M.Shaheen, Keele University

How numerical ability in students is improved by the relationship between Neuroscience and Education

Neuroscience has been criticised for adding a scientific attire to its interdisciplinary counterparts. In this poster we will be looking at the relationship between Neuroscience and Education and how this relationship is submissive to the progression of learning and education in the classroom. There is a proven immaturity in the performance and research of numerical reasoning in the field of education.
By outlining present and future methods of intervention, from a neuroscientific approach, the critical nature of interdisciplinary intervention is highlighted.

THE GENERATION WHO CANNOT ADD ✚ ✖ ✚ And what are we doing to do about it?

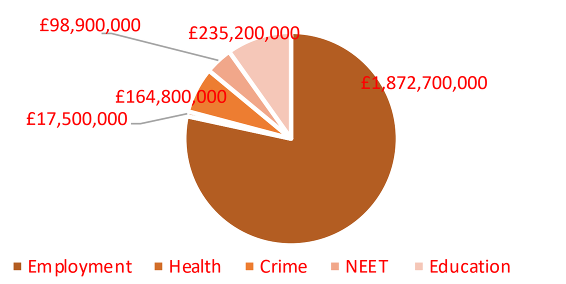


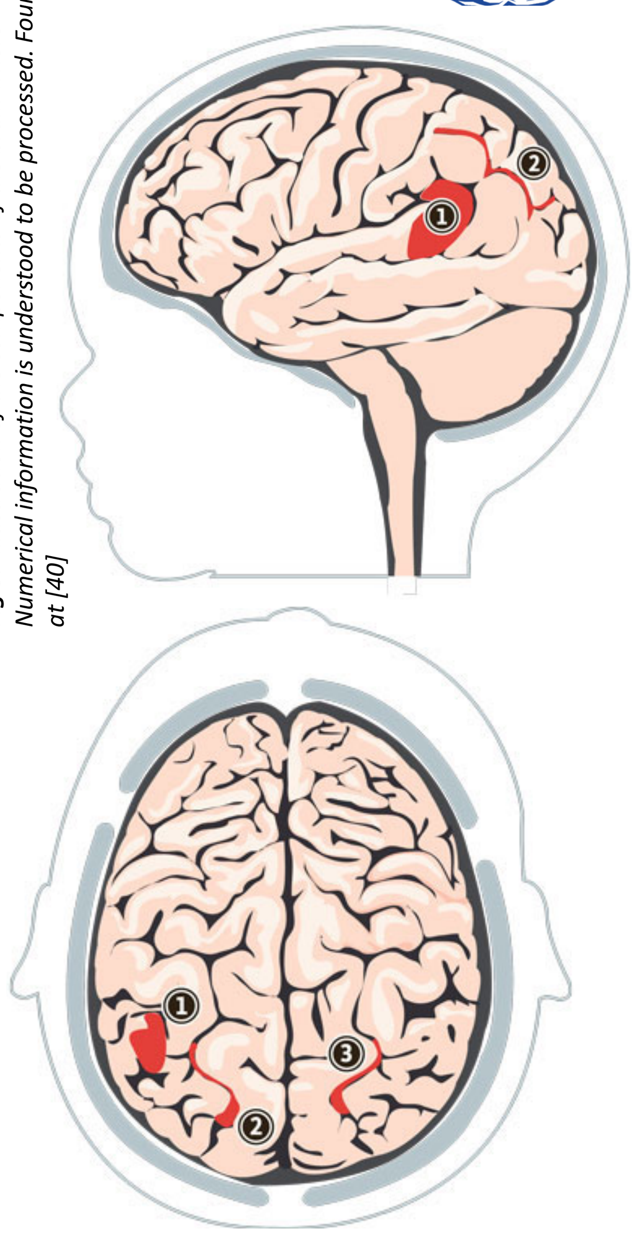
Fig 1. The breakdown of the annual, lifetime, long term costs of an annual cohort of 35,843 children to the public purse incurred as a result of failure to address early numeracy difficulties. Total cost equating to £2389.1 million [1]. A detailed account of findings is given by [1]

- Approximately 20% of the population have a low numeracy skills. Depending on the diagnostic criteria, 3-13% have acquired a more serious disability relating to numbers [32]
- Men and women with poor literacy and poor numeracy had the lowest levels of full- time employment in their age-group. We see that there is a clear disparity in results where 95 percent of their time was spent in full time employment whilst incompetent spent 75/70 percent of that time unemployed. Men and women with poor numeracy were more than twice as likely to be unemployed as those with competent numeracy [33][34]
- The implications of a widespread incompetency at mathematics has mental, social and educational effects. See Fig 1. [1].
- In investing money into intervention methods, the turn out profit exceeds the cost that is put into compensating for incompetency. A progressively better intervention method will therefore deem profitable [33][34][32][35].

Mental arithmetic

from the inside

Fig 3. Illustration of the components of the brain where Numerical information is understood to be processed. Found at [40]



Math is a series of conceptual and procedural competencies. Numerical cognition is non unitary and various parts of the brain can be identified in having a integral role in processing simple and complex mathematical knowledge. The bridge between simple numerical problems to more complex ones is dependent on numerosity and magnitude. By identifying this bridge, methods can be employed to improve its scaffolding

1 Parietal Cortex

Associated with numerical representation in the brain [2], with sensitivity to very specific numbers more than others [2][3]. The left IPS to right IPS is developed through age relatively [4][5]. Other visuomotor activities are governed in this area too. Because of this numerical ability is understood to assess the magnitude of space numbers and time, independently [2][6]

2 Temporo-parietal junction

The role of the Left angular gyrus allows the retrieval of arithmetic facts [7] when solving addition, multiplication,
addition and subtraction. The numerical judgement of symbolic information is better identified in this area of the brain than non symbolic information (such as dots). [8][7]

3 Prefrontal Cortex

The role of the prefrontal cortex is predominantly involved in the domain activities related to executive function, problem solving etc. [9]. Simultaneously, the PFC and Parietal Cortex are involved when doing arithmetic [7][11][12]

Theory of numerical learning

The Triple Code model [10] allows us to understand the stages in which mathematical information is encoded. A quantity system provides a non verbal semantic representation of size and distance (non-symbolic). A verbal system is employed for repetition and rote learning using the left angular gyrus in phonologically, lexically and syntactically encoding information. Using the superior parietal lobe, verbal methods are used to help students orient with spatial attention. [28]
Magnitude and non symbolic representation of numerical information is widely encoded in the right IPS, shared by animals, distinct from literacy [13][14][15][28]
Approximate Number system (ANS)- The larger the numbers are, the greater the rate of imprecision. A greater discrepancy is observed in larger numbers [13][16][28]
Subitising effect is seen that for items less than 4, estimation time is equal. As items increase, time for estimation does also. [17] [28]
Spatial orientation is also rather pertinent in the representation of information. Children observe numbers using a logarithmic scale (due to magnitude effects [14]). This is further supported by the use of body parts as a counting tool [18][20][28].

When things go wrong

Developmental Dyscalculia & Math Anxiety

Developmental dyscalculia (DD) affects 3.565% of the population [19][21] with a greater effect on life achievement than dyslexia, its literacy counterpart [21][1]. DD is understood to incorporate problems that pertain to the inability to subitize a small number of objects, present magnitude well and retrieve simple mathematical facts. Acquiring numerical meaning via symbols becomes increasingly difficult due to the inability to process numerical magnitude correctly (or well)[21][22][23]. Deficits are observed in parietal, temporal and frontal areas (by deficient fibre projections [25][22]) suggesting a Disconnection syndrome is present [28]

Math anxiety is rather pertinent to mention due to its relation to both cognitive ability but also emotional factors [26][27][28]. Continuous failures are fed as information into the brain which results in the learning of this behavior, with little effort and progression given to improving numerical ability. Therefore the cognitive effect of math anxiety is a product of social and emotional influence[28][29][31]

Intervention ✚ ✖ ✚ ✖ ✚

Present & Future

Targeted intervention using neural and anatomical mapping: the componential nature of arithmetic and its mapping across the brain helps identify areas with specific functions [21] Targeted programmes use intense individualized intervention per day. Working with the lowest 5%, progression is effective and substantial. A less costly approach is also observed with Catch Up numeracy using Numeracy recovery scheme [36] has observed an improvement as much as twice in performance than matched non-targeted intervention. See Fig 2. There is also information in the way in which DD is diagnosed and understood. Better neuro markers during mapping whilst numerical tasks are being conducted helps provide a better and more targeted response and prediction of future progression of DD [36]

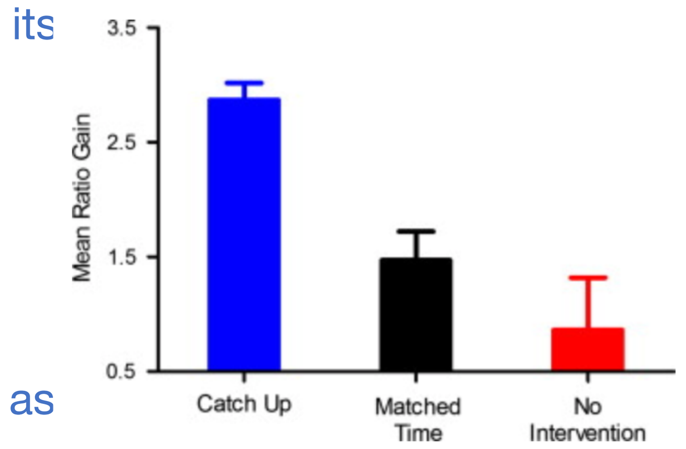


Fig 2. The effect of the Catch Up intervention program [36]. 395 students received the intervention program. Control groups were made of Matched Time individual strength and weakness and those with no intervention. A detailed account and findings outlined in [36]

Computer-based programmes: A neuro inspired computer-based math game had presented a correlation between change in numerical perception and DD [37]. Atypical brain activity observed In DD and other math disorders has shown positive effects from game like activities [37][36]. This is supported by both fMRI and EG with presence of neuromarkers [36]

Future of conversation? The relationship between neuroscience and education is one that has predominantly existed independently. There seems to be a great deal of explaining provided by each field respectively with very little conversation. Because of this, the applicatory benefit of what is founded on educational or neurological grounds remains deprived of its full purpose and power. Better conversations between neuroscience and education will allow the assessment of the efficacy of any type of intervention used in either fields. It allows us to make more progressive and conversational improvements, both at a behavioural and neural level. There is immense benefit of optimization of efforts and by pairing this with cognitive ability we see that there is a direct and substantial effect in better and more informed improvements in education