CHAPTER – 7
DISCUSSION

7.0 DISCUSSION

This chapter considers the significance of the results obtained in each study, both from a scientific perspective and from that of education. It also considers implications for the future development of India, with its aim of again becoming a knowledge-based society – as it always was in ancient times. Basically, these studies represent the first full investigation of effects of using the Vedic Maths approach to maths teaching. Previously, a single case study of Vedic Maths methods has been published (Pagedar, 2015). Many studies have investigated effects of regular practice of Yogā in the classroom (Ferreira-Vorkapic et al., 2015). In India, it is intended to introduce Yogā practices to improve the quality of life of school children, and stem increases of anxiety and depression generated by emphasis on exam performance. Any study providing evidence for benefits to school children of particular Yogā practices is therefore of potential value.

Each section below discusses the results obtained from one of the three studies, but it should be borne in mind that the whole series of four studies represents a revolutionary investigation into the potential of Vedic Maths methods to improve mathematics education and achievement in school students.

7.1 STUDY 1: PILOT STUDY

Study 1 reported comparative effects of three interventions on Math Anxiety by Math-anxiety Rating Scale-Revised MARS-R; cognitive flexibility and selective attention by the STROOP test; self-defeating and self-enhancing thoughts by Children's Cognitive Assessment Questionnaire CCAQ; and working memory by the Digit Span test. All three interventions appeared to influence the various measured parameters to varying degrees.

In MARS-R, Math Anxiety with its two subscales, Learning Math Anxiety and Evaluation Math Anxiety, is the primary variable. Vedic Maths brought the most benefit for Math Anxiety levels, followed by Yogā Prāṇāyāma (Figure 5). Jogging did not reduce Math Anxiety levels to any significant extent. Why the Vedic Maths group received the most benefit compared to the other groups seems obvious: it directly enhances math problem solving skills bringing confidence to students concerned about their maths ability. Yogā Prāṇāyāma improvements are consistent with its known ability to reduce anxiety in general. That Vedic Maths outperformed Yogā Prāṇāyāma shows the power of that method.

The Vedic Maths group also showed the greatest improvement on the STROOP test (Figure 6). The Jogging group's initial values were lower than those of the other two groups on Word score, and its final (post) value did not even reach the pre values of the other two groups (Table 4, Figure 6). These measurements seem confusing, and require further investigation.

Scores on the CCAQ test measuring self-defeating and self-enhancing thoughts improved most for the Yogā Prāṇāyāma group followed by the Vedic Maths group (Figure 7). The Jogging group's initial negative evaluation increased, but not significantly (Table 5).

The Digit Span test, which measures working memory and focused attention (Rosenthal et al., 2006), did not show significant change after any intervention, nor between any pair of groups (Figure 8). This result may be due to low sample size and the short intervention period. It needs further investigation.

7.2 STUDY 2: FIRST MAIN STUDY

Results confirmed experimental hypotheses with good statistical significance, Math Anxiety reduced most in the Vedic Maths group (Cohen's d = 0.57 for TMA in Vedic Maths), and seemingly less in the Yogā Prāṇāyāma group, though between group differences were not significant. Scores on CCAQ improved most in the Yogā Prāṇāyāma group, less in the Vedic Maths group, but not in controls – with a similar caveat. (Cohen's d varies from 0.35 to 0.95 for various CCAQ parameters for Yogā Prāṇāyāma). The immediate scientific question is why should such results obtain?

Systematic reviews of RCT's of Yogā provide evidence for benefits of Yogā Prāṇāyāma for anxiety (M. Sharma et al., 2013; Weaver et al., 2015). Changes in the Yogā Prāṇāyāma group are consistent with such predictions and G* power analysis. Changes observed in the Vedic Maths group may be attributed to the intervention. Similarly, studies comparing Yogā practices to eyes closed rest obtain different results for experimental and control groups: eyes closed rest showing little if any change. Positive effects observed in the Yogā Prāṇāyāma group may therefore be attributed to the intervention.

Reasons for using a Yogā Prāṇāyāma comparison group were as follows: because of their known anxiety reducing effects, Yogā Prāṇāyāma practices can be taken as a benchmark with which to compare other methods of anxiety reduction. They are effective for any kind of stressful condition. Evaluation of their comparative ability to reduce Math Anxiety is therefore relevant to our understanding of the usefulness of Vedic Maths to education, the main topic of this thesis.

Students' reactions to the classes and written appreciations at the time offer insight into the success of the classes. Typical examples read: (1) "Vedic Maths simplified mathematics and by reversing the illusion that maths is difficult created renewed interest in the subject." (2) "Thank you for teaching us (Vedic Maths), it was more interesting and enjoyable than ordinary maths classes." (3) "Attending these classes created a lot of confidence in me, … I shall do great in future maths classes particularly on integration."

This study obtained good statistical significance in all subscales of both MARS-R and CCAQ tests except the 4th CCAQ subscale, On Task. The others showed within group pre-post improvements, significant at $p < 0.05$, but did not reach significance between groups. Improvements on other subscales for both Yogā Prāṇāyāma and Vedic Maths groups suggest considering Yogā Prāṇāyāma as an activity to improve cognitive skills, and Vedic Maths as a potential teaching aid in school children.

7.3 STUDY 3: SECOND MAIN STUDY

The reported results were not entirely as hypothesized. The Yogā Prāṇāyāma group performed best overall on the tests, possibly because the sequence of Yogā Prāṇāyāma practices settles the mind and may bear some similarity to the Mindfulness Based Intervention. The Vedic Maths group was observed to increase in Mindfulness by a small amount, but with high significance, but was not observed to decrease significantly in aggression as had been hypothesized. Increased confidence in a single subject may not necessarily translate into decreases in self-reported feelings of aggression, particularly as the learning environment did not change for teaching other subjects, and the learning environment has been found to be a significant factor in stress generation (Taylor et al., 2013).

A possible reason for the observed increase in Mindfulness in the Vedic Maths group may be that giving students choice of how to perform calculations enhances their ability to reflect internally on their own preferences, thus increasing their capacity for a more internally directed orientation of awareness. It can also be argued that adding a fun element to the learning process involving pattern recognition, a right hemisphere activity (Roser et al., 2011), may have improved participants' capacity for being in the present moment (Ostafin et al., 2012).

The Yogā Prāṇāyāma group improved far more on Mindfulness than the other two groups ($p = 0.0001$ in both cases), and alone decreased highly significantly in Aggression and significantly on Negative Emotion Regulation. Several studies have reported increases in emotional regulation resulting from mindfulness training (Hayes et al., 2004). For one group to both increase in a measure of Mindfulness and decrease in Aggression and Negative Emotion is consistent with these results. In support of this, Yogā, including Nāḍī Śodhana Prāṇāyāma as used in this study, has been found to be very effective in changing levels of key endocrine molecules associated with stress such as epinephrine and norepinephrine (Selvamurthy et al., 1998). This may explain its effectiveness in decreasing self-reported aggression on the Nonphysical aggression Scale from Pittsburgh Youth Study. The observed effect of Yogā Prāṇāyāma on mindfulness is important. Although the practice is not specifically designed to increase mindfulness, it is extremely calming and centring for participants' awareness, and evidently increases mindfulness as a beneficial side-effect (R. P. Brown et al., 2009). Further studies of this may be helpful.

Yogic Kriyā Kapālabhāti washes away carbon dioxide and increases oxygen concentration; it also revitalizes functions of brain cells. Nāḍī Śhodhana brings sympathetic and parasympathetic balance in the ANS, which would lead to clarity of mind and improved concentration (Nagendra, 2005). This could be an explanation for overall improvement in Yogā Prāṇāyāma group. In contrast, the decrease in aggression observed in controls seems anomalous. When 12 group comparisons are made in a single study, one change reaching $p < 0.05$ by chance is not unusual, so this may have been due to the statistics, rather than the control intervention itself.

Such results suggest that application of Prāṇāyāma methods to decrease effects of stress in society might prove valuable. Teaching them in schools would make a highly beneficial life-long skill available (Khalsa et al., 2012), just as mindfulness-based interventions (MBI) are seen as achieving (Felver et al., 2016).

Regarding possible connections between MAAS measured mindfulness and emotion and behaviour regulation, we performed various correlations between pre-measurements of the 243 participants in a post hoc analysis. Correlations between mindfulness and aggression reached significance, Pearson's $r = -0.45$, $p < 0.0001$, for pre-values, with similar values for post- values, while those between pre values of mindfulness and negative ERQ were $r = -0.214$, $p=0.001$, while post values showed $r = -0.236$, $p=0.001$. While the first is clearly expected, the second result is interesting, in that those with higher scores on mindfulness felt less need to hide negative feelings, possibly indicating that their general levels of negativity were less, or that negative feelings may block mindful awareness (Garland et al., 2015). The same might also be said about the first correlation, those with high levels of outward aggression, presumably originating in internal frustration, may be less capable of being in ‘present moment’ states of mindfulness (Borders et al., 2010).

However, a similar analysis of correlations between the ERQ positive and ERQ negative scales yielded extraordinary results: Pearson’s $r = 0.24$, $p < 0.0002$, pre-values, and $r = 0.35$, $p < 0.0001$ post values. Positive correlations between supposedly independent scales, even correlations of this magnitude, are not to be expected. Interpretation of this correlation is difficult, but may mean that the test needs revalidation in India, where English may not be the speakers’ mother tongue.

7.4 COMBINED DATA

7.4.1 Vedic Maths and MARS-R

Results displayed in Table 14 show that scores on both LMA and EMA subscales of MARS-R decreased significantly for the Vedic Maths groups in the Study 2 and Study 3 experiments. Total Math Anxiety therefore decreased highly significantly as well. In contrast, scores for the control group did not change significantly, as was to be expected. Results therefore establish that Math Anxiety will decrease significantly in students who learn to perform mathematics calculations using Vedic Maths methods. These results are in agreement with the smaller and shorter pilot study, which obtained similar results.

Geist implies that many of the rote ways of learning and teaching mathematics over time are partly the cause of the stress that students experience (Geist, 2010). The absence of those factors may also have contributed to the observed decrease in Math Anxiety. Vedic Maths techniques are not rote methods.

Learning to perform calculations by the methods of Vedic Maths is clearly not a technique that directly reduces anxiety levels, as occurs with such practices as Transcendental Meditation (Grosswald et al., 2008), for example. It must therefore be that learning Vedic Maths gives students such increased confidence in their mathematics ability that anxiety levels systematically decrease. But while LMA is considered a form of 'state anxiety', EMA is considered a kind of 'trait anxiety'. The latter is therefore considered more susceptible to improvement over time scales as short as those over which the experiments were carried out. The former, LMA, on the other hand, might be expected to improve less over these relatively short lengths of time. It is therefore of interest to look at the effect sizes obtained in the two experiments. For the Study 2 data, reduction in TMA yielded the substantial Cohen's d effect size of 0.57, while for the Study 3 data, it yielded d = 0.44. As expected LMA Cohen's d was less than the EMA Cohen's d. Combined Study - LMA Cohen's d = 0.26; EMA Cohen's d = 0.46. Pilot Study – LMA Cohen's d effect size = 0.66; EMA Cohen's d = 0.85.

To explain these results, we may note that Vedic Maths uses pattern recognition, and introduces an element of fun into learning mathematics and tackling mathematics problems. The human brain is naturally structured for its cognitive states to cognize 'forms', and patterns represent kinds of form that the brain naturally encodes. It is possible that pattern recognition stimulates release of serotonin or endorphins (The Harvard Mahoney Neuroscience Institute, 2010) associated with good feelings. The result is reduction in math-anxiety, and its replacement by memories of enjoyment.

7.4.2 Vedic Maths and Cognitive Skills (CCAQ):

Study 2 data suggested that the Vedic Maths group improved better on positive self-evaluation and reduced more on negative self-evaluation after 15 days of Vedic Maths intervention compared to the control group. Study 3 data similarly showed significant improvements in Vedic Maths group compared to controls. The system seems to bring students '*aha*' experiences. These studies show that Vedic Maths reduces negative self-talk while taking a math test, and promotes positive and on task thoughts. These help to make students more attentive when solving maths problems, reducing mathematics-related anxiety. This means that they may corroborate findings of reduced Math Anxiety.

One domain of mathematical cognition, called computational difficulty, requires attentive behaviour and processing speed (Fuchs et al., 2008). In stimulating students to 'think about' problems, Vedic Maths methods can help in analyzing patterns, thus improving processing speed during a math task. This suggests that it improves students' computational ability. This will further improve students' mathematical cognition, resulting in better performance in the various 12th Standard examinations, and increasing their options in choosing a career.

An interesting finding was that the smaller Study 2 study yielded better results than Study 3. One reason may be that Study 2 was a randomized control trial, whereas in Study 3, three classes were arbitrarily assigned to the three groups. Of these, the control group consisted of students who were more inclined towards maths, e.g. they did not take biology as a subject in their senior secondary course, whereas in the Vedic Maths group, while all students studied maths, some were more inclined towards biology than maths. Further investigation will provide better insight about this question. Another factor which may be relevant is that the Vedic Maths group had a higher ratio of females to males than the control group. Females of all ages tend to rate themselves lower in maths ability, and to experience greater mathematics anxiety than males (Dowker et al., 2016).

Studies suggest that student attitudes to mathematics tend to deteriorate with age (Dowker et al., 2016), with negative implications for mathematical development, mathematics education and adult engagement in mathematics-related activities. Our studies yielded fascinating results in final board examinations in mathematics and other subjects requiring mathematics. Student not only reported comfort and fun while solving numerical problems, when they applied Vedic Maths Sūtras to their regular classroom problems; they also reported that solving competitive exam problems by application of Vedic Maths Sūtras was faster and easier. Also, after introducing Vedic Maths as teaching aid in regular college maths classes, college results not only improved in pre-university board exams, but also in competitive common entrance examinations – see next section.

To summarize: Vedic Maths can help: (i) improve processing speed by pattern recognition, and (ii) attentive behavior by reducing negative self-evaluation and enhancing positive self-evaluation, thus improving students' computational skills. We may conclude that Vedic Maths is a good remedial option to reduce negative thoughts and enhance positive thoughts during mathematics tests, thus improving self-efficacy and performance of school students. This in turn may play an important role later in life in deciding on a career using mathematics. Vedic Maths methods may provide a tool to break barriers in learning mathematics, and help progress in this subject area.

7.4.3 Digit Span Test

Despite being used an assessment in all three studies, no significant improvements on the Digit Span test were seen in any of them, neither in the Vedic Maths groups, nor the Yogā Prāṇāyāma groups. The Digit Span Test assesses working memory, which many studies have shown to play a fundamental role in the ability to perform arithmetic calculations. This seems intuitively valid, the ability to properly remember the parts of a calculation is obviously required to perform the whole calculation. But this result obviously raises a fundamental question: ‘If working memory did not improve, what was the basis for the observed improvements in all areas of mathematics as indicated by results on final exams, and as implied by the significant reductions in Math Anxiety?’

This question makes the null results on the Digit Span test of extreme interest. Evidently, working memory is not the only factor required to perform a arithmetic calculation, or indeed to solve any mathematics problem. Sections 8.6 and 8.7 below discuss the role of patterns and ideas in finding the solution to mathematics problems, and how these may be enhanced by Vedic Maths methods. The null results on the Digit Span test therefore supports the concept that the mind functions primarily by using ideas, as we all experience, rather than just being an algorithmic number crunching machine like a digital computer – which some computer scientists would have us believe.

7.5 ANALYSIS OF EXAM RESULTS

Inspection of Table 18 and Figure 14 makes it clear that improvements in cohort scores between the four classes taught Maths without use of Vedic Maths and Geogebra from 2010 to 2013, and the two classes in 2014 and 2015 who received them, are highly significant academically as well as statistically. The numbers of students involved are sufficiently large to make the power of these results highly robust. The common-sense effect size for the Mann-Whitney U test on all Maths results is 0.751, with a less appropriate Cohen’s d of 0.87. When a G* Power analysis is performed using the more accurate Mann-Whitney 0.751, with cohort sizes of 312 and 340, the value of beta is incalculably small for alpha set to any value above 0.0001. By setting a required alpha, α, to 0.000002, beta (β) comes out about equal, also 0.000002, i.e. power = 0.999998. Some say that studies of school students should be far larger to be taken seriously, but any question of relatively small numbers in each cohort is offset by the levels of statistical significance, α and β.

This means that the results obtained are very robust indeed. Although, among studies of mathematics teaching, 652 students may seem a relatively small sample, the values of alpha and beta effectively confirm the statement, ‘Incorporating teaching through Geogebra, animated slides and Vedic Maths teaching vastly improved student performance on Mathematics Final Exams’.

For distinctions and full marks on maths results, the group batches yield contingency tables given in Table 3. Odds Ratio 4.2 and $p < 0.0001$ for distinctions, and Odds Ratio 9.36 and $p < 0.0001$ for full marks, both yielding respectable effect sizes and statistical significances.

The reported results in Chemistry also improved, which might be interpreted as indicating higher quality of students taking final examinations during the last two years. However, such an interpretation is contraindicated by lack of improvement in mean scores on physics theory examinations, obtained when scores on practical examinations have been excluded. The high levels of improvement in Maths scores (17% in means, up to 19% between 2013 and 2014) are therefore real and their significance should not be discounted.

Also striking are the increased numbers scoring over 85%, Distinction, and full marks, 100%. Whereas these numbers in Physics and Chemistry did not change significantly, those on Maths increased from 27% distinctions to 61% distinctions, and 1% full marks (same as Physics and Chemistry) to 8% full marks (100%). Again, it is not simply the statistical p value (0.000000000001) that is highly significant, the beta value indicates highly robust results.

The results therefore indicate that introduction of teaching through Geogebra, animated slides and Vedic Maths teaching methods coincided with great improvements in exam results. Though similar to improvements informally reported in other countries after introduction of Vedic Maths methods (Glover, 2005b), no such levels of improvement in mathematics exam results have previously been reported in India, or at least not to our knowledge. They must surely be due to the methods of maths teaching adopted: the Vedic Maths curriculum, and the visual aids described above.

Teaching and learning through visuals like Geogebra and power point simulations are thought to support experimental, problem-oriented and discovery-based learning of mathematics, all key features of mathematics education (M. Hohenwarter & Preiner, 2007). The high levels of improvement reported in the present studies also provide evidence in favor of this view, though further research may be needed to quantify this aspect in more detail.

7.6 USE OF PATTERNS IN VEDIC MATHS

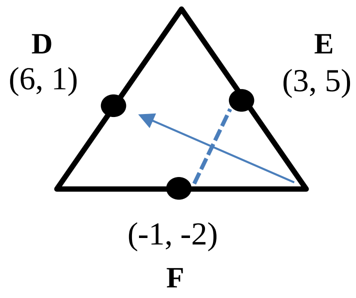
This section discusses the use of patterns in Vedic Maths, both because their use seems fundamental to Vedic Maths methods, but also because they may be fundamental to cognitive processes. The discussion begins with an example.

7.6.1 An Example (Jammu and Kashmir Common Entrance Test, 2007):

The midpoints of a triangle are D(6,1), E(3,5) and F(-1,-2), then the vertex opposite to D is

(a) (-4, 2) (b) (-4, 5) (c) (2,5) (d) (10,8)

Answer:



Vertex opposite to D is

[(3+(-1)-6), (5+(-2)-1)]=[-4, 2]

Procedure: (F+E-D) Sūtra Used: Urdhwa Tiryakbhyam (Vertically crosswise)

After knowing the pattern, it is easy for a student to perform mental calculations. So, recognizing hidden patterns will produce an 'aha' effect when recognizing the simplification process. The Vedic Maths system suggests a unique technique of calculations based on simple rules and principles which shorten the laborious inductive and deductive methods of conventional mathematics. Every second is precious in any of the career-deciding examinations mentioned in Appendix 1.

The example illustrates how Vedic Maths methods increase mental agility, boost self-confidence, enhance observation skills, and help save time. A single extra mark can make a huge difference in student rank, e.g. reduce rank 300 to 200, increasing the chance of entering training for the desired job.

7.6.2 Popularity of Vedic Maths

Students who have learned school mathematics according to Vedic Maths methods, give it a high popularity rating. Many teachers have speculated why this should be the case. Among the reasons offered are its novelty; also the differences between learning mathematics according to conventional teaching, where the student generally receives a single, fixed method for solving a given kind of problem, and the choice of methods offered by Vedic Maths. Choice permits students to select their favoured method from a variety of possible ones in order to obtain answers to each problem.

In India, learning mathematics by Vedic Maths methods holds a special appeal: it follows ancient principles of instruction, where students sat near (Upaniśad) the teacher, and learned from his lips (Radhakrishnan, 1953). The Sūtra method has its own traditions (Patanjali, 2015; B. N. Sharma, 1986; Vidyabhusana, 1930), and an extended history. But this alone does not explain why modern students should respond to it with such enthusiasm. Here we suggest an entirely new idea to explain the inherent exhilaration and happiness that accompany recognition of a way to solve a problem. We suggest that discovering, or just recognizing, an approach to appropriately solving a problem stimulates the endorphin system, a new dimension in understanding the power of creative thinking. First, we therefore review the role of the endorphin system in human biology.

7.6.3 Vedic Maths and competitive exams

In recent years stress has become a major factor affecting lives of children facing competitive professional examinations in the years before university (Kadapatti et al., 2012). This may be due to monotonous book-based teaching methods, which have created learning difficulties in education (Penso, 2002). Mathematics is a subject that many students find very challenging, and which can increase students' reported levels of stress (Geist, 2010) more than other subjects. Most high paid private sector jobs like basic engineering or other professional degrees require mathematics as a major subject. These circumstances have made emotional stress a major problem for students attempting to enter the college or university course of their choice (Spangler et al., 2002). Frustration can lead to increase in aggression (Gustafson, 1989) towards teachers and fellow students, and other antisocial behaviour patterns (Veenstra et al., 2006). In schools, competitive professional examinations select those entering higher education for various professions. Today, they put new pressures and workloads on schoolchildren that some even argue to be unnecessary. Reducing the effects of such pressures is a matter of national urgency.

Every student dreams about their future career. Some think to choose police service, some army, banking, business, hotel management, railways, engineering, education department, architecture, research etc. Different fields require different skills: Bodily-kinesthetic, Linguistic, Logical-Mathematical, Musical, Visual-spatial, Naturalist, Interpersonal, Intrapersonal skills; all are well known (Mcfarlane, 2011; Gardner, 1999) and used to make educational experience happier at institutions like Aurobindo schools. Logical-Mathematical skill plays a major role in careers where systematic, organized approaches are required. This skill includes calculation, generalization, categorization, inference, classification, cause-effect related statements or propositions and hypothesis testing (Hernández et al., 2010). In Gardner's words, this skill involves abilities to detect patterns, reason deductively and think logically (Mcfarlane, 2011). Patterns can be visual, full of colours, thoughts and numbers. Logical mathematical persons are inclined to think conceptually and abstractly. They effectively handle puzzles, experiments, classifications, categorizations and working with numbers and formulae. They are good at identifying relationships between different things. They can understand complex ideas and perform scientific investigations. On the other hand, students with high visual-spatial intelligence are good at remembering images, and fine details (H. Gardner, 1999). One study using brain imaging techniques found that logic and mathematics emerge and evolve through visuospatial cognition and language (Houdé et al., 2003). Links between these two skill sets have thus been established.

A possible way to nourish these skills is to introduce Vedic Maths methods (Bharati Krsna Tirthaji Maharaja, 1992) for problem solving. Vedic Maths offers easier means to perform mental calculations, which in turn decreases duration of time spent on a problem. Time estimation experiments, using subtests of the Wechsler Adult Intelligence Scale (WAIS) intelligence test conclude that time estimation specifically predicts mathematical intelligence, and that both rely on spatial ability (Kramer et al., 2011). Vedic Maths methods are faster and pattern focused, and may positively impact visuospatial cognition, enhancing logico-mathematical skills.

All Indian time bounded competitive examinations such as JEE Mains, JEE Advanced, K-CET, BITSAT, EAMCET, GATE, CAT, MAT, NDA, CDS, SSC etc. test speed of calculation and logical mathematical skills. Appendix 1, Table 21 lists examinations and respective courses deciding student careers where Vedic Maths methods can reduce time duration compared to conventional methods.

India's present examination-oriented education system puts students under stress, specifically cognitive stress. Math Anxiety can be remediated by i) direct math interventions and ii) reducing negative emotions. This thesis explores Prāṇāyāma (well known to reduce anxiety) and Vedic Maths (also known as speed maths) as remedial options to reduce negative thoughts and enhance positive thoughts during mathematics tests, thus reducing Math Anxiety and improving performance on exams.

7.7 IMPLICATIONS THAT VEDIC MATHS METHODS RELEASE ENDORPHIN

7.7.1 Endorphins and the endorphin system

Recognition that the human nervous system contains endogenous morphine-like molecules was one of the most startling discoveries of late 20th century biology (Pert, 2012). So pejorative were the associations of morphine, and so strongly did respectable citizens rail against those who used them, that the discovery that the human nervous system contained an entire system devoted to their expression – and their experience (!) – was difficult to assimilate and rationalize. Since that time, other associated discoveries have been made, two in particular that one of the thesis guides has been directly or indirectly connected with.

The first such discovery, and one that is very revealing, is that if infants are exposed to molecules that interfere with their endorphin functions, their personality development is severely compromised in that they are at greater risk of developing an autistic spectrum disorder. The major pathway, which has been found to lead to autism this way, is the consumption of milk from Holstein Friesian cows (Woodford, 2009). Digestion of milk from HF cows and some other Bos Taurus breeds causes release of a 7-member polypeptide from beta casein, Beta Caso-Morphin-7 (BCM7), during digestion. (This does not happen with native Indian, Bos Indicus, breeds.) The gut of new-born and very young infants is designed to absorb small proteins like immunoglobulins directly from their mother’s milk in order to strengthen their immune system at the very start of life. A short peptide like BCM7, if released during digestion, is therefore immediately absorbed.

When BCM7 is directly injected into the bloodstream of rats, they are immediately put into an almost schizophrenic state, in which they will damage themselves, and commit vicious aggressive attacks on their neighbours (Woodford, 2009). They seem in great distress and cannot function socially. Direct tests show that their endorphin receptors are interfered with, and that the BCM7 enters the receptor, blocking it permanently, but without stimulating any good feelings. The conclusion proposed from these simple observations is that stimulation of endorphin receptors is intimately involved in successful function of both animal and human nervous systems. Their on-going function is a required aspect of normal personal behaviour.

7.7.2 Endorphin and Yogā: A second observation about autism that may relate to endorphins is that stimulating the mirror neuron system seems to be a successful way to treat the condition. The suggestion that this might be the case was first made by no less a scientist than V.S. Ramachandran (Oberman et al., 2007; Ramachandran et al., 2011). But successful treatment of autistic children by these means was first achieved by Dr Shanta Radhakrishna, the principal of a special school for disadvantaged children in Bangalore. Dr Radhakrishna completed her PhD in medical applications of Yogā, by observing the results of a specially designed program of Yogā for children with autistic spectrum disorders, which she developed and ran for several years at her school with considerable success (Radhakrishna, 2010).

A major design aspect of Dr Radhakrishna’s program was that the child’s parents had to be present at every Yogā teaching session, and their role was to put their child into the position adopted by the Yogā instructor directing the class (Radhakrishna, 2010). Clearly, achieving a similar position to the instructor should stimulate the mirror neurons to fire, and their successful firing should, according to presently known laws of nervous system function, cause increased stimulation of the mirror neuron circuits in the future by means of neural plasticity.

The successes achieved by Dr Radhakrishnan on the children in her PhD research (Radhakrishna, 2010) were quite extraordinary: all the children showed major improvements on a wide ranging battery of tests covering every aspect of autism deficiencies; so great were the improvements that after two years the study participants were effectively out of the classification of autism. Their parents, in particular, were outspokenly appreciative and complimentary about the program's achievements (Radhakrishna, 2010). As persons intimately familiar with all their children's behaviour patterns and habits, parents are undoubtedly as good judges as any scientific test.

The implications that we propose to make from this second observation of children with autistic spectrum disorders is that the condition can be helped by stimulating mirror neuron function. From this there is a secondary deduction to make, based on the observation that autism can be brought on by, and largely attributed to, failure of the endorphin system to provide its pleasant feelings to please the person in question. Autism thus involves a failure of the mirror neuron system to function, as Ramachandran suggested (Oberman et al., 2007), and hypothesized above (Radhakrishna, 2010; Ramachandran et al., 2011). It is thus very probable that *correct activation of the mirror neuron system is associated with endorphin release, and with all the pleasant feelings associated with it*. This idea leads to our main proposal.

7.7.3 The role of the Endorphin System in Normal Behaviour

A major recognition by modern psychologists involved in training children, or even animals, is that good behaviour and successful achievements require appropriate rewards (Spruijt et al., 2001). From this perspective, a teacher smiling and appearing pleased when a student does well, is more important that expressing displeasure when students fail to perform. A student who continually seeks to please the teacher will work far more effectively, than one who only works out of the fear of possible consequences of not doing so.

This principle of '*Rewards for Good Behaviour*' is so deep that it must surely be built into the human nervous systems itself – and indeed into animal nervous systems in general (Ambroggi et al., 2008).

What could be better placed to achieve such a purpose than the endorphin system? Endorphins give one's feelings a boost (Breuning, 2015). If released as a result of mirror neuron function, it would be the nervous system's way of saying that imitation represents a useful behavioural pattern, long-term persistence in which will serve the person well. Such feedback from the nervous system to the organism would be abundantly valid: from a very early age, babies and young children learn more by imitation (and experimentation) than by instruction.

Consider then, this hypothesis: *endorphin is released to encourage kinds of behaviour that will increase success in life*, i.e. the endorphin system constitutes the body and mind's own positive feedback system, internally validating appropriate behaviour. The suggestion that this may be the case arose by considering the example of how autism resulted from blockage of endorphin system function (Weizman et al., 1984), and how stimulating mirror neurons reversed it (Yorke, 2010). Next, let us generalize this principle to other kinds of behaviour**.**

7.7.4 The Endorphin System in Human Behavior: a General Role

The general role of the endorphin system is to encourage kinds of behaviour that will increase success in life by providing positive feelings as feedback when such behaviour is expressed (Breuning, 2015).

Similar to the statement above, behaviour patterns of value to achievement and success are reinforced when students receive appropriate rewards for expressing them. In other words, learning good behavioral patterns may be facilitated by positive feedback. This principle is well recognized by child psychologists, and sports psychologists, so it is almost inevitable that over the millions of years of biological evolution nature has implemented something similar.

Vertebrates emerged from the sea some 380 million years ago; mammalian development was accelerated by the demise of the dinosaurs about 66 million years ago; some warm blooded land animals like birds (related to dinosaurs) and mammals survived the catastrophe, whereas monsters became extinct (NCERT, 2013). Land vertebrates tend to be social animals with consequent need to learn specific patterns of behaviour, and all the social messages that such behavioral patterns encode. Animal behaviour is not simply guided by instinct, but must be learned from practices of the family group into which animals are born, i.e. patterns that have already been structured into forms appropriate to the environment in which they live (Tierney, 1986).

The only practical way for an animal to learn the behavioral practices of their family group is by copying them, an action that will automatically cause mirror neurons to fire. To encourage such copying, individuals are rewarded in some way. This also applies to adults in the group, who must also be programmed to reward imitative behaviour in their offspring and other group members.

Imitation of adults by juveniles will be facilitated if firing the mirror neuron system brings a positive subjective reward (Iacoboni, 2009). Similarly, recognition of imitation by their young may elicit an appropriate positive response in parents and other adults in the social group, if perceiving the imitation makes the adult feel good. This means that the mirror neuron system may stimulate rewards for the young animal on two levels: first and most important, intrinsic because of connections to the endorphin system, as has here been hypothesized, and secondly and secondarily, extrinsic, due to positive feedback from other animals in the group. For these reasons, coupling of the mirror neuron and endorphin systems probably plays a fundamental role in behavioral learning in social animals.

What of other forms of behaviour? What patterns of behaviour might be worth reinforcing by eliciting positive feedback from the endorphin system? In human societies, one can envisage several general patterns for which our species' success would be strengthened by similar kinds of reinforcement process. Clearly, satisfying the basic needs and instincts would qualify: eating, drinking, sleeping, reproducing and rearing offspring ("Theories of Motivation," n.d.). But higher animals consciously living in challenging environments, with which they continuously interact, require reinforcement of further behaviour patterns (Department for Education and Skills Welsh Government, 2012). For example, behaviour patterns that help overcome new and challenging situations, and behaviours that can remove stress so caused, restore health when it is compromised, and maintain optimal function in various ways.

For example, nervous systems are designed so that deeply resting promotes removal of the stress from adverse events (J M Broadley et al., 2003), and that of associated memories like the slaughter of another member of the social group. Elephants mourn the loss of a fellow group member for a period of two days following a death. Reports from ancient Yogā traditions, affirm that deep rest to the mind induced by meditation is accompanied by an intensified sense of inner happiness (Campos et al., 2016), the neurochemical nature of which still remains to be studied. Another pattern of behaviour meriting positive reinforcement is when an animal recognizes a solution to an unfamiliar problem (Dow, 1990).

7.7.5 The Endorphin System and Creative Thinking

Creative thinking is much valued in human society. We live in an age where inventiveness is highly rewarded, because whole societies may benefit. New technologies are protected by patents. The founders of Apple and Google, not to speak of Microsoft, are some of the most richly rewarded people on the planet – and for good reason, their inventions have changed the lives of vast numbers of people, often making them happier and more at ease.

Great inventions either tackle problems that most people consider insoluble, or create opportunities that no one has realized are possible. We all take the internet for granted, but the amount of information now available for download is far more than any human can digest in a life time. Similarly, the amount of entertainment in the form of films and music is far greater than a lifetime of viewing or listening can take in.

Creative thinking works in everyone to a greater or lesser extent. At some time, all of us are faced by situations with which we are not familiar; we all need to be able to take such eventualities in our stride. Living life in the world as we find it requires more than a healthy routine to keep up with the day-to-day humdrum; it also requires initiative to do new things, and the ability to deal with the unexpected, and to succeed when doing so. Creative thinking when faced by unanticipated new situations is a capacity of intrinsic value to life in the world and worthy of encouragement.

Clearly the world rewards capacity to deal with such problems creatively – it provides good external feedback, and extrinsic rewards, and does so even for life in the wild. The hypothesis that nature offers some *intrinsic* reward to encourage the process of creative thinking therefore seems reasonable. Consideration of the creative arts confirms the hypothesis. Leaders in painting, music, sculpture and architecture and other fields requiring creative design, engineering or composition, report that forming and implementing their creative ideas brings high *intrinsic* enjoyment. Whether creation or performance, all such activities employ inherent human creative capacities.

From a practical viewpoint, a member of any species that actively creates new ideas, or implements useful new actions and activities, is doing something of high intrinsic value. How to respond if the rainy season is delayed? What to do if an ocean current is temporarily reversed? Living creatures have had to tackle such questions for millions of years. In dealing with climate change or preserving endangered species, humans do the same today.

Because of historical needs dating back through the history of life, the mind has been inherently structured to encourage creative thinking. Our assertion here is that it does so by giving positive feedback, special rewards of an inherently pleasurable nature, probably in the form of endorphin release. This is certainly not a modern development. As suggested, generating new ideas that appropriately apply in the life of their species is important for all animals living in challenging environments. All require new kinds of adaptation. Humans today apply new ideas through systems of science and technology, and all forms of art and communication. Those engaged in such processes find them delightful and rewarding.

Creative insights are universally recognized to bring a special form of pleasure (Dow, 1990). Even putting one's attention on another person's artistic or literary creations may bring something of the same – the viewer may experience a vicarious sense of the original creator's creative talent. It is probable that nature has long encouraged such activities in those capable of them. What better way than by releasing endorphin when an appropriate new idea is generated? And implemented.

We all know that when maths problem solving is taught in ways stifling creativity, the process generates low levels of enthusiasm in the student, if any; more likely, boredom. When the same tasks are taught in ways that encourage use of students' inherent creative potential, they respond quite differently – with refreshing levels of enthusiasm. In light of the foregoing, we suggest that they are experiencing the brain's intrinsic reward for using creative thinking processes – a healthy shot of endorphin from the endorphin system, and a corresponding sense of bliss in the mind.

Applying these ideas to Vedic Maths offers a possible explanation for why learning mathematics through Vedic Maths Sūtras is more enjoyable than learning the fixed routines of ordinary mathematics education. If endorphin release is a normal reward by the nervous system for creative thinking, then the methods of Vedic Maths, involving creative thinking in its procedures, will inevitably prove more enjoyable than solving problems the conventional way, by using fixed methods. People know well that, ultimately, routine and repetitive processes prove boring. If creative processes release endorphins, then the methods of Vedic Maths, identifying possible procedures, and then choosing between them, should definitely release them.

There is considerable evidence that *ideas are more fundamental than language*. Multi-lingual people translate directly from the level of ideas to the level of words, without reverting to their mother tongue. The Vedic science of Shiksha refers to the level of ideas as Pashyanti, and places it prior to the level of words apprehended mentally, Madhyama. Generating ideas is therefore something natural to the mind. It should be able to make that a habit. Endorphins are well-placed to encourage that. The proposal that their release is used to provide operational feedback to creative thinking processes seems a natural extension of what is already known.

As emphasized above, students find the approach of Vedic Maths enjoyable – often remarkably so. Systematic, repeated observations require systematic explanation. Reasons should be offered why learning to apply the Vedic Maths Sūtras and Upasūtras is enjoyable for all students. No other academic subject in the school final exam syllabus seems to offer such pleasurable rewards.

Although the purpose of the endorphin system has not been fully worked out, it is known that stimulating it makes people happy and calm, even euphoric i.e. like experiences seen in maths classes taught using the Vedic Maths procedures. Making connections between the two fields, endorphin neurophysiology on one hand, and educational psychology on the other, is natural.

Logically, the reasoning was presented in 3 steps: first, a key observation that suppressing the endorphin system in infants leads to autism. Our first conclusion was therefore that that system must play an important role in generating healthy attitudes and mental function. Second, another major use of the brain: deciding on courses of action in novel situations, or how to achieve some new goal. Third, reasons why creative thinking processes should be stimulated through appropriate intrinsic rewards.

From the apparent repression of the endorphin system in the first step, we made a very general hypothesis about the natural feedback role of the endorphin system: *Endorphin* *is released to encourage kinds of mental process that will increase competitive success in a competitive environment*. Finally, we used the observation that methods used by Vedic Maths generate mental activity in this category. They should therefore stimulate endorphin release. This line of reasoning more deeply explains the remarkable positive feedback given to teachers using Vedic Maths by students. It also begins to explain the decreases in Math Anxiety.