Dyscalculia wheres the difficulty education essay

Mathematics is a subject that is challenging for almost every learner, during all the years of education. However, there are a great number of pupils that experience this challenge, in an even worse degree. These learners have to deal with a difficulty called, dyscalculia. Dyscalculia is a specific learning difficulty, which characterises a number of people, who face severe difficulties in mathematics, and it is caused by a combination of biological, environmental and cognitive factors. The focus of this essay, will be on explaining in more detail, two specific difficulties that are related to dyscalculia. These difficulties are, the numerosity difficulties, which are basically difficulties in understanding the most basic principles of mathematics, and the difficulties with number processing and calculation, which are related to the way individuals, process the numbers, in order to make mathematical calculations and solve arithmetical tasks.

A new phenomenon has drawn the attention of researchers in the area of learning difficulties, the last few years. This phenomenon is associated to the area of mathematics, and specifically, to the difficulties that learners have in the particular area. A great number of pupils have difficulties in understanding the complex concept of mathematics, something that does not necessarily mean that these difficulties are caused by a learning disability. However, there are several learners that have an " extreme difficulty in Mathematics" (Reid, 2003, p. 252), a difficulty that is related to a specific type of learning difficulties, which is called dyscalculia.

Dyscalculia can be defined as " a condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have

problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence" (DfES, 2001). In other words, learners, that are dyscalculic, may have difficulties, not only in the procedures that are important in solving a maths problem, but also they may have difficulties in understanding the basic notions of mathematics, such as what does the magnitude of a number represents or what the maths symbols signify. Therefore, the difficulties that dyscalculic learners face, in the area of mathematics, can be rightly considered as more severe than the difficulties that pupils, who don't have a specific learning difficulty, face in maths.

Regarding the causes of dyscalculia, there seems to be a variety of biological, environmental and cognitive factors that lead to this learning difficulty. In particular, a study by Shalev et al. (2001) revealed, that children, who have siblings with dyscalculia, are at a very high risk of becoming dyscalculic, in comparison with the general population. This study supports the idea that was firstly introduced by Kosc (1974), which proposes that dyscalculia is related to genetic factors. This idea is also supported, by a research with monozygotic and dizygotic twins, which revealed a percentage of 58% and 39% respectively, between the siblings, in the emergence of dyscalculia (Alarcon et al., 1997).

In addition to this, there also seem to be some differences between dyscalculic individuals and individuals who don't have a difficulty in maths, in the way their brain functions, during mathematical procedures (Shalev and Gross – Tsur, 2001). According to several researchers (Levin et al., 1996; Levy, Levy Reis and Grafman, 1999), who studied the brain activity of two

dyscalculic adults during " arithmetic processing" (Shalev and Gross – Tsur, 2001, p. 339), there seems to be a unilateral activation of the frontal and parietal areas of the left hemisphere of the brain and also a deficiency in the parietotemporal region of the specific brain hemisphere, in dyscalculic individuals. On the contrary, individuals, who don't have a specific learning difficulty, during mathematical procedures, have a bilateral activity on their " prefrontal and inferior parietal cortices" (Rueckert et al., 1996 in Shalev and Gross – Tsur, 2001, p. 339) rather than a unilateral activation. One cannot be sure though how accurate is this fact about dyscalculic individuals, because the studies, that took place in order to examine the brain differences of dyscalculic individuals in comparison with the general population, had a sample of only two people with dyscalculia, who were adults. This small sample may not be very representative of the dyscalculic population in general, and therefore the suggestion that there are differences in the brain activity of dyscalculic individuals, in comparison with individuals without maths difficulties, during mathematical procedures, may not be factual and may need further examination.

Furthermore, there are several researchers, who don't believe that dyscalculia, is a learning difficulty that has a biological basis. They consider a number of environmental factors to be more accurate in explaining the nature of dyscalculia (Shalev and Gross – Tsur, 2001). Specifically, they believe that factors, like not having the opportunity for a proper education (Miller and Mercer, 1997; Gifford, 2005) or not being confident about your mathematical skills (Gifford, 2005), is the reason why several learners have dyscalculia. However, one cannot be absolutely sure that the difficulties, an

individual has in maths, because of these factors, could truly cause dyscalculia or if they just characterise an average person, who has several difficulties in maths which can be reduced by improving these factors. Maybe further research, which will examine if dyscalculia stays persistent even after improving these factors, could solve this reflection.

Another environmental factor, which may lead to dyscalculia, is the anxiety that is generated to the learner, because of maths (Ashcraft, 1995). According to Ashcraft (1995), maths anxiety can cause dyscalculia, because learners with this type of anxiety tend to feel really nervous when they have to deal with maths, something that makes them to do mathematical calculations really quickly. Therefore, the learners, because of their hastiness in making mathematic tasks, they may have low performance and inaccurate results in mathematics, something that could be considered as dyscalculia or it could make the situation for a dyscalculic learner even worse (Ashcraft, 1995). Also, maths anxiety could lead to low self – confidence. Still, it is more possible that maths anxiety worsens and not causes dyscalculia or math difficulties in general, because if dyscalculic learners are " forced" to make arithmetical procedures hastily, then they probably will make more mistakes or they won't be able to solve a maths problem at all, because of the pressure they might feel. Furthermore, maths anxiety is something that all students and not only dyscalculic students may experience at some point, as a result of the complex nature of mathematics, and therefore its causal role for dyscalculia is questionable. Overall, one may assume that maths anxiety is not necessarily a causal factor for dyscalculia, but it is a characteristic that a dyscalculic learner could present.

Regarding the cognitive factors that are responsible for dyscalculia, there seems to be a belief that a dysfunction on the visuospatial abilities or the verbal and auditory comprehension abilities, of an individual, can cause dyscalculia, as well as other cognitive disabilities (Rourke, 1993). In addition, several other researchers (Geary, 1993; Koontz and Berch, 1996) believe that problems with the working memory, can also lead to dyscalculia, because it affects the effort of learners in performing mathematical procedures. According to a research by Temple and Sherwood (2002) though, children with dyscalculia didn't have any differences in comparison with children without dyscalculia, in any of the tasks that measured their working memory, and also a correlation between the working memory and the arithmetic ability measures, was not found. Therefore, it is not certain if working memory difficulties have a causal role in dyscalculia or if they appear at the same time with the difficulties that are linked to dyscalculia (Butterworth, 2005).

Overall, a combination of all the factors, that are considered to play a causal role in the development of dyscalculia, may clarify in a better way the concept of dyscalculia. This is because, dyscalculia seems to be a disability that is more possible to be generated by a great number of factors, just like dyslexia (Frith, 1997), rather than by only one, and therefore, it could be better understood if it was seen as whole. That is, to be seen from all the aspects that could generate it, rather than from one aspect only.

A better understanding of dyscalculia may also arise by examining the difficulties that are linked to it, and not only be examining the causes of it. Specifically, there appear to be several difficulties that can be identified on

dyscalculic learners, difficulties, which in a way, are connected with each other.

These difficulties have to do, with the way learners comprehend mathematics from their simplest form to their most complicated one. In particular, they have difficulties with understanding arithmetical concepts, like the numerosity of a number that refers to understanding the magnitude of a number, with the processing of mathematical facts and the calculation of them, which refers to how a learner processes the numbers and the maths symbols that he sees in order to solve a task, and also with difficulties that may be associated with other learning difficulties, such as dyslexia and ADHD, because of the high co morbidity there is between dyscalculia and these two learning difficulties (Shalev and Gross – Tsur, 2001; von Aster and Shalev, 2007). For example, in the case of co – existence of dyscalculia and dyslexia, the learner has maths difficulties that are related to language, such as reading mathematical problems and solving maths exercises following the correct sequence (Reid, 2003; Bennett, 2006). In the case of dyscalculia and ADHD, a possible difficulty that a learner may have, is not being able to finish a maths task, because of the lack of concentration he may present, something that usually characterises learners with ADHD. This difficulty may also be present to dyslexic learners as well, because of the high co morbidity there is between dyslexia and ADHD, and therefore a learner may have dyscalculia, dyslexia and ADHD concurrently (von Aster and Shalev, 2007). From this, one can assume that there are four categories of dyscalculic learners; learners with dyscalculia alone, learners with dyscalculia and

dyslexia, learners with dyscalculia and ADHD, and learners with dyscalculia, dyslexia and ADHD.

Even though the issue of the difficulties that a learner may present, because of the co morbidity between dyscalculia and these two other specific learning difficulties, seems to be really exciting and interesting, this essay will focus on the difficulties that characterise learners with dyscalculia alone. Specifically, it will focus on the difficulties that dyscalculic learners have with numerosity, number processing and calculation of mathematical procedures, rather than on the difficulties that result from this co morbidity.

In particular, the first difficulty mentioned above, which is numerosity, refers to the abstract form of numbers, which reveals their magnitude (Butterworth, 2005), and it should be the first thing that learners should learn, in order to be able to understand mathematics. As Butterworth (2005, p. 3) indicated, numerosity can be the " basis of arithmetic". The numerosity refers to an abstract type of numbers, because it is possible for numbers to be arranged in different sets that can be represented by different parts, which may have abstract or concrete substance, like straws, sticks, " sounds" etc. (Butterworth, 2005, p. 3). In addition, when several parts are being put in a specific set to form a number, something that represents the numerosity of this set, the learners can easily understand them, in comparison when they see these parts (e. g. dots on dice) in a different order (Mandler and Shebo, 1982). Therefore, numerosity is significant in learning and understanding the numbers, and what these numbers represent, especially when it is presented in specific groups.

According to Butterworth (1999), there are four principles that a learner should follow in order to comprehend what numerosity is. Firstly, he must know the " one – to one correspondence principle" (Butterworth, 1999 in Butterworth, 2005, p. 4), which refers to the ability of a learner to recognise when the numerosity of two sets of numbers is the same, by examining the parts of each set which must correspond to each other (Butterworth, 2005). In other words, in order for two sets to have the same numerosity, they must be constituted by exactly the same number of parts. Secondly, it is important for the learner to understand that numerosity is a variable and not a fixed concept and that different sets may have different or the same numerosity. Thirdly, the learner must have in mind that numerosity can be abstract, and therefore the sets may be represented not only by concrete things but by invisible, " abstract things" (Butterworth, 1999 in Butterworth, 2005, p. 4) as well. Finally, it is important for a learner to be able to identify numerosities of sets of four objects the most, without needing to count them verbally. One can suppose that these principles are truly essential in order for a learner to be able to understand the complex meaning of numerosity, because in fact, these principles compose the concept of numerosity. Therefore, by being able to comprehend these aspects, a learner will be able to understand numerosity as well.

Regarding the abilities that a learner must have, in order to have an appropriate understanding of numerosity, Piaget (1952) talked about three basic abilities. The ability to " reason transitively", the ability to understand the stability of the number of items in a set, and the ability to recognise the abstract nature of the items that form a set despite their personal

characteristics, like their colour or shape (Piaget, 1952 in Butterworth, 2005, p. 4). Specifically, the first ability refers to logical calculations that a learner can make, after examining several facts. For example, if there are three items, from which the two have the same size and the third is smaller, then the learner must be in position to identify that the third item will be smaller not only from the first item, but from the second item as well. The second skill that should characterise a learner, in order to possess the idea of numerosity, is to know that the number of items in a set will not change if there is a modification in their sequence, except if an item is removed or added to the set. The third ability, is relevant to the suggestion made by Butterworth (2005) regarding the abstract character of numerosity and also the " one – to – one correspondence principle", because it has to do with the fact that the characteristics of the items of a set cannot affect its numerosity, and therefore it is possible, two sets that are structured by different items, to have the same numerosity.

The principles, mentioned by Butterworth (2005), and the abilities, mentioned by Piaget (1952), about the comprehension of the concept of numerosity, may be affected in dyscalculic children, because these children have already problems in understanding the general idea of numerosity (Butterworth, 2005). Specifically, children with dyscalculia seem to have difficulties in comparing the magnitudes of several numbers (Geary, Hamson and Hoard, 2000) and also in counting tasks (Koontz and Berch, 1996), something that could lead to the conclusion, that these children have numerosity difficulties, as numerosity is the basis of this type of abilities.

Regarding the counting skill, in order for a child to be able to count, he must firstly know the counting words, then he must connect each counting word with only one object, and finally he must have the awareness that, the last counting word he says, is the total number of all the things in a group that he counted, something that basically is the numerosity of the group (Butterworth, 2005). These three characteristics represent the three " principles", which were suggested by Gelman and Gallistel (1978) to be essential for the ability to count, and they are called, the " stable order principle", the " one – to – one principle" and the " cardinal principle", respectively (Gelman and Gallistel, 1978 in Butterworth, 2005, p. 7). Two other principles were indicated by Gelman and Gallistel (1978 in Butterworth, 2005, p. 7) as well, which are the " abstractness" and the " order – irrelevance", and refer to the ability to recognise the abstract nature of numbers, something which was noticed by Piaget (1952) as well, and the awareness that the order, in which a learner starts to count the items in a group, is not important, as long as he counts each item only once. The principles indicated by Gelman and Gallistel (1978), depend on the principles of numerosity and therefore, in order for a learner to encompass these principles, he must first encompass the idea of numerosity (Butterworth, 2005)

A dyscalculic learner may have difficulties with counting, because as it was noticed by Geary (1993) and Koontz and Berch (1996), dyscalculic children may have several difficulties with their working memory, and therefore they will find it difficult to count a large amount of objects. This is because, they probably won't be able to maintain in their memory the number of the items

that they have already counted, in order to count the rest of them and therefore to find the total number of the items. This difficulty seems to be associated with the third principle, which was indicated by Gelman and Gallistel (1978), because if a learner is not able to remember the items that he counted until one point, he may then consider as the last number of a set, which will represent the total of the items as well, an incorrect number. In addition, sequential and visuospatial difficulties (Bennett, 2006; Rourke, 1993), that usually characterise dyscalculic learners, may also affect a dyscalculic learner's skill to count, because he may find it difficult to count an item only once, following the " one – to – one principle" (Gelman and Gallistel, 1978 in Butterworth, 2005, p. 7), because of the confusion he may have about the sequence of the items. Therefore, one can assume that this kind of difficulties, affect not only the ability of a dyscalculic learner to count, but his knowledge about numerosities as well, as numerosity is essential for counting.

These particular difficulties, can lead to the appearance of other maths difficulties as well. These difficulties have to do with the number processing and calculation abilities. According to McCloskey, Caramazza and Basili (1985, p. 173), the number processing skills, have to do with the ability of a learner to understand and produce numbers, and the calculation skills, refer to the " facts and procedures" that are necessary in making mathematical calculations. In particular, McCloskey et al. (1985, p. 173) referred to two different systems that are related to these skills, which are the " number – processing system" and the " calculation system".

The number – processing system, is composed by two subsystems, the " number comprehension subsystem", and the " number production subsystem" (McCloskey et al., 1985, p. 174). These subsystems include two units, the " Arabic numbers" unit and the " verbal numbers" unit, which have to do with the appearance in which the numbers are presented, either in digit or in oral / written form correspondingly. Each of these units is divided into a " lexical – processing" and a " syntactic – processing" element (McCloskey et al., 1985, p. 173). These two elements are associated to the ability, to recognise each part of a number (lexical – processing) and to the ability to recognise, according to its elements, the specific number (syntactic – processing). For example, if the number 516 is presented to a learner, either in Arabic or verbal form, he must be able to recognise the meaning of each number of the set, something that has to do with the lexical element, and to understand that, with this order, the specific number, will have five hundreds, one tens and six units, a procedure that depends on the syntactic element (McCloskey et al., 1985).

Dyscalculic learners may present difficulties on one of the subsystems of the number – processing system and consequently, on one of the units or the elements that these two subsystems include. Specifically, a research by Benson and Denckla (1969) with one dyscalculic individual, revealed a difficulty in the production of numbers of both forms and in the lexical processing of numbers, whereas the individual's comprehension and syntactic processing components, were fine. In addition, McCloskey et al. (1985) noticed in two dyscalculic individuals, that one of them had difficulties in distinguishing the magnitude of two numbers when those numbers were

presented verbally, and the other individual had difficulties when the numbers were presented digitally.

Even though the difficulties indicated by Benson and Denckla (1969) and McCloskey et al. (1985) are difficulties that a person could notice in dyscalculic learners, one cannot be sure about the reliability of the results of the specific studies, because the sample they used was really small and because the studies took place several years ago, and consequently the particular results, may not be adequate for today. However, some of these difficulties, like in the case were the individual had to compare two numbers about their magnitude, seem to be associated to the concept of numerosity mentioned above, and therefore these difficulties, may be sufficient in characterising dyscalculic learners.

Regarding the calculation system that was indicated by McCloskey et al. (1985), it is constituted by three units and it depends in some point on the number – processing system. These three units, work independently from each other, and have to do, with the way the maths symbols, or words, are processed, with the " arithmetic facts", and with the " calculation procedures" (McCloskey et al., 1985, p. 179).

The first unit refers to the ability of a person to understand what calculation he must do, in relation to the maths symbol or word that is presented to him (McCloskey et al., 1985). For example, when a person sees the symbol " x" or hears the word " multiply", he knows that the operation he must do, is multiplication. However, a dyscalculic learner may confuse the arithmetic symbols and, even though he may know the right answer, he may answer

incorrectly. Something similar happens when the arithmetic symbols are presented with words, but with the difference that when maths problems are related to language, there is a belief by several researchers (Reid, 2003; Bennett, 2006) that these problems are more associated to maths dyslexia rather than to dyscalculia, and therefore this suggestion is more related to the co – existence of dyscalculia and dyslexia, rather than to dyscalculia itself. Overall, difficulties with the arithmetic symbols or words may be generated by visuospatial (Rourke, 1993) or language difficulties (Reid, 2003; Bennett, 2006) that sometimes characterise dyscalculic learners, thus dyscalculia can be characterised by difficulties with the operational symbols as well.

The second unit is related to the ability of an individual to maintain and retrieve from his long – term memory, the correct answers of specific mathematical facts (McCloskey et al., 1985). An example of arithmetic facts, is the knowledge of a learner about the times tables. This unit is independent from the first one, because a learner may have difficulties in recognising the operational symbol, but his answer may be correct when another symbol is used, or he may do the right operation but retrieve the incorrect arithmetical fact. For example, Ferro and Botelho (1980), noticed in a dyscalculic learner, that instead of adding two numbers when she saw the symbol "+", like for example 9 + 2, she multiplied them and answered 18 instead of 11. In addition, McCloskey et al. (1985) observed that a dyscalculic individual couldn't retrieve the correct answer in a case of multiplication, even though he understood the concept of multiplication adequately. Several dyscalculic learners may face difficulties in learning or in retrieving arithmetical facts

(Russell and Ginsburg, 1984; Kirby and Becker, 1988; Geary, 1993; Temple, 1994; Ginsburg, 1997; Jordan and Montani, 1997; Geary and Hoard, 2001; Shalev and Gross – Tsur, 2001), and a reason for this may be the fact, that some dyscalculic individuals have difficulties with their working memory (Geary, 1993) or with their long – term memory, as well (Reid, 2003). This, may limit the ability of a learner to maintain or to retrieve a mathematical fact from his long – term memory, and therefore to cause him difficulties that characterise dyscalculia.

The third unit of the calculation system refers to the abilities that learners have in making mathematical calculations (McCloskey et al., 1985). These abilities are related to the way learners comprehend and learn the procedures of executing math calculations, something that in dyscalculic learners is usually impaired (McCloskey et al., 1985; Temple, 1994; Butterworth, 2005). For example, dyscalculics may have difficulties in completing procedures in which they have to carry a number, whilst doing a maths operation, because of the fact that they may put the number on the wrong place, something that leads to wrong calculations. Also, they may have difficulties with procedures, in which they must do two different mathematical operations at the same time. Both of these difficulties, may be the result of sequential difficulties (Bennett, 2006), or again of memory difficulties (Geary, 1993; Reid, 2003), that are considered to be related to dyscalculia, and therefore dyscalculics may face this kind of difficulties, as well.

The specific model for number processing and calculation abilities, even though it was created several years ago, is in general lines, sufficient in

explaining this type of abilities, in relation to dyscalculia. In addition, the aspects described in the model, seem to be have a common ground with the numerosity, described above, regarding the causes of the difficulties that dyscalculics may present. Therefore, one can assume that similar methods can be used, in order to help a dyscalculic learner to limit his difficulties with numerosity and with number processing and calculation abilities. Specifically, several researchers suggest that multi – sensory methods (Bennett, 2006) in combination with the learners' learning styles (Chinn, 2001; Marolda and Davidson, 2000; Sharma, 1989) can be vital in teaching and helping dyscalculic learners. This is because, by focusing on the way that an individual learns the best, one can help this individual to grasp the concepts of numerosity and of number processing and calculation, in the greatest extent, and by using multi – sensory methods, he will make the learning for the individual to be fun, less stressing and more motivating. With this way, the learner will probably feel more confident, and therefore more determined to improve his difficulties in mathematics.

In conclusion, dyscalculia is a very recent issue in the area of learning difficulties, and