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Web Application for Screening Dyslexia in Greek Students

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Abstract: Dyslexia's diagnosis is made taking into account reading and writing skills and is carried out by qualified scientific staff. In addition, there are screening tests that are designed to give an indication of possible dyslexic difficulties. Their main advantage is that they create a pleasant environment for the user and reduce the stress that can lead to false results. An online application was created for the first time, as far as authors' knowledge, for screening Dyslexia in Greek high school students named «DyScreTe». Thus, a sample of 240 students between 16 and 18 years old in Greece was taken, of which 120 were diagnosed with dyslexia by an official authority in Greece, and 120 were typically developed. The main hypothesis that was examined is that students who were diagnosed with dyslexia by official authorities in Greece had significantly lower performance in the respective software tests. The results verified the hypothesis we made those children with dyslexia in each test had a lower performance compared to the type developed in successful responses, except for the intelligence test. After random sampling, it was shown that the new online application was a useful tool for screening dyslexia. However, computer evaluation cannot replace the diagnosis by a professional expert, but with the results of this application, the interdisciplinary team that deals with the differential diagnosis will create and evaluate, at a later time, the appropriate intervention program.

Keywords: Dyslexia, Internet application, Screening tests

Introduction

It has been shown experimentally that students with developmental dyslexia have deficits in reading skills such as omissions of letters, incorrect reading of sentences and words, but they are mainly characterized as slow readers. Nevertheless, the etiology of dyslexia should not be investigated only in the reading disabilities of individuals but also in other cognitive skills, such as spelling, working memory, mathematical ability, visual and auditory retrieval and discrimination (Fletcher, 2009).

An extensive list of skills related to visual and auditory stimulus processing, mathematical ability and working memory function has been suggested as causative factors of dyslexia. Nonetheless, it is now taken for granted that dyslexia cannot be linked to a single causal factor, as it is associated with a wide range of problems. The fact that dyslexics face a wide range of difficulties inevitably lead scientists to conclude that different forms of dyslexia are related to different weaknesses of the individual (Fletcher, 2009).

A screening test indicates a high probability of dyslexic difficulties. Screening of dyslexia is done by assessing mainly a child's reading skills, which should be significantly lower than expected for his age group. One of the biggest difficulties faced by dyslexics is the ability to match effectively written texts (graphs) with sounds (phonemes). This difficulty emerges from the attenuated audio processing, which ultimately affects the phonological processing.

However, computer-based evaluation (screening) cannot replace diagnosis by a professional expert, but is a very useful tool in order to decide whether a child should visit an expert for official evaluation or not. Moreover, the interdisciplinary team that deals with the differential diagnosis of a child has the knowledge to create the appropriate intervention program, something that cannot be done by a computer (Watson & Willows, 1995).

Literature Review

According to Singleton (2001), computer-assisted dyslexia screening provides a simple, direct, and objective way for teachers to assess children who have learning difficulties, screen existing or potential learning problems and obtain basic diagnostic information and generally measure children's progress. Moreover, it evaluates individual responses to support children with special learning disabilities and obtain information that will be useful to psychologists at a later time, during an intervention program

The main advantages of computer-based screening are the objective and standard presentation besides the faster management of participants' results. In addition, greater evaluation accuracy is achieved, since less training of managers is required, as well as time and cost savings. Finally, the results are immediately available; the process is enjoyable for children and confidential for adults. On the other hand, the critical issues and risks involved in computer-based evaluation are that boys have an advantage over girls and usually creating computer-generated tests needs time and money. Furthermore, computer tests are limited in some aspects of evaluation and there are risks, since technology may not cover certain areas of neuropsychology (Singleton, 2001). Some widely used computer based applications for screening dyslexia are Lucid CoPS Cognitive Profiling System, Lucid Rapid, CoPS Baseline, LASS Secondary, Lass Junior, Lass 11-15 and Lucid Adult Development Screening (LADS).

Research Contribution

There was no on-line application for screening Dyslexia aimed at high school students in Greece according to the authors' knowledge. The main purpose of this research was to create a web application for screening dyslexia to Greek students from 16 to 18 years old. For that reason, the application «DyScreTe» was created. Its name comes from the words Dyslexia Screening Test.

Internet Interactive Application

The advantages of a web application are that users have access to their files in any space they wish as soon as they have an internet connection and it does not require manual updates. Desktop applications at regular time intervals require installation-level updates with many instructions that bother users. In contrast, web applications perform automatic updates by pressing a button and the user simply waits a few seconds (Karakos, 2007).

In addition, web applications do not require special features from the computers. Moreover, online applications can be accessed by all users with a simple internet connection even if it is not very fast. Finally, desktop applications are much more expensive than online applications. The first ones are linked to a one-time payment and users do not have the option to purchase them for a specific period of time. An online application gives the opportunity to the user to buy it for a limited time. In this case it is likely that a private school will need to screen special learning difficulties in September and October when students are enrolled. This feature is not provided by a desktop application where users are required to pay for the application for a full year (Karakos, 2007). On the other hand, the disadvantages of web applications are that application cannot run without internet access. Moreover, not all countries have the proper speed to run applications properly and this is one of the main reasons why desktop applications still exist. Moreover, desktop applications are more secured than web applications since they are vulnerable to malware attacks (Karakos, 2007).

Objectives and Hypotheses

The originality of the research is the creation of an online application for screening dyslexia in students in Greece between 16 to 18 years old. The user is given the opportunity to screen dyslexia in high school students with a simple internet connection and without the existence of computers with special requirements. Moreover the time needed to complete 8 out of 10 tests is measured. According to the literature review, the main

hypothesis of the research is that children with dyslexia will show significant differences both in the mean scores and in the time of completion of all tests, compared to their typically developed classmates.

Then, according to the basic hypothesis analyzed, three sub-hypotheses emerge, according to which it is scientifically proven that the test will have the correct results at acceptable levels of confidence. Specifically, according to previous research, such as Skues and Cunningham (2011) and Bonifacci and Snowling (2008) it is expected that children, who have already been diagnosed with dyslexia by an official authority, will achieve lower scores in all tests, with the exception of the intelligence assessment test (1st Hypothesis). In addition, the research of Van Viersen et al., (2015) suggests that children with developmental dyslexia are not expected to have significant differences compared to their typically developed classmates in the intelligence assessment test (2nd Hypothesis). Finally, based on the results of the research of Boets and De Smedt (2010) and Träff and Passolunghi (2015), children diagnosed with dyslexia will complete the tests slower, with the exception of the intelligence assessment test (3rd Hypothesis). Thus, a large enough sample has been tested from the Greek students who executed the internet application. In addition, probabilistic sampling was performed and the sample was checked for regularity. An equal dispersion test was then performed. The above tests make the sample capable of drawing conclusions through it for the whole population and ensure the validity and reliability of the results that are required in any experimental research.

More specific, the method of collecting the sample ensured small sampling errors, which makes it representative of its population. In addition, the estimators who interpret the sample data are sufficiently capable of using inferred statistics to draw safe conclusions through the sample in the population. It is worth mentioning that in this research comparisons have been made between the tests in order to ensure their validity and reliability. Predictions were then made between trials, which enhances the ability of «DyScreTe» software to screen dyslexia.

Methods

Participants

Since the population of students with dyslexia is scattered and quite large, the selection of a random sample is a time consuming and costly process. Specifically, it has been estimated that only 5,52% of the Greek student population are students with dyslexia (Vlachos et al., 2013). In addition, the sample collection took place during the school years 2018 - 2019 and 2019 - 2020, which does not allow simple random sampling, due to time and cost. (Creswell, 2011). For the needs of the research, inductive statistics were performed, ie conclusions will be drawn through the sample to the population. The sampling method chosen is stratified or layered sampling. Its main feature is the reduced standard errors of estimators. Safe conclusions can therefore be drawn from the examination of the sample in the whole population (Neyman, 1992). More specific, the students were selected as subsets according to their age group. The separation of the sample was carried out in independent layers and specifically the first consists of 16 years old students, the second of 17 years old students and the third of 18 years old students. In this way the independence between the layers is achieved (Imbens & Lancaster, 1996). In addition, with the above way of selecting the sample, the homogeneity between the layers is achieved, as all the students, depending on which layer they are placed in, have been taught the same part of the material. Then, after defining the mattresses, the selection of students in each mattress was done randomly (Trost, J. E., 1986).

In addition, the above procedure was performed independently for the two experimental research groups. Specifically, a sample of the same size was collected for both the experimental group and the control group. The students in the experimental group should have been officially diagnosed with dyslexia without co-morbidity of other disorders. The schools in which the sampling took place are in the suburbs (southern and northern) and in the center of Athens. It is worth noting that the process was conducted with the consent of the school principal, the parents and of course the students who participated in the process. In the next stage, sampling was performed for the control group, which consists of students of the same sex and the same age group as students who were diagnosed with dyslexia. The main goal was to have uniformity between the two teams.

The size of the sample for proper quantitative data analysis is a very difficult decision and depends on many factors. Initially the general rule, that applies to both quantitative and qualitative research, is that the larger the sample the more representative it is of the population. In details, the higher the sample, the smaller the sampling error and the sample is representative of its population. It is understood that selecting a larger sample takes more time and the process is costly. The goal of each researcher is to minimize the sampling error, which is the difference between the sample value and the actual value that corresponds to the population (Creswell, 2011).

In this research the number of participants is very specific and limited. Access to students with dyslexia is not a simple process and can only take place under certain conditions. The exact population of students with dyslexia in Greece is changing rapidly and it is not easy for the researcher to access the population. In the present study, mathematical formulas from Cohen's 1988 tables were used to calculate the sample. According to these tables, a sample of 240 students was selected so that generalizations could be made at a 95% confidence level. The selected students are aged from 16 to 18 years and attend the classes 1st, 2nd and 3rd Grade of High School (lyceum). The research sample consists of 240 students with an average age of 16,8 years and a standard deviation of 1,09.

The experimental group consists of students who have already been diagnosed with dyslexia by an official authority of the Greek Government and specifically the participants in the research were diagnosed by KESY, ie the Educational and Counseling Support Centers. The students who participated in the research had been diagnosed with developmental dyslexia and did not appear any other developmental disorder. Specifically, the experimental group of students that participated in the research consists of 120 students. The control group consists of students who according to the informal evaluations of their teachers do not present any special learning difficulty. In addition, they have not been diagnosed with learning disabilities in the past. The control group that participated in the research consists of 120 students. The basic software tests are ten and are divided into those that examine verbal and non-verbal skills. Following the literature the main criterion for the selection of the software tests was to have, as much as possible, the maximum reliability and validity in the evaluation of the parameters of dyslexia in students.

Instruments

The program «DyScreTe» consists of ten tests which will be described shortly. The first test involves pseudowords (nonreal words). Specifically, the pseudowords are displayed on the screen and the student must recognize whether or not the displayed word is a pseudoword or a real one. The reason for this test is that people with direct dyslexia have the ability to read familiar, simple and easy spelling words. However, they cannot read pseudowords correctly and words that they did not use in their speech before a brain injury. Direct dyslexia is the rarest type of dyslexia (Lytton & Brust 1989). Lyon (2003) states that in the case of direct dyslexia, words are read aloud but their meaning is not understood. It is also difficult for people with direct dyslexia to read low frequency words or pseudowords.

The second test involves reading texts. Specifically, two texts are displayed on the screen and after each text there are four questions. In this test, a student's ability to read as well as to understand a text, in relation to time, is tested. Therefore, after the children read the text, they are asked to answer some questions to prove its comprehension. This test is included in the software in the light of the fact that reading disorders usually deal with problems in the rapid and accurate decoding of written speech. These disorders can lead to reading comprehension problems that are described as a key feature of a specific reading disorder or dyslexia (Mouzaki & Sideridis, 2007).

The third and fourth tests concern the examination of spelling. The third test concerns historical spelling and the fourth is grammar spelling. In particular, in the third test a series of twenty words are displayed on the screen where the historical spelling is examined. Thus, in the fourth test twenty words are displayed where the grammar spelling is examined and the student must choose the correct spelling from three choices given. These tests are included because a student, in order to be able to learn to spell, must have acquired the knowledge of letters, the knowledge of the spelling system of his language and have such a memory ability that allows the retrieval of letters and their phonetic correspondences in words with historical spelling. At the stage of productive spelling students have the ability to use spelling rules correctly. Thus, they need to practice more systematically on these rules as well as on historical spelling. At this stage students make mistakes that mainly concern historical spelling. Finally, developmental dyslexia is a special learning disability which is presented as difficulty in acquiring reading skills and later as instability in spelling and as a lack of fluency in handling written words.

The fifth test concerns the comprehension of audio texts. Specifically, the student listens to two recorded texts and after each text he has to answer four questions with multiple answers. In dyslexic individuals, the large cell system of the brain malfunctions, displays cells smaller than normal. This abnormality seems to affect all the functions with which the large cell system is connected, with the most basic the visual and auditory functions which affect the skill of reading. Therefore, an attempt is made to explain on a neurological basis, the

phonological deficits of the case of developmental dyslexia, which no one can deny that is present in the entire dyslexic population. Large cell theory, therefore, links deficits in phonological awareness with problems of visual and auditory nature (Reed, 1989).

The sixth test examines the student's mathematical ability in three areas (known object, arithmetic and problem solving). Dyslexic student are unable to memorize basic arithmetic data, retain rules and techniques. Moreover, they have a deficit in recalling arithmetic operations from long-term memory and have difficulty in any task related to numbers (Geary & Hoard, 2001).

The seventh test is a test in which memory and specifically working memory is tested. In details, students are given a series of thirty-five different letter sequences, where the first sequence contains two numbers, the second three numbers, the third four numbers, the fourth five numbers, the fifth six numbers, the sixth seven numbers, etc. The students will be called to choose the correct sequence of letters from the three options given to them. If a child could not remember two sequences in a row or three sequences in general then the test stops. Plaza et al. (2002) report in their research that students with dyslexia and special learning disabilities perform lower than normal developed ones in memory skills. In addition, the short-term working memory in these students presents weaknesses, resulting in difficulty in the sequence and in carrying out activities that require automation.

The eighth test examines visual memory. This test has a number of image patterns that a part of them is missing. The missing part is appeared in the screen for 4 seconds and then it disappears. The children have to fill in the missing part of a series of pictures given to them. The reason why this trial is included in the program is that in a very recent case study of a 13-year-old boy from Greece diagnosed with dyslexia, Terzopoulos (2015), suggests that children with dyslexia have difficulties in visual memory.

The ninth test examines children's visual ability. This particular test has a series of picture patterns where a part of them is missing. The children had to complete the pattern from a series of pictures given to them. The difference between this and the previous test is that the missing part is appeared in the screen continuously together with the series of pictures given. The reason for this test is previous research that shows that dyslexic students experience short-term memory impairment more when the tests involve schematic representations (Mc Dougall, Hulme, Ellis & Monk, 1994). In addition, children with dyslexia often perform lower in tests that involve the presence of visual perception. Many researchers believe that dyslexic students have a visual impairment and therefore perform poorly on visual tests. (Hammond & Hercules, 2000).

Finally, with the tenth test the intelligence of the students is evaluated. The examinee is given an array of ten images that simulate the scale of standard Raven matrices for the examination of non-verbal intelligence. In this way the intelligence of the students is evaluated which is expected to be similar in both the experimental group and the control group, ie the typically developed students (Raven, 1976). In addition, with the creation of the test, an attempt is made to evaluate some skills of students in combination, such as the sense of symmetry and the perception of the individual in the connection of shapes with the symbols that is required for both children with dyslexia and typically developed their classmates (Williams & McCord, 2006).

Procedure

The great advantage of the «DyScreTe» web application is that one student can perform all the tests without supervision. The tests have a continuous flow so that the student has the feeling that he is playing. The ideal place to take the test is a quiet one and in case the program has to be performed more than once by the same student the conditions must be the same. A suitable place where the application can be run in a school is the library or the computer lab. In those areas there are available computers and internet connection that are necessary conditions for running «DyScreTe» software. The instructions for taking the tests are the following. First the application administrator has to check if there is an internet connection and if the computer responds to the mouse movements. In addition to the smooth operation of the mouse it should be checked whether the audio settings are activated, since the application contains acoustic tests.

It is worth noting that the mouse is the main external unit of the computer that is necessary for the use of the application and must work properly without getting stuck. The tests contain time measurements and any failures with the mouse may cause delays and irritation to the user. Moreover, the user of the program, ie the student must sit directly in front of the computer screen because the tests contain text reading and the correct height of the screen is very important so that the process is comfortable and relaxing.

Data Analysis

Upon completion of the sample collection process, the Statistical analysis of the data was carried out with the help of the IBM SPSS Statistics Version 23.0.0.0 statistical software. The sample selected in the research is 240 students and specifically 120 students were the experimental group and 120 the control group. In order to perform data analysis, the normality of the sample of the two groups above was checked. After the normality test performed, it was found that the sample follows the normal distribution (Shapiro & Francia, 1972). The normality of the sample ensures that it is representative of the population. After that the main hypothesis and the three sub-hypotheses were checked An ANOVA (Analysis of Variance) table was used to compare the results of children with dyslexia with those of the control group, ie the typical developed children.

Results

«DyScreTe» is based on a main hypothesis to prove the accuracy of its results. The main hypothesis that was examined is that students who were diagnosed with dyslexia by official authorities in Greece had significantly lower performance in the respective software tests. For that purpose, a sample of 240 students aged between 16 and 18 years old was taken, of which 120 were diagnosed with dyslexia by an official authority in Greece and 120 were typically developed. The results verified the hypothesis we made that students with dyslexia in each test had a lower performance compared to the typical developed in successful responses, but also the three sub hypotheses that were mentioned earlier were verified. An ANOVA (Analysis of Variance) table was used to compare the results of students with dyslexia with those of the control group, ie the typical developed students. The ANOVA table showed that students with dyslexia had a statistically significant ($p < 0.01$) lower average of correct answers compared to the typical developed students in all tests, except the Raven test (as it was expected) as shown in Table 1.

Table 1. ANOVA table presenting the results of dyslexic students and the typical developed

Tests	Dyslectic Children		Typical developed	
	Average	Standard Deviation	Average	Standard Deviation
Pseudowords	14,33	1,57	18,19	1,02
Reading	4,2	0,80	7,1	0,82
Historical spelling	14,57	0,68	18,02	0,72
Grammar spelling	12,43	0,87	17,43	0,84
Listening	5,13	0,57	8,02	0,74
Mathematic ability	14,03	1,40	25,75	1,52
Working Memory	13,03	0,69	28,10	0,75
Visual distinction	8,02	0,77	14,30	0,86
Visual memory	7,03	0,94	14,12	0,90
Raven test	14,85	0,77	14,90	0,70

Moreover in Table 2 it is shown the time that a student needed to complete each test, for the eight tests where time was measured. The results verified the hypothesis we made that students with dyslexia needed more time to complete each test compared to the typical developed. An ANOVA (Analysis of Variance) table was used to compare the results of students with dyslexia with those of the control group, ie the typical developed students. The ANOVA table showed that students with dyslexia needed a statistically significant ($p < 0.05$) higher average of time compared to the typical developed ones in all tests where time was counted, expect Raven test which measures students' intelligence.

Table 2. ANOVA table presenting the results of dyslexic students and the typical developed concerning time needed to complete the test

Tests	Dyslectic Children		Typical developed	
	Average	Standard Deviation	Average	Standard Deviation
Pseudowords	1,32	0,42	0,54	0,25
Reading	6,77	0,84	4,60	0,87
Historical spelling	2,84	0,55	1,23	0,33
Grammar spelling	3,47	0,57	1,42	0,44
Listening	4,02	0,68	2,05	0,34
Mathematic ability	14,20	0,98	8,12	0,75
Visual distinction	6,24	0,52	3,87	0,40
Raven test	13,78	0,96	13,79	0,96

Table 3. ANOVA table presenting the statistical difference between the scores of dyslexic students and typical developed ($p<0.05$)

Tests		Sum of squares	Mean Square	F
Pseudowords	Between Groups	244,367	244,367	130,221
	Within Groups	773,911	1.67	
Reading	Between Groups	598,578	598,578	1198,077
	Within Groups	202,035	0,620	
Historical spelling	Between Groups	511,325	511,325	1102,011
	Within Groups	179,22	0,650	
Grammar spelling	Between Groups	422,444	422,444	599,477
	Within Groups	299,424	0,824	
Listening	Between Groups	812,784	812,784	2027,344
	Within Groups	138,789	0,302	
Mathematic ability	Between Groups	7984,984	7984,984	3785,977
	Within Groups	812,433	3,744	
Working Memory	Between Groups	14870,984	14870,984	25444,088
	Within Groups	233,785	0,722	
Visual distinction	Between Groups	2768,233	2768,233	3444,022
	Within Groups	247,248	0,796	
Visual memory	Between Groups	4347,874	4347,874	6785,244
	Within Groups	320,244	0,724	
Raven test	Between Groups	1,974	1,947	2,876
	Within Groups	174,470	0,432	

Table 4. ANOVA table presenting the statistical difference between time needed to complete the tests between the dyslexic students and the typical developed ($p<0.05$)

Tests		Sum of squares	Mean Square	F
Pseudowords	Between Groups	49,748	49,748	1035,587
	Within Groups	16,187	0,0057	
Reading	Between Groups	374,658	374,658	574,578
	Within Groups	244,784	0,812	
Historical spelling	Between Groups	233,444	233,444	1788,684
	Within Groups	74,435	0,457	
Grammar spelling	Between Groups	382,477	382,477	1487,537
	Within Groups	92,772	0,355	
Listening	Between Groups	115,478	115,478	661,498
	Within Groups	62,222	0,247	
Mathematic ability	Between Groups	2896,589	2896,589	5471,412
	Within Groups	184,365	0,578	
Visual distinction	Between Groups	786,022	786,022	2774,369
	Within Groups	85,178	0,347	
Raven test	Between Groups	0,007	0,007	0,008
	Within Groups	342,336		

In Table 3 it is shown that statistically significant differences were observed between the two groups in the control of the mean values of the students' scores in all tests, expect the Raven tests. In more detail, the p-value<0.05, therefore at a level of statistical significance of 5%, it appears that the average between the students of the experimental group (dyslectic students) and the control group (typical developed) differ. Moreover, statistically differences were observed between time needed to complete all the tests between the experimental group and the control group at a level of statistical significance of 5%, expect the Raven test as it is shown in Table 4.

Discussion

As it has already mentioned there were no on-line application for screening dyslexia in Greek school students aged from 16 to 18 years old. For that reason, the program «DyScreTe» was created. The «DyScreTe» consists of ten basic assessment tests which were derived from an extensive study of the literature in combination with specialized pro-gramming knowledge. It is a simple and discreet yet effective and pleasant tool for screening dyslexia for students in Greek high schools. «DyScreTe» is based on a main hypothesis to prove the accuracy of

its results. The main hypothesis that was examined is that the students who were diagnosed with dyslexia by official authorities in Greece had significantly lower performance in the respective software tests. Thus, a sample of 240 students from high school in Greece was taken, of which 120 were diagnosed with dyslexia by an official authority in Greece and 120 were typically developed. The results verified the hypothesis we made that students with dyslexia in each test had a lower performance compared to the typical developed in successful responses, except the intelligence test.

Conclusion

Detailed screening of dyslexia is essential for students who experience difficulties in their daily school life to create appropriate intervention strategy which strengthens their school performance and raises their self-confidence. With the «DyScreTe» program, different types of errors in the tests and response times could be analyzed in order to understand in depth the functions of the brain and to intervene more effectively in the student's everyday school life.The «DyScreTe» software assesses students on tests that examine reading ability, spelling, auditory processing, visual recall and discrimination, students' ability to solve mathematical problems, and tests that assess short- and long-term memory and also intelligence. By evaluating the above tests, the screening of dyslexia in high school students is carried out with a fairly high probability. Thus, it is a useful tool to evaluate in great detail the above tests so that specific deficits emerge and more information could be acquired about the above cognitive deficits. It is worth mentioning that dyslexic students have been observed to use their brains differently than their typically developed ones.

Research on dyslexia has shown that some of the most effective dyslexia interventions are based on the Orton – Gillingham method. One of the component of this method is that intervention is personalized to meet the needs of the student and to move at their pace. «DyScreTe»'s results could give to the intervention team specific data concerning the difficulties that student under consideration faces. In this way the intervention team could plan a detailed program. Moreover «DyScreTe» application could be used during the intervention to show student's progress and it can be changed according to them. To sum up the results of the program could be crucial for the construction of intervention program both in order to identify as detailed as possible the difficulties of the student and to monitor and evaluate an intervention program if it is needed.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Acknowledgements or Notes

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