Int J Edu Sci, 21(1-3): 13-27 (2018)
DOI:10.31901/24566322.2018/21.1-3.1034

Arithmetical and Numerical Learning Difficulties in Stroke Cases: A Case Study of Arabic Speakers

Mogbel Aid K. Alenizi

Department of Education, College of Arts and Sciences, Rafha Male Campus, Northern Border University, Rafha, Kingdom of Saudi Arabia (KSA)
Telephone: +966-502570134, E-mail: alenizimogbel@gmail.com

KEYWORDS Acalculia. Anomia. Aphasia. Comprehension. Word Retrieval

ABSTRACT Twenty-seven cases of stroke and five normal subjects as control group were studied to see if their numerical and arithmetical abilities were affected. The tests devised for the cases of strike were aimed at finding out if the patients having aphasia always have acalculia and vice versa; does occurrence of one indicate the presence of the other; or do they occur independent of each other. The study also examines if patients having number recognition problem have anomia, word finding difficulties as well; if number recognition and arithmetical disorders occur as mutually exclusive, or inclusive problems. The study also aimed at comparing the number recognition and numerical processing deficit in cases of suffering neurological damage in the left hemisphere with those of suffering neurological damage in the right hemisphere. Finally the study also reflects the nature of difficulty in handling numbers and numerical processes in the subjects under study.

INTRODUCTION

Calculation is understood as a multi-componential cognitive function and studies have shown that the components of this cognitive function may, sometimes be selectively impaired (Bailey 2013; Liberman 2002). Anatomically it has been suggested that acalculia is associated with the lesion of the left parietal lobe (especially the Angular gyrus), procedural duscalculia has been associated with lesion of frontal lobes (Wirz 1995; Hurford 1987). Researchers suggested that arithmetic ability is associated with small number of foci, with the most significant region located in the left inferior parietal lobe (Broadman area of 39 and 40) (Goodglass and Kaplan 1983; Dehaene and Cohen 1995, 1997; Girelli and Delzer 2007; Narang 2008). In 1995, Dehaene and Cohen designed a more specific model of neuronal network known as Triple- Code Model of Calculation. Their model postulates three main representations of numbers in the brain. A visual Arabic code located to the left and right inferior occipito-temporal areas of the brain. It represents number as the strings of digit. A verbal code located in the perisylvian area of the dominant hemisphere. It represents numbers as sequence of words. A magnitude code is located in the left right parietal areas of the brain.

One form of the phonological storage hypothesis suggests that arithmetic fact is stored in the memory phonologically (Webb 1995; Varley 1997). This theory posits that arithmetic facts are accessed from memory using a phonological representation of the problem. Studies on brain injury patients provide several insights into the cognitive processes involved in arithmetical abilities (Parkin 1996; Levin et al. 1993). Dehaene et al. suggested that mathematical fact knowledge such as overlearned multiplication table is mediated by language in the left hemisphere, while quantitative processing includes subtraction and division which is mediated by the intra parietal sulcus region bilaterally (Howard 1995; Dehaene and Cohen 1995, 1997).

Most of the recent studies are focused on the facts retrievals in arithmetical abilities among the children (Geary et al. 2012; Ritchie and Bates 2013). The cognitive determinants in relation to mathematical skills, that is, a domain general or domain specific approaches and inhibition have been focused of many studies (Cohen et al. 2013; Niklas et al. 2016; Fuhs and McNeil 2013; Gilmore et al. 2013). Monkeys' electrophysiological recordings of parietal cortex shows that neurons on the intraparietal cortex respond to the objects which are presented, and specific numerosities are aligned to the fundus of intraparietal cortex. These responses were mostly in the dimensions of space, time and object size but there was no evidence whether the

numerical responses were different from these (Landerl et al. 2004; Butterworth 2011). It is quite well established from the available studies that the neurological bases of brain disorders or so to say acquired disorders do cause learning difficulties among the learners (Siegler 2011, 2012; Bailey 2012, 2013). In the past two decades, neural basis of numerical cognition has been significantly explored in many studies (Menon 2013, 2015). Dehaene et al. (2003) proposed three different representational codes for numbers and their neural correlates. However most of the studies focused on the mathematical operation and their corresponding neural bases but to see the brain injury bilingual cases respond to various learning disabilities is of importance. Therefore the present experimental study aims to explore and assess the nature of numerical difficulties exhibit by the brain stroke cases or some other kinds of head injury.

Aims and Objectives of the Study

Disruption in language and/or speech suffered due to injury/trauma to the brain may lead to disruption in language and speech in a number of different ways and the language/communicative deficit has been identified as one or the other of several types of aphasics disorder. Similar insult/injury or trauma to the brain may also lead to number recognition and number processing difficulties as well. Studies on these types of disruption in language, speech, numbers and arithmetical processing in cases of brain damage have actually led to more questions than answers. The present study seeks to find answers to at least some of those questions which are tentatively posed as the following:

1. Does occurrence of aphasia in cases of strokes always imply the numerical and arithmetical deficit a well? Does acalculia, the arithmetical deficit imply the presence of aphasia as well? Or do they sometimes occur independent of each other?
2. Does number recognition deficit imply the existence of anomia (word recognition problem) as well, and vice versa? Does anomia (word finding/naming difficulty) often lead to number recognition problem as well?
3. What is nature of numerical deficit in cases of LHD as compared to the cases of RHD?
4. What is the nature of correlation, if any, between LHD/RHD and type of number recognition and processing difficulties?
5. How do people of varying degrees of neurological damage score on numerical processing tests with increasing complexity?
6. Is there any kind of hierarchy in processing unary, binary, and multi digits numbers, and in different arithmetical operations of addition, subtraction, multiplication and division?

METHODOLOGY

Subject's Selection

Out of a random sample of twenty six cases, test was conducted on 21 cases of strokes/accident causing damage to different parts of the brain and 5 subjects serving as normal control group. Medical reports reveal that in the LHD group out of 10 cases, 2 patients had cerebral stroke, 6 had cerebral tumour and 2 patients suffered brain injury. In cases of left and right hemisphere damage, 3 are stroke patients and other 3 patients had brain tumour and head injury; and in RHD group 3 stoke patients and in case of other two patients, the brain damage is due to head injury or brain tumour. All of them were native speakers of Arabic language and know English as well. All these subjects were patients in the Neurogical Research Center and QRH Medical College. The brain lesion of these subjects was confirmed either by CT scan or by MRI scan from which this information was procured with the help of medical experts in the hospital.

The test consisted of two components, one to identify if the patients suffered from aphasia/anomia or not, and the other, a more detailed number test, graded according to the level of complexity involved in the arithmetical operation.

Based on the information given in their medical records the subjects were categorized in into three groups:

1. Left Hemisphere Damage, LHD 10 cases
2. Right Hemisphere Damage, RHD 5 cases
3. Left and Right Hemisphere Damage, L and RHD 6 cases

The medical history of all the subjects is given in Appendix 1.

Test Procedure

An Aphasia language test along with graded number test was performed on each of them

to test their language as well as number deficit. The language test was designed especially for the Arabic language with focus on language deficit in production, comprehension, picture naming as well as in recognition of numbers. Various aphasia test batteries were examined. BADE and WAB, and also Minnesota Test but as is always the case, the adaptation of a test meant for English language to an Arabic language and Arabic culture leads to major gaps in the test results. Adaptation of test for Arabic language as discussed elsewhere by the author, in effect leads to developing an entirely new test battery.

Since the present study is focused on acalculia and numerical operations rather than aphasia and its subtypes, it was decided to follow "modular" approach and conduct the 1st module in all the cases and 2nd subsequent modules only if need be. Just to be able to say if the patients has aphasia or not the following units were used (as developed for speakers of Arabic language).

A. Auditory Verbal Comprehension
(1) No. of units 6; 2 marks each; total marks 12
(2) No. of units 28; 2 marks each; total marks 56

B. Written Comprehension
(3) No. of units 32; 2 marks each; total marks 20

C. Serial Writing (incl. numbers):
(4) No of units 20; one mark each; total marks 20

D. Dictation of numbers
(5) No of units 2; 5 marks each; total marks 10

E. Word picture matching and word finding
(6) No of Units 11; 2 marks each; total marks 22

Total marks allotted to this part of the test were: 184.

Number test section consists of addition, subtraction, multiplication and division. The distribution of corresponding marks for each unit in single, double and triple digits sums are shown in Table 1.

Scoring

For each language test two points were given for every correct response. Responses were expected at least in two communicative modalities. One mark is given if the subject responded in one modality only. Similarly in number test two points were marked for each correct response, for verbal and gestural response one point and for written response two points were given.

Two test items nos. 4 and 5 serial number test and dictation of numbers test can be interpreted for language ability as well as the mathematical performance of each case. Three different test scores are presented serially. Altogether seven tables are made to show the percent scores on language and mathematical tests for each case. Each table represents the overall language ability score with comprehension and production scores marked separately. The third column shows the overall language ability including all the scores of language tests. The overall mathematical score is further added in the table to show the overall mathematical deficit that occurs in different subjects with injury to different parts of the brain. Scores of each group in

Table 1: Structure of Number test

	Unary		*Binary*		*Triple digit*	
	No. of units	*No. of marks allotted*	*No. of units*	*No. of marks allotted*	*No. of units*	*No. of marks allotted*
Addition	6	12	8	16	8	16
Subtraction	6	12	8	16	8	16
Multiplication	6	12	8	16	8	16
Division	6	12	8	12	8	12

	No. of units	*No. of marks allotted*
Tables (Addition and Multiplication)	6	60
Sample Arithmetical Exercise	7	28

language as well as number tests are compared across groups.

Analytical Procedures

Out of various software's available for the statistical analysis, SPSS (Statistical software for social sciences) is used for the statistical analysis of the data in the present study, SPSS offers a statistical tool called ANOVA (Analysis of the Variance) tests for the statistical analysis of the given data. ANOVA is the appropriate technique for analyzing continuous variables when there are three or more groups to be compared. Analysis of variance, or ANOVA, is the standard technique for qualifying and positioning sample variance in experimental data. Both ANOVA tools, One-way and Two-way are powerful and user-friendly. For the present study, one-way ANOVA has been used.

ANOVA test gives the results in the form of the tables. The table of descriptive statistics gives the mean, standard deviation and standard error. This table also provides the confidence intervals and intervals upon which error bars were based. Another important part of the output is a summary table of Levene's test. This test is designed to test the variance of the groups which are found to be the same. If Levene's test is significant (that is the value of significance is less than 0.05) then we can say that the variance is significantly different. SPSS output shows the main ANOVA summary. The tables are divided into between group effects (effects due to the experiment) and within group effects (this is the unsystematic variation in the data). The between group effect is the overall experiment (the effect of the gender on formant frequency, fundamental frequency and the duration of the vowel). The sum of squares for the modal represents the total experimental effect whereas the mean of squares for the modal represents the average experimental effect. The row labelled within group gives details of the unsystematic variation within the data. The table tells us how much unsystematic variation exists (the residual sum of squares). It then gives the average amount of unsystematic variation, the residual mean squares. The test of whether the group means are the same is represented by the F-ratio for the combined results of the group effect. Finally the SPSS tells us whether this value is likely to have occurred by chance. The final column labelled significance indicates how likely it is that an F-ratio of the size would have occurred by chance. Social scientists use a cutoff point of .05 as their criterion for statistical significance and the same cut off has been used for the present study (Table 1).

Data Elicitation

Language Test Results

The overall results of normal control group shows that participants' cognitive abilities are not affected and are preforming well in the tasks (see Table 2). The language test results of the other groups showed that there was a clear division between two broad groups; the LHD and RHD whereas 5 cases of RHD consistently scored anywhere in the range of 95 to 100 percent in different test units. Two persons were illiterate and did not attempt the written part. Hence 71 percent score in one section (see Table 3).

Table 2: Overall results of normal control group: Percent scores

S. No.	*Language ability test*			
	Subjects	*1L 60*	*2L 28*	*3L 184*
22	GB	100	100	100
23	DS	100	100	100
24	GS	100	100	100
25	HB	100	100	100
26	MBH	100	100	100

Table 3: Overall results of language test: RHD group

S. No.	*Language ability test*			
	Subjects	*1L 60*	*2L 28*	*3L 184*
5	ARK	100	100	100
6	MCT	100	100	100
7	DB	100	100	100
13	SD	100	100	100

LHD groups showed a lot more variation. The third group suffering LHD and RHD also showed varied results in language tests. One more group of three patients with LHD had to be nearly sampled out because of their severe aphasic conditions. They did not respond to any section of the test at all. Two subjects with LHD did not show any language deficit at all. This made another group "LHD with non-aphasia" and the

remaining five cases of "LHD with aphasia" made the third group for comparison (see Table 4).

Table 4: Overall results of language test: LHD group

S. No.	*Language ability test*			
	Subjects	*1L 60*	*2L 28*	*3L 184*
LHD with Severe Aphasia				
23	DS	100	100	100
24	GS	100	100	100
25	HB	100	100	100
LHD with Aphasia				
1	KHB	27	11	27
2	BD	100	0	53
3	Ab	100	50	58
9	BN	100	0	48
11	DCH	95	76	60
LHD with Non-aphasia				
8	PCD	100	100	100
12	RMB	100	100	100

Language test results in cases with L and RHD consistently pointed towards aphasic conditions varying from mild to severe to extremely severe, with two patients in the last category not responding to any test item at all. The other four cases also showed that cases at serial no. 10 to 16 with practically 0 percent scores in production and 50-100 percent in comprehension had to be kept in a separate group (See Table 5).

Table 5: Overall results of language test: L and RHD groups

S. No.	*Language ability test*			
	Subjects	*1L 60*	*2L 28*	*3L 184*
LHD and RHD Extremely Severe				
17	GM	0	0	0
18	MCR	0	0	0
LHD and RHD Severe				
10	AH	100	0	50
16	SMG	50	0	24
LHD and RHD Mild				
8	JM	100	50	61
12	MB	100	100	72

Language and Number Recognition Test Results

Serial number writing and dictation of number test (column no. 4) also show similar results. RHD group performs much better than LHD or L and RHD groups. LHD and L and RHD groups show similar performance with an average of 16.6 percent and 16.5 percent score in serial number and dictation of number test.

Number Test Results

Overall three groups selected for comparison of their overall language scores and number test scores are – LHD with aphasia, RHD, and LHD + RHD group (Tables 6, 7, 8, 9 and 10). The average scores are presented for a general comparison below:

Coming to the numerical deficit we find that generally speaking performance of RHD group is better than the other two groups with the average of 61 percent in number test 1, 61 percent in number test 2 and 52 percent in number test 3. RHD score in number test is lower than the scores of the same group in the language ability test (see Table 8). There are two reasons for it. One is that the case no. 14 (SCH) is completely illiterate, never had any formal education. So she could not write any of the number tests. Because of her zero percent score the average percentage has come down. The other reason is that the RHD group shows generally lower level of cognition as a result of stroke and brain injury. Three cases out of five in this RHD group show mathematical deficit although they have no sign of Aphasia. Case no. 14 (SCH) who is illiterate could not perform the number test even verbally. So her score in number test 1 which is single digit test is only 19 percent and in the binary digit test it is only 2 out of 88 percent. Case no. 5 (ARK) and case no. 13 (SD) in the same group show scores in the range of 50 to 60 percent depending on the complexity of the test, (unary number test, binary number test and triple digit number test). These three cases out of total five RHD cases show that there can be numerical / arithmetical deficit without aphasia.

Number test scores of all the three groups show that generally speaking single digit arithmetical operations are easier to handle and arithmetical operations becomes difficult to handle for cases of brain injury with increasing complexity of numbers (see Tables 7, 9 and 10). All the three groups show better performance in test number 1 (single digit test) and these groups score the minimum marks in number test 3 (see Tables 7 and 9). LHD with aphasia and L and RHD groups both show better results in language ability test and poor performance in the number tests (see Table 10).

Table 6: Average scores of the three groups: LHD with aphasia, RHD and Land RHD

	Compre-hension ability	*Production ability ability*	*Overall language (Incl. writing)*	*Serial No. writing and no. dictation*	*No. test 1*	*No. test 2*	*No. test 3*
LHD with aphasia	84.4	27.4	49.2	16.6	27.4	9	3
RHD	100	100	92.4	65.8	61	61	52
L and RHD	87.5	37.5	51.75	16.5	17	8	0

Table 7: Language and number test results in control group

S. No.		*Language ability test*				*Number test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4L N 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
22	GB	100	100	100	100	100	100	100	100
23	DS	100	100	100	100	100	100	100	100
24	GS	100	100	100	100	100	95	95	97
25	HB	100	100	100	100	100	91	100	97
26	MBH	100	100	100	100	100	100	100	100

Table 8: Language and number test results in RHD

S. No.		*Language ability test*				*Number test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4L N 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
5	ARK	100	100	71	33	51	50	40	46
6	MCT	100	100	99	63	100	93	84	93
7	DB	100	100	100	100	75	95	100	92
13	SD	100	100	100	100	60	64	36	57

Table 9: Language and number test results in LHD

S. No.		*Language ability test*				*Number test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4L N 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
LHD with Severe Aphasia									
19	BK	0	0	0	0	0	0	0	0
20	NG	0	0	0	0	0	0	0	0
21	DN	0	0	0	0	0	0	0	0
LHD with Aphasia									
1	KHB	27	11	27	33	8	0	0	6
2	BD	100	0	53	0	25	0	0	7
3	AB	100	50	58	17	49	30	7	27
9	BN	100	0	48	0	24	15	8	14
11	DCH	95	76	60	33	31	0	0	2
LHD with Non-aphasia									
8	PCD	100	100	100	100	100	91	100	97
12	RMB	100	100	100	100	100	100	100	97

Mean Percentage of Correct Responses in Subjects

In order to show the mathematical performance of each group separately, the mean percentage of correct responses for each subtest is counted and tabulated accordingly. The table below represents the mean percentage of correct response of each group in various arithmetical subtests and an attempt has been made to show the multiple comparisons among all groups (see Table 11).

Number Test Results in Arithmetical Operations

The comprehensive result in Table 11 shows the percentage distribution of the scores in all the arithmetic tasks. Group A, D, E and F are selected for comparison among the different

Table 10: Language and number test results in L and RHD

S. No.	Subj.	Language ability test			Number test				
		1L 60	2L 28	3L 184	4L N 30	5N 80	6N 88	7N 88	8N 286
LHD and RHD Extremely Severe									
17	GM	0	0	0	0	0	0	0	0
18	RCR	0	0	0	0	0	0	0	0
LHD and RHD Severe									
10	AH	100	0	50	0	9	0	0	2
16	SMG	50	0	24	0	6	0	0	2
LHD and RHD Mild									
8	JM	100	50	61	33	20	0	0	9
12	MB	100	100	72	33	33	32	0	28

Table 11: The mean percentage of correct responses in arithmetical tasks in different groups

Tasks		Total marks	LHD (10 cases)			RHD (5 cases)	L and RHD (6 cases)			NC (5 cases)
			A	B	C	D	E	F	G	
Number Recognition	Serial number writing	20	25	100	0	79	50	0	0	100
	Dictation numbers	10	0	100	0	60	0	0	0	100
Addition	Unary number	12	41.6	100	0	80	50	20.8	0	100
	Binary number	16	8.7	100	0	67.5	25	0	0	100
	Triple digit number	16	6.2	100	0	65	25	0	0	100
Subtraction	Unary number	12	35	100	0	80	41.6	16.6	0	100
	Binary number	16	7.5	100	0	70	25	0	0	100
	Triple digit number	16	7.5	100	0	65	25	0	0	100
Multiplication	Unary number	12	43.3	100	0	50	25	4.1	0	100
	Binary number	16	16	100	0	45	0	0	0	100
	Triple digit number	16	2.5	100	0	36.2	0	0	0	100
Division	Unary number	12	30	100	0	50	0	4.1	0	100
	Binary number	12	6.6	100	0	50	0	0	0	100
	Triple digit number	12	0	100	0	45	0	0	0	100
Tables	Addition table	40	10	75	0	50	25	0	0	100
	Multiplication table	20	0	100	0	50	25	0	0	100
Simple Arithmetical Exercises		28	8.5	71.4	0	55.7	10.7	0	0	71.4

A = LHD with aphasia (5); B = LHD with non-aphasia (2); C = Severe LHD (3); D = RHD (5); E = L and RHD mild (2 cases); F = Severe L and RHD (2); G = Extremely Severe L and RHD (2); NC = Normal Control Group

specific cases. Addition test results for LHD with aphasia, LHD with non-aphasia, Severe LHD and RHD cases are shown below in Table 12. Similarly subtraction, multiplication and division results are also compared for all the four groups (see Tables 13, 14, 15).

Table 12: Addition test

	A	D	E	F
Unary number	41.6	80	50	20.8
Binary number	8.7	67.5	25	0
Triple digit number	6.2	65	25	0

Addition Tests Results

1. The performance of the RHD group is definitely better than the other groups.
2. The performance of RHD group is comparable with L and RHD group in case of single number addition.

Table 13: Subtraction test

	A	D	E	F
Unary number	35	80	41.6	16.6
Binary number	7.5	70	25	0
Triple digit number	7.5	65	25	0

Table 14: Multiplication test

	A	D	E	F
Unary number	42.3	50	25	4.1
Binary number	16	45	0	0
Triple digit number	2.5	36.2	0	0

Table 15: Division test

	A	*D*	*E*	*F*
Unary number	30	50	0	4.1
Binary number	6.6	50	0	0
Triple digit number	0	45	0	0

3. LHD and also L and RHD groups show different degrees of deficit in handling two digits and three digit numbers. This is related to severity of the case.

Subtraction Test Results

1. The performance of the RHD group is definitely better than the other three groups in some points and it is also comparable with the result of the same group in addition test.
2. Performance of LHD and L and RHD groups is also comparable in serial number writing and dictation of number test. These scores are also comparable with the scores in Addition test. Depending on the severity of the case the number deficit in generally more in the two and three digit numbers as compared to single digit numbers.

Multiplication Test Results

1. The performance of RHD group is definitely better in multiplication in comparison with the other three groups.
2. The performance of all three groups in multiplication test shows a greater deficit as compared to their respective performances in Addition and Subtraction tests. The scores generally correspond with the severity of the case. For example LHD and L and RHD cases show 0 to 2.5 percent score in three digit multiplications.
3. In two digit multiplication, the performance of LHD cases (16%) is better than two groups of L and RHD with zero percent score.
4. The performance of different groups in single unit multiplication test shows interesting figures. RHD group single digit multiplication score is 50 percent and LHD group shows 43 percent score, L and RHD group (mild shows 25% score) and L and RHD severe group shows 4.1 percent average score. The hierarchy of L and RHD severe to L and RHD mild to LHD to RHD as the most effected to the least, is interesting.
5. Multiplication is one arithmetical exercise which shows deficit in case of injury to different parts of the brain, left or right or both, even in single digit operation.

Division Test Results

1. As seen in other mathematical operations the performance of RHD group is better than all the three other groups in division as well.
2. As far as LHD and L and RHD groups are concerned three digit division is the most difficult as all of them are showing 0 percent score.
3. In case of two digit division test the L and RHD group again shows 0 percent score whereas L and RHD groups show a marginal improvement of 6.6 percent score.
4. The most interesting results are obtained in single digit operation, where L and RHD group shows the lowest score 0 to 4.1 percent in mild and severe (mild group is showing 0%). LHD group shows 30 percent score in single digit division test in comparison with a score of 50 percent in the same test for RHD groups.
5. Perhaps division is one mathematical operation, which shows the greatest deficit in the LHD and L and RHD groups. In RHD group, the deficit in division is nearly the same as that in multiplication.
6. Another point that can be made on the basis of this result is that, LHD and RHD cases show similar deficit even on single digit division depending on severity of the case. These results are reinforced by the comparison of the scores of these four groups in other exercises like addition and multiplication tables.

SPSS output for correlation between the deficits of various mathematical operations in the groups A, D, E and F are consolidated in the given below (see Table 16).

RESULTS

The correlation table shows that the correlation between all the arithmetical operations is significant for Group A with significance value above .05. In case of Group D the correlation

Table 16: Deficit correlation between the groups

Correlation	*Gp A*	*Gp D*	*Gp E*	*Gp F*
add/sub	Insignificant	Insignificant	Insignificant	Insignificant
add/multi	Insignificant	Significant	Insignificant	Insignificant
add/div	Insignificant	Significant	Significant	Insignificant
sub/multi	Insignificant	Significant	Insignificant	Insignificant
sub/div	Insignificant	Significant	Insignificant	Insignificant
multi/div	Insignificant	Insignificant	Insignificant	Insignificant

between Addition and Subtraction and the correlation between Multiplication and Division is insignificant while the correlation is significant for the rest of the arithmetical operations. In case of Group E the correlation is significant only for addition and division while the correlation is insignificant for the rest of the arithmetical operations. For group F the correlation is insignificant for all the arithmetical operations (see Table 12).

Language and Number Test Results

Tables 17, 18 and 19 give the statistically significant correlation between the results of language deficiency tests and the damaged parts

Table 17: Overall results of normal control group: Percent scores

S. No.		*Language ability test*				*Number ability test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4LN 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
22	GB	100	100	100	100	100	100	100	100
23	DS	100	100	100	100	100	100	100	100
24	GS	100	100	100	100	100	95	95	97
25	HB	100	100	100	100	100	91	100	97
26	MBH	100	100	100	100	100	100	100	100

Table 18: Overall results of LHD group: Percent scores

S. No.		*Language ability test*				*Number ability test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4LN 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
1	KHB	27	11	27	33	8	0	0	6
2	BD	100	0	53	0	25	0	0	7
3	AB	100	50	58	17	49	30	7	27
8	PCD	100	100	100	100	100	91	100	97
9	BN	100	0	48	0	24	15	8	14
11	DCH	95	76	60	33	31	0	0	12
12	RMB	100	100	100	100	100	91	100	97
19	BK	-	-	-	-	-	-	-	-
20	NG	-	-	-	-	-	-	-	-
21	DN	-	-	-	-	-	-	-	-

Table 19: Overall results of LHD and RHD group: Percent scores

S. No.		*Language ability test*				*Number ability test*			
	Subj.	*1L 60*	*2L 28*	*3L 184*	*4LN 30*	*5N 80*	*6N 88*	*7N 88*	*8N 286*
4	JM	100	50	61	33	20	0	0	9
10	AH	100	0	50	0	9	0	0	2
15	MB	100	100	72	33	33	32	0	28
16	SMG	50	0	24	0	6	0	0	2
17	GM	-	-	-	-	-	-	-	-
18	MCR	-	-	-	-	-	-	-	-

of the brain. The table contains the results of ANOVA and Post Hoc Tests.

Table 20 clearly shows that the number deficiency and language deficiency relations are same in case of control group and RHD, control group and LHD, control group and RLHD and LHD and RLHD while the number deficiency and language deficiency relations are different in case of RHD and LHD and RHD and RLHD.

LHD = Left hemisphere damage

RHD = Right hemisphere damage

RLHD = Left and Right hemisphere

1L = Language Comprehension Test

2L = Language Comprehension ability

3L = Overall language test including 1L and 2L, other tests word/pic naming etc.

4LN = Serial Number writing and dictation of numbers

5N4 = Number test 1

DISCUSSION

The performance of the RHD group is definitely better than the other three groups in practically all the three types of operations. The performance of RHD group is comparable with L and RHD group in case of single number addition. LHD group and also L and RHD groups show different degrees of deficit in handling two digits and three digit numbers (see Tables 12, 13, 14 and 15). This hypotheses regarding "+_Aphasia; +_Acalculia" performance of LHD and L and RHD groups is also comparable in serial number writing and dictation of number tests. These scores are also comparable with the scores in Addition test. Depending on the severity of the case, the number deficit is generally more in the two and three digit numbers as compared to single digit numbers. The performance of RHD group is definitely better in multiplication in comparison with the other three groups. The performance of all three groups in multiplication test shows a greater deficit as compared to their respective performances in Addition and Subtraction tests. The scores generally correspond with the severity of the case. For example LHD and L and RHD cases show 0 to 2.5 percent score in three digit multiplications. (Needs further examination with new series of specially designed tests). In two digit multiplication, the performance of LHD cases (16%) is better than two groups of L and RHD with zero percent score. The performance of different groups in single digit multiplication test shows interesting figures. RHD group in single unit of multiplication score is 50 percent and LHD group shows 43.3 percent score, L and RHD group (mild shows 25% score) and L and RHD severe group shows 4.1 percent average score. This hierarchy of L and RHD severe to L and RHD mild to LHD to RHD, as from the most effected to the least, is interesting and needs further study with detailed study of medical and recuperative history. Multiplication is one arithmetical exercise, which shows deficit in case of injury to different parts of the brain, even in single digit operations.

As seen in other mathematical operations the performance of RHD group is better than all the three other groups in division as well. As far as LHD and L and RHD groups are concerned three digit division and two digit division test is the most difficult as all of them are showing zero score. The most interesting results are obtained in single digit operation, where L and RHD group shows the lowest score 0 to 4.1 percent in mild and severe (mild group is showing 0%). LHD group shows 30 percent score in the same test for RHD group. This is again independent of the

Table 20: Statistically significant correlation between the results of language deficiency tests and the damaged parts of the brain

Deficiency	*Control group and RHD*	*Control group and LHD*	*Control group and RLHD*	*RHD and LHD*	*RHD and RLHD*	*LHD and RLHD*
1L	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
2L	Insignificant	Significant	Significant	Significant	Significant	Insignificant
3L	Insignificant	Significant	Significant	Insignificant	Significant	Insignificant
4LN	Insignificant	Significant	Significant	Insignificant	Significant	Insignificant
5N	Insignificant	Significant	Significant	Insignificant	Insignificant	Insignificant
6N	Insignificant	Significant	Significant	Significant	Significant	Insignificant
7N	Insignificant	Significant	Significant	Insignificant	Significant	Insignificant
8N	Insignificant	Significant	Significant	Insignificant	Significant	Insignificant

6N = Number Test 2; 7N = Number Test 3; 8N = Overall results of Number tests

aphasic condition. Perhaps division is one mathematical operation, which shows the greatest deficit in the LHD and L and RHD groups. In RHD group the deficit in division ability is nearly the same as that in multiplication.

The correlation between control group and RHD in terms of language and number abilities is insignificant throughout, that is, insignificant for all the 8 tests. Insignificant here means that the value of significance in ANOVA test is above .05. The correlation between control group and LHD in terms of language and number abilities is insignificant only for 1L, that is, Language Comprehension Test while this correlation is significant for the rest of the language and number ability tests because the value of significance given by ANOVA test is less than .05. The correlation between control group and RLHD in terms of language and number abilities is also insignificant only for 1L, that is, Language Comprehension Test while this correlation is significant for rest language and number ability tests because the value of significance given by ANOVA test is less than .05.

The correlation between RHD and LHD in terms of number and language ability is significant only for language production ability, that is, 2L and Number Test 2, that is, 6N. The correlation is insignificant for all the rest of the number and language ability tests. The correlation between RHD and RLHD in terms of number and language ability tests is insignificant for language comprehension test, that is, 1L and number test 1, that is, 5N while the correlation is significant for all the rest of the number and language ability tests. The correlation between LHD and RLHD in terms of number and language ability tests is insignificant for all because the value of significance given by ANOVA test were more than .05 for all the tests.

Number Recognition and Word/Picture Recognition

The overall scores of language tests, that is, 184 includes the marks for serial number writing test (20), number dictation test (10) and word picture matching, picture naming tests (22). Scores of different groups of cases for these tests were also compared separately to find out if those having number recognition/word/picture recognition (Anomia) also had number processing difficulties (Acalculia) and vice versa.

While these cases continue to be under study for anomia as well as acalculia, number recognition abilities as well as number processing abilities, this brief comparison across groups shows that number processing deficit may be present in LHD as well as in cases of RHD irrespective of the existence or non-existence of an aphasic condition.

While the question of number recognition through auditory perception and/or visually through written medium and number processing abilities all may need further examination with focus on 'localization' hypotheses, the following cases are of special interest since they throw further light on the question of aphasia, anomia and acalculia in cases of damage to different parts of the brain.

Two cases of RHD (A5 and A14) score 100 percent in word finding test and score less than 20 percent and 5 percent respectively in number tests. These are the two cases where we can say with certainty that there is no 'anomia', not much problem with number recognition, but definitely number processing deficit as indicated by their scores in number tests (5% and 20%). In L and RHD cases, A15 gets 100 percent in picture matching and picture naming but 27 percent in number tests; A16 scores 51 percent in word

Table 21: Scores (in percent) in these tests

	Serial number writing 20	*Dictation of numbers 10*	*Word/pic matching 22*	*Number tests 256*
RHD Average of 10 cases	90%	80%	100%	93-100% 7 cases 1 case 50% (no writing) 2 cases score less than 5%
2 cases (no response)	-	-	-	-
L and RHD				
A – 15	50%	0%	100%	27%
A – 16	0%	0%	51%	2%
2 cases (no response)	-	-	-	-
LHD 2 cases (no aphasia, no acalculia)	100%	100%	100%	100%
7 cases (averages)	25%	0%	88%	Less than 10%

picture matching and picture naming tests. The same person scores only 2 percent in number processing. Hence these two cases of neurological damage in both the hemisphere also show that anomia and acalculia can exist independent of each other; and also that recognition of numbers and recognition of objects/names from pictures may also involve separate independent processing. This certainly needs further testing. Seven cases of LHD have aphasia and numerical deficit. Some of them still score well in word finding and picture naming tests, that is, no anomia and yet there is acalculia; score 5 percent and 55 percent shows much less of anomia, but serious difficulties in numerical processing (see Table 21).

Brain imaging studies showed that less active frontal and parietal brain areas causes deficit in the mathematical cognitive abilities (Kucian et al. 2006). Cases with dyscalculia also show difficulties in other cognitive tasks related to these areas. There is no dearth of studies yielded ample insights into the cognitive structure and the related neural systems that suggest insights into the fundamental deficits of dyscalculia (Dehaene and Cohen 1995, 1997; Girelli et al. 1996; Hittmair-Delazer et al. 1995; Levin et al. 1996; Temple 1991; Geary et al. 2000). Though the two dimensions are not linked, the arithmetic deficit is associated with the cognitive deficit among the cases with learning disability (Geschwind et al. 1987; Geary 1993). There is a large scale study available that suggest that the number of children affected by AD in school age population is quite similar to the children with dyslexia or reading disabilities (Gross_Tsur et al. 1996). Various research works have suggested the nature of understanding and production of numbers among the normally developing children is quite different from the ones with brain injury (McCloskey and Macaruso 1995). It is quite evident that comprehension and production of numbers is facilitated by the ability to process verbal dictations (especially representations of numbers in Arabic) (Dehaene 1992). Cases with LHD show difficulties in lexical access (stating the number word when close to correct number word) and number syntax (difference number system in different languages). However number comprehension deficits is sometimes related to the inferior parietal cortex of either hemisphere (Temple and Posner 1998).

Number production and comprehension skills have not been systematically in AD, especially the adults with brain injuries. The present data reveals that RHD group of subjects perform much better than the other groups in number test 1 whereas LHD and L and RHD scored somewhere similar which suggests that RHD cases are more appropriate to respond to the interventions than the cases with damage in the other hemispheres. In production skill, RHD is much ahead and respond very well to the test whereas L and RHD and LHD very poor. Similar trend is observed in the overall language ability including writing. In number dictation, RHD is way ahead in terms of score that LHD and L and RHD groups scored. Addition test result reflect that LHD and L and RHD groups show different patterns of two to three digit numbers but that depends on the severity of cases. Mild L and RHD and severe l and RHD show significant difference in their dealing with single and multiple digit addition activity; though in single digit operations there is significant difference but the severe cases could not even do the binary and triple digit operations. However there is something very significant to notice is that LHD with aphasia cases have poorly scored in binary and triple digit operations across the mathematical operations (like addition, subtraction, multiplication. division). In language ability test and number ability test, it could be seen that both LHD and RHD performed better in the former test whereas not latter test.

CONCLUSION

Thus, the study shows that RHD group performs better that the other group in terms of operations like multiplication, addition, and subtraction. L and RHD groups show that the severity of their cases affects addition skills when it comes to two to three digits. They are found to perform better in single digit cases. LHD and L and RHD groups exhibit greater deficit in multiplication than addition and subtraction operations. In two digit multiplication operations L and RHD group perform very poor this shows their severity of cases. However, both LHD and RHD exhibit number processing deficit, in terms of presence of aphasic and non-aphasic conditions. In terms of picture matching and picture naming abilities, L and RHD cases exhibit that anomia and acalculia exist independent of each

other. LHD cases show serious difficulties in in numerical processing but their scores are quite encouraging in word finding and picture naming tests. However there is no anomia or number recognition ability found in RHD cases but number processing deficit is definitely indicated by the low scores in the respective tests. Neuroimaging studies on a bigger sample would add significantly to the understanding of the brain which eventually will help in finding the appropriate intervention techniques and tools.

RECOMMENDATIONS

The following recommendations are proposed in order to improve upon the current interventions programs or design new programs:

1. The data supports that the educators involved in special educational needs should be particular about the cases clinical background also before designing the intervention tools and techniques.
2. Brain injuries in different parts of the brain affect differently the cognitive abilities so the RHD cases' intervention methods will be entirely different from the ones of LHD and L and RHD cases.
3. More complex operations are not processed easily so these are expected to be implemented at the much later stage when the subjects are very comfortable with the simple operations.
4. LHD and L and RHD cases require much patient approach towards the development of robust interventions.
5. New software and apps should be used to encourage simple mathematical operations so that they are motivated to try more complex ones as well.
6. Multisensory techniques need to be used while working on number recognition and production skills.
7. Educators should also be particular about the cultural and linguistic background of the cases.

REFERENCES

Bailey D 2013. *Interdisciplinary Working in Mental Health*. UK: Palgrave Macmillan.

Bailey DH 2012. Competence with fractions predicts gains in mathematics achievement. *J Exp Child Psychol,* 113P: 447-455.

Butterworth B 2011. Neural basis of mathematical cognition. *Current Biology,* 1(6): 618-621.

Cohen KR, Dowker A, Heine A, Kaufmann L, Kucian K 2013. Interventions for improving numerical abilities: Present and future. *Trends in Neuroscience and Education,* 2: 85-93.

Dehaene S, Cohen L 1997. Cerebral pathways for calculation: Double dissociation between rote verbal and quantitative knowledge of arithmetic. *Cortex,* 33: 219-250.

Dehaene S 1992. Varieties of numerical abilities. *Cognition,* 44: 1-42.

Dehaene S, Cohen L 1995. Towards an anatomical and functional model of number processing. *Mathematical Cognition,* 1: 83-120.

Dehaene S, Piazza M, Pinel P, Cohen L 2003. Three parietal circuits for number processing. *Cogn Neuropsychol,* 20: 487-506. Doi: 10. 1080/02643 290244000239.

Fuhs MW, McNeil NM 2013. ANS acuity and mathematics ability in preschoolers from low income homes: Contribution of inhibitory controls. *Developmental Science,* 16: 136-148.

Geary DC 1993. Mathematical disabilities: Cognitive, neuropsychological, and genetic components. *Psychological Bulletin,* 114: 345–362.

Geary DC, Hoard MK, Bailey DH 2012. Fact retrieval deficits in low achieving children and children with mathematical learning disability. *J Learn Disabil,* 45: 291-307. Doi: 10.1177/0022219410392046.

Geary DC, Hamson CO, Hoard MK 2000. Numerical and arithmetic cognition: A longitudinal study of process and concept deficit in children with learning disability. *Journal of Experimental Child Psychology,* 77: 236-263.

Geschwind NA, Galaburda AM 1987. *Cerebral Lateralization*. Cambridge, MA: MIT Press.

Gilmore C, Attridge N, Clayton S, Cragg L, Johnson S, Marlow N 2013. Individual differences in inhibitory control, not non-verbal number acuity, correlate with mathematics achievement. *PLoS ONE,* 8: e67374. Doi: 10.1371/journal.pone.0067374.

Girelli L, Delazer M, Semenza C, Denes G 1996. The representation of arithmetical facts: Evidence from two rehabilitation studies. *Cortex,* 32: 49–66.

Girelli L, Delzer M 2007. Numerical Abilities in Dementia. *Aphasiology,* 13(2): 681-694.

Goodglass H, Kaplan 1983. *The Assessment of Aphasia and Related Disorders*. Philadelphia: Lea and Febiger.

Gross-Tsur V, Manor O, Shalev RS 1996. Developmental dyscalculia: Prevalence and demographic features. *Dev Med Child Neurol*, 38(1): 25-33.

Hittmair-Delazer M, Sailer U, Benke T 1995. Impaired arithmetic facts but intact conceptual knowledge- a single-case study of dyscalculia. *Cortex*, 31: 139–147.

Howard SK 1995. *Handbook of Speech and Language Disorders*. Hong Kong: Marcel Dekker Inc, Basel.

Hurford JR 1987. *Language and Number: The Emergence of Cognitive System*. Oxford: Basil Blackwell Ltd.

Kucian K, Loenneker T, Dietrich T, Dosch M, Martin E, von Aster M 2006. Impaired neural networks for approximate calculation in dyscalculic children: A functional MRI study. *Behavioral and Brain Functions,* 2: 31-39.

Landerl A, Bevan B, Butterworth 2004. Developmental dyscalculia and basic numerical capacities: A study of 8-9-year-old students, *Cognition,* 93: 99-125.

Levin HS, Goldstein FC, Spiers P 1993. Acalculia. In: KM Heilman, E Valenstein (Eds.): *Clinical Neuropsychology*. 3rd Edition. New York: Oxford University Press, pp. 91-122.

Levin HS, Scheller J, Rickard T, Grafman J, Martinkowski K, Winslow M, Mirvis S 1996. Dyscalculia and dyslexia after right hemispheric injury in infancy. *Archives of Neurology*, 53: 88–96.

Liberman P 2002. On the nature and evolution of the neural bases of human language. *Yearbook of Physical Anthropology,* 45: 36-62.

McCloskey M, Macaruso P 1995. Representing and using numerical information. *American Psychologist*, 50: 351–363.

Menon V 2013. Developmental pathways to functional brain networks: Emerging principles. *Trends Cogn Sci*, 17: 627-640. Doi: 10.1016/j.tics.2013. 09.015.

Menon V 2015. Arithmetic in the child and adult brain. In: R Cohen Kadosh A Dowker (Eds.): *The Oxford Handbook of Numerical Cognition*. Oxford, UK: Oxford University Press, pp. 502-530.

Narang V 2008. *Mapping Language, Mind, and Brain*: *Studies in Biolinguistics; Disorders of Communication: Aphasia, Acalculia and Dysarthria.* Volume II of the Report of a Five Year Project, JNU. New Delhi: Yash Publications.

Niklas F, Cohrassen C, Tayler C, Schneider W 2016. Parents supporting learning: Literacy and numeracy in the home learning environment. *International Journal of Early Years Education,* 24(2): 121-142.

Parkin AJ 1996. *Explorations in Cognitive Neuropsychology*. Oxford: Blackwell.

Ritchie SJ, Bates TC 2013. Enduring links from childhood mathematics and reading achievement to adult socio-economic status. *Psychol Sci,* 24: 1301-1308.

Siegler RS 2011. An integrated theory of whole number and fractions development. *Cogn Psychol,* 62: 273-296.

Siegler RS 2012. Early predictors of high school mathematics achievement. *Psychol Sci,* 23: 691-697.

Temple CM 1991. Procedural dyscalculia and number fact dyscalculia: Double dissociation in developmental dyscalculia. *Cognitive Neuropsychology,* 8: 155–176.

Temple E, Posner MI 1998. Brain mechanisms of quantity are similar in 5-year-old children and adults. *Proceedings of the National Academy of Sciences USA*, 95: 7836–7841.

Varley R 1997. *Language Disorders in Children and Adults*. England: Whurr Publishers Ltd.

Webb WG 1995. Language batteries in aphasia. In: H Kirshner (Ed.): *Handbook of Neurological Speech and Language Disorder*. Volume 33. New York: M Dekker Inc, pp. 431-444.

Wirz SL 1995. *Perceptual Approaches to Communication Disorders*. England: Whurr Publishers Ltd.

Paper received for publication on August 2017
Paper accepted for publication on December 2017

APPENDIX 1

The subjects and their medical details

S. No.	*Case*	*Medical history*
1	A 145/M//rh/LHD	Left putaminal haematoma with extension into the left fronto-temporal and periventricular region and intraventricular extension with mass effect
2	A 362/M//rh/LHD	Subcute infarct in the left basal ganglia, Head of Caudate Nucleus and periventricular region with mild mass effect
3	A 469/M//rh/LHD	Lacunar infarct in the genu of the Left Internal Capsule, Posterior Limb of the Right Internal Capsule, Bilateral Frontal and Left Parietal Preventricular regions
4	A 870/M//rh/LHD	Left pontine sub acute infract
5	A 1067/M/rh/LHD	Hyperdense blood density lesion of maximum cross sectional dimension of 53x 2.1cm and having a blood fluid level within it and with peri lesional edema is noted involving the left capsular area, insular cortex, and extending upto the periventricular and the high parietal region. Small hypodense lesion of alternation in right lentiform nucleus, external capsule and thalamus.
6	A 1165/M//rh/LHD	Large gliotic area noted involving the left temporo occipital region connecting with the occipital horn of left lateral ventricle
7	A 1223/M//rh/LHD	Subacute SDH over left fronto temporo perital occipital convexities with compression of left lateral ventricle and midline shift of 0.5 cm.
8	246/M//rh/LHD	Hematoma head of the left caudate nucleus with mass effect an extension onto the entire ventricular system. Cerebral atrophic changes with periventricular leukomalaia
9	A 944/M//rh/LHD	Left fronto-temporal monongiomaa
10	A 564/M//rh/RHD	Lacunar infarct in the right frontal lobe and the genu of corpus callosum
11	A 679/M//rh/RHD	Lacunar infract in the right frontal lobe and the genu of the corpus callosum
12	A 762/M//rh/RHD	Right basal ganglia haemaota with minimal effect
13	A 1350/M//rh/RHD	The white matter differentiation of the brain. Parenchyma is noted without any foci of altenation. Whether Cerebral Sulci and gyri are normal. Ventricular system, basal cisters, Posterior fossa contents are normal. Bony calvarium is intact and Seller and Suprasellar areas are normal.
14	A 2279/M//rh/RHD	NA
15	A 2356/M//rh/RHD	NA
16	A 2468/M//rh/RHD	Na
17	A 2656/M//rh/RHD	Na
18	1465/F//rh/RHD	Large heterogenous blood density measuring 2.8 x 1.9 cm with peritoneal edema invading right thalamus, Basal Ganglia Capsular region and extending to the periventricular region causing compression of occipital horn ipsilateral lateral ventricle
19	A 1975/F//rh/RHD	NA
20	A 2055/F//rh/RHD	NA
21	A 2130/F/rh/RHD	NA
22	A 2573/F//rh/RHD	NA
23	A 1570/M//rh/LHD and RHD	Acute Cerebral Infection. Cerebral degenerative changes
24	A 1649/M//rh/LHD and RHD	Hematoma Right Basal Ganglia with mass effect and focal gliotic lesion in the Left Basal Ganglia. Lacunar Infract is prominent and Robin space in the head of left caudate sacks.
25	A 1760/M//rh/LHD and RHD	NA
26	A 1853/M//rh/LHD and RHD	NA