What Motivates Us To Learn? Collaborative Peer-Learning and the Recruitment of the Mesolimbic Dopamine Reward System

IAN CLARK

Abstract

Effective peer-interaction entails the spontaneous negotiation of meaning among collaborative learners. The "two-body" and "second person" approaches have begun to explore the "dark matter" of social neuroscience: that is, the connection between human minds during live social interaction. Studies following this interactive turn indicate that when young learners are given expanded opportunities to actively and equitably participate in peer-learning activities they receive dopaminergic rewards from the mesolimbic system in the human brain. These natural rewards are experienced as feelings of well-being, contentment or even excitement during peer-interaction. It was found that the production of dopamine reinforces the desire to continue the interaction and heightens feelings of anticipation for the next peer-learning activity. The purpose of this article is to review and discuss how the neural dynamics within and between the brain structures identified by social neuroscientists motivate individuals to learn in collective settings.

Keywords: intrinsic motivation, social cognition, social interaction, peer-learning, intersubjectivity, mutuality, reciprocity, collaboration

Introduction

The proposition that social interaction is constitutive of, and essential to 'good learning' is now a conventional wisdom entrenched in the educational research literature by theoreticians from both socio-cultural and cognitive schools of thought (Vygotsky, 1978; Bandura, 2001). This is because there is compelling evidence that peer-learning holds considerable potential to improve student performance (Kayi-Aydar, 2013; Mynard & Almarzouqi, 2006), ensure outcome equity (Benard, 1989; Hedin, 1987; Reyes & Elias, 2011) and enhance instructional efficacy (van Zundert, Sluijsmans & van Merriënboe, 2010). The exploration of peer-learning from a scientific perspective prompts the question: What is the relationship between "live" social interaction and the reward-related networks of the human brain, which when activated by interactions with others encourage learners to participate in peer-learning activities which promote higher order social cognition? Social cognition has its roots in social psychology and seeks "to understand and explain how the thoughts, feelings, and behavior of individuals are influenced by the actual, imagined, or implied presence of others" (Allport, 1985, p. 3). The twenty-first century is the time of social neuroscience, presenting an opportunity for educators to reflect on classroom strategies that capitalize on learners' preference for collaborative learning activities (AAG/APMG, 2002–2008).

"Two-Body" and "Second Person" Neurosciences

For those social neuroscientists who take a "two-body" (Dumas, 2011) or "second-person" (Schilbach et al., 2013) perspective thinking and learning is socially constructed between interacting human brains. Peer-learning is therefore an intricate social negotiation which recruits the neural processes underlying social interaction and involves both emotional and social cognition (Sakaiya et al., 2013). Thinking and learning is a superlatively interactive or "live" process (Black & Wiliam, 2006; Schilbach, 2014) that demands and develops spontaneous (Kostrubiec et al., 2012) and flexible (Decety & Jackson, 2004) thinking capacities in the regions of the brain responsible for social cognition. Redcay et al. (2010) demonstrated the efficacy of "live" interaction to recruit the reward-related networks in the human brain by conducting a study of face-to-face interaction during functional magnetic resonance imaging (fMRI) recording. It was found that the brain structures associated with social cognition and reward were more strongly recruited during "live" interaction than when merely observing a recording of live interaction. Krill and Platek (2012) elaborated on the research findings of Redcay and colleagues in their study called *Working Together May Be Better: Activation of Reward Centers During a Cooperative Maze Task*. They found that learning interactions should not only be "live" but also of a cooperative or reciprocal nature to be truly effective motivators for deep and sustained learning. Further, Japanese research on the neural processes that underpin collaborative learning relationships (Sakaiya et al., 2013) found that the intensity of emotion associated with reciprocal peer-interaction centres in the mesolimbic dopamine reward system. It is the release of these chemicals that causes feelings of pleasure and a sense of reward to the participants and motivates them to more actively engage in learning (Guionnet et al., 2012; Krill & Platek, 2012; Redcay et al., 2010; Sakaiya et al., 2013; Schilbach et al., 2013). Evidently, interaction with a collaborative peer is necessary for learning to become and remain a rewarding experience.

The Neural Basis for Peer-Interaction

Recent studies (e.g., Timmermans et al., 2012) propose that meta-cognitive skills, such as reflection, are acquired *during* social interaction. Our brain's biological functions are constantly molded by the interaction between internal reflection and external feedback as we attempt to model (or simulate) other minds during an interaction (Schilbach, 2014). Using positron emission tomography (PET) and fMRI, Schilbach and his colleagues (2013) noted that passive/observational learning entails more limited neural activity than active social engagement between learners. Interactive styles of learning together entail an intricate negotiation, which recruits the neural processes underlying reciprocity (mutual engagement) in social interaction and involves both emotional and social cognition (Sakaiya et al., 2013).

Social Interaction and the Reward-Related Networks of the Brain

Reward related signals play a "key role in the establishment and maintenance of social relations" (Schilbach et al., 2013). Reciprocity is very important in humans (Melis & Semmann, 2010), central to their social relations, and intimately connected with high social cognition (Brosnan et al., 2010). Evidence from neuroimaging and psycho-physiological studies has demonstrated "profound differences in neural processing related to the reciprocity of social interaction" (Schilbach et al., 2013, p. 395). Put another way, cooperative peer-interactions *cause* significant changes in brain chemistry, which influence the quality and duration of the peer-learning activity (Yamasue et al., 2009). The positive feelings experienced by learners as they begin an interaction deepens their involvement in social- and peer-interaction which they experience as a rewarding sense of self- and social awareness with lifelong effects. Salamone and Correa (2012) found that dopamine neurotransmitters 'fire' *before* we perform an action. This means that the expectation of a collaborative interaction, based on past experience, recruits the social reward-networks in the brain. Learners therefore anticipate and look forward to the next learning interaction. This response makes it much more likely that learners will employ social strategies which lead them to begin and sustain the next interaction to a mutually agreeable conclusion.

Agency, Reciprocity and Reward

"To be an agent is to intentionally make things happen by one's actions [...] The core feature of agency enables people to play a part in their self development, adaptation, and self-renewal with changing times" (Bandura, 2001, p. 2). When learners are engaged as active participants in collaborative peer-learning tasks they are in an 'agentic relationship'. This means that the participants in an interaction prefer to be the influencer or controller. When they feel that they are guiding the other they feel valued, and the reward-systems of the brain induce a sense of well-being and self-esteem. Such socio-emotional states depend upon interactive turn-taking. This is a socially negotiated arrangement that circulates reciprocal feedback among learners so that everybody experiences a sense of leadership and self-worth. Learning relationships of this quality cannot be attained without persistent modeling by teachers and frequent opportunities to participate in structured or "scaffolded" (Wood, Bruner & Ross, 1976) peer-learning.

The ventral striatium (VS) in the midbrain and other reward processing structures are recruited during cooperative (Schilbach et al., 2013) and spontaneous (Guionnet et al., 2012) interaction. Similarly, Tabibnia and Lieberman (2007) found that the VS is "a region receiving rich dopaminergic input from the midbrain that is involved in positive reinforcement and reward-based learning" (p. 93). In Schilbach's study (2013), the 'VS effect' was triangulated by questionnaire responses, which confirmed that cooperative social interaction "was experienced as more pleasant and less effortful" (p. 403) than doing the opposite of their partner. In addition, the amygdala plays a key role in reward-processing activity. Sakaiya et al. (2013) found a link between amygdala activity and cooperative learning interactions. Amygdala activation was greater for cooperative social strategies than during interactions which the interactants perceived as unpredictable. When the participants in Sakaiya and colleagues' (2013) study were exposed to unpredictable interaction strategies they reported a diminished desire to continue the learning interaction. This was confirmed by interviews in which the participants expressed a preference for changing partners or discontinuing the interaction entirely. The main finding from the study is that when humans interact in ways which permit insights that build an understanding of the intentions of others the amygdala and associated reward-related structures are recruited.

Humans prefer to learn with other cooperative humans. Recent findings indicate that the reward-processing regions are more recruited when people learn together instead of learning with a computer. This finding prompts allusion to Skinner's early behaviorist thesis (1954), in which he proposed the inner-mental life of public school students to be so overwhelming for typical teachers in typical schools that they must resort to the use of machines to direct students toward their learning goals. A marked decline in the popularity of didactic high-repair strategies employed by some teachers has, (unsurprisingly when Skinner's thesis is considered), been paralleled by the explosive growth of computer-assisted classroom learning as educators attempt to create a learning environment which caters to the needs of twenty-first century learners. However, as already noted, recent neuro-scientific studies (e.g. Rilling et al., 2008; Krach et al., 2008) have reported "very different implications" of the reward circuitry between interacting with humans and computers (also, Sakaiya et al., 2013; Urgen et al., 2013). The implications are clear. Educators should carefully consider how computers are used and the appropriation of school resources toward training for teachers in interactive styles of classroom instruction (Black & Wiliam, 2006; Desforges, 2005) which engage students as active participants in their own learning progression (Black & Wiliam, 1998).

The Development of 'Adult-Like' Levels of Social Cognition

Social cognition is the study of how people process social information, especially its retrieval and application to social situations. Pre-teens and children as young as 8 years old can routinely recall and restructure, (i.e. reflect on) the content of past and present thinking and learning (Fair et al., 2008). The foundational work of Fair and colleagues (2008) indicates that the brain is a relatively functional structure at the age when meta-cognitive skills such as the capacity for reflection become developed. Supekar et al. (2010) conducted a similar study, which confirmed that conducted by Fair and colleagues. Supekar et al. (2010) found that by the age of 8, some connections between substrates (interacting, but often anatomically separate regions of the brain) were mature and others were in an earlier state of maturation (cf. Vygotsky, 1987). In accordance with the earlier study by Fair and colleagues (2008) Supekar et al. (2010) found that despite sparse functional connectivity 8 year old children can reach "adult-like levels" in sub-structures implicated in social cognition. These emerging findings indicate that this is an age at which peer-learning may begin to become an effective instructional strategy. Therefore, children should be systematically assessed for their ability to establish and sustain reciprocal peer-relationships, which support individual learning in social situations, from around this age.

Conclusion

Johnson and Johnson (1983) emphasize that,

> [...] there is no type of task on which cooperative efforts are less effective than are competitive or individualistic efforts, on most tasks [...] concept attainment, verbal problem-solving, categorization, spatial problem-solving, retention and memory, motor, guessing-judging-predicting, cooperative efforts are more effective in promoting achievement (p. 146).

"Two-body" and "second person" perspectives characterize peer-interaction as equitable, mutually engaging and reciprocal interactions (Schilbach et al., 2013; Storch, 2002). Collaborative social interaction depends upon the establishment and maintenance of inter-subjectivity; a persistent process that sustains any learning-interaction for its entire duration. Advanced social cognition entails interactions between external and internal information and feedback (Black & Wiliam, 2009), which continuously construct and reconstruct knowledge for each participant in a "live" interaction. The process of knowledge construction requires some degree of inter-subjectivity between learners because without mutual empathy the affordances required for effective peer-interaction will not create cooperative learning dispositions among learners, which lead to the collaborative interactions which support 'good learning'. Redcay et al. (2010) found that those neural systems recruited for everyday social interaction are "consistently linked" to the activation of the mesolimbic dopamine reward system. The same study emphasized "the powerful and pervasive drive" for humans to seek out social interactions, and reiterated that contingent interactions with another person recruits the reward systems (also, Guionnet et al., 2012; Sakaiya et al., 2013; Schilbach et al., 2013). After working together with teachers in the UK and US to implement interactive teaching practices, Black and Wiliam (2006) reflected upon this experience. They noted, "the involvement of students both in whole-dialogue and in peer group discussions, all within a change in the classroom culture [. . .] was creating a richer community of learners where the social learning of the students was becoming more salient and effective" (p. 17).

References

Allport, A. (1985). The historical background of social psychology. In G. Lindzey & E. Aronson (Eds.), *Handbook of social psychology* (pp. 1–46). New York: Random House.

Assessment Action Group/AiFL Programme Management Group (AAG/APMG). (2002-2008). AifL—Assessment is for learning. Retrieved from http://www.ltscotland.org.uk/assess

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology, 52*, 1–26.

Benard, B. (1989). Towards family. *Prevention Forum*, *9*, 7–14.

Black, P., & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan, 80*, 139–148.

Black, P., & Wiliam, D. (2006). Assessment for learning in the classroom. In J. Gardner (Ed.), *Assessment and learning* (pp. 9–25). London: Sage.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*, 5–31.

Brosnan, S. F., Salwiczek, L., & Bshary, R. (2010). The interplay of cognition and cooperation. *Phil. Trans. R. Soc. B, 365*, 2699–2710. doi: 10.1098/rstb.2010.0154

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3*, 71–100.

Desforges, C. (2005). *On learning and teaching*. National College for School Leadership. Cranfield, UK: NCSL Publications.

Dumas, G. (2011). Towards a two-body neuroscience. *Communicative and Integrative Biology, 4*, 349–352.

Fair, D. A., Cohen A., Dosenbach, N., Church, J., Miezin, F., Deanna, M... Schlaggar, B. (2008). The maturing architecture of the brain's default network. *PNAS, 105*, 4028–4032.

Guionnet, S., Nadel, J., Bertasi, E., Sperduti, M., Delaveau, P., & Fossati, P. (2012). Reciprocal imitation: Toward a neural basis of social interaction. *Cerebral Cortex, 22*, 971–8. doi: 10.1093/cercor/bhr177

Hedin, D. (1987). Students as teachers: A tool for improving school climate and productivity. *Social Policy, 17*, 42–47.

Johnson, D. W., & Johnson, R. T. (1983). The socialization and achievement crises: Are cooperative learning experiences the solution? In L. Bickman (Ed.), *Applied social psychology annual 4* (pp. 119–164). New York: Sage Publications.

Kayi-Aydar, H. (2013). Scaffolding language learning in an academic ESL classroom. *The ELT Journal, 67*, 324–335. doi: 10.1093/elt/cct016

Kostrubiec, V., Zanone, P-G., Fuchs, A., & Kelso, J. (2012). Beyond the blank slate: routes to learning new coordination patterns depend on the intrinsic dynamics of the learner—experimental evidence and theoretical model. *Frontiers in Human Neuroscience, 6*. doi: 10.3389/fnhum.2012.00222

Krach, S., Hegel F., Wrede, B., Sagerer, G., Binkofski, F., & Kircher, T. (2008). Can machines think? Interaction and perspective taking with robots investigated via fMRI. *PLoS ONE, 3*, e2597. doi: 10.1371/journal.pone.0002597

Krill, A. L., & Platek, S. M. (2012). Working together may be better: Activation of reward centers during a cooperative maze task. *PLoS ONE*, *2*, e30613. doi: 10.1371/journal.pone.0030613.t002

Melis, A., & Semmann, D. (2010). How is human cooperation different. *Phil. Trans. R. Soc. B, 365*, 2663–2674.

Mynard, J., & Almarzouqi, I. (2006). Investigating peer-tutoring. *The ELT Journal, 60*, 13–22. doi:

10.1093/elt/cci077

Redcay, E., Dodell-Feder, D., Pearrow, M., Mavros, P., Kleiner, M., Gabrieli, J., & Saxe, R. (2010). Live face-to-face interaction during fMRI: A new took for social cognitive neuroscience. *Neuroimage, 50*, 1639–1647.

Reyes, J., & Elias, M. J. (2011). Fostering social-emotional resilience among Latino youth. *Psychology in the Schools, 47*, 723–737. doi: 10.1002/pits.20580

Rilling, J. K., Goldsmith, D. R., Glenn, A. L., Jairam, M. R., Elfenbein, H. A., & Dagenais J. E. (2008). The neural correlates of the affective response to unreciprocated cooperation. *Neuropsychologia, 46*, 1256–1266. doi: 10.1016/j.neuropsychologia.2007.11.033

Sakaiya, S., Shiraito, Y., Kato, J., Ide, H., Okada, K., Takano, K., & Kansaku, K. (2013). Neural correlate of human reciprocity in social interactions. *Frontiers in Neuroscience, 7*, 239. doi: 10.3389/fnins.2013.00239

Salamone, J., & Correa, M. (2012). The mysterious motivational functions of mesolimbic dopamine. *Neuron*, *76*, 470–485. doi: 10.1016/j.neuron.2012.10.021

Schilbach, L. (2014). On the relationship of online and offline social cognition. *Frontiers in Human Neuroscience, 8*, 278. doi: 10.3389/fnhum.2014.00278

Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlict, T., & Vogeley, K. (2013). Toward a second-person neuroscience. *Behavioral and Brain Sciences, 36*, 393–462. doi: 10.1017/S0140525X12000660

Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review, Spring*, 86–97.

Storch, N. (2002). Patterns of interaction in ESL pairwork. *Language Learning, 51*, 119–58.

Supekar, K., Uddin, L., Prater, K., Amin, H., Greicus, M., & Memon, V. (2010). Development of functional and structural connectivity within the default mode network. *Neuroimage, 52*, 290–301.

Tabibnia, G., & Lieberman, M. D. (2007). Fairness and cooperation are rewarding. *Annals of the New York Academy of Sciences*, *1118*, 90–101.

Timmermans, B., Schilbach, L., Pasquali, A., & Cleeremans, A. (2012). Higher order thoughts in action: consciousness as an unconscious re-description process. *Philosoptical Transactions of the Royal Society London B: Biological Science, 19*, 1412–23

Urgen, B. A., Plank, M., Ishiguro, H., Poizner, H., & Saygin, A. P. (2013). EEG theta and Mu oscillations during perception of human and robot actions. *Frontiers in Neurorobotics*, *7*.

van Zundert, M., Sluijsmans, D., & van Merriënboe, J. (2010). Effective peer assessment processes: Research findings and future directions. *Learning and Instruction, 20*, 270–279. doi: 10.1016/j.learninstruc.2009.08.004

Vygotsky, L. S. (1987). Mind in society: *The development of higher psychological processes*. Cambridge: Harvard University Press.

Vygotsky, L. S. (1987). Thinking and speech. In R. W. Rieber & A. S. Carton (Eds.), *The collected works of L. S. Vygotsky, Volume 1: Problems of general psychology* (pp. 39–285). New York and London: Plenum.

Wood, D., Bruner, J., and Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychiatry and Psychology*, 7(2), 89–100.

Yamasue, H., Kuwabara, H., Kawakubo, Y., and Kasai, K. (2009). Oxytocin, sexually dimorphic features of the social brain, and autism. *Psychiatry and clinical neurosciences*, *63*, 129–140. doi: 10.1111/j.1440–1819.2009.01944.x