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Review article

Education and the social brain

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ABSTRACT

The study of the social brain offers a number of opportunities for enhancing classroom education. This review focuses on the *mentalizing network*, a set of brain regions that support thinking about the thoughts, feelings, and goals of others. This network typically competes with brain regions supporting analytical thought and memorization. Rather than treating classroom learning and socializing as antithetical to one another, this paper suggests our natural social tendencies can be leveraged to improve learning, by making the content and process of education more social. Recommendations are made for history and English classes, as well as for STEM fields. Finally, it is proposed that educating adolescents about the social brain itself will reap educational rewards.

Contents

1. Introduction

Western civilization's use of formal classroom education extends back to at least the first century A.D. when Jewish scholars called upon the community to financially support learning of the Talmud, the book of Jewish laws and customs. Education was for all children above the age of six in classes of no more than 25 students [8]. Since the 15th century, we have seen a slow steady march towards the modern classroom in which a wide range of subjects are regularly taught to children. Within the United States, the typical student will participate in nearly 20,000 hours of classroom education by the age of 18, vastly more time than is spent on any other activity over the course of development. Nations around the world have a made an institutional bet that devoting our children's time to classroom education is the best way to promote individual success and societal progress.

From this perspective, the research on educational attainment is especially disheartening. For more than 75 years, studies have consistently found that only a small fraction of what is learned in the classroom is retained even a year after learning. Clearly, we do not devote 20,000 hours of children's lives so that they can retain the knowledge for a few months before it slips away (see Fig. 1; [9,47]). Why spend hours teaching something that has a vanishingly small chance of becoming part of students' permanent store of adult knowledge? That children struggle to learn what is taught is nothing new. An Egyptian child's clay tablet from 3000 B.C. was inscribed with the words "Thou didst beat me and knowledge entered my head" [27]. If so few classroom hours lead to permanent improvements in a typical child's knowledge, it is

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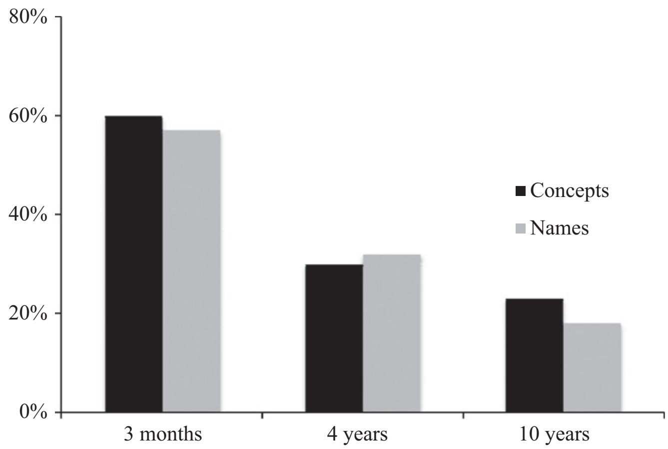


Fig. 1. Percentage of recall for conceptual recall of factual and conceptual knowledge from a college course at different intervals following completion of the course [9].

worth rethinking our approach to both the process and content of classroom education. This review suggests that exploring new educational strategies in light of what has been learned about the social brain may be a relatively untapped yet fruitful approach to improving classroom education. To this end, I will first review some of the basic findings from social cognitive neuroscience and then suggest a number of ways our knowledge of the social brain could be used to update how material is taught in the classroom.

2. The social brain

Humans are distinguished from other primates in terms of, encephalization, the ratio of brain to body size (Fig. 2a). Studies suggest that the best predictor of increasing encephalization across primate species is the size of the groups that each species lives in [10]. Larger groups can cooperate in ways that significantly enhance group survival, but only if the social relationships are properly managed to minimize conflict within the group [23]. Comparative anatomy demonstrates a stronger relationship between encephalization and social complexity variables like group size, than with than other factors like analytic innovation (Fig. 2b). Among primates, humans possess both the highest encephalization ratio and live in the largest groups. One consequence of these evolutionary pressures appears to have been the development of a large-scale network in the brain that supports keeping track of other people and making sense of their mental lives in terms of motives, goals, thoughts, feelings, and dispositions.

This *mentalizing network* (see Fig. 3a; [25,26]) consists primarily of dorsomedial prefrontal cortex (DMPFC) in Brodmann areas (BA) 8/9, precuneus and adjacent posterior cingulate cortex (PC/PCC), tempoparietal junction (TPJ), and anterior temporal cortex (ATC). One critical process that this network appears to support uniquely in humans is keeping track of another's beliefs that are different from one's own [33,50]. Although humans can do this reliably by around age four, no other species has provided convincing evidence of being able to perform this trick.

Below DMPFC, is medial prefrontal cortex (MPFC) in BA10 (Fig. 3a), which has largely been associated with identity, self-evaluation, and self-relevance [17] and thus is considered a central node in a *self-processing network*. Although this region has been most commonly associated with self-knowledge, per se, there is reason to think this region complements the functions of DMPFC by allowing for person-specific idiosyncratic knowledge in contrast to DMPFC's more general storehouse of social knowledge [49]. From this perspective, accessing self-knowledge recruits MPFC because our theory of our own mind is highly idiosyncratic, not because the region supports self-knowledge, per se. Of note, BA10 is the only prefrontal region definitively known to be disproportionately larger in humans than other primates [40]. Additionally, recent work demonstrated that moving rhesus monkeys from smaller to larger groups selectively increases gray matter in BA10 [37]. It is possible

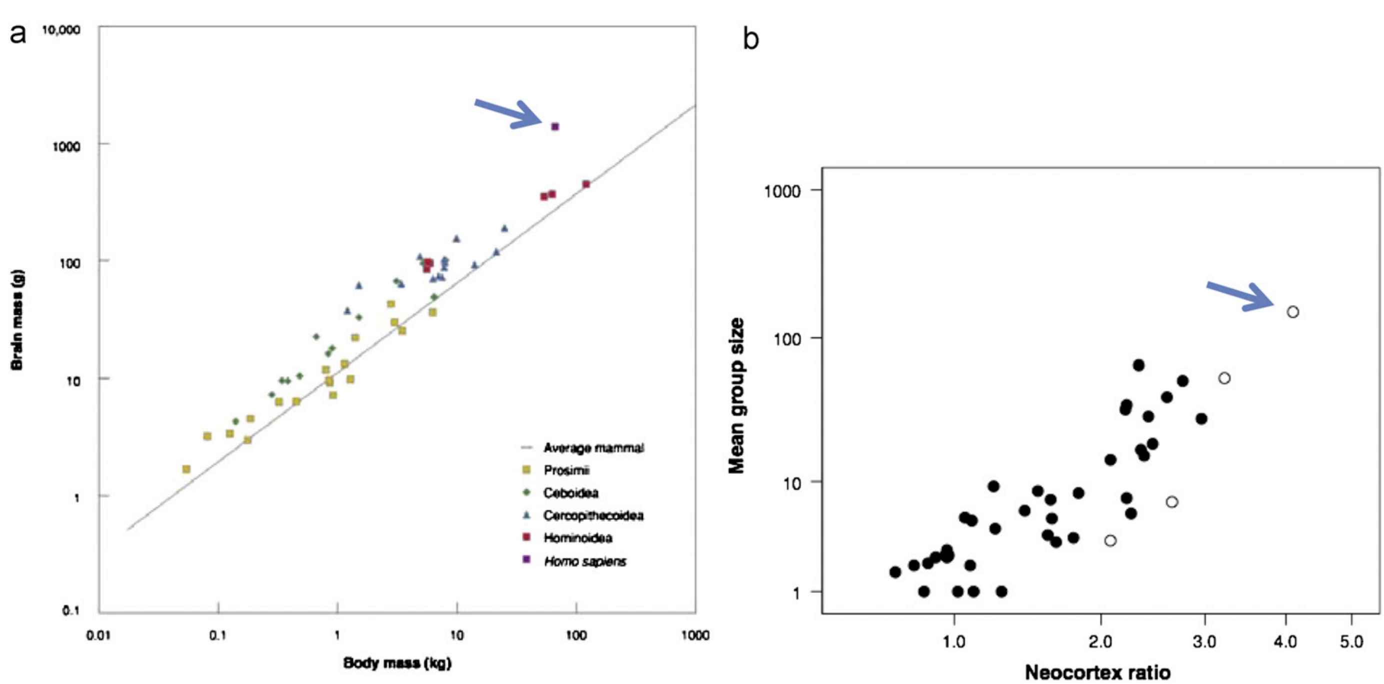


Fig. 2. Our distinctly social brain. (a) Encephalization represented as the relation of brain mass to body mass in several primate species. Arrow points to humans which are the most significant outlier, indicating disproportionate brain mass relative to body mass [From [38]]. (b) Social group size plotted against a measure of encephalization for many primate species indicating that there is a tight fit between these two measures. Humans are indicated by the arrow. [From [11]].

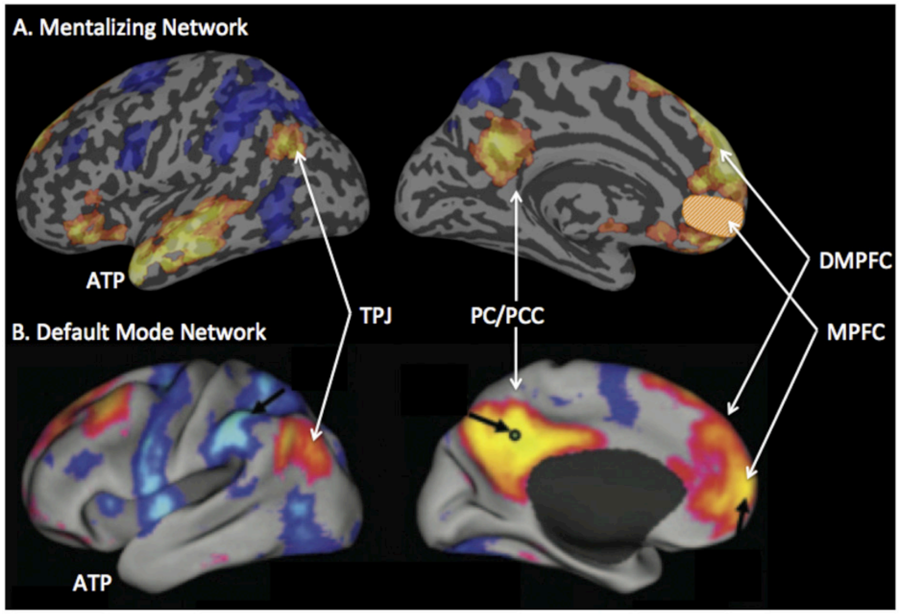


Fig. 3. The mentalizing network and default mode network. (A) Yellow and orange cluster are more active during a mentalizing task and blue clusters are less active [data from [45]]. Medial prefrontal cortex (MPFC) was not present in this task but is visually added here to highlight the region involved in self-processes. (B) Yellow and orange clusters are more active during a resting state and blue clusters are less active during the resting state [From [14]]. Although anterior temporal cortex (ATC) is no present in this study, it is commonly observed in resting state studies. *Note*: TPJ=tempoparietal junction, PC/PCC=precuneus/posterior cingulate cortex, DMPFC=dorsomedial prefrontal cortex; MPFC=medial prefrontal cortex; ATC=anterior temporal cortex. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

that having to develop specific theories of new individuals contributes to the growth of this brain region.

Another distinctive feature of the mentalizing and self-processing networks is that they tend to be more active than other regions of the brain when we are free to think as we please, compared to when we have external inducements to perform other mental tasks [41]. Regions that respond this way are referred to as the *default mode network* (Fig. 3b) and apart from the addition of the medial temporal lobe, the default mode network is nearly identical to the combined neuroanatomy of mentalizing and self-processing networks [4].

Although our cultivated interests in ourselves and the social world around us can undoubtedly promote intentional recruitment of these regions when given several moments in the scanner to do nothing in particular, these cultivated interests do not explain all such effects during rest periods. Newborn infants with little to no awareness of the social world or themselves show reliable default network activity [15,43]. Also, even when adults are only given a few seconds between cognitive task trials this network is still robustly activated [4,44] indicating that our conscious directing of our own thinking is unlikely to be driving these effects. Together, such results suggest that the mentalizing and self-processing networks were selected over the course of evolution to be continuously activated during spare moments, potentially increasing social cognitive expertise and preparing us to make sense of and interact with the world in a social manner.

Currently, a major problem for education is that the brain is biased towards activation of this mentalizing network, yet activation of this network seems to compete with the *working memory network* in lateral frontoparietal regions (see Box 1) that is central to analytical processing and general intelligence [19,36]. Our brains can pay attention to dry history facts or a lesson on long division using the working memory network, but what the brain really wants to do, particularly during adolescence, is explore and master the social world using the mentalizing network. Currently, most classroom education treats this neurocognitive competition as a zero-sum battle between actual learning and social distractions like note passing or texting during class. It is worth considering the possibility that the social brain's natural tendencies can be leveraged to enhance classroom education.

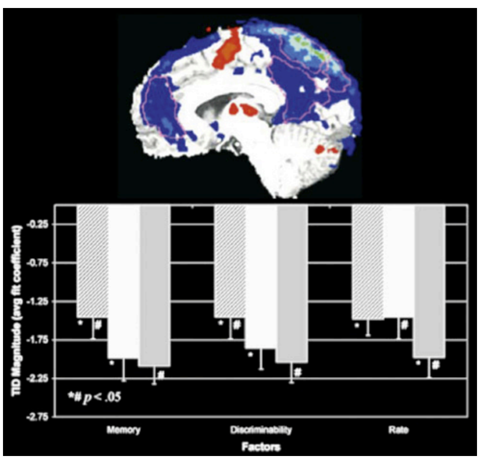
3. The mentalized classroom

3.1. History class

High school history courses often focus on the political and military facts of history. What year did the US enter World War II? Where did Nelson Mandela spend 27 years in prison before becoming the nation's president? Which US President helped create the League of Nations. The facts as currently taught are commonly devoid of the social content and implications that the mentalizing network seems to naturally crave, leading minds to wander to other distractions that impede learning. Yet historical events, as they are occurring, are nearly always infused with multiple mentalistic narratives that we use to understand the events while they are still 'current events'.

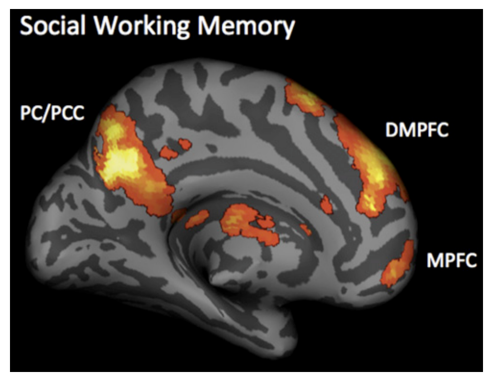
Consider the current diplomatic standoff between the US and Iran. US policy towards Iran requires US leaders to assess the true beliefs of Iranian leaders regarding their goals for uranium enrichment. Emotionally, US leaders are driven by fears about the ramifications of an Iran armed with nuclear weapons and what that would mean for Israel, our closest ally in the Middle East. Strategically, Democrats and Republicans are positioning themselves on Iran in order to weaken or embarrass their opponents for the next election. This is rich with social and mentalistic drama at multiple levels but in history courses, this social cognitive drama is typically stripped away. In fairness, because thoughts and feelings are never observed, they can only be speculated upon and thus may be of questionable accuracy as classes reach further back into history. For such reasons, historians may worry about including such speculative aspects in the official record. Nevertheless, structuring the presentation of historical events in terms of plausible social cognitive narratives

[BOX 1. Antagonism between social and non-social thinking. Two large-scale neural networks supporting social and non-social functions (i.e. the mentalizing and working memory networks) operate antagonistically in many contexts. At rest, the activity of these two networks are inversely correlated such that momentary increases in one are associated with complementary decreases in the other (Fig. 3b; [14]). Additionally, cognitive tasks that increase in difficulty or working memory load, produce load-dependent increases in lateral frontoparietal working memory regions and parallel load-dependent decreases in medial frontoparietal mentalizing regions (see Fig. B1; [29]). Finally, during analytical tasks, increased activity in the mentalizing network is associated with poorer task performance (Anticevic et al. [24,48,53]); Mason et al. [54] as mentalizing constitutes a distraction in these contexts. Though antagonistic responses between these networks are the norm, there are findings demonstrating that the networks activate in concert [7,30,44,52].



Box Figure 1 Brain regions, shown in blue, that parametrically *decrease* with increasing levels of cognitive effort [Adapted from [29]]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

[Box 2. Training the mentalizing network. Given that many of the proposals set forth in this paper depend on the effectiveness of the mentalizing system, an important question is whether the functioning of this system can be enhanced through training. Currently, there is no clear answer to this question, yet there are some reasons to be optimistic. First, a number of social skills training programs that include perspective-taking or Theory of Mind specific components have been successful in improving these abilities [5,28,42]. Within cognitive neuroscience, the closest parallel has been working memory training. Training techniques have been successful in improving working memory performance, enhancing lateral frontoparietal responses during working memory tasks, and increasing performing on tasks generally linked to fluid intelligence [18,22]. Recently, the medial frontoparietal regions of the mentalizing network have been observed to increase their activity parametrically with the amount of social information to be processed, much like traditional working memory regions do in response to non-social information (see Fig. B2; [30]). From an operational standpoint, these regions of the mentalizing network may constitute a *social working memory* network that is amenable to improvement through training**]**.



Box Figure 2 Social working memory regions. Brain regions that parametrically *increase* their activity as a function of increasing levels of social cognitive load.

may well improve retention of the agreed upon key facts. It is like hiding medicine inside a piece of candy; the child enjoys the candy but it serves as a vehicle for the medicine too.

3.2. English class

English class is another example where social cognition is intrinsically relevant and yet has largely been removed from the curriculum. English curricula devote a great deal of time on learning how to write properly. Lessons focus on spelling, grammar, syntax, topic sentences, and the five-paragraph paper. Typically these are presented as a set of facts and rules to be learned and implemented in one's writing. The organizing principle behind all of these facts and rules lurks in the shadows, rarely making an explicit appearance in the classroom: good writing is all about getting ideas from your mind into the minds of other people, so that they understand you and are persuaded or moved by you. This is a mentalizing concept that would be both accessible and helpful to students if emphasized.

There is an argument to be made that English class should be replaced by a class more broadly focused on communication which would place the primary focus on all the tools we need to effectively communicate with others. Understanding the minds of one's audience and how they are likely to receive what has been written is the essential principle behind the rules of writing. Everyone learns that it is bad form to use the passive voice, but few learn that the reason for this is that it requires the reader to do more mental work to understand passive language. The passive voice is not wrong because it violates a sacred principle. It is wrong, in most cases, because it is harder to follow. General improvements in perspective-taking, a form of mentalizing, would enhance the learning and application of most best practices in writing because it would allow individuals to more accurately simulate how their writing will be experienced by others who read it (see Box 2). This is more critical than any particular rule and allows individuals to decide if a particular rule applies in a particular context for a particular audience.

4. Leveraging the social brain

English and history classes are natural entry points for the social brain given its clear role in those subjects. Many subjects are less amenable to increasing the social component of the course content in order to bridge the divide between the mentalizing and working memory networks. Most STEM fields (science, technology, engineering, and math) focus on content that lacks a meaningful social context. In these subjects, rather than focusing on the content to be learned, it is possible that increasing the socially motivated aspects of the learning process will yield benefits.

4.1. Learning-for-teaching

In the early 1980s, several studies demonstrated that reading content from a social cognitive perspective enhances memory formation [6,20,21,46]. In the original study [16], participants read statements about everyday behaviors. Some participants were told to memorize the information because there would be a recall test later on. Other participants were told ''to form an overall impression of what the person who performed these various actions is like'' and were not informed about the later recall test (memorization was explicitly discouraged). Contrary to what we might intuitively expect, the social encoding group demonstrated significantly better recall of the facts than those with full knowledge of the subsequent recall test.

It has long been assumed that the reason for the social encoding advantage is that while social encoding and memorization both strengthen memory traces using the same mnemonic system, social encoding must do so more effectively. However, a conceptual replication of this effect using fMRI (Fig. 4a; [31]) suggests a different explanation of the social encoding advantage. The neuroimaging study used materials similar to those in the earlier studies and found that during memorization, successful encoding was associated with increased activity in regions historically associated with successful memory encoding, left inferior frontal gyrus and medial temporal lobe. In contrast, successful encoding during the social encoding condition was associated with DMPFC within the mentalizing network and not with traditional memory regions.

The educational implications of these results are potentially tremendous. They suggest that the mentalizing network has mnemonic powers separate from those traditionally associated with learning and memory. Moreover, casual social encoding appears to trump intentional memorization in terms of memory

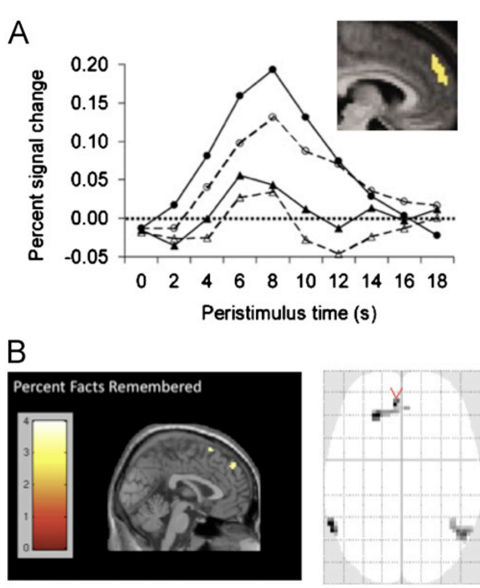


Fig. 4. Brain regions associated with memory for socially encoded information. (A) Highlights the DMPFC region that is more active during social encoding of information that was later recall accurately (closed circles) than other conditions and outcomes. Open circles represent social encoding that led to inaccurate recall. Close and open triangles represent memory encoding trials that led to accurate and inaccurate recall, respectively. [From [31]]. (B) The DMPFC region that is more active when encoding information that is later accurately communicated to another person. The scale indicates the t-statistic values. Glass brain demonstrates that only mentalizing regions show this effect [12].

performance, at least in studies that have compared the two. The dissociable effects of oxytocin on social and non-social memory provides additional evidence for social memory relying on a distinct neurocognitive system. Although oxytocin administration impairs memory for non-social information [3,13], it selectively enhances memory for social information [34,51].

The application of the social encoding findings to the classroom is limited by the fact that the material to be learned was always social in these studies. If the mentalizing system's mnemonic powers could be harnessed to similarly enhance the learning of non-social information it would be of great utility in the classroom. One such approach involves learning material for the sake of teaching others, rather than for the sake of being tested on it. This approach may invoke the mentalizing network due to the social motivations involved rather than the social content.

Bargh and Schul [2] conducted the first careful study of *learning-for-teaching*. They found that individuals who learned non-social Scholastic Aptitude Test passages for the sake of teaching another person showed the same kind of recall advantage over individuals with a memorization goal that was observed in the social encoding studies already discussed. Critically, participants were tested prior to being able to teach the material and thus the effects are attributable to encoding processes, rather than the process of integrating the information during the act of teaching. If these results turn out to depend on the mentalizing network rather than traditional memory encoding regions, it would suggest that merely having a social motivation during encoding is sufficient to engage the processes of this distinct mnemonic system.

One fMRI finding is suggestive of the role of the mentalizing system in socially motivated learning [12]. Individuals in the scanner were presented with paragraphs describing ideas for television pilots and were asked how much they would want to pass these ideas on to a hypothetical boss who would make decisions about which pilot ideas to consider further. Upon exiting the scanner, participants were recorded while speaking about each idea, ostensibly so that the video could be played for the hypothetical boss. The percentage of facts accurately recalled about the shows as the participants' attempted to pass on this information was correlated with activity in the mentalizing network during initial encoding (see Fig. 4b). Accurate memory was not associated with initial encoding effects in traditional memory regions. This provides very preliminary evidence that social motivation alone may be sufficient to engage the mentalizing system during encoding of non-social information.

4.2. Peer tutoring

If the goal is to engage social motivations during the encoding of non-social information, then peer tutoring may be the solution. Rather than trying to prevent student interactions during class, the view from the social brain is that such talking should be encouraged but focused to maximize the benefits. Peer tutoring is currently used, though not broadly and not in ways that optimize its social motivational benefits.

Peer tutoring involves one student teaching another student. Consistent with the learning-for-teaching findings, multiple studies have demonstrated that peer tutoring benefits educational attainment of both tutors and tutees, with tutors often benefiting more [1,35,39]. In some ways this has been seen as a limitation of peer tutoring because the intention has been to specifically enhance tutee learning. From the current perspective, a broad program focused more on tutor learning (through socially motivated teaching), with all students functioning as both tutors and tutees might promote the greatest educational attainment.

It is no secret that starting in junior high, adolescents become less engaged in the classroom and less interested in the views of adult authority figures like parents and teachers. What they are motivated by is the social environment of their peers and their status within that social environment. An 8th grader may not listen to his math teacher, but there are strong odds that he would want to make a good impression on his slightly older and cooler 10th grade tutor. Similarly, 10th graders may be more willing to put in the effort to teach an 8th grader well than they are to learn the same material for themselves. Knowing they are responsible for another's learning may kickstart a variety of prosocial motives, not to mention the fear of looking bad in front of their slightly younger peers.

5. Social brain class

If we retain less than half of what we learn in school, perhaps we should use some of that wasted time to learn something else. Our brain craves to understand itself, the social world, and the relation between the two. Neural and hormonal changes during adolescence make this an even more pressing goal [32]. Why not match at least some of what we are teaching to what the brain is most biologically prepared to learn about? Mature social skills are at least as essential to getting ahead in most careers as other analytical skills. Being able to work effectively with team members, superiors and subordinates, is critical to success. Networking in various capacities clearly drives careers forward. Very few people have careers for which such skills would not improve their careers. Can anyone make the argument that algebra is as important as social intelligence to most people's professional or personal development? Does anyone believe that everyone around them has as much social intelligence as they need?

Despite the central role that our social knowledge and abilities play in our everyday lives and despite the near-constant social information processing of the default network from birth, our social expertise is lacking. People are susceptible to a wide variety of social cognitive and self-processing errors and biases including: naïve realism, fundamental attribution errors, false consensus effect, affective forecasting errors, ingroup favoritism, overconfidence and a long long list of others. Training won't eliminate all of these, though it would likely diminish some. What it will do is provide a shared language for discussing and considering these errors when they occur, helping people to understand that the errors that others make usually aren't malicious or intentionally self-serving.

Although these topics typically are not taught until students are in college, junior high students can clearly grasp these concepts. We all have experience with these phenomena either in ourselves or in observing others. Most kids can think of a time when they thought that many more people would agree with them than actually did (false consensus) or an event that they thought would make them unhappy for much longer than it really did (affective forecasting). Formal education could give students a language for talking about these everyday experiences accurately and allow them to understand why these things happen and what if anything can be done about it. Education focused on these social cognitive phenomena of daily life will help the developing social brain to accurately model its social environment. There is little doubt that such a class would be able to hold students' attention better than the typical class on most other subjects.

6. A concluding thought

The ideas presented here should be understood in context. These are plausible routes to enhancing different kinds of learning based on what we know about the social brain. These are not recommendations based on years of integrating social neuroscience with classroom education. At this point there is no formal social neuroscience of education, but there should be. The brain is wired to be social, particularly at the moment when interest in the classroom drops precipitously. Figuring out how to keep 8th graders interested and learning effectively is as important as any challenge in our society. That our social and educational interests currently run in opposite directions in junior high suggests we are not taking advantage of the social brain to inform the analytic mind. We do not, but we could and we should.

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