Understanding and emotion in mathematics learning

By

Brian Butterworth & Anna Bevan

Background

Many children fail to understand the arithmetic they are being taught at school. We take the view that failing to understand is at the root of much anxiety, distress, and disruption in class.

Since the formal teaching of mathematics proceeds in a step-by-step cumulative manner, when the child begins to fall behind, the gap between his or her own understanding and the understanding demanded by the curriculum target can get wider and wider, creating a vicious circle of avoidance and the child falling farther and farther behind the targets. See Figure 1 below.

(The quotes below come from focus groups of 9 year olds organised by ability level, which have been recorded and transcribed.)

Low ability children typically fail to understand the content of the lesson. “I sometimes don't understand whatever she [the teacher] says”. Then they lose track: “When you listen to the teacher, then you turn your head and you don't know nothing.” “I say what do I have to do. I always forget.”

This leads to failures on maths tasks, a bad experience in itself. In the UK at least, these failures are witnessed by the whole class, a further bad experience: “It makes me feel left out.” They compare themselves unfavourably with others: “I wish I was like a clever person and I blame it on myself.”

They get thoroughly miserable: “I would cry and wish I was home with my mother”. “I feel like screaming.” They get teased and stigmatised: “He just comes up to me and says ‘ha ha – you don't know anything – you are so dumb.”

This leads to negative self-labelling: “You feel stupid.” “All you can be is a dustbin man.”

Instead of spending more time trying to understand the maths, which would be the rational choice, these children try to avoid maths or mentally opt-out during the lesson: “I would spend my time sharpening my pencil … until it's so tiny I'll have to go and get my other one.” “The teacher asks ‘anybody who doesn't understand?’ And they don't put their hand up because they think that – they're … They're too frightened that someone will tease them.” “They waste their time crying.” This often leads to disruption in class, or trying to monopolise the teacher's attention.

Therefore, failing to understanding is a causative factor in the daily suffering of these low ability children, and their suffering causes them to avoid doing the work that could improve their maths.

There are many reasons for failing to understand maths, but as many as 5% of any class will suffer from dyscalculia, a congenital condition that affects the ability to understand simple number concepts.

Intervention

1. The vicious circle can be broken by interventions targeted at each child's current level of understanding. Structured teaching, small steps, use of concrete materials, slow pace, transparent language and plenty encouragement are essential to effective intervention. This will lead to happier experiences of doing maths.
2. Adaptive e-learning programmes can be helpful, since they are self-paced, structured, and private.
3. Drills are not useful and can be counterproductive because they induce stress without helping the child understand the concepts.
4. Low ability children should be screened from the scrutiny of their peers to prevent teasing and stigmatisation of their failures.

5. For dyscalculics, improving understanding will be slow, and needs to proceed at a different pace from the rest of the class.

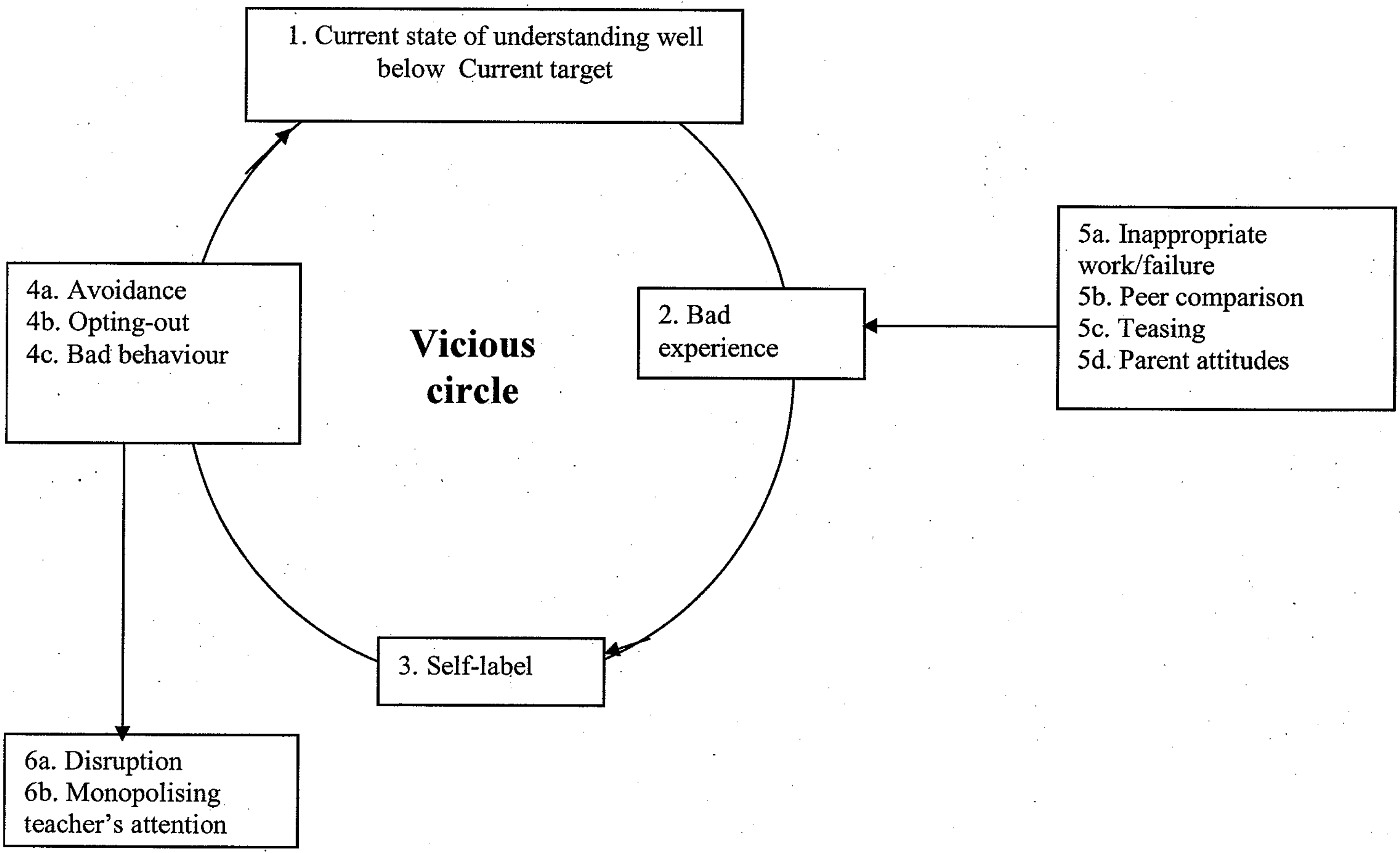

FIGURE 1

THOMAS D'ANSEMBOURG

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"The Nonviolent Communication Process"

developed by Dr Marshall Rosenberg

Many of our communication problems and existential difficulties stem from the fact that we are not clearly aware of our basic needs. This often makes it hard for us to express practical, positive and feasible requests that will help us to cope with our needs.

Lacking such awareness, we often expect other people to meet the needs that we ourselves are incapable of articulating. If those needs are not met, we hold others responsible and express this by judging, blaming, criticising, insulting or coming to blows: "I don't have the words to express my sadness, loneliness, fear, anger, my need for a sense of identity, a sympathetic ear, some respect, my need to make sense of things. So I get depressed, take drugs or hit out!"

This type of behaviour cuts us off from ourselves, because we do not try to understand properly what is happening inside us. It also cuts us off from other people, who react to our judgments not by hearing our needs but by going on the defensive. In turn, we do not try to understand the needs of others either. These patterns of communication can often divide and separate.

Violence, be it internalised or externalised, is the expression of a tragic lack of the vocabulary needed to talk and listen to one another.

Most misunderstandings, for instance, are a combination of failing to speak out and failing to listen. We don't know how to listen because we haven't learned to connect with ourselves, let alone other people.

We can, if we so wish, learn to clarify and articulate our feelings and needs genuinely and with empathy. We can also, if we so wish, learn to connect with other people's feelings and hear their needs, genuinely and with empathy, in order together to find solutions that satisfy both parties.

In practical terms, Nonviolent Communication (NVC) encourages us to identify blocks in our habitual patterns of communication, so habitual in fact that we fail to see the subtle but violent impact they have on us and on other people.

NVC offers us a basic lesson, one that ought to be on every school curriculum from the outset, namely the ability to know and respect oneself with empathy, so as to know and respect other people with empathy.

The Nonviolent Communication Process developed by Marshall Rosenberg (Doctor of Clinical Psychology) continues the work of Carl Rogers and Thomas Gordon. It has been taught and practised for over 30 years in many countries by a network of certified trainers. Marshall Rosenberg is an internationally reputed man of peace, the author of numerous publications including "Nonviolent communication: a language of life: create your life, your relationships and your world in harmony with youtr values" 2nd edition (published by Puddledancer Press) and the founder of the Center for Nonviolent Communication www.cnvc.org – www.nvc-europe.org. He has helped to found many schools that are based on and teach his method.

The demand for NVC training courses in schools – both for teachers and students – is on the rise (in Belgium, for instance, NVC trainers are finding it hard to keep up with demand).

Emotion, Learning and Education

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Position paper by
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The role of understanding in learning

I want to focus on the role of *understanding* in learning. Learning a given set of facts is one thing, learning abstract theories is another, but learning to understand how the theories make sense of the facts should be the obvious goal of education.

Nevertheless, the very concept of understanding has been very step-motherly treated in research. To be sure, the tradition of hermeneutics puts "Verstehen" in the centre, but here the objects of study are in the first hand literary works or objects of art. When it comes to investigating, for example, the role of more mundane "aha"-insights in ordinary students and the role of these insights in the learning processes, research is still in a virginal state. A focal theme for educational science should be to compare educational practices that foster understanding to those that do not.

On way of characterising the concept is to say that understanding is *seeing a pattern* among all the pieces of data within a knowledge domain. For example, a child who realizes that the letters in a text correspond to separate speech sounds has cracked the reading code. The rest is practice. Or a pilot trainee who suddenly understands how underpressure can lift a wing will immediately be in a better position to understand the theory of aerodynamics. The "aha"-insight occurs when the pieces fall into place in the pattern.

The great advantage of seeing a pattern is that it can be applied to new types of problems that go beyond the training set. A student who has understood can answer not only questions that are taken just from the textbook, but also use it for new tasks. The deeper you understand, the more you can generalise your knowledge. And when you have understood, it is also much easier to explain your knowledge area to others. In other words, the one who understands can teach.

We know that experts differ from novices in their way of solving problems, but we know very little about the differences in cognitive processes that make experts so efficient. Presumably, this is connected with the experts having a better understanding of their knowledge domain.

Similarly, I believe that every student recognizes the joy of suddenly understanding a difficult problem or suddenly seeing a pattern in a complicated domain. And an experienced teacher can easily perceive when a student has understood. But there is a want for psychological tests for when understanding occurs during a learning process.

A major drawback of educational IT tools is that these systems do not have a clue whether the user understands. (The tutoring systems proposed by Laurillard is one step in this direction, but there is a long way to go). On the other hand, I believe that certain educational IT tools, in the hands of an experienced teacher/supervisor, can be effective in promoting understanding. In particular, I want to point to tools for *visualising* abstract data and correlations and to programs for *simulating* various processes.

From the perspective of cognitive neuroscience one would also like to know what happens in the brain when, for example, an "aha"-insight is experienced and what are the emotional and motivational correlates of such an insight. I believe that the more often you have en experience of understanding, the more motivated you will be to pursue your studies. In brief, understanding is a key motivational factor in education.

For all these problem areas, the relevant research does not fall within the traditional disciplinary borders, but require new kinds of interdisciplinary initiatives. I believe that a better understanding of understanding from various perspectives within the cognitive sciences will have a great impact of how educational systems should be designed. We need to know much more about how to learn to understand and how understanding brings motivation to students.

Emotions and learning - taking the evidence seriously

A few thoughts on what cognitive neuroscience can and cannot offer

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While the study of emotions has always been at the heart of psychology, emotions were not given much attention when the 'cognitive revolution', framed by the computational paradigm, began three decades ago. In the last ten to fifteen years this picture has clearly changed and we now witness an increasing number of studies examining the role of emotions on nearly all aspects of everyday cognition. This is certainly true also in the field of cognitive neuroscience (which examines the relationship between cognition and the nervous system).

To give just a few examples, cognitive neuroscience has demonstrated: (i) that emotions play a regulatory role in memory consolidation - to the extent that emotional distress can even cause brain areas to shrink, (ii) that emotions bias our cognitive information processing style, and (iii) that they constitute a vital part of decision making, even in the type of decision making that originally was considered to be based entirely on 'rational' cost-benefit analysis.

While all these insights are important in their own right, I think that the greatest potential for cognitive neuroscience, with respect to influence the educational system, lies in its focus on the biological foundations of learning. By describing human cognition, and its neural underpinnings, as a product of evolution, cognitive neuroscience has a unique opportunity for explaining why some things are so difficult to learn while others are so trivially easy. To put it simply; we are natural born learners but we may not be natural born students. However, if we understand what sorts of problems the brain was 'designed' to solve we are in a much better position to 'trick' the brain into learning things it was not designed for.

The first step towards this is to take the evidence seriously. When we know: (i) that the brain is to a large extent designed for action, (ii) that much of our knowledge is gained implicitly by doing things, and (iii) that emotional engagement is the door to enduring memories, how can it be that the educational system (in Denmark at least) is designed for organisms that don't move, encode things like a tape recorder, and lack preferences? (Clearly, I'm exaggerating. In fact, I'm amazed with what students are able to learn given their neural machinery. And this is not a tribute to the educational system but rather a tribute to the flexibility of human cognition).

In this respect it is symptomatic that the Danish Ministry of Education currently appears to be preoccupied with making detailed descriptions of what should be taught at any particular time while there appears to be little interest in *how* things should be taught. How can this be?

I think that part of the explanation is that pedagogy is not (yet) an empirically based science but rather a matter of belief (shame on me if I'm mistaken). Thus, one cannot advocate for a particular (universal) method of teaching - it is up to the people doing the teaching. This is not to say that people working in the educational sector are unaware of what works and what doesn't (I do think that practice is clever). However, they may not know *why* it works.

I believe cognitive neuroscience has a lot to offer pedagogy in terms of explaining how memory works, precisely why emotional engagement is important and so forth. Unfortunately, the neuroscientific knowledge is not easily accessible for people working outside the field. Consequently, one of the biggest challenges facing the neuroscientific community is to convey this knowledge in a manner that is comprehensible without sacrificing the scientific soberness (which may be easier said than done).

I think that this can be done by describing the general principles of cognitive functioning while at the same time insisting that cognitive neuroscience cannot prescribe a specific way of teaching. Thus, cognitive neuroscience can explain why emotional engagement is important in a learning situation but not how emotional engagement should be achieved. In fact, there may be many ways of achieving emotional engagement and it is in this sense that practice is clever.

In conclusion, I'm not a firm believer in neuropedagogy. I don't think that neuroimaging blobs have any direct bearing on how students should be taught (this is indeed "a bridge too far" to quote John Bruer). However, I do think that cognitive neuroscience can establish principles that should be taken into consideration if we want to improve the educational system. In fact, given that cognitive neuroscience appears to have great appeal to both policymakers and the general public we are in a unique position to set a new agenda for educational learning - we can help people take the evidence seriously.

The question is of course how we can accomplish this? A symposium like the present is one, but hopefully not the only, way. One may wonder whether cognitive neuroscience should be part of the teachers' curriculum? Or whether principles of cognitive functioning should be taught in school to increase the students' meta-cognitive abilities? I think these questions are worth discussing.

Katrin Hille

First lessons on Emotions & Learning from the Ulm Project

The Transfer Center for Neuroscience and Learning was founded as a project of the University of Ulm in April 2004 and has been in operation to date for six months. The institute was set up to research the neurobiology of learning and to apply research findings in educational settings – in essence to bridge the gap between neuroscience and education.

A multi-disciplinary and multi-faceted approach is needed to join the best of both worlds. A five step program has been developed that starts from the research question through the end result of improved educational practices.

The following example of our research on emotions and learning highlights these five steps.

Step 1: Creating the relevant question
The relevance of our questions needs to be related to educational practice. The answer to the questions may not only multiply the knowledge of a scientific domain but also help educational practice. The question in our Emotion & Learning program is: in what way can emotions promote learning and teaching.

Step 2: Neuroscience in the laboratory
Our research in Ulm (Erk et al. 2003, as discussed by Spitzer at the Emotions & Learning planning symposium 2003) indicates the benefit of positive emotional context for learning.

Step 3: Neuroscience inspired research within educational settings
The research findings from step 2 (the lab) are applied to less controllable educational settings with a higher ecological validity.

The aspects of Emotion & Learning are currently being researched with 2 studies:

1) We measure the heart rate as an indicator of emotional arousal of students over the course of 23 hours. This explorative study gives insight to the emotional events of a normal school day for 100 students of different ages, gender and school types.

2) We measure learning with different types of teaching compare the traditional teacher-centered method with a student-driven method where primary school students decide themselves how they want to explore a topic.

A third study is being planned to operate within the educational setting - designed to replicate the behavioral effects of the emotional context (Erk et al., 2003).

Step 4: Replication of results in selected schools
Upon positive results of step 3 the field trial is extended with teachers changing their education practices. The results are evaluated by both the researchers and teachers alike.

Currently the study on emotions and learning has not reached this stage.

Step 5: Rolling out the evaluated concepts
If the methods of step 4 verifiably improve educational practices the concepts are rolled out to other schools. This is achieved through contacts to school administration, teacher's colleges and continuing education.

It is only when step 5 is completed that a successful transfer from neurosciences to learning has been achieved.

Many of the steps require a solid partnership between neurosciences and education.

Problems have arisen with different vocabularies, different professional understandings and different fields of expertise. Nevertheless, the benefits outweigh problems as the scientific research gains momentum and new ideas/proposals for studies are generated.

The constant contact to schools and their administrations verifies that our topics are of relevance and that their results are eagerly awaited.

Cognitive performance and learning, related to motivation, psychosocial & emotional factors: Position paper for the conference on Emotion, Learning and Education (Copenhagen 2004)

J.Jolles[1]

1. Introduction on the 'Brain & Learning' viewpoint.

A conference on 'Brain & Learning' and the implications of a new learning science as proposed by OECD-CERI has been organized in the Netherlands in february 2004. J.Jolles was the chairman of the organizing committee which was installed by the Dutch Science Foundation (NWO). A report has been made which gives the direction in which the field should develop in the next five years. The committe has the opinion that an important place should be taken by research into emotional and motivational mechanisms underlying learning and by evidence-based interventions in an educational setting. According to the committee, it is essential to take the whole life-span into consideration, according to the motto 'A Life Long Learning for All', as has also been proposed by OECD-CERI.
With respect to the Netherlands, NWO has started the development of a strategy document describing the research in the period of 6 years to come. 'Cognition in relation to development, education and emotional/motivational factos' has great potential of beeing a major topic in this strategy. The researchprogramme in the domain of cognitive developement and cognitive aging in Maastricht (Brain & Behavior Institute) has quite some possibilities in this respect. The Maastricht group participates in the international LifeLongLearning Network under the auspices of OECD. We run several large crosssectional and longitudinal studies on the domain of cognitive developement and aging. The Study of Attentional function Maastricht (SAM) and the Maastricht Aging Study involve several thousands of healthy subjects aged 5 through 85. These studies are ideally suited for the extension into education-based research in the following years. In the next paragraph, some statements are given as starting point for a strategic discussion in the Copenhagen meeting (8/9 november 2004).

2. Summary of major statements on emotion/motivation, learning and education

Cognitive versus social learning in adolescence and the role of emotions and motivations. The adolescence is the period in which the brain is optimally suited for cognitive learning. However, the adolescent boy or girl is much more interested in social interactions with peers. Negative attitudes and perceptions can develop in that period with respect to the importance of learning '(learning is for nerds', artihmetic is totally unimportant'). This has major implications for the learning trajectory which the student follows. Brain research, on the other hand, shows that individual differences in brain maturation could determine the way the subject copes with environmental stimulation. Psychosocial circumstances thus could modulate further maturation of the brain and thereby 'tune' further learning in positive but also negative direction. It is of major importance to study the role of emotions and motivations in this target group, especially in relation to optimizing learning motivation. Learning could be stimulated in settings which favor the social interactions which adolescents are interested in.

Motivational processes and learning attitudes. Animal and brain research on the basic mechanisms underlying learning have shown that particular emotional stimuli but also motivational factors are essential for optimal learning. Memory consolidation is dependant upon a minimum level of emotional or motivational stimulation. Likewise, recent cognitive psychological research is compatible with this notion. This research suggests that better incentives could be developed for the stimulation of motivation and

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learning attitude. It is suggested that particularly 'negative emotions' should be changed. The learning context should be changed in such a manner that learning and knowledge acquisition induces a positive emotion in the learner. Dedicated 'applied' research should be performed in this direction.

Negative emotions and stress can disrupt optimal learning. The emotional development of the child and adolescent is of crucial importance for the development of an optimal information processing ability. Knowledge acquisition is dependent upon an optimal 'rewarding' atmosphere in which the knowledge is presented. Stress and associations with 'negative' character are known to disrupt learning. This is known from animal experiments and learning in humans. The OECD report on Brain & Learning is compatible with this notion as 'selfcontrol' and 'selfcompassion' are of importance, in which emotional factors play a major role. Emotional and motivational factors are especially relevant in subjects with a learning disability or brain dysfunction and in aging subjects beyond the age of 30 years. Motivational/emotional factors are especially important in these groups because learning does not proceed as 'automatic' in these subjects as in young or young adult subjects. It is deemed of utmost importance to develop and evaluate learning interventions in these groups and apply them in practice. Both cognitive factors and psychological factors are relevant in this respect. Cognitive factors have to do with the nature of knowledge acquisition, psychological factors have to do with the 'attitude' towards change (eg 'This is too difficult, why would I try?').

The developing brain needs an 'external' motivator up till adulthood. Recent neuroscientific research shows that functional brain maturation proceeds up into the third decade of life. Adolescents are thus not fully 'ready'to take their role in society although many adolescents think they are. From a brain research point of view, this finding suggests that didactic/educational concepts which state that the educator should retreat and that education should change into 'facilitating' the autonomous learning process in children/adolescents should be considered with caution. It can be questioned whether children and adolsecents are already able to find their own way in the diversity of knowledge domains. The role of a good teacher but also that of the parents as external 'motivator' should be reconsidered in a positive way. Research suggests that the educator should not only be the passive facilitator and 'tutor' who can give directions when asked, but should have a more pro-active attitude and motivate the student to engage in fields or domains in which he/she would never have started on his/her own. More evidence-based research should be performed where self-initiated learning and leaning based upon external motivators are directly compared.

Motivational problems in students could be due to inappropriately organized education. Brain areas which are involved in planning, problem solving, social learning, self-monitoring and social monitoring as well as self-initiation and impulse-management develop until well in adulthood. They have to do with the anterior areas in the brain. Environmental factors, learning experience, culture and other psychosocial factors could therefore be of major importance for optimal learning. It is therefore probable that motivational problems are especially due to insufficiently organized education which does not take inherent motivations and interests of the student and 'culture' into consideration. Important issues to evaluate in new 'evidence based' educational research are 1) the role of information processing styles (language thinkers versus perception thinkers), 2) the role of diurnal rhytms, 3) the role of emotions and stress ('angry children can not learn'), 4) the possible use of 'gaming' and social interactions via the computer, 5) hormonal changes in the adolescence but also the difference between boys and girls in motivation, 6) the effects of movement on learning and individual learning styles.

Motivational processes, learning attitudes and curiosity. A possibly very relevant role is that of 'curiosity' which according to quite some brain research is innate. Quite some indications exist that curiosity is not stimulated by the present school systems. The curiosity appears to be related to brain-based attention to 'novelty'. New research should be performed in the educational setting which is directed at finding strategies to stimulate curiosity. It is important in this respect to change the educational system from 'knowledge-centred' into 'learner-centred'. It is relevant in this respect that the brain circuits underlying emotions are different from those underlying the primary motivations, but that they overlap in anterior brain areas. Use of insights from brain resarch and cognitive research should be relevant in this respect.

On the role of emotional distress. Quite some children develop a negative attitude towards learning. They have negative experience with respect to some aspect of cognitive learning (eg problems with reading or arithmetic), some aspect of motor learning (beeing 'clumsy', bad performance in sports, or some aspect of social learning (not beeing able to make friends). These negative experiences can have a major influence on behavior, emotions and attitudes. Quite some children can develop a phobia towards cognitive or motor learning or social interactions. The prevalence of anxiety of depression in children is high and this can have a major influence on their further developement, choice of school type and thus determine their whole life. This is the more important because of the fact that individual differences appear to exist in brain and cognitive developement. Children who are 'late' in development of a particular function could reach an asymptote later and even reach a higher asymptote than children who have a faster development. More research should be performed into these aspects of individual development and into strategies to preclude the development of emotional problems, anxiety and depression.

Brain-Science & Education

—Identification of factors affecting cognitive and behavioral development of children based on cohort study—

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The objective of this research is to determine the impacts of social and living environments upon the physical, mental, and verbal development of children. In particular, a long term follow-up study is being conducted to determine the course of developing the ability of recognizing and communicating with others. The results will be used to identify the essentials of the various problems found in the current educational and child-raising areas and propose the guidelines for resolving them.

Specifically, this research conducts the following studies:

- Follow-up study of about ten thousand infants and five-year-old children throughout Japan.
- Questionnaire survey on environmental factors related to growth and development.
- Creation of standard methods of observation and behavior recording and longitudinal observation.
- Through investigation of a specific group and its opposite group in terms of developmental psychology.

Research Period
Five years beginning in 2006 (to be determined)
(Preparatory investigation and research will be conducted and evaluated for two years beginning in 2004)

Food for thoughts: linking education to emotion, motivation and learning

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Education is an admirable thing, but it is well to remember from time to time that nothing that is worth knowing can be taught.
Oscar Wilde (1854-1900)

Learning is key to all flexible behaviour but effective learning can only occur given the right motivational and emotional factors. Education is clearly related to learning, albeit perhaps in more nebulous ways than most people realise. At least two aspects of the meaning of *education* (as defined by the OED) are of special interest in the following: *a)* the process of nourishing or rearing and *b)* systematic instruction, schooling or training. This position paper states the case for linking education to the neuroscientific study of emotion, motivation and learning, and specifically to the study of hedonic processes which ultimately govern much of our behaviour.

Of men and rats

In the beginning of the last century behaviourism came to the fore of scientific investigations. The first behaviourists considered the brain an uninteresting black box, from which the only interesting output was the behaviour: where, in the final analysis, subjective experience can be described simply as patterns of stimuli and responses, where response follows stimuli directly, and where all behaviour can be changed provided proper reward and punishment is administered (Skinner, 1938; Thorndike, 1911).

To a large extent this view has shaped much of neuroscience to this day. In order to study something as apparently vague and soft as emotions, researchers originally turned to behaviourism to operationalize the investigation of emotions in experimental animals. Initially the use of fear conditioning paradigms in rats was extremely effective in elucidating the functional role of various brain structures (LeDoux et al., 1990). In fact, the paradigm was so effective that many still consider one of the main structures, the amygdala, as the fear centre of the brain. Such a view is of course oversimplified, as demonstrated by other research which has demonstrated a clear role of the amygdala in both positive and negative reinforcement learning and in consolidation of memory. Furthermore, the fear conditioning paradigms illustrate the problems of extrapolating from data in rats to humans, where many of the functions of the amygdala would appear to have been taken over by the orbitofrontal cortex (Kringelbach and Rolls, 2004).

In a much deeper sense, however, behaviourists are misguided to think that conditioning can describe all learning processes in the human brain. Specifically, such a simplistic view leaves little room for the important elements of imagination, creativity and play which surely must be some of the driving forces for learning. Much learning depends on internal motivation rather than external reward, and if we are to make new strides in understanding and providing effective learning, neuroscience has to develop a better understanding of this internal motivational system (e.g. see McGraw, 1978).

Fluid absorption

The nature of the internal motivation underlying effective learning is a most interesting phenomenon which everyone will have experienced while playing in childhood. Many will have retained the ability to reach this state of what is perhaps best described as 'fluid absorption', when typically engaged in really pleasurable pursuits that afford us fundamental pleasure with no promise of external reward.

Lately, functional neuroimaging has finally given the opportunity to explore other aspects of human emotion than those offered by behaviourism (Kringelbach, 2004a). Specifically, scientists have begun to explore creativity (Geake and Hansen, 2004) and subjective experiences such as placebo (Petrovic et al., 2002) and the hedonic processes underlying subjective pleasantness (Kringelbach et al., 2003). Converging neuroimaging studies have identified the brain structures including the orbitofrontal and the anterior cingulate cortices correlated with the subjective pleasure of e.g. food (Kringelbach, 2004b).

In other words, neuroscience is making some headway with beginning to understand some of the hedonic motivational processes that drives learning and ultimately must be understood to link learning to an educational framework. In an aside it should be mentioned that such hedonic processes are not only of academic interest but very much a tangible issue when considering the real importance of childrens' diet on learning processes, and in particular the growing obesity levels in children.

Reading and learning in the brain

An important example of how knowledge of these brain processes could affect our educational system is reading, which is currently perhaps *the* most important key skill in acquiring and consolidating knowledge. Reading is a unique human ability – but at the same time reading is just a highly specialised example of general learning combining multimodal hearing, vision and speech in the brain. What is special about reading are the interactions between arbitrary symbols and those language representations that some have argued are prerequisites for consciousness. The development of reading systems has certainly greatly facilitated human communication of mental states across time and space, and thus could be argued to be the perhaps most important driving force of human cultural evolution.

The breakdown or partial development of reading systems can have devastating personal, social and economic consequences for an individual and for the society as a whole. Reading problems are also far more common than is normally recognised and for example developmental dyslexia is affecting between 5-15% of the general population.

Currently, there is no scientifically proven cure for developmental dyslexia, and while dyslexia is clearly caused by a complex set of interacting neural systems, it is also clear that a cure will require a much better understanding of the interactions between perceptual learning and emotional factors.

Furthermore, the scientific study of reading processes requires a temporal resolution on the scale of milliseconds. While we are currently using MEG to investigate the temporal dynamics of reading (Pammer et al., 2004), much more research is needed to understand the linkages between learning and education. In particular it would crucial to obtain a rudimentary understanding of the brain areas involved in play and states of fluid absorption. The rewards of such an understanding could potentially lead to a belated reversal of Oscar Wilde's adage and perhaps in time provide a far more effective education for everyone.

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Expanding Interdisciplinary Research on Executive Attention, Learning and Transfer to Include Motivation and Emotion

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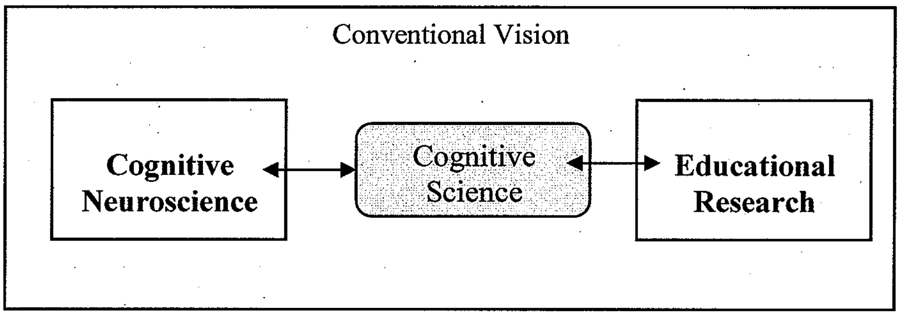
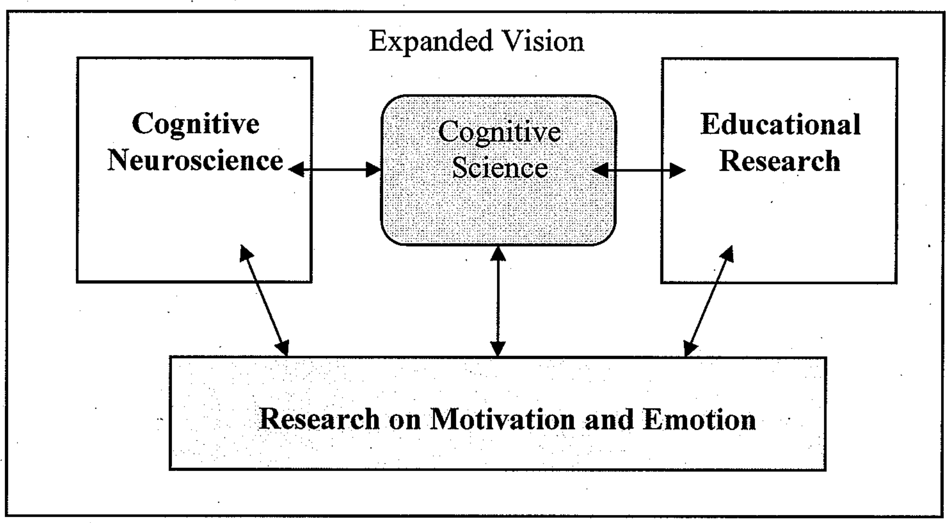
A variety of researchers, organizations, and policy documents have called for meaningful cross-talk between the field of cognitive neuroscience and educational research (Bruer, 1999; NSF, 2003; OECD, 2002). Links between neuroscience and education are typically conceived as occurring through the utilization of learning theories from cognitive science (see Fig. 1), as these fields are thought to hold many points of contact and synergy to inform one another, especially concerning basic mental operations within educational skills such as reading and mathematics. We seek to expand this vision by exploring issues of motivation and emotion (see Fig. 2), which also hold several points of contact in which motivation and emotion phenomena observed within brain studies, cognitive experiments, and classroom activities can help to forge meaningful links between brain science and learning.





Our respective research programs illustrate the type of connections that might fruitfully occur between cognitive neuroscience and educational research. In general terms, McCandliss, through cognitive reading intervention studies and fMRI studies, and Lobato, through ethnographic research in mathematics classrooms, have discovered similar connections between attention-focusing and transfer. Specifically, Lobato and her colleagues (Lobato, Ellis, & Muñoz, 2003) have demonstrated how features of instructional environments, which they call *focusing phenomena*, influence what students attend to mathematically and how these features, in turn affect how students generalize their learning experiences. Focusing phenomena are observable features of the classroom environment (including aspects of teachers' actions, artifacts, curriculum, and students' actions) that regularly direct students' attention toward certain mathematical properties or patterns and away from others. Drawing upon the distinction between three types of attention (as described by Fan, McCandliss, Sommer, Raz, and Posner, 2002), focusing phenomena can be described as more than becoming *alert* or *orienting* to a task, but most importantly as involving *executive attention* (i.e., the biasing focus on one of several conflicting sources of information).

Brain imaging and intervention studies in the area of reading also suggest a connection between the processes of attention-focusing and transfer (McCandliss, Beck, Sandak, & Perfetti, 2003; McCandliss et al, 2001). For example, in a set of studies, McCandliss, Schneider, and Smith (1997) explored the learning of an artificial orthography by adults in two conditions. Half the learners were encouraged to focus their attention on letters within the artificial word-characters as they learned, while the other learners focused on just the overall shape of the word-characters. While all learners studied the same material, there were differences in the type of information to which their attention was focused during learning. When new words were presented, there were dramatic differences in transfer between the two groups. Only the group for whom they explicitly focused attention on grapheme-phoneme correspondences demonstrated transfer to new items. Furthermore, these differences in attentional focus during learning affected the brain areas active during later processing of this material within fMRI scans and 'brain wave' (ERP) experiments. Such results showing ways in which learning can be dependent on <u>how</u> attention is focused demonstrates an important counterpoint to many recent findings of implicit statistical learning effects in cognitive psychology, and stresses the critical role that a teacher's guiding of attention can have on learning and later transfer of that learning to novel situations and material. By looking for cross-disciplinary connections and brain bases for relationships between attention and transfer, educational and cognitive researchers may be able to move from what Kelly (2004) calls "contingent claims" to "necessary principles" in investigating the impact of particular educational activities.

Despite the importance of this interdisciplinary connection between attention-focusing and transfer, we believe that critical aspects of the learning phenomena, such as motivation, are either ignored or assumed to be held constant in many learning studies. For example, in the work reviewed above we both made assumptions of highly motivated learners which may not have been warranted or which will not hold in other settings. To address these factors, we would like to work with other ELE conference participants to explore attention, learning, and transfer in ways that touch on issues of motivational aspects of learning, adaptive learning algorithms, and the brain mechanisms of motivation and reward.

One potentially fruitful connection between emotion/motivation processes and the role of attention in learning and transfer holds that negative emotional processes may at times disrupt attempts to focus attention on the most relevant aspects of a learning situation. As such, this **attentional disruption hypothesis** may help ground discussions regarding how emotional/motivational processes studied at the brain, cognitive, and classroom levels may affect learning. We will explore this hypothesis from a number of perspectives.

- Butterworth and Bevan (see ELE Position Paper, 2004) suggest that a vicious cycle is produced for dyscalculic learners in which attentional resources are diverted to emotional processing, making these resources unavailable for learning. This may hold implications for the role of focusing attention in learning, and may provide a framework for linking observations about emotion/motivation at the brain, cognition and classroom levels.
- Servan Schriver (OECD Meeting London, 2001) and others suggests that interventions that help individuals enter a calm focused state (minimal emotional disruption) may positively affect classroom learning performance on standardized tests.
- At the cognitive and brain levels, Bush, Luu, Posner (2000) examined attentional disruptions within healthy adults performing simple cognitive tasks, and found distinct brain regions associated with attentional disruptions caused by emotional vs. cognitive factors.

We would like to work with other ELE participants to generate a set of hypotheses regarding the linkages among brain-based theories of attention, cognitive and perceptual processes, and emotion, which can create concrete suggestions for remediation elements that are beneficial for both learners and teachers. We would also like to apply the ideas generated in conversation with other ELE attendees to the design of research studies, either lab studies or classroom studies, which take seriously the notion of expanding the attention-focusing, learning, transfer framework to include an examination of motivation and emotion.

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How the student meets and solves a novel problem

Selection of cognitive and neural mechanisms of task solution – the importance of cue constellation and individual experience

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Often teaching situations are approached with the implicit or explicit assumption that the student initially meets a novel problem or task as a "tabula rasa". This implies that the student does not spontaneously harbour any hypothesis or conceptualisation regarding the situation in question. Such mental representations are only assumed to be formed gradually during the learning process. Another common assumption is that the mental representations of a particular topic or cognitive solution strategies to a given problem are fairly uniform across most if not all students.

Research in cognitive neuroscience has, however, shown these assumptions not to be justified. When first meeting a novel task the individual spontaneously generates a hypothesis regarding the potential task solution – or alternatively activates a pre-existing hypothesis. Additionally, studies within this field have demonstrated that a given task may be solved at the same level of proficiency utilising a variety of solution strategies. Although such strategies may in a more superficial analysis appear to be identical, they actually differ substantially with respect to the cognitive and neural mechanisms involved.

Cognitive and behavioural analyses have now for more than half a century demonstrated that both man and other species spontaneously select, evaluate, and potentially dismiss a series of cognitive/behavioural solution strategies when faced with an unknown task. The gradual development of an adequate solution to the task is the result of a systematic evaluation of a multitude of potential solution strategies – rather than exclusively the product of a gradual operant process in which individual responses are reinforced and gradually combine into adequate solution behaviour.

The general practice has been to distinguish something as a separate strategy if behaviourally and conceptually it can easily be distinguished from other methods of task solution. For instance, within the spatial domain distinctions have been made between allocentric and egocentric solution strategies. Allocentric strategies utilise a cognitive representation of the relationship between a multitude of distal, navigational cues (for instance in the form of a "cognitive map") while egocentric strategies utilise navigation from a fixed start position and movements determined according to the body axes of the subject.

Our studies – utilising animal models and primarily a multitude of spatial tasks – of the neural and cognitive mechanisms of problem solving in intact and brain injured individuals have, however, demonstrated such a picture to be too simplistic. Even when a superficial examination of the subjects' behaviour does not differ, a more detailed scrutiny of neural and cognitive mechanisms may reveal that two individuals employ dissimilar solution strategies with respect to both the neural substrate and the cognitive algorithm of task solution.

For instance, allocentric navigational tasks may be solved utilising either a "mapping" type strategy the neural mediation of which relies heavily on hippocampal and cholinergic mechanisms and to a lesser extent on prefrontal cortical mediation or a "non-mapping" strategy which is mediated by a neural substrate less dependent on hippocampal and cholinergic mechanisms while receiving a more significant contribution from the prefrontal cortex.

An allocentric navigational task of the "mapping" type can – after a period of posttraumatic training and "rehabilitation" – be solved at a normal proficiency in individuals subjected to lesions of the hippocampus, the prefrontal cortex, or both of these structures. None of the three lesion-groups apparently differs in the quality of the eventual task solution. A more detailed cognitive analysis, however, reveals that while individuals subjected to individual lesions of either the hippocampus or the prefrontal cortex are eventually able to demonstrate a full cognitive representation of the goal position, individuals lacking both of these structures solve the task utilising a mechanism not relying on such a cognitive representation. Apparently a neural substrate including the hippocampus and the prefrontal cortex normally allows a task solution relying on a cognitive representation of the goal position – but a neural substrate independent of these two structures can still mediate a solution strategy of the same proficiency and superficially indistinguishable from the one of normal individuals.

Once selected the degree to which a strategy is adhered to or subsequently dismissed obviously depends primarily on the degree of success the strategy is having allowing a proficient task solution. What may be less obvious, however, is what mechanism or mechanisms lead to the initial selection of one or another cognitive strategy. It seems that both external factors in the form of cue constellation and other information offered to the subject is of substantial importance in the process leading to the selection of a particular strategy. Also more "internal" factors such as the previous experience of that particular individual seem to matter in this process.

We are in the context of education primarily considering the above results with respect to their implications for the posttraumatic rehabilitation training and functional recovery of brain injured patients. There can, however, be no doubts that even in the education of neurally intact individuals it is important to consider the fact that what may superficially appear to be completely identical ways of approaching and/or solving a particular problem may in fact on both the cognitive and neural levels be completely different processes. Furthermore, the educator should take into account that by modifying both the previous experience and not the least the ways of presenting a particular problem he or she is likely to bias the student in ways that motivate the application of dissimilar cognitive strategies and neural substrates of task solution.

The positions briefly outlined above are primarily based on the research published in the following publications:

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Relationships between emotions and learning

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There is, to my knowledge, no single agreed on conceptualising of the relationship between emotions and learning. In this paper I will consider what can be meant when we speak of the relationship between emotions and learning, and shortly suggest four ways of understanding this relationship. These suggestions are meant as an inspiration for further conceptualization and definition of the relationship between emotions and learning, and should not be considered as an exhaustive list.

Associative learning – Emotional learning can be described as associative learning. Different endo- and exogenious stimuli can be paired with emotional reactions. LeDoux has described how amygdala seems to be particularly important as a centre for some sort of implicit emotional memory, where aversive stimuli are associated with emotional reactions (LeDoux, 1998). Damasio and colleagues has described how ventromedial prefrontal cortex seems to play an important role in learning to associate thoughts with emotions (Damasio, 1994; Bechara et al., 2000). When those associations are formed, they seem to have the potential for automatically influencing behaviour and thought (given the presence of trigger stimuli). That is at least the case if these emotions are intense, or not critically reflected upon (for further information on the latter see: Berkowitz et al., 2000). Relevant questions could be: What is the fundamental nature of this sort of learning? What is the relationship between procedural and declarative learning in this context? Do amygdale and ventromedial prefrontal cortex support the same or different sorts of learning?

Development of complex emotions – In early childhood there seem to exist only simple reflective response patterns and basic emotions. More complex emotions, as for example jealousy, hatred and despair appear later in the development. The development of these complex emotions throughout the ontogenesis, must be based on some kind of emotional learning. This kind of development is probably much related to the development of more analytical and abstract cognition, and could be related to basic emotions that become fused with cognition. Lane & Pollermann has for example, based on a neo-piagetian approach, described the development of complex emotions as related to different stages in cognitive development (2002). Damasio has described the development of learned complex emotions as related to the function of ventromedial prefrontal cortex (1994). Some interesting questions regarding this sort of emotional learning could be: What are the difference and the relationship between simple and complex emotions? How do complex emotions develop? How is this development related to the brain?

Emotional influences on cognitive learning – Emotions can influence cognitive processes such as perception, memory, thinking and decision making. They can introduce bias and lead us in certain directions. Positive affect seems to be related to top-down processesing of information, and to rely on existing knowledge structures (Bless, 2000; Fiedler, 2000). It has also been suggested that positive affect is associated with creativity and originality (Isen, 1999). Negative affect seems to be related to bottom-up, data driven processing, and to focus on information in the environment (Bless, 2000). Affect can further influence the process of learning. It will in general be easier to learn material congruent with the current affective state that one is in, and the following recollection of that same material will be enabled by a corresponding affective state (Bower & Forgas, 2000). Relevant questions could be: what is the effect of general positive and negative (mood-like) states versus the effect of more specific emotions? Does the present affect always effect our information processing in an affect congruent fashion, or will this depend on the kind of information processing strategy currently used (see Forgas, 2000)?

Understanding and regulation of emotions – It is possible to learn how to interpret, judge and regulate ones own and others emotions. There are important individual differences regarding the ability to correctly monitor and competently manage emotions. Some people cannot experience and/or describe emotions (fx people who suffer from prefrontal brain damage or alexithymia (Damasio, 1994; Larsen et al., 2003)). In non-clinical populations as well as in clinical, there seem to be persons who pay scant attention to emotions. This could be interpreted as a difference in what one could call emotional intelligence (see Bar-On & Parker, 2000). A growing body of evidence support a notion that the ability to understand and regulate emotions is something that can be learned. Interesting questions could be: Why are there individual differences in the ability to understand and manage emotions? What is the effect of this individual variability in relation to for example learning, social relationship and health?

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Position Paper

Learning, Emotion, and Education, Copenhagen, Nov. 8-9th

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Learning in an educational setting goes beyond the processes involved in learning how to read and count. How and what we learn has often both a social and an emotional flavor. This paper discusses two aspects of emotional learning of significant individual and societal concern that has attracted far too little attention from both basic scientists and educational researchers: (1) the processes involved in learning from others through social observation, and (2) the way individual factors, such as belongingness to a certain social group, can affect what we learn about others. The flexibility of human biology and culture provides ways to attain adaptive knowledge that are both faster and safer than information hard-wired by phylogenetic selection or acquired by individual trial and error learning. In fact, most of what we learn may be transferred through others.

Guided by models of learning in non-human animals, new lines of research on learning through social observation in humans are emerging with the goal of linking the neural mechanisms of social learning with their behavioral functions in an ecological setting. First, the documentation of mirror neurons in primates indicates that action and perception share a common neural code. Mirror neurons have been implicated in both action and emotion understanding (Galeese, Keyes, & Rizolatti, 2004) - functions integral to goal-directed social learning. In the same vain, behavioral research on fear learning in primates has reported a number of similarities between fear responses acquired by direct experiences (Pavolvian conditioning) and, indirectly, through observation of fear expressions in a conspecific (Mineka & Cook, 1993; Hygge & Ohman, 1979; Olsson & Phelps, 2004). These lines of study have recently been extended by findings of common neural mechanisms involved in fear acquisition during social observation and in later retention of the acquired fear response (Olsson, Nearing, Zeng, & Phelps, 2004). Interestingly, some of these neural structures, e.g. the amygdala, recruited during both the acquisition and retention of observational fear, have previously been identified as critical to fear conditioning across species (LeDoux, 1996). Other structures, such as the insular cortex and anterior cingulate cortex, are known to be related to both self-experienced emotional states and the 'mirroring' of the corresponding emotional state in others, and are hypothesized to be pivotal in emotion understanding and empathic processes (Preston & de Waal, 2001; Singer et al., 2004).

Together, these lines of investigation demonstrate that well developed animal models of mirroring mechanisms and learning can serve as inspiration in the exploration of mechanisms underlying human emotional learning in social settings. In addition to Dewey's classical phrase 'learning by doing', and the more traditional 'learning by instruction', 'learning by observation' seems to be a viable complement in the attainment of emotionally relevant knowledge. Recently, scientists with a focus on the application of research on emotion, have emphasized the importance of emotional perspective-taking in children's moral development (Izard, 2002), which resonates well with the increasing evidence of the role played by emotions in moral reasoning (Haidth, 2003). However, social contexts are inherently complex and many factors mediate the transfer of knowledge between individual humans. For example, both empathic behavioral responses and mirroring on a neural level are modulated by the degree of similarity between the observer and the model (Preston & de Waal, 2003). Moreover, educational scientists report that the degree of experienced similarity with the teacher/model interacts with the type of learning that is best attained by the learner. For example, whereas similarity is advantageous in transferring social skills (Schunk, 1987), dissimilarity favors the transfer of e.g. writing skills (Schunk, 1991). Moreover, weak learners are known to improve more by observing other weak models, whereas strong learners profit more by observing other high performance models (Braaksma et al., 2002).

However, it is reasonable to assume that many other attributes of the teacher/model, such as trustworthiness and approachability, can also impact the transfer of knowledge. This assumption introduces the second theme of this paper: how the acquisition of emotionally relevant knowledge about others can be affected by social group membership – another concern with educational relevance. Unfortunately, valenced judgments are sometimes made about individuals because of qualities unrelated to their behavior, illustrating a core aspect of prejudice – an ailment in a society, which honors egalitarian principles. For example, aversive biases may be based on the belongingness to a certain social or ethnic group. Although there is a long tradition of psychological research on cognitive and behavioral effects of stereotyping, there has been far less interest in how these biases are acquired in the first place. It may be that group belongingness, both of the learner and the individual to whom the learning applies, interacts with the valence of the learning content. Thus, aversive learning to out-group versus in-group members may be facilitated and more resistant to extinction or modification. This assumption is supported by a recent study, using a Pavlovian conditioning paradigm, which shows that White and Black subjects display an extended resistance to extinction to faces of other-group members, but not to own-group faces (Olsson, Eberhardt, Banaji, & Phelps, in preparation). These findings suggest that group membership can affect what is learned about others, which echoes earlier findings of quick and strong aversive learning, and resistance to extinction to 'fear-relevant' stimuli, such as snakes (Mineka & Cook, 1993), and pointed guns (Hugdahl & Johnsen, 1989). It is known that the amygdala is involved in both Pavlovian and socially mediated fear learning. There is also converging evidence for amygdala involvement in judgments of traits such as fear and trust and racial belongingness (Adolphs et al., 1999, Winston et al., 2002, Hart et al., 2000). Again, there seems to be a role for animal models of emotional learning in the exploration the mechanisms involved in emotional learning about others.

In summary, this paper has surveyed a selection of research on how we learn from, and about, others – two topics fertilized by empirical findings on many different levels and ripe to be better integrated with applied research. In this paper, the focus has been on aversive learning – the most investigated form of emotional learning. In the spirit of applied integration, it is important that the mechanisms involved in appetitive (reward) learning in the corresponding social setting are further explored.

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Jeffrey Peyton

My work with puppets and teachers has proceeded under a key assumption: Find a way to systematically inject play energy into the flow of communication in classrooms, and you will have harnessed important raw chemicals from the brain—needed for thinking and communication—energy by which to warm and propel the field of education. Make playful communication second nature on a systematic scale, and a strategic means to transform the learning culture is suddenly available. Playful communication has the power to surprise and destabilize the rigid character of conventional communication practiced by adults in the world's classrooms. Playful communication has the potential to exert broad impact and overnight transformation on the learning culture. This may sound like a tall order for such an amusingly innocuous tool as hand puppetry, but puppet play is a highly contagious and emotionally charged visual language. "We need languages that fit the present time—that can deal with the collective as well as the individual and that transcend traditional boundaries of tribe, nation, and culture," wrote Peter Senge. Puppet Play, practically applied, qualifies as one such language. The hand puppet is a force of nature—a symbolic bloom of organic art on the hand—at once a tool, a media, a language, and a technology capable of integrating, transmitting, and transferring information and opening the mind.

Puppets are widely known for their magical capacity to bring down psychological walls or perhaps pass through them. Somehow the little buggers always get a response. They always make it past the censors and the gatekeepers—Resistance, Fear, Control and Rigidity. In a world where classrooms are increasingly consumed with a strictly academic mission, play in the classroom stands out. The simple act of puppet play engaged in by child and adult in which a lifelike form or behaving entity is made to move and talk produces a catalytic, predictable impact on classroom group dynamics. My work, which involves teachers making their own puppets and putting them to work, has generated an extensive base of teacher anecdotes and video documentation attesting to the changes which classrooms undergo after introducing and working with the puppet medium. "I can hardly believe that a paper puppet can be so magical." "The children were mesmerized." "This has been one of the most enjoyable first few weeks of school I can remember," wrote one teacher.

When autistic children begin speaking in the presence of a puppet, the medium typically works to unlock internal, psychobiological structures and pathways. Puppets send a signal to disarm and that 'it's safe to come out'. Without puppets it is often very difficult to broach sensitive subjects, but because puppets can symbolize and articulate and project a given issue embodied in a 'third party', they make reaching children much easier and less threatening, This has implications for neutralizing the conditions of stress and fear that lead to alienation, violence, suicide, obesity, and substance abuse—and for preventing adult-induced variations of these widespread conditions related to child development and education. Play may send a strong enough message to derail the current train of testing and accountability.

Using puppets, a teacher can personally transform common learning barriers— oppositional behavior, negative moods, defensive attitudes—into a windfall of learning benefits and surprises. Children become more responsive and motivated. Perhaps most important, adults find themselves suddenly having fun. Teachers who tend to keep themselves and their emotions at arm's distance in the classroom become fully involved with the puppets and the children's response to them. The element of play induced by puppets calls up in teachers and children something vital to a learning process struggling o rise above itself. What many teachers describe as "magical" in puppets, I submit, could be the brain's deep need and response to aural, physical, kinetic, visual, emotive stimulation produced by a powerful species-specific, play- and art-based behavior.

In 2002, using near-infrared Optical Topography. (Hitachi, Inc), I worked with Dr. Tom Bass of Children's Hospital of the Kings Daughters, Norfolk, Virginia, who assisted me in designing a protocol to "image the brain at play." The project showed a significant increase in cortical blood volume during puppet play as compared to the performance of similar activity in a familiar routine manner. The study has since been recognized by Pediatric Academic Societies and is pending publication by the Journal of Child

Neurology. Dr. Tom Zeffiro, Director of The Center for Functional and Molecular Imaging at Georgetown University Medical Center, has agreed to collaborate with me to further define and study physiologic changes in the central nervous system associated with play.

Beyond puppets and imaging, the larger issue of play behavior in classrooms offers an incredibly rich arena for research. More research in this area would serve to legitimize play in the eyes of school policy-makers, beyond its recognized importance in early childhood education, and help to establish play as a 'natural learning resource' capable of ameliorating many systemic issues challenging education. Imaging may give us a clear snapshot, but it is more important to establish working models in classrooms and schools around the world where play's impact on communication and the overall learning can be documented.

Interest and respect for play can be fostered in both real and virtual communities. Building play into commercial products would also foster and promote play. Puppetools represents a working model of that potential, and I would like to propose that it be considered for adoption by the OECD Project on Brain Research and Learning Science in its evolving plans for web-based teacher training and participation. The capacity for childlike thought and symbolic use of the imagination is precisely the soil that Einstein, Edison, and DaVinci tapped into and became the playground in which they conducted their work. That soil is the birthright and the internal springboard for learning—residing within each human being—but especially within each child. This capacity—and the principles of human evolution that underlie it—represents the foundation upon which our relationship with the young should be guided.

Ulrike Rimmele

Stress, Learning and Education

Stress affects learning and memory. Whereas some level of stress is beneficial to learning and memory, a high level is detrimental. This position paper will discuss the neurobiological underpinnings of these observations and potential new research fields therein. In addition, it will be discussed how the knowledge of basic research could be used for application in educational settings.

Basic research showed that the amygdala, the hippocampus and stress hormones, such as glucocorticoids (GCs), epinephrine and norepinephrine, play a crucial role in mediating the effects of stress on learning and memory. From animal studies it is known that direct stimulation of the amygdala can modulate (i.e. enhance or impair) memory. Thereby, the effects of amygdala stimulation on memory involve noradrenergic mechanisms within the amygdala. Drugs and hormones, such as GCs, can influence this system and thus modulate memory formation. Evidence from human research affirms the important role of the amygdala in modulating memory storage in emotionally stressful situations: A mild stressor, leading to emotional arousal, enhances memory involving noradrenergic mechanisms and is correlated with enhanced amygdala activity (McGaugh and Cahill, 2000). Furthermore, GCs seem to interfere with this system. Experimentally manipulated GC levels cause memory impairment for emotionally arousing stimuli, but memory enhancement for neutral stimuli (Rimmele et al. 2003). Overall, medium levels of GCs facilitate learning and memory, whereas highly elevated GC levels, such as under severe and prolonged stress, have an impairing effect (Sapolsky, 2003). Thereby the same level of GCs may have different effects on learning of neutral or emotional stimuli.

Knowledge of neurobiological mechanisms of memory modulation by stress hormones and the amygdala and their possible physiological and cognitive manipulations could be important in educational settings. Therefore basic research studies as well as field studies in educational settings are needed. Besides further investigation of the neurobiological mechanisms, which underlie the effects of stress on learning and memory (role of stress hormones, amygdala and other parts of the brain), psychological, neuropharmacological and neuroimaging studies on prevention and regulation of stress should be carried out. Thus, possible preventive measures against stress should be further investigated to provide insight into how people deal best with stressors and thereby maintain or even improve their cognitive performance. One preventive measure against stress is physical activity. In a recent study, we found that elite sportsmen exhibit a lower psychological (lower anxiety and more calmness) as well as physiological (lower cortisol level) stress response to a psychosocial stressor (Rimmele et al., submitted). A further study will investigate the possible reasons of the lower stress reactivity in elite sportsmen. In this study we will investigate sportsmen with different levels of fitness and competitivity to find out about physiological and cognitive mechanisms for coping with stress. Furthermore, psychological strategies, such as reappraisal or expressive suppression of a stressful stimulus, could be investigated with neuroimaging methods to find out more about protective mechanisms against stress. Findings of a recent fMRI study indicate that activity in the amygdala can be up- or down-regulated according to reappraisal strategies of up-regulation or down-regulation of fear (Eippert F. et al., submitted). Possibly, similar effects could be found in cognitive regulation of stress.

With the results of these new studies, a preventive program could be developed in which students could learn how to regulate their emotional arousal and stress and thereby restructure their cognitive performance leading to maintenance and improvement of learning.

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Alan Watkins

Training in Emotional Management Can Improve School Performance

There are a number of compelling strands of academic research that have lead us to believe that the information generated by the body, and the heart in particular, is important to determining what happens in the brain in terms of its:

a.) Cognitive function (incl. perception, clarity, memory and creativity)
b.) Regulation of hormonal function
c.) Regulation of autonomic function (incl. blood pressure)
d.) Involvement in Mood, Emotion and Quality of Life

This evidence comes from a number of seemingly unrelated fields of academic research

1.) Panic Disorder Research
2.) Vagal Nerve Stimulator Research
3.) Autonomic Failure Research
4.) Post traumatic Stress Disorder Research
5.) Positive Psychology Research
6.) Tibetan Monk Research
7.) Heart Rate Variability Research

The challenge for neuroscientists is to start to move away from the exact discipline of the laboratory and into the imprecise arena of field research, such as seen in a school classroom. Failure to do so may result in another generation failing to capitalise on the significant advances in our understanding of how individuals learn.

It is clear that emotions generated in our bodies affect the brain and learning. Filed research now needs to characterise how best to teach emotional awareness and improve emotional management skills if we are to unlock the learning potential in children and adults and create true lifelong learning experiences.

Pilot data form work in five schools in the UK has shown that such a goal is achievable. Thus it is possible to improve school attendance, reduce behavioural disruption, reduce teacher stress levels, increase staff morale and improve academic performance. However such benefits require the implementation of a well-structured and well delivered programme. The challenge is to ensure the full implementation of such a programme and the transfer of key skills into a school to ensure that the benefits such a programme generate are sustainable over time after the programme stops.

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