual to the next, including age[9], gender[10], impulsivity[11], orientation towards intrinsic compared with extrinsic rewards[12], as well as hormonal and genetic differences[13]. One should expect, therefore, a wide range of individual differences in response to reward within a group.

Neuromodulators that help us learn

This activity in the brain's reward system is not just important for encouraging a student to attend to a learning activity, it is also known to increase the likelihood of remembering the experience. This occurs through an interaction of reward and memory circuits thought to involve neuromodulators such as dopamine[14] (see Figure 3). Estimates of this activity have also been able to predict learning performance in educational learning games[15].

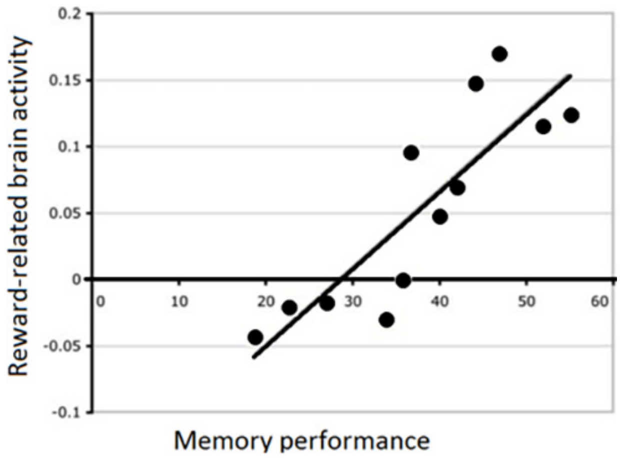

Figure 3. In one study of memory (see FN1), 12 adults were offered monetary incentives to remember information. Activation in the brain's reward system (related to dopamine uptake) predicted the subsequent memory performance of a participant[14].

Novelty

Novelty can also help orient our attention, releasing neuromodulators in the brain that can increase engagement and promote learning[16]. Novel contexts can help engage students initially with a new topic, or help encourage them to apply and practice their freshly learnt knowledge in new scenarios—which is important for consolidating their understanding, memory, and transfer of that knowledge. Topics that engage curiosity have been shown to stimulate activities in the brain's reward regions that are very similar to those activated in Figure 2.[17]

Students sharing knowledge

Our motivation to share attention is a uniquely human characteristic and fundamental to many teacher-student interactions. When self-initiated, it also involves activation of reward-related brain areas[18], attesting to the desirable nature of successfully prompting someone else to share attention with you. This helps explain how asking students to communicate their ideas in different ways can engage their interest in their learning, whether through addressing the class or through helping one another in pairs to master skills. This activation of the reward system for shared attention may underlie how we initially learn to share attention and learn from observing and listening to others (see Figure 4).

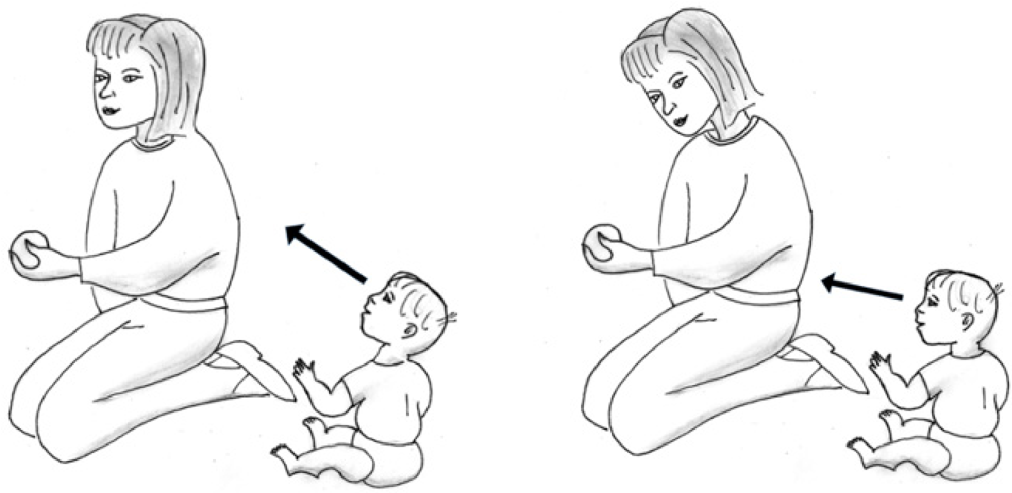

Figure 4. Researchers have shown that infants will occasionally notice a parent looking towards what he/she is holding, and will then tend to look in that direction.[1] It is known that in children, as well as adults, spontaneous joint attention activates those brain regions that process reward and are bound up with our motivation. This may be one of the first and most important lessons that a child learns—since learning to share attention provides a "platform" for learning many other things, including language.

Individual differences

Not only is every student's genetic background different, but our experiences interact with these differences and shape how our brain is connected, how it functions, and even its structure (see author's brief, "The Plastic Brain"). So, although the same general processes explain how our brains work, all brains end up being different from each other, and there are significant individual differences in our individual response to different types of reward and in what makes us curious. Teachers discover what engages their students through learning about their interests, their existing understanding, and observing their responses to different approaches.

Some learners, across their lifespan, generally have more difficulty in focusing their attention on their learning than others. They show a lack of concentration, short attention span, and physical restlessness. These symptoms can prompt a diagnosis of attention deficit hyperactivity disorder (or ADHD). These individuals tend to show less activity in brain regions that anticipate reward[19], helping to explain the difficulties they experience when trying to engage in their studies. This can be very frustrating for the student, as well as disruptive to others' learning. In some cases, medication (e.g., methylphenidate) is used to enhance this response to reward. For the classroom teacher, the research suggests the types of strategy discussed above can become even more important. Students diagnosed with ADHD benefit from a greater focus on the use of praise, prizes, and privileges to encourage appropriate behaviours as well as reprimands, and an organized approach to peer-tutoring[20].

Plasticity and a growth mindset

Students' core beliefs about learning influence their response to challenges. Students benefit from a "growth mindset," based on the belief that ability comes about through effort rather than being fixed. This can increase students' resilience and set in motion positive recursive cycles that increase success over time. Interventions that improve student awareness of the plasticity of the brain, and their role in constructing their own abilities, have been shown to improve their growth mindset and their persistence in their academic studies, reduce dropout rates[21], and improve self-concept and academic outcomes[22].

References

1. Oberwelland, E. *et al.* Look into my eyes: Investigating joint attention using interactive eye-tracking and fMRI in a developmental sample. *Neuroimage* 130, 248-260, doi:10.1016/j.neuroimage.2016.02.026 (2016).

2. Fales, C. L., Becerril, K. E., Luking, K. R. & Barch, D. M. Emotional-stimulus processing in trait anxiety is modulated by stimulus valence during neuroimaging. *Cogn. Emot.* 24, 200-222, doi:10.1080/02699930903384691 (2010).

3. Izuma, K., Saito, D. N. & Sadato, N. Processing of social and monetary rewards in the human striatum. *Neuron* 58, 284-294, doi:10.1016/j.neuron.2008.03.020 (2008).

4. Howard-Jones, P. A., Jay, T., Mason, A. & Jones, H. Gamification of learning deactivates the default mode network. *Frontiers in Psychology* 6, 16, doi:10.3389/fpsyg.2015.01891 (2016).

5. Farooqi, I. S. *et al.* Leptin regulates striatal regions and human eating behavior. *Science* 317, 1355-1355, doi:10.1126/science.1144599 (2007).

6. Knutson, B., Adams, C. M., Fong, G. W. & Hommer, D. Anticipation of monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience* 21, 1-5 (2001).

7. Koepp, M. J. *et al.* Evidence for striatal dopamine release during a video game. *Nature* 393, 266-268 (1998).

8. van Duijvenvoorde, A. C. K., Zanolie, K., Rombouts, S., Raijmakers, M. E. J. & Crone, E. A. Evaluating the negative or valuing the positive? Neural mechanisms supporting feedback-based learning across development. *Journal of Neuroscience* 28, 9495-9503, doi:10.1523/jneurosci.1485-08.2008 (2008).

9. Van Leijenhorst, L. *et al.* Adolescent risky decision-making: Neurocognitive development of reward and control regions. *Neuroimage* 51, 345-355, doi:10.1016/j.neuroimage.2010.02.038 (2010).

10. Hoeft, F., Watson, C. L., Kesler, S. R., Bettinger, K. E. & Reiss, A. L. Gender differences in the mesocorticolimbic system during computer game-play. *Journal of Psychiatric Research* 42, 253-258 (2008).

11. Joseph, J. E., Zhu, X., Lynam, D. & Kelly, T. H. Modulation of meso-limbic reward processing by motivational tendencies in young adolescents and adults. *Neuroimage* 129, 40-54, doi:10.1016/j.neuroimage.2015.12.005 (2016).

12. Linke, J. *et al.* Motivational orientation modulates the neural response to reward. *Neuroimage* 49, 2618-2625, doi:10.1016/j.neuroimage.2009.09.013 (2010).

13. Caldu, X. & Dreher, J. C. Hormonal and genetic influences on processing reward and social information. *Ann.NY Acad.Sci.* 1118, 43-73, doi:10.1196/annals.1412.007 (2007).

14. Adcock, R. A. Reward-motivated learning: mesolimbic activation precedes memory formation. *Neuron* 50, 507-517 (2006).

15. Howard-Jones, P. A., Demetriou, S., Bogacz, R., Yoo, J. H. & Leonards, U. Toward a science of learning games. *Mind, Brain and Education* 5, 33-41 (2011).

16. Schomaker, J. & Meeter, M. Short- and long-lasting consequences of novelty, deviance and surprise on brain and cognition. *Neurosci. Biobehav. Rev.* 55, 268-279, doi:10.1016/j.neubiorev.2015.05.002 (2015).

17. Min Jeong, K. *et al.* The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science (0956-7976)* 20, 963-973, doi:10.1111/j.1467-9280.2009.02402.x (2009).

18. Schilbach, L. *et al.* Minds made for sharing: Initiating joint attention recruits reward-related neurocircuitry. *Journal of Cognitive Neuroscience* 22, 2702-2715, doi:10.1162/jocn.2009.21401 (2010).

19. Furukawa, E. *et al.* Abnormal striatal BOLD responses to reward anticipation and reward delivery in ADHD. *Plos One* 9, 9, doi:10.1371/journal.pone.0089129 (2014).

20. Gaastra, G. F., Groen, Y., Tucha, L. & Tucha, O. The effects of classroom interventions on off-task and disruptive classroom behavior in children with symptoms of attention-deficit/hyperactivity disorder: A meta-analytic review. *Plos One* 11, 19, doi:10.1371/journal.pone.0148841 (2016).

21. Paunesku, D. *et al.* Mind-set interventions are a scalable treatment for academic underachievement. *Psychological Science* 26, 784-793, doi:10.1177/0956797615571017 (2015).

22. Blackwell, L. S., Trzesniewski, K. H. & Dweck, C. S. Implicit theories of intelligence predict achievment across an adolescent transition: A longtitudinal study and an intervention. *Child Development* 78, 246-263 (2007).

FN1. Figure drawn from Adock et al. (2006) in which the percent change in blood oxygenation level-dependent (BOLD) signal in the right ventral tegmental area (VTA) during the interval when the stimulus was presented for recognized versus forgotten high-value content against each individual subjects' high-confidence recognition rate corrected for high-confidence false alarm rate.