

## **ART: A Cognitive Screening Tool for Reading and Arithmetic Difficulties**

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### **ABSTRACT**

Cognitive functions are known to be the crucial foundation on which all learning as well as acquisition of many of our everyday activities and tasks, rest. Research in cognitive psychology has highlighted its importance for the mastery of academic subjects especially reading and arithmetic ability. Educational neuroscience is an evolving branch which explores the connection between the underlying neural and cognitive aspects of academic learning. Most of the exploratory work in this new area is being carried out among children who are 'at risk' of academic difficulties. Hence the aim of the present research work was to develop a screening measure for identification of children with reading and arithmetic difficulties. There is a dearth of a quick, yet comprehensive screening measure which tests cognitive functions apart from reading and arithmetic skills in children. It therefore becomes imperative that we identify, as early as possible, children 'at risk' for learning difficulties and attempt to assess the relevant cognitive skills and plan and execute intervention programs to improve the efficacy of these cognitive skills. A screening measure was thus developed which consisted of three domains: cognitive abilities, reading comprehension and arithmetic ability. This measure was administered on 1091, third, fourth and fifth grade children from English medium schools in South Bangalore, following the ICSE syllabus. The data obtained was subjected to item analyses and the final screening tool - Arithmetic and Reading Test (ART) - was developed, which comprised of tests for reading comprehension, arithmetic ability and cognitive functions, i.e., attention and concentration, visual perception, visuo-spatial ability, processing and working memory. Psychometric properties were established and the ART was found to be reliable and valid. Test-retest reliability of the ART was 0.76. The tests in the ART were found to be internally consistent. Concurrent validity of the reading and arithmetic measure of ART was found to be 0.43 and 0.36 with performance in school examinations, i.e., marks in English and Mathematics respectively. The cognitive skills assessed were found to be significantly correlated to English and Arithmetic performance in school examinations. These results indicate the importance of cognitive functions in Education. The findings of this research have important implications for cognitive remediation research where children identified using this screening measure can be provided cognitive training program aimed at improving specific cognitive skills which thereby would enhance their reading and arithmetic skills.

**Keywords:** *Cognitive skills, reading comprehension, arithmetic ability, cognitive assessments*

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*“The vast majority of us imagine ourselves as like literature people or math people. But the truth is that the massive processor known as the human brain is neither a literature organ nor a math organ. It is both and more.”*

*John Green*

Cognitive functions are known to be the crucial foundation on which all learning as well as acquisition of many of our everyday activities and tasks, rest. Research in cognitive psychology has highlighted its importance for the mastery of academic subjects especially reading and arithmetic ability (Semrud-Clikeman, 2005). The scope of education and cognitive psychology has widened to include Educational neuroscience which explores the connection between the underlying neural and cognitive aspects of academic learning in order to bridge the gap between theoretical principles and practice. Most of the exploratory work in this new area is being carried out among children who are ‘at risk’ of academic difficulties. Educators are now giving importance to the role of cognitive skills when dealing with children in schools and remediation centers.

### **Neuropsychological features of reading and arithmetic difficulties**

Research on specific brain areas in reading and arithmetic difficulties (Sandak, et al. 2004; Landi, et al. 2013; Quinghua, He, et al. 2013; Simos, et al. 2008; Rykhlevskaia, et al. 2009) have brought to light the finding that specific cognitive functions mediate the role of learning. Studies have shown that reading difficulties can be experienced by children due to multiple cognitive factors such as visual difficulties; problems with processing speed; rapid auditory processing; general language deficits or phonemic awareness skill deficits (Wolf and Bowers, 1999; Scarborough and Dobrich, 1990; Fletcher, et al., 1994; respectively, as cited in Sandak, et al., 2004). Attention, visual perception and working memory have been implicated as being necessary for both reading as well as arithmetic (Wasserman, 2012; Meng, et al., 2011; Swanson & Jerman, 2006; Karzmark, 2009).

A review by Semrud-Clikeman (2005), on the neuropsychological aspects for evaluating learning disabilities, highlighted that an evaluation of children with learning problems must consider measures of working memory, attention, executive functions and comprehension (listening and written). According to her, in order to evaluate the child’s learning skills :

- One must understand the child’s ability to process language, to understand what he or she hears, and to organize information;
- The speed with which the child processes information (Information processing); and
- The child’s attention, ability to hold information in the mind while solving a problem (working memory), and ability to self monitor the reading process (executive functions).

An exhaustive survey of existing research on cognitive functions linked to reading and arithmetic abilities has highlighted five cognitive functions- attention and concentration, visual perception,

visuo-spatial ability, information processing and working memory. These cognitive functions thus became the focus of this study.

### **Reading and arithmetic assessments in India**

Psychological tests have been developed in India which have been used as screening as well as diagnostic measures for the identification of children with reading and arithmetic difficulties. In the Indian setting, teachers or parents who find that their child is underperforming in academics tend to refer the child to psychologists for the purpose of understanding the difficulties. Psychologists then administer assessment batteries which encompass tests on reading and arithmetic achievements as well.

A review of existing batteries in India reveals that there are some standardized assessments developed for Indian children for the identification of learning problems, mostly from a clinical perspective, for the purpose of diagnosing learning disorders. The commonly used tests/batteries are: NIMHANS index of Specific learning disabilities (Kapur, 1991), Grade level assessment device (GLAD; Narayan, 1997), Wide Range Achievement Tests (WRAT) (Wilkinson and Robertson, 2006); Kaufman's Test of Educational assessment (Kaufman and Kaufman, 2004); Woodcock-Johnson's Tests of Achievement –IV (Woodcock, McGrew & Mather, 2001); etc.

However these batteries have their own limitations. They are generally used in hospitals and clinics for diagnosis of learning disabilities, and are time consuming as they require at least an hour for administration and they follow an individual mode of assessment. Their administration requires training and expertise on the part of clinicians/psychologists. Moreover, these assessments fail to identify 'at risk' children who tend to perform poorly in schools despite not fulfilling the criteria for learning disabilities on these batteries. Morgan, Singer-Harris, Bernstein and Waber (2000), proposed that children who get adequate scores on achievement batteries and yet perform inadequately in school, should be evaluated for neurodevelopment vulnerability as these children tend to have difficulties with information processing and verbal fluency. They have suggested the use of curriculum based measurement in order to identify these children.

### **NEED FOR THE STUDY**

Deficits in certain cognitive functions have been shown to lead to impairment in these skills as well as other difficulties. There is a dearth of assessments which can be held in the classroom settings and identify cognitive deficits as well as problems with reading and arithmetic ability. There is thus an urgent need to identify the 'at risk' children as early as possible in order to provide them with the necessary skills to overcome these difficulties. The aim of the present study was thus to develop a screening questionnaire to assess reading skills, arithmetic skills as well as cognitive skills namely attention, visual perception, visuo-spatial ability, information processing and working memory.

## METHOD

**Objective:** To develop a screening measure, Arithmetic and Reading Test (ART), comprising of cognitive, reading and arithmetic tests to identify children in the third, fourth and fifth grades who have difficulties with reading and arithmetic.

**Hypothesis:**

1. Reading comprehension will be significantly correlated with the different cognitive functions assessed viz., attention and concentration, visual perception, visuo-spatial ability, processing and working memory.
2. Number calculations will be significantly correlated with the different cognitive functions assessed viz., attention and concentration, visual perception, visuo-spatial ability, processing and working memory.

**Research Design:** A survey research design was implemented and purposive sampling method was used to select the schools and the students for the purpose of data collection.

**Research population:** The population consisted of all the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grade students of English medium schools following the ICSE board of educational curriculum in the city of Bangalore. A single board was selected to ensure sampling uniformity as all schools affiliated to that board would follow a similar syllabus and timeline. The choice of grades was made based on the findings from research which indicated that some children in these grades usually go through a 'fourth grade slump' where they experience academic difficulties (Sanacore and Palumbo, 2009). The following inclusion-exclusion criteria were followed:

**Inclusion criteria**

- Children of 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grades in schools following the ICSE curriculum.
- Children from English medium schools

**Exclusion criteria**

- Children who cannot speak or understand English.

**Research sample**

A total of 1091 students from 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grades were taken up as the research sample for development and standardizing the arithmetic and reading test [ART]. Table 1 represents the distribution of children:

Table 1

*Sample distribution*

	Grade 3	Grade 4	Grade 5	Total
School 1	125	103	112	340
School 2	160	188	165	513
School 3	25	22	26	73
School 4	55	50	60	165
<b>Total</b>	365	363	363	1091

The grade-wise division of the total number of students who had participated in the assessment is given in table 2:

Table 2

*Sample description*

Grades	N	Gender	Mean age and SD
3	365	189 Girls 176 Boys	8.8±0.64
4	363	158 Girls 205 Boys	9.8±0.71
5	363	165 Girls 197 Boys	10.8±0.7

*Measures planned and developed for the assessment.*

1. **A personal information sheet** which elicited the demographic variables important for the study as well as marks obtained in the last English and Mathematics examinations conducted in the school.
2. **Reading screening Measure:** This was developed for the purpose of assessing reading ability. It included sentence verification tests to assess reading comprehension.
3. **Arithmetic screening measure:** This was developed to assess arithmetic ability in terms of number computations.
4. **Cognitive functions measure:** This included tests developed to measure specific cognitive functions underlying reading and arithmetic skills. The cognitive functions assessed were: attention and concentration, visual perception, visuo-spatial ability, information processing and working memory.

**Reading screening measure:** The item pool for the scale was developed after an extensive review of existing reading assessments and consultations with 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grade English school teachers. Literature and language textbooks of the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grades which were based on the ICSE syllabus were also reviewed. Based on the above, the reading comprehension test was developed.

## ART: A Cognitive Screening Tool for Reading and Arithmetic Difficulties

Reading comprehension was assessed using the Sentence verification technique (SVT) developed by Royer, et al (1979). The rationale for choosing this technique was that it can be easily adapted to school curriculums and it is easy to develop. It also gives a quick assessment of whether the student has been able to grasp the passage read. Development of SVTs involved the selection of three passages, labeled A, B and C, after consulting 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grade textbooks. For each passage, 24 sentences were developed based on the following 4 sentence verification types –

**Originals-** Sentences which are exact copies of sentences in the passage.

**Paraphrase-** Sentences in which word changes were done while still retaining the meaning of the sentences.

**Meaning change-** Sentences in which one or two word changes were done which led to a sentence with a completely different meaning.

**Distractors-** Sentences which were consistent in theme with the original passage but were different with regard to meaning and wording.

All the sentences were forced-choice type and the student had to indicate whether the sentence was ‘correct’ or ‘incorrect’ based on the paragraph that they had read. Errors on this test indicated that the child had a difficulty with regard to comprehension of the passage read.

For the purpose of administration, three versions of the screening measure were developed. In each version, two of the three passages were selected; and for each passage, 12 of the 24 questions developed were given. Thus each student received two passages with 12 questions for each passage.

**Arithmetic screening measure:** The item pool for this measure was developed by surveying the available arithmetic assessments, textbooks and by consulting mathematics teachers in schools. Based on all these, the following subtest was developed:

**Calculations:** This comprised a set of basic numerical computations which were aimed to assess only the arithmetic component of mathematics. There were a total of 12 computations.

**Cognitive functions measure:** The items of this measure were developed after a review of literature to identify the key cognitive functions underlying reading and arithmetic skills. The existing cognitive functions assessments were reviewed and accordingly the pool was generated. The following were the subtests developed to assess the various cognitive functions mentioned above:

**Attention and concentration –**

**Place values test:** This consisted of a set of 24 numbers and the student was instructed to identify specific numbers which were placed either in the 10<sup>th</sup>, 100<sup>th</sup> or the 1000<sup>th</sup> position. This was to assess attention and concentration underlying both reading and arithmetic skills. The student had

## ART: A Cognitive Screening Tool for Reading and Arithmetic Difficulties

to remember the place and value and then focus his/her attention to identify the correct numbers in the presence of other distracting numbers..

Example: Underline the numbers that have 3 in the tens place.

1323 82323 32435 13239 35312 91331 923231324323

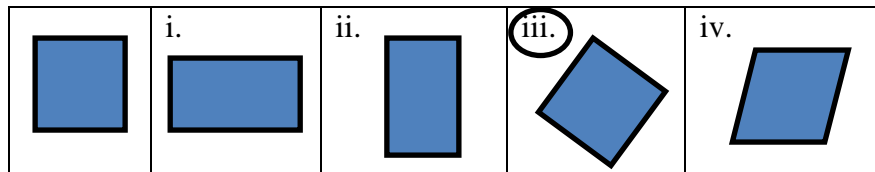
### VISUAL PERCEPTION

*Number match test:* A series of five numbers were given of which two were exactly identical which the student had to find and underline. This was to assess visual perception, an important component of both reading and arithmetic skills. The student had to look at each stimulus given and identify which of the numbers matched. He/she had to discriminate between the various sets of numbers to identify the matching sets of numbers. There were ten sets of five numbers each, on this subtest. For example:

54351 54355 54315 54351 54354

### VISUO-SPATIAL ABILITY

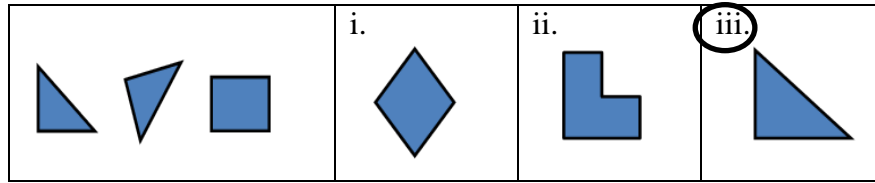
*Shape match test:* A target shape was given which had to be matched with another shape from a row of different shapes. This was to assess visuo-spatial ability, found to be important for reading and arithmetic ability. This test required a mental rotation of all the two-dimensional shapes in order to identify the right figure and hence requires the skill of spatial visualization. In this test, there were a total of nine sets, with each set having a target shape and four possible choices to choose from. An example:



### INFORMATION PROCESSING

*Shape design test:* A set of shapes were given which had to be pieced together in such a way that it formed a new shape. Several possible new shapes were presented, out of which the student had to select the appropriate shape. This was to assess information processing, a cognitive skill necessary for reading and arithmetic ability. This test required the mental processing of individual shapes and combining them in order to form a new shape. There were a total of six sets on this subtest, with each set having a target group of shapes and three possible shapes to choose from.

Example:



### WORKING MEMORY

**Word Find:** A string of 46 meaningful words were presented which were not separated by any space between them. The student had to recognize the words and separate them. This was developed to assess working memory which is an important component underlying both reading and arithmetic. In this test, the student had to identify each letter, connect a series of letters and hold the information briefly in mind in order to identify which of the series makes a meaningful word. This whole sequence of activities requires working memory. The total number of words correctly identified comprised the score.

Example: catcupbluetreewarmhuttip had to be separated ascats/cup/blue/tree/warm/hut/tip

### TESTING PROCEDURE

**Pilot testing:** The measures were initially shown to 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> grade English and Mathematics teachers and suggestions from them were incorporated. An initial try-out was done on three children to check for errors, ease of understanding and to assess the difficulty level. Changes were accordingly made and a final draft was prepared. None of the items were eliminated, but the instructions were reworded for ease of understanding.

**Main study:** This measure was then administered on the main study sample. Consent was first obtained from the school Principals and two class periods, each of 40 minutes duration, was allotted for carrying out the assessments. The mode of administration was group and within the classroom. Testing was conducted for each grade separately. The researcher conducted the assessments and any clarifications raised by the students were personally answered. The recent school achievement marks with regard to English and Mathematics tests were recorded for all the students for the purpose of later statistical analysis.

**Analysis:** To select the final items for the test, two characteristics of the items were considered:

- *Item difficulty* – This is a measure of the proportion of students who responded accurately to each of the items. Items having an item difficulty level between 40% and 80% were selected.
- *Item discrimination* – This measure differentiates between high and low scorers, on every item. Two criteria were used for categorizing students as ‘high’ and ‘low’ scorers: (i) total subtest score and (ii) performance in English achievement in schools. Independent sample t- tests were performed to test the significance of difference between the high and low scorers with respect to both these criteria. Those items which were able to



## ART: A Cognitive Screening Tool for Reading and Arithmetic Difficulties

significantly differentiate on both the criteria were considered for inclusion into the final test.

After the completion of item analyses, unsuitable items were removed while those meeting the above two criteria were retained. After the procedure the final test was arrived at.

### The Final Test: ART

The ART consists of eight subtests assessing reading, arithmetic and cognitive skills. Table 3 depicts the subtests and the specific components assessed by them:

Table 3

#### *Subtests of ART*

S.No.	Components assessed	Subtests of ART
1.	Reading skills	Sentence Verification Test
2.	Arithmetic skills	Number Calculations
3.	Cognitive skills:	
3.1	Attention and concentration	Place values test
3.2	Visual perception	Number Match test
3.3	Visuo-spatial ability	Shape Match test
3.4	Processing	Shape Design test
3.5	Working memory	Word Find

The scoring procedures for the tests were then developed.

### ART FINDINGS

#### Psychometric properties

##### *Reliability and Validity of ART*

**Test-retest reliability:** The ART was administered and re-administered after four months to 127 students in the 4<sup>th</sup> and 5<sup>th</sup> grades. Table 3.4 depicts the correlations between the first and the second administrations.

Table 4

#### *Test-retest correlations of ART subtests(N=127)*

S.No.	ART subtests	<i>r</i>
1.	Sentence Verification tests	0.441**
2.	Calculations	0.559**
3.	Place Values	0.265**
4.	Number Match	0.508**
5.	Shape Match	0.345**
6.	Shape Design	0.298**
7.	Word Find	0.747**
	ART total	0.757**

Note: \*\*p<0.01

Table 4 reflects the adequacy of the reliability of the ART. The test on the whole has good reliability. All the subtest correlations were found to be significant at the 0.01 level. Word find test for working memory had the highest correlation while for the other subtests the correlations ranged from mild-moderate.

**Internal consistency**

Two measures were computed: split half reliability and Cronbach’s  $\alpha$ .

The odd - even split half correlation coefficients were computed to determine Split-half reliability for the ART. Table 5 reflects the correlations obtained (Guttman Split-half coefficient and Cronbach’s  $\alpha$ .)for each of the subtests on the ART administered on 127 students.

**Table 5**

*Split half reliability of the ART subtests (N=127)*

S.No.	ART subtests	Split half coefficient	Cronbach’s $\alpha$
1.	Sentence Verification test	0.762**	0.663
2.	Calculations	0.833**	0.735
3.	Place Values	0.923**	0.913
4.	Number Match	0.849**	0.841
5.	Shape Match	0.708**	0.731
6.	Shape Design	0.451**	0.282
7.	Word Find	0.970**	0.954

Note: \*\* $p < 0.01$

Table 3.5 indicates that for all the subtests except for shape design test for information processing ability, high reliability coefficients were obtained. George and Mallery (2003) has proposed that Cronbach’s alpha of 0.7 and above is considered acceptable.

**Validity of ART**

Concurrent validity was established for which the scores on ART were correlated with English and Mathematics achievement in school as these provide good indicators of the child’s performance in the subject areas. Pearson’s product moment correlation method was used. As reflected below, the correlations were found to be significant thus indicating that the test was valid. Table 6 reflects the correlation details on the subtests of the ART and achievement in schools.

**Table 6**

*Concurrent validity of the ART(N=127)*

S.No.	ART subtests	English achievement	Mathematics achievement
1.	Sentence Verification tests	0.427**	
2.	Numerical Calculations		0.357**

Note: \*\* $p < 0.01$

**Sensitivity and Specificity of the ART**

In order to evaluate the effectiveness of a screening test, it is necessary to ascertain the sensitivity and specificity of the test in accurately identifying participants having a particular characteristic. The sensitivity of the sentence verification test (reading comprehension measure) of the ART was found to be 58% while the specificity was 83%. For the number calculations test (arithmetic ability), the sensitivity was 44% and the specificity was 75%.

The above discussion on the psychometric properties and sensitivity-specificity values indicates that ART is a reliable and valid instrument which can be used in the classroom settings for the purpose of a quick identification of children with reading and arithmetic difficulties.

***Cognitive correlates of Reading comprehension***

In order to explore the relationship between reading comprehension and the cognitive functions assessed, a correlation coefficient was computed. Table 7 reflects the findings:

**Table 7**

*Pearson’s product moment correlations between reading comprehension and various cognitive functions of 1091 third, fourth and fifth grade students:*

Cognitive functions	Subtest	Reading comprehension (SVT)	English achievement (school)
Attention and concentration	Place values	0.287**	0.15**
Visual perception	Number match	0.331**	0.22**
Visuo-spatial ability	Shape match	0.222**	0.22**
Information processing	Shape design	0.262**	0.20**
Working memory	Word find	0.514**	0.38**

Note: \*\*  $p < 0.01$

Table 7 indicates that reading comprehension as assessed using SVT as well as achievement in English examination are significantly correlated with all the five cognitive functions assessed. Reading comprehension is thus significantly and positively associated with attention and

## ART: A Cognitive Screening Tool for Reading and Arithmetic Difficulties

concentration, visual perception, visuo-spatial ability, information processing and working memory. Thus better the functioning on these cognitive skills, better would be the reading comprehension. The results therefore imply that these cognitive functions are necessary and would help in comprehension of text. There is ample research supporting the link between each of these cognitive skills and reading comprehension. The role of attention has been highlighted by Wasserman (2012); executive functions like planning and working memory along with attention, decoding, fluency and vocabulary by Sesma, Mahone, Levine, Eason and Cutting (2009); visual perception, information processing and visuo-spatial ability by Mc Closkey and Rapp (2000) and Cullingford (2001, as cited in Westwood, 2004). Relative to all the cognitive functions assessed here, working memory was found to have the highest relationship.

### *Cognitive Correlates of Arithmetic ability*

To identify the cognitive correlates of arithmetic skills, Pearson's product moment correlations were computed and the results are reflected in table 8.

**Table 8**

*Pearson's product moment correlations between number calculations of the ART and the various cognitive functions*

<b>Cognitive functions</b>	<b>Subtests</b>	<b>Calculations</b>	<b>Arithmetic achievement</b>
Attention and concentration	Place values	0.511**	0.121***
Visual perception	Number match	0.465**	0.232**
Visuo-spatial ability	Shape match	0.296**	0.215***
Information processing	Shape design	0.324**	0.199***
Working memory	Word find	0.332**	0.204**

*Note:* \*\*p<0.01; \*\*\*p<0.001

Table 8 indicates that arithmetic ability as assessed by the calculations component of the ART as well as Mathematics examination marks are significantly correlated with all the five cognitive functions assessed viz., attention and concentration, visual perception, visuo-spatial ability, information processing and working memory. The obtained results indicate that better the functioning on these cognitive skills, better would be arithmetic ability. The results therefore imply that these cognitive functions are necessary and would help in arithmetic ability, specifically in numerical computing.

Relative to all the cognitive functions assessed, attention and concentration was found to show the highest relationship. Geary (2004), had identified four key cognitive deficits namely, working memory, visual-spatial information processing, attention and inhibitory processes and language systems, all of which played an important role in acquisition of math skills. Swanson (2006) as well as Tannock, et al. (2011) has highlighted the important role of working memory, especially visual working memory in the mastering of math concepts. The evidence for the role

played by visual perception and visual-motor integration in arithmetic ability has been highlighted by Stefanie, et al. (2012). The results obtained in this study also corroborate these findings.

## **CONCLUSIONS**

The key conclusions of this research is that cognitive skills as assessed using the ART measure was found to be significantly correlated to reading comprehension and arithmetic ability. Reliability and validity analysis indicated that ART is a reliable and valid tool for identification of children with reading and arithmetic difficulties. It has immense utility in schools where third, fourth and fifth grade teachers can use it in the classroom settings for a quick identification of at risk children with difficulties. Since the five cognitive functions highlighted in this research have been found to be crucial for reading and arithmetic skills, these can be targeted by special educators/psychologists for the purpose of remediation in children with learning difficulties. Hence ART can act as a useful screening measure in educational settings and can be also be used in the context of educational remediation research.

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