Mental Workload on the Children in Multilingual Environment

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ISLAMABAD

August 2023

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A thesis submitted in partial fulfillment of the requirements for the degree of

MS Biomedical Sciences

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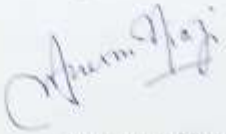

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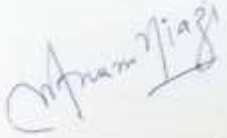

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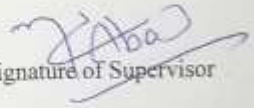

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Titled: Mental work load on the children in multilingual environment be accepted in partial fulfillment of the requirements for the award of MS in Biomedical Sciences degree.

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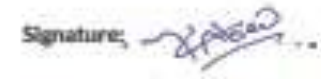
Signature: 

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Copyright Statement

Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which You setup in my mind to improve it. Indeed, I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout in every department of my life.

I would also like to express special thanks to my supervisor Dr. Muhammad Nabeel Anwar for his help, guidance, tremendous support, and cooperation throughout my thesis, for planning and arranging my whole thesis work in sequential manner and guiding me in every step of my work. Each time I got stuck in something; he came up with the solution. Without his help I wouldn't have been able to complete my thesis. I appreciate his patience and guidance throughout the whole thesis.

I would also like to pay special thanks to my co-supervisor Dr. Muhammad Jawad Khan for initiating the topic of project, for helping my thesis work in initial stages of thesis work.

I would also like to thank Dr. Syed Omer Gillani and Dr. Adeeb Shehzad for being on my thesis guidance and evaluation committee. I am also thankful to Dr. Aneeqa Noor for her support and cooperation. I am also thankful to Dr. Saima Zafar, Dr. Umar Ansari, Dr. Syed Omer Gillani, Dr. Murtaza Najabat, Dr. Asim Waris Ali, and Dr. Amer Sohail Kashif for teaching me outstanding course work.

I would also like to pay special thanks to best teacher of my life Dr. Amer Sohail Kashif who taught me Research Methodology and Neural Engineering courses. I must admire his tremendous lectures, teaching methodology, the way of planning whole course, presentation methodology, and knowledgeable assignments and quizzes. I can surely say that I have learned my research interest subjects in depth which he has taught. I respect his hard work, honesty, discipline, time management, and positive attitude towards his profession. In short, I adore his whole personality as a best teacher.

Finally, I would like to express my gratitude to all the individuals who have rendered valuable assistance to my study.

Dedicated to my exceptional parents, and siblings whose tremendous support and cooperation led me to this wonderful accomplishment.

Abstract

Background: The children in Pakistan study in a multilingual environment. They have books of subjects; Mathematics, Science, Social Studies, and Islamiyat in English language, most of the time teachers give instructions only in English language. However, their home tongue is different from English e.g. Urdu, Punjabi, Saraiki, Pushto, Balochi, and Sindhi etc. Children speak with their parents and siblings in their own language.

Objective: Children in schools face a multilingual environment. That may cause more workload during class time. The workload is comprised of 6 components; mental demand, physical demand, temporal demand, performance, effort, and frustration. The main objective of this study is to measure the workload on children, who are studying in schools in multilingual environments.

Method: We tested 187 samples of children studying in public and private schools facing multilingual environments. The ages of children were 11-14. We designed 3 experiments for this subjective study, a home language survey, and three task questionnaires. We designed tasks questionnaires of mathematics in English language, translated that mathematics questions in Urdu language, and English Grammar task questionnaires from the SAT KS2 paper for grade 7. We also designed a home language survey to assess the language they speak with their parents, siblings and friends, the language of teacher's instructions in the classroom, language in which children can efficiently understand and learn their subject's concepts. We also measured the workload on children due to the multilingual environment with a workload measuring tool; NASA-TLX test.

Result: The result of this study showed that children faced more mental workload when they solved the Mathematics task in English and less mental workload in Urdu. When we see other subscales of workload, children required more physical demand, temporal demand, and effort when they solved the task in English as compared to the Urdu language. They also showed lower performance and felt frustrated when they solved tests in the English language.

Conclusion: Children showed more mental workload when they performed tasks in English language and less mental workload in the Urdu language. Books should be in the national language; Urdu and the teacher should give subject-relevant instructions in the tongue language.

Application: These conclusions can contribute to the developing field of education called “educational ergonomics”, indicating that a reliable measurement tool can identify children who are facing more workload. School environment and factors of human psychology can be improved for children’s better mental health.

Key Words: *Workload, Mental Workload, NASA-Task Load Index, multilingual environment, educational ergonomics.*

Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

1.1 Mental Workload

The workload is necessary element in our daily routine activities, so the measurement of workload is very essential. The definition of workload can be comprehended in many ways: the capacity of workers related with the work to be done (Meshkati, et al., 1995). The workload comprises of two types that are physical and mental (Mehta & Agnew, 2011). As there are two types of workloads, so the method of assessment of physical and mental workload is different. The origin of measurement of physical workload is assessed from the physical work in industries. There were many tasks in which rather than workers physical capacity, more mental capacity is used. Mental tasks use cognitive capabilities of a person. There are several methods that can be used to assess the mental workload. Researchers design different techniques to measure the mental workload. From practical and usefulness point of measuring the mental workload in working ergonomics, a design is formulated which consists of creating the primary task design, secondary task design, subjective rating design and physiological or psychophysiological design (Meshkati, et al., 1995).

1.2 Measurement of Mental Workload

Assessment of mental workload of workers can be carried out using a variety of procedures; that are subjective and objective (Hart & Staveland, 1988). As objective procedure in scientific research is accompanied with testability and reproducibility of any research question or area which still need to work with the help of instrumentations in laboratories. While subjective procedure in scientific research generally based on observations of events, survey questionnaires or structured interviews, from the participants (Hancock & Meshkati, 1988). As objective procedure is expensive and cannot bear the cost of inaccurate results. Therefore, another alternate has been developed for measurement of mental workload, which is subjective method. The subjective method for workload measurement, which is popularly used by researchers is the NASA TLX (NASA Task Load Index). This method is developed by Sandra G. Hart (from the Aerospace Human Factors Research Division, NASA AIMS Research Centre, California) and Lowell E. Staveland (from San Jose State University) in year 1988 (Hart &

Staveland, 1988). At the beginning, NASA TLX comprises of two parts: sources of workload comparison cards and rating scales of workload subjects. Rating scales shows the six subjective subjects presented on a single page, which consists of mental demand, physical demand, temporal demand, performance, effort, and frustration. For numerical data measurement, pairwise comparison of subjects of workload is done. There are definitions of each subject of workload before rating sheet of subscales. The descriptions will help participants to answer more accurately. They are graded within 100-points range with a 5-point step of each subscale. These scales ratings are then combined into tasks load index. So, workload subject's results can be shown in numerical form (Hancock & Meshkati, 1988).

1.3 Evolution of NASA TLX

Initially, NASA TLX was developed by Sandra G. Hart and Lowell E. Staveland in 1988, and further both work for more than two decades in growth of its usability for measuring subjective workload in broad range of applications. At that time, it was only available as a paper and pencil form on NASA (National Aeronautics and Space Administration) website, developed under NASA ARC (AIMS Research Centre) (Noyes & Bruneau, 2007). Among them, other researchers also used this test in different setup for measuring workload of workers. There is explanation of practical application of NASA TLX test (Rubio, et al., 2004). From the launch year, researcher used this test for 20 years in its original application (aeronautics), focus and language studies. Six subscales of workload and weighted averaging idea had proven an easy for used comparable sensitive for experimentations over two decades after its formation. In 2006, Sandra G. Hart done a survey and wrote that more than 550 studies have used or reviewed NASA TLX test which can provide a facility for new generation users (Hart, 2006).

In 2008, a study examined the extent of measurement of invariance of NASA TLX test and raised the awareness in scientific societies. A survey of 200 participants reported the quality of mental workload they experienced while driving in rural and urban areas across the country. Results showed that researchers should clearly examine that which type statistical tests should be used, if participants are under different conditions; mean scores, mean differences, standard deviations, and invariance etc. (Bustamante & Spain, 2008). To find the solution of research question in scientific and biological studies, to measure any subject of life, statistical test should be used (Walsh, 2014).

After paper and pencil version, NASA formed computer-based version, for comfortable procedure for participants and researchers. The cost difference between the two versions is also considerable. It was examined that there is notable difference between the workload scores obtained from two types of media. The computer-based version scoring more workload, but both versions can be implicated (Noyes & Bruneau, 2007). A program for practical application of computerized version of NASA TLX was described. The computerized version helps in simple collection of scores, post processing, and storing raw data. The software collects raw data from the subject and compute the weighted or unweighted workload score, as output of text file. The software was developed in Visual Studio 2005 and efficient for running on pocket personal computers with Windows 2000 and higher (Cao, et al., 2009). Free of cost, user-friendly, computerized version of NASA TLX is also described by other researchers and participants are explained (Sharek, 2011).

A survey also used the comparison method of both version on industry workers to analyze the physical and mental workload. In a lab experiment, 29 participants carried out a uniform environment task, NASA TLX on paper and then on smart watch by using the touchscreen. After analysis, the workload score in the paper version was notably lower than obtained from the smart watch version. However, to find the relative difference between the different levels of difficulty of cognitive tasks, any version of NASA TLX can be used. People working in any institute as employee or in their practical life such as industry, hospital, education sector or offices can easily implement computer or mobile version (Mach, et al., 2018). Research has also showed that gender difference is also exist in terms of level of workload and physical or mental collapse in multinational companies. After survey of 40 participants in multinational company, showed that there is positive relation between workload and burnout. There is also notable differences between women and men scores of workloads which tells that women are categorized by significantly higher level of workload and burnout than men (Aniţei, et al., 2015).

1.4 Mental Workload on Children

NASA-Task Load Index is reliably using test for past 3 decades. Initially it was using on adults, after that it was using on children for workload assessment additionally in 20’s of this century. After 2020, NASA-TLX test is rapidly using for adults as well as children. Searching by using the Google Scholar and Google Chrome search engines, there was a vast number of

research papers and review papers in which study of workload was carried out. Currently, the number is about 2,300,000 results. A notable number of papers are defining the workload and considerable number of papers are assessing and measuring the workload. Researchers gave us many methods for quantitative study of workload. From all of them, researchers have proved that NASA TLX is most reliable method of assessment of mental workload. 23,000 results were showing on workload measurement by NASA TLX. After deep search, reading, and analysis, we came to the point that there is a lot of research has been carried out on workload on workers working in industries, employees doing their jobs in offices, nurses and doctors in hospitals, patients admitted in hospitals, and many other departments of life. But there is little work on workload on students studying in educational institutions. Apart from that, rare research on mental workload on children of elementary and primary schools has been carried out. After searching on Google Scholar, workload on children by NASA TLX, only 5000 results were showing, but this is necessary to mention that due to word “children”, most of results were came in a search which were not according to the topic. After very deep and keen survey on Google Scholar, we can surely say that there were around 50 papers in which workload on students related to their education was concerned. Out of them, around 15 papers were concerned about workload on elementary and primary school children. We also came to another point that, after 2020, researchers have worked on workload on students more significantly.

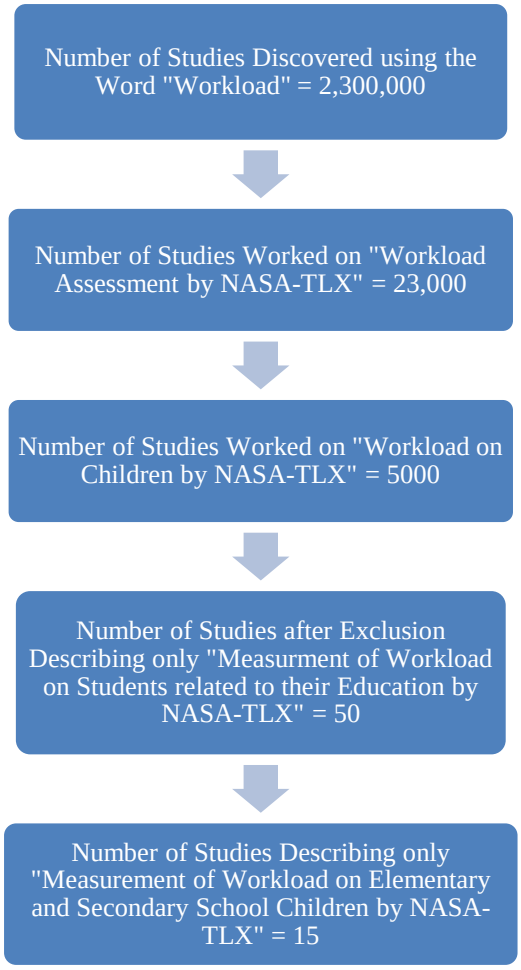


Figure 1. **Systematic Literature Review Flow Chart**

Research on 200 e-learning students suggests that during online study, there is more difficulty in focusing on lectures and adequately producing more workload on students. The assessment of workload was identified by NASA TLX test and SOFI method. The research used both six workload subject's scores, weighted procedures, and pairwise comparison methods (Febiyani, et al., 2021). Due to pandemic in Covid-19, another survey on 223 students carried out using NASA TLX test, to evaluate the mental workload on students taking lectures online. Results suggests that e-learning cause more workload on students (Beena & Sony, 2022). After survey on students of Indonesian university was conducted, results showed that students have an elevated level of difficulty in e-learning readiness. Among all the workload factors, mental workload was significantly higher in online learning than face to face learning (Widyanti, et al., 2020). Study on 367 phycology students showed that positive academic context will improve

student's performance and reduce the feeling of overload and vice versa (Rubio-Valdehita, et al., 2014).

A comparative study on assessment of mental workload on college students taking alcohol not taking alcohol has carried out. Results showed that alcohol effects the cognitive functioning, problem solving ability, induce more workload on students taking alcohol as compared to students who are not taking alcohol. NASA-TLX test was used to find the more level of workload on short term population and alcohol abusers (Hardy, et al., 2022). Even though, Cognitive Load Theory (CLT) has been examined for many years, but its theoretical clarity and methodological approach has been criticized. A study has carried out to investigate the reliability, validity, and sensitivity of mental workload tests, mainly applied in educational ergonomics. In first experiment, there was third-level environment of classroom, and three tests were used to find the mental workload; that were NASA-Task Load Index, the workload profile, and the rating scale mental effort. In this design, the lecturer gave questionnaires and test with no interactions with students. In the second experiment or design, which are inspired by the Cognitive Load Theory, the same content was converted to multimedia video and then students solve the questionnaires and tests. In third experiment and design, which was extension of second design, but addition of inquiry activity was performed. Results suggest that these tests used for measuring mental workload are highly reliable. Numerical values of mental workload in three different design conditions, showed that there is slightly notable difference of mental workload, hence the sensitivity achieved was low (Longo & Orru, 2018). E-learning studies showed more workload due to use of gadgets, internet problems, and finding peaceful place in their study, using NASA Task Load Index (Reyes, et al., 2021).

Research on children delivering online lectures, to check the performance of cognitive activities was carried out. Children fulfil two online discrimination assignments in which they matched sample shape with a correct shape out of four shapes coming on the computer screen. Children completed such two assignments, an easy task in which stimulus appeared on the screen for 7 seconds, and a harder task in which stimulus appeared for 2.5 seconds. After completing the task, children measure their workload using NASA-TLX test, their performance in the online tasks suggested that delivering online lectures does not negatively influence the ability of children to complete discriminative tasks. Children's workload score was less decisive (White, 2022). A study measured workload in a classroom using presentation tool Mentimeter to regulate

the NASA-Task Load Index. Children performed two cognitive tasks and assessed the workload, indicating that workload measurement is useful tool in the classroom (Connor, 2020).

Research to enhance the analysis process of eye gaze assistive technology by means of development of an assessment framework. Study wanted to reduce the prohibitive cost and technical issues. For such purpose, low-cost eye tracker and measurement of level of fatigue and frustration were measured using NASA-Task Load Index (Perfect, 2018). A survey investigated the effects of varying degree of cognitive and memory tasks while measuring postural motion on two batch of children, one with matching age group and developing children, another with diagnosed developmental coordination disorder (DCD). 38 volunteer's children performed a digital cognitive and memory test at two levels of difficulty, high and low, followed by NASA-TLX test. Postural variability of the head and body of children were reported as the biochemical feedback for finding the task difficulty and gifted and typical students facing difficulties in their studies (Chen, et al., 2012). Research used Brain Computer Interface (BCI) for subject-specific calibration to improve the performance. It is true that children whose restricted attention and ambition may limit the duration of bearable calibration periods. A process of adding scoring system, giving reward after task completion which is called "gamification," can increase the attention, motivation, and task performance in children. 32 typically developing children take part in two sessions, to perform two ideal paradigms: words spelling using visual P300 event-related potential (ERP300), and cursor control using sensorimotor rhythm (SMR) modulation, after that gamified and non-gamified calibration. In this study, motivation, frustration, and mental workload evaluated by NASA-TLX test (Kelly, et al., 2023).

54 children (30 boys and 24 girls), age ranging from 10-13 years old participated in the study for evaluating the performance of grade 6^{th} and 7^{th} children in different settings of two different English medium schools in the Lucknow, India. The children were tested in four setups, and 4 groups of children were made. The four setups were as individual participate in the lab environment and in the field for think-aloud sessions, as pairs of participants in lab and field for constructive interaction sessions. For evaluating usability, natural environment is called field testing. Usability testing in artificial environment is referred as laboratory testing. First usability test session was conducted in school computer lab and another in specialized laboratory setup in another part of the school. In the test sessions, children have use International Children's Digital Library (ICDL), which is featuring collections of books for different age groups. During the test

sessions, children interaction and screen activities with ICDL were recorded using desktop screen recorder Cam Studio for later analysis. The children solved five tasks; searching books by country, tittle, language, award winning books in English, and reading a specific book in their preferred language. After setups usability sessions, children complete the subjective workload test; NASA-TLX, to assess the workload and behavior in two settings. The results showed that children show different performance as in field and lab testing, field testing made children less frustrated. Pairs of children in field testing show less effort and mental workload. In gender study, girls showed higher performance level during individual field session, higher mental demand in laboratory sessions as compared to field sessions. Boys showed higher performance when assessed individually in field and lab sessions, higher mental workload when assessed individually in field and lab session as compared to paired wise study (Khanum & Trivedi, 2013).

Cynthia Laurie-Rose and her co-worker in a study worked on workload on children of elementary school studied in 4^{th} and 5^{th} grade. They used modified versions of NASA TLX test with children to test its effectiveness by using differential level of workload, to know the relationship between workload and performance of typical and gifted children, and to establish a criterion of validity for workload assessment. They compose two types of tasks, a puzzle task, and a discrimination task to emphasize mental and temporal demand, respectively. They tested 29 institute-labeled gifted children (19 boys and 10 girls) and 38 typical children (18 boys and 20 girls), recruited from 4^{th} and 5^{th} grade, of public schools in Ohio. 12 letter-shaped bodied made up of five squares called pentominoes were used for puzzle task called “a dog and a rooster”. In low resource demand puzzle task, students outlined within of each of 12 pentominoes. In high resource demand puzzle task, the interior of pentominoes were completely blank. The researchers gave students a maximum of 3 minutes to complete the puzzle. The discrimination tasks were completed on an iBook Mac computer, programmed using Superlab 4.0, with identical resource demand, except for stimulus given time. In low resource demand task, stimuli retended on the screen for 7 seconds and for higher resource demand task, stimuli retented for 2.5 seconds. The intertrial time was 0.5 seconds. Results suggested that gifted children reported notably lower level of workload than typical children. The puzzle task needed more workload than discrimination task. Children reported notably higher workload in the high resource demand state than in low resource demand state. Mental and temporal demand subscales reported higher

ratings than physical demand, performance, and frustration, and effort subscale reported higher ratings than performance and frustration. All effects in main subscale ratings were moderate to large. In another experiment, they assessed whether the youngest children of elementary school could evaluate the workload effectively. 37 students recruited from 1st and 2nd grade from the same public school in Ohio. There were 14 boys and 23 girls. The apparatus, materials, and procedures were identical to first experiment. After every task, they gave instructions about NASA-TLX test and its subscale simplified definitions. For scale's rating, they let children use wooden apparatus called moveable peg. Children move that peg to left and right for rating of specific scale. The results of second experiment suggested that the NASA-TLX test is useful for assessment of workload for even youngest elementary school children (Laurie-Rose, et al., 2014).

Cynthia Laurie Rose and her co-worker in another study explore the effects of spatial uncertainty, field independence/dependence, and gender study on vigilance performance, and measurable workload on elementary school children (Laurie-Rose, et al., 2017). Due to attention deficit disorder, child development insight is increasing, however, research with children has distinct from adult's vigilance research (Laurie-Rose, et al., 2015). After thorough literature review, on measurable workload on adults as benchmark, we were able to identify the detail of workload study on children. They adapted the NASA-TLX test for children with above-average and average cognitive abilities, after the completion of low and high information processing demanding tasks. They used simplified definitions of subscales and modified NASA-TLX test to evaluate the workload in typical and gifted children. They recruited 48 students; 24 girls and 24 boys of 4th and 5th grade from one school in Westerville, Ohio (Laurie-Rose, et al., 2017).

In recent studies, Cynthia Laurie-Rose, and her co-workers in workload assessment studies, in children they also used unweighted scores (Laurie-Rose, et al., 2017). Study in 2017, they formed two vigilant conditions, spatial certainty, and spatial uncertainty. In both conditions, all parameters were identical except for stimuli placement within the visual display. They compose a set of 12 4-letter strings for both normal and critical signals. The 4-letter strings were obtained from following letters: A, B, C, D, H, and T. They chose those letters because of high discrimination from each other, normal events displayed all 12 strings in capital letters and in critical events, displayed in small letters. In critical events, capital letters appeared in any one quarter of computer screen, in bold, black, and Times New Roman against a white background.

The vigilance condition tasks were displayed via a Macintosh iBook computer with children sitting around 15 inches from the computer screen. The vigils were run without interruption for 14 minutes. The stimuli were presented for 0.2 seconds at the rate of 30 vigils display per minute with new vigil set at 0.2 second's difference. For cognitive testing, they assess the children by asking them to identify the simple shape with complex shape. Children were allowed for 3 minutes to complete the task. After each vigil condition task, the children solved the modified NASA TLX test (Laurie-Rose, et al., 2017). Nygren in 1991, used the unweighted scores in his study (Nygren, 1991). Wiebe, Roberts, and Behrend in 2010 found that, there is nearly no difference between weighted and unweighted NASA-TLX test evaluation. For children, they used only unweighted scores (Wiebe, et al., 2010). Many studies have identified that field-independent individuals disembodied from their background, whereas field-dependent individuals face more difficulty with such tasks. Results from studies revealed that field-independent and dependent individuals show notable differences in adults as well as in children (Guisande, et al., 2012). The results showed that field-independent and dependent children performed distinctly. Field-independent children compared with field-dependent children revealed superior performance, but they were not differing in overall workload. The findings also showed that spatial uncertainty exerted effects on workload, the psychophysical scales of spatial uncertainty showed significant determinant of vigilant performance in children. The findings also suggested that field-dependent girls gave a more lenient response criterion than field-dependent boys. This study demonstrated that, the communication between children and researchers were advantageous. Further, they also suggested that this unweighted study can be used for adults. In gender study, they suggested that boys' and girls' performance was equally well, and boys experienced greater overall workload than girls, so they conclude that boys require greater mental expenditure than girls. This study also suggested that this research is reliable and provide complete account for measuring workload demand on children in school setting and in other departments (Laurie-Rose, et al., 2017).

1.5 Multilingual Environment

Context is defined by different people in their own way. Three researchers in their study defined context as the person's environment, location, identity, and time (Ryan, et al., 1997). Another researcher in his study defined context by including the whole environment as in aspects

of experiences in different settings (Hull, et al., 1997). The properties of the context; the person, tasks, and environment are important in finding their usability. Any change in the relevant feature of the context of use might change the product usability (Bevan & Macleod, 1994). Researchers have shown that, in evaluations of workload studies, as compared to adults, children are mostly affected by the circumstances and context, in which our environment is also included. Children show different behavior in different settings and environment. They feel more comfortable and relaxed in their natural environment. They act confidently in their own environment. As there are many studies and research has been done on physical context of person's capabilities, however, there is more need for understanding the ultimate results of different contexts through psychological prospect. That is why understanding of the effect of context and impacts on the method of usability evaluation is required. For understanding the relationship between the physical context and the human's behavior, we select the acquired theory, "behavior settings." This theory was presented by Roger Garlock in late 1940's. According to opinion of this theory, individual's behavior is affected by the environment in which he/she is. Behavior settings comprises of two portions; behavior, and the individual settings in which he/she is. Behavior of an individual is the way he/she act towards different settings. Setting is combination of things, place, and time (Barker, 1978). After grasping the opinion of this theory, we gave the statement that:

"Individuals can be same across numerous settings, but they would show different behavior depending on the environment."

1.6 Educational Ergonomics

Human factors that affect the behavior of human is educational psychology (Stone, 2008). Woodcock (2007) pointed that hybrid branch of educational ergonomics is emerging field of sciences which linked the factors of human behavior with educational psychology (Woodcock, 2007). In this way, Smith (2007) told the advantages of applying this branch of science enhance student learning in cognitive activities in elementary and secondary education has recognized wisely (Smith, 2007). Koriat (2012) done a great work in allocation of ideas and procedures among emerging psychologists, educational professionals and experimental neuroscientists to realize the potential of practical advantages (Koriat, 2012). Through such efforts, educational ergonomics enhanced the students learning by applying the good practices by

educators, designing beneficial and low workload learning experience for children's unique nature and abilities (De-Bruin, 2012). Kahneman (1973) said that in science factor of human behavior, distribution of attentional resources promote research on workload (Kahneman, 1973). Sweller (1988) said that educational psychologists have been advised by an opinion similar to resource distribution which is called cognitive load theory. Both ideas told that the mental operations performance to fulfil the demands of specific task which leads to the expenditure of a limited and deferent reservoir of attentional resources (Sweller, 1988).

Generally, we can say that resource distribution and cognitive workload theory suggest that when task requirements are objectively high, participants will use more "processing units" from their attentional resources, as a result greater mental workload demands and lower performance are experienced. After deep research, we came to the knowledge that formal construction of workload tests was conducted on adults but also in children. In school settings, elevated workload test scores can tell us the information about overload. This workload assessment test can be used with elementary school-aged children for workload assessment.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 Sample Size

We tested total 187 children of age 11-14 from 5 public schools. From total 187 random samples, 112 were girls and 75 boys. Children were participated from grade 7^{th} at public schools in Rawalpindi Pakistan.

2.2 Protocol Design

We designed 3 sets of experiments. In experiment 1, children solved mathematics task in English language and in experiment 2 they solved mathematics test in Urdu language. As our national language is Urdu and children speak Urdu language in home and schools. Our concern is that, teacher should give the class instruction in Urdu language. In experiment 3 children solved the English grammar task as English is international language, children should also learn basics of English language.

2.3 Home Language Survey

We also construct the home language survey, so that children can gave their opinion on the language, they speak with their parents and siblings at their home, and which language they speak in classroom and can grasp the concepts of subjects. We design this home language survey, so that class instructions should be given in which language.

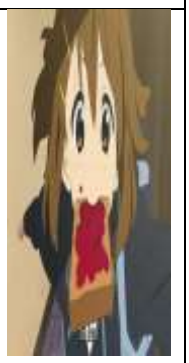
2.4 Tasks Questionnaires

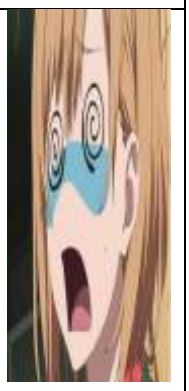
We made 3 tasks questionnaires mathematics in English language from KS2 SAT papers for grade 7. We picked mostly word problem questions from SAT mathematics, we added total 10 questions from KS2 SAT mathematics. Further, we translate those 10 question in Urdu to compare the results that children mostly understand in which language. We also make English grammar test from SAT English grammar test. We picked 10 questions for assessment. We picked all the questions for assessment from latest SAT test 2022 questions papers.

2.5 NASA TLX Test

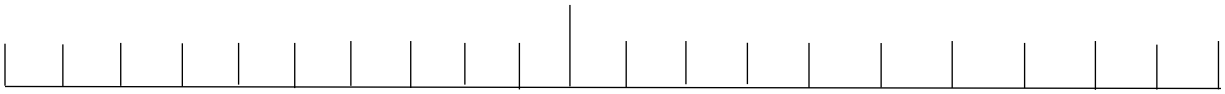
To assess the workload on children, we used the NASA TLX test. As workload comprises of 6 elements, mental demand, physical demand, temporal, performance, effort and frustration. As our main focus is on mental demand but other elements of workload are also important. We simplified the subscale definition of 6 elements of workload. So that children can read it easily. We also give instruction about this subscale definition in Urdu for understanding. NASA TLX test also consist of rating sheet. For removing the confusion for children, we gave the rating sheets scaling from 0-20. 0 is minimum scale and 20 is maximum scale, and 10 is midpoint. For more understanding, 0 means the failure in the test and 20 means the successful in the test.

Table 1. **Actual and Simplified NASA-TLX Subscales Definitions** (Laurie-Rose, et al., 2014)**.**

Subscale	**Actual NASA-TLX Definition**		**Simplified NASA-TLX Subscale Definition**	
Mental Demand	How much intellectual and cognitive activity was needed to complete the task, for example, thinking, decision making, brain storming, calculating, analyzing, searching etc.		How much thinking process did you have to do? Did you do a lot of mental work and figuring out, or not very much? Was the task easy or difficult, simple or complicated, demanding or easy-going? Look at the girl in the picture, on the left side, she is not thinking very hard. On the right side, she looks like that she is thinking very hard. After completing the task, you have to mark the rating sheet according to amount of thinking process.	
Temporal Demand	How much time stress did you feel due to speed at which the task is performed? Was the pace of the task slow and easy, or fast and worried?		How hurried did you feel? Was it steady or rapid? Did you feel that you were rushed or not rushed while solving the task? On the left side, girl looks like she was leisurely going. While on the right side, she looks like, she was very hurried. After completing the task, did you feel that you handled the task easily or you were feel rushed? Mark the rating sheet according to the time	

			pressure you felt.	
Physical Demand	How much bodily activity was required, for example, your arm and hand muscles movement, while doing the task? Was the task physically less or high demanding?		Did you have done a lot of muscle activity or not while performing the task? On the left side, the girl looks like she had not done a lot of bodily activity like pushing, pulling, and moving. On the right side, the girl looks like she had done a lot of bodily activity like pushing, pulling and moving. After completing the task, what do you feel that you have done a lot muscular activity or not? Mark on the rating sheet that how much pushing, pulling, turning, and moving you had done.	
Performance	How rewarding do you think after completing the task? How contented and satisfied you were after accomplishing the task?		How successful do you think you were in accomplishing this task? Do you think you did excellent job? On the left side, the girl looks like depressed after completing the task. On right side, she looks like she is happy and proud after accomplishing the task. Mark the rating sheet that how much successful do you feel after completing the task.	
Effort	How tough time you have encounter to work mentally and physically to accomplish your task?		How hard did you have try to complete the task? Did you done a little bit or a lot of effort? On the left side of the picture, the girl looks like she had done not much effort. While on the right side of the picture, girl looks like she had done a lot of effort. Mark the rating sheet that how much effort did you done while performing the task.	
Frustration	How stressed, irritated, annoyed, unsecured, and discouraged you feel during the task?		Did you feel relaxed or stressed? Did you feel contented or irritated? Did you feel gratified or unhappy? On the left side of the picture, the girl looks like she is relaxed. While on the right side, the girl is irritated.	

Mental Demand How mental demanding was the task?



Very Low Very High

Physical Demand How physically demanding was the task?

Very Low Very High

Temporal Demand How hurried or rushed was the pace of the task?

Very Low Very High

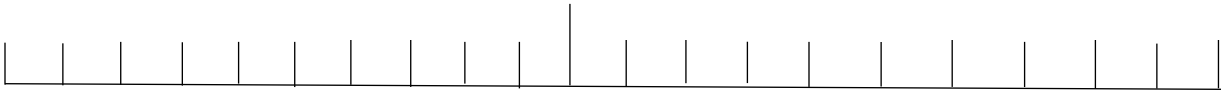
Performance How successful were you in completing what you were asked to do?

Failure Success

Effort How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration How insecure, discouraged, irritated, stressed, and annoyed were you?



Very Low Very High

Figure 2. **Rating Sheet of NASA-TLX Scaling from 0-20. 0 is Minimum Scale and 20 is Maximum scale. 0 is 0% and 20 is 100%. 10 is Mid-Point Scale and 50%** (Hart & Staveland, 1988)**.**

2.6 Data Collection and Survey

We done the data collection from 5 schools and that was a random schools survey. In the beginning of the test in every school, we take permission from the school authorities. At the start of the test, I greeted and introduced myself to children, give instruction to the children about the all 3 experiment and purpose of the survey in Urdu language. Especially I explain in detail about the importance of the participation in the test, understand them that they will not be punished for doing it wrong and bad performance. I asked them verbally many questions about their subject books, and their comfort and understanding with languages. The questionnaires had blank spaces to provide answer, such as their name, age, school, number of minutes taken to complete the task, time was filled by myself.

2.7 Experiment 1

As we design 3 sets of experiment. In first experiment, 187 children of grade 7 from 5 schools solved the mathematics test in English language. At the beginning of the task, children were gave instruction in Urdu to solve the test. We gave instructions about Home language survey, NASA TLX test and its simplified definition about math task questions. On the first page of the test, children have to provide answer to such as name, school, age and total time in which they complete the best. Time was filled by researcher.

2.8 Experiment 2

In second experiment, 187 children have to solve the mathematics test in Urdu language. They have to mention their name, school and age by themselves. Total time given by children was provided by us. Workload and subscale definition were told again and again for a good results rating sheet.

2.9 Experiment 3

In third experiment, 187 children solve the English grammar test. The test was made from KS2 SAT English grammar. There were the best question in the test. Children have also solve the rating sheet after completing the test. The purpose of English test is that, as English is international language, children should know about the basic of English language and grammar.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 Data Analysis

We use the paper and pencil manual of NASA-TLX test for assessment of workload on children due to multilingual environment. During the Experiment 1, when children solved the mathematics test in English, they asked me a lot of question regarding the word problem scenario, method used in that particular question, and meanings of the words in questions, while in Experiment 2, they asked me less questions. We collected the results in the form of hard sheets. As we designed three sets of experiments for this study, we had a pile of test sheets. First, we make data of NASA-TLX frequencies on hard sheets, make results, and analyze the results. For making soft form results and graphs, we use the Statistica software application and compile the results. On y-axis, the independent quantity NASA-TLX rating scores from 0-20 points are mentioned. While on x-axis, the dependent quantity NASA-TLX frequencies of points marked by children are mentioned. We formed the frequencies graphs for six workload subjects mental demand, physical demand, temporal demand, performance, effort. As mathematics task is cognitive activity for children, we mainly concerned with mental demand, so our main focus is on frequency graph of mental demand when children marked in experiment 1 and experiment 2. In completing cognitive task, other workload subjects; physical demand, temporal demand, effort, performance, and frustration are also concerned. We use the correlation graph plot between NASA-TLX points and frequencies for this study. For analysis of results, we should know that when the scatter plot points make a straight line on the graph, it shows the stronger linear relationship between the variables on x-axis and y-axis and the higher correlation. If the scatter plot points are such that graph line runs from the lower left to upper right of the graph region, it shows the positive or direct correlation between the two variables. It means that an increase in the value of one variable is more likely to be associated with an increase in the value of another variable. If the scatter plot points are closer to the line, the stronger the correlation. If the scatter plot points tend to form a cluster around a graph line and runs from the upper left to lower right of the graph region, it shows the negative or inverse correlation between the two variables. It means that an increase in the value of one variable is more likely to be associated with a decrease in the value of another variable. The correlation coefficient, Pearson's r, ranges

between +1 and -1. +1 is a perfect positive correlation, -1 is a perfect negative correlation, and correlation near zero shows that there is no association between scores on the two variables.

3.2 Mental Demand

The correlation (r) = 0.10487, when children solved Mathematics test in English language. The correlation (r) = -0.2807, when children solved Mathematics test in Urdu language. As (r) value is positive when children solved the Mathematics test in English language, so we can say that children face more mental workload and (r) value is negative when children solved the Mathematics test in Urdu language, so we can say that children face less mental workload in comparison of first two experiments. After analysis from the graphs formed from Statistica application, we came to the result that children required more mental demand while solving the Mathematics test in English and less mental demand is required while solving the Mathematics task in Urdu language.

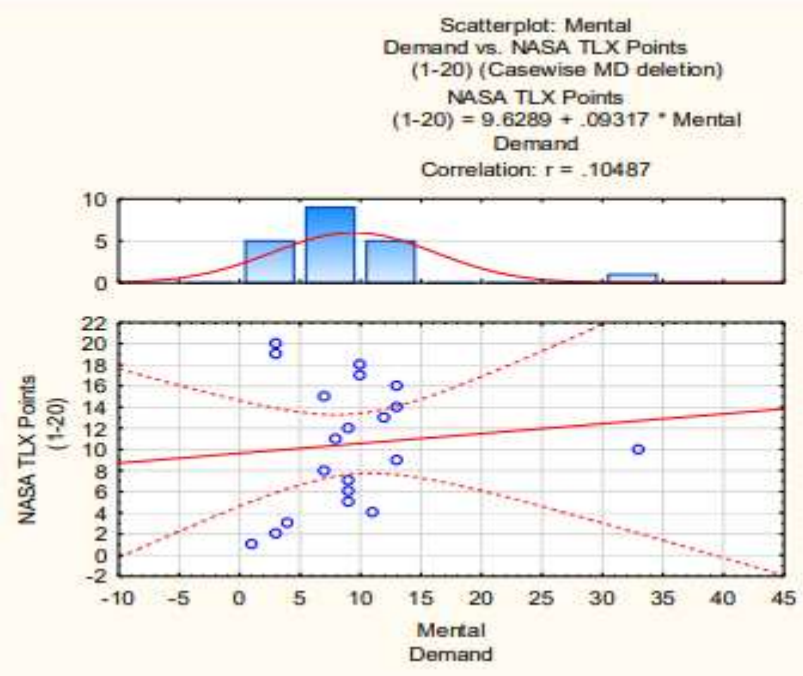


Figure 3. **Graph between NASA-TLX Points and Frequencies of Mental Demand when Children solved Mathematics test in English Language**. The mental demand correlation (r) = 0.10487, when children solved mathematics test in English language. As (r) value is positive, however, children required more mental demand while solving the Mathematics test in English language.

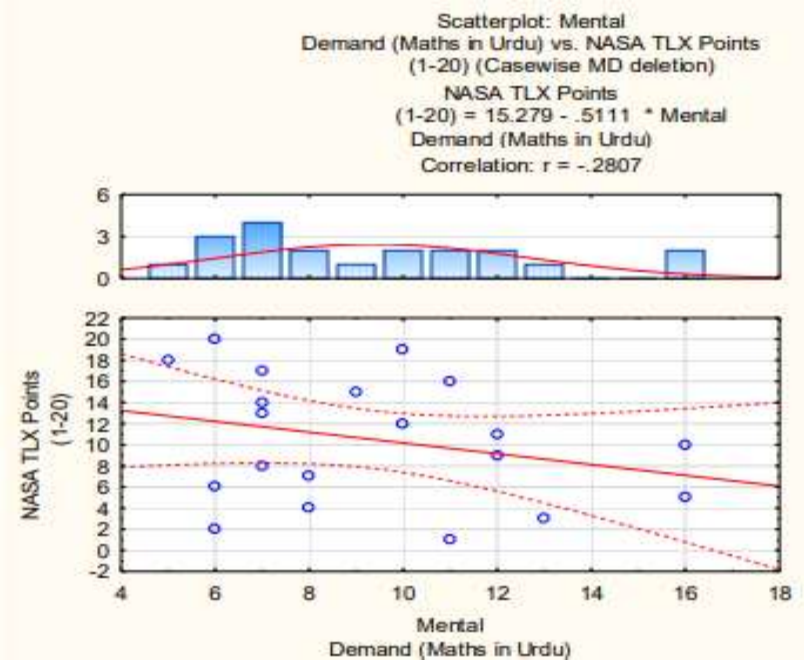


Figure 4. **Graph between NASA-TLX Points and Frequencies of Mental Demand when Children solved Mathematics test in Urdu Language.** The mental demand correlation (r) = -0.2807, when children solved mathematics test in Urdu language. As the (r) value is negative, however, children required less mental demand while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Mental Demand	0.104872
Mental Demand (Maths in Urdu)	-0.280674

Figure 5. **Comparison of Correlations of Mental Demand of Two Groups of Children solved Mathematics test in English and Urdu Language.** The mental demand correlation (r) = 0.10487, when children solved mathematics test in English language. The mental demand correlation (r) = -0.2807, when children solved mathematics test in Urdu language. As the correlation (r) = 0.10487 is positive, which shows that children face more mental workload when they solved the test in English language, and (r) = -0.2807 is negative which shows that children face less mental workload when they solved the test in Urdu language.

3.3 Physical Demand

Correlation (r) = -0.2892 when children solved the Mathematics test in English language and (r) = -0.699367, when children solved the Mathematics test in Urdu language. As both correlations are negative, which indicates Mathematic task is cognitive activity which required less physical activity. As (r) = -0.6994 is more negative number than (r) = -0.2892, which shows if we compare the physical demand of first two experiments, children face less physical workload when they solved Mathematics test in Urdu language. After deep data analysis of graphs from Statistica application, we came to the point that more physical demand is required while solving the mathematics test in English language and less physical demand is required when children solved the mathematics test in Urdu language.

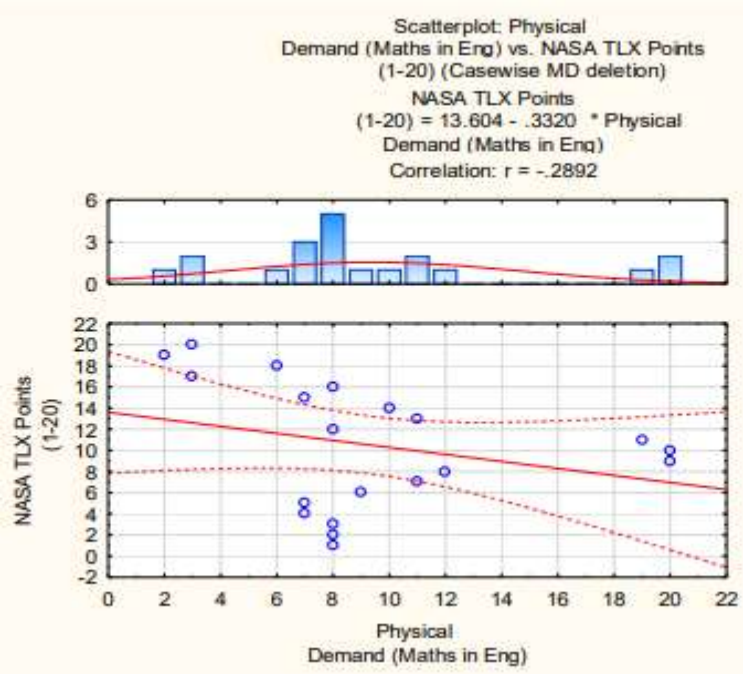


Figure 6. **Graph between NASA-TLX Points and Frequencies of Physical Demand when Children solved Mathematics test in English Language**. The physical demand correlation (r) = -0.2892, when children solved mathematics test in English language. Children required more physical demand while solving the Mathematics test in English language.

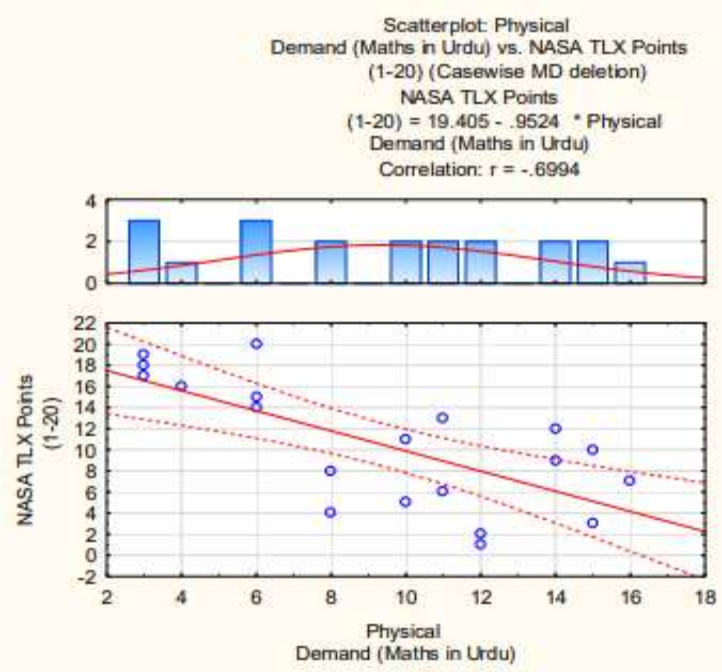


Figure 7. **Graph between NASA-TLX Points and Frequencies of Physical Demand when Children solved Mathematics test in Urdu Language.** The physical demand correlation (r) = -0.6994, when children solved mathematics test in Urdu language. Children required less physical demand while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Physical Demand (Maths in Eng)	-0.289169
Physical Demand (Maths in Urdu)	-0.699367

Figure 8. **Comparison of Correlations of Physical Demand of Two Groups of Children solved Mathematics test in English and Urdu Language.** The physical demand correlation (r) = -0.28917, when children solved mathematics test in English language. The physical demand correlation (r) = -0.69937, when children solved mathematics test in Urdu language. As the correlation (r) = -0.69937 is more negative number and significant, which shows that children face more physical workload when they solved the test in English language as compared to when they solve same test in Urdu language.

3.4 Temporal Demand

Correlation (r) = 0.16062 when children solved mathematics test in English language, and (r) = -0.2246 when children solved the test in Urdu language. As (r) = 0.16062 is positive value, and (r) = -0.2246 is negative value, which indicates that children take more time when they solved the test in English language, and they take less time when they solved the mathematics test Urdu language, in comparison of Experiment 1 and 2. After analysis from the graphs, we came to the point that, more time is required while solving the Mathematics test in English language and less time is required while solving the same test in Urdu language.

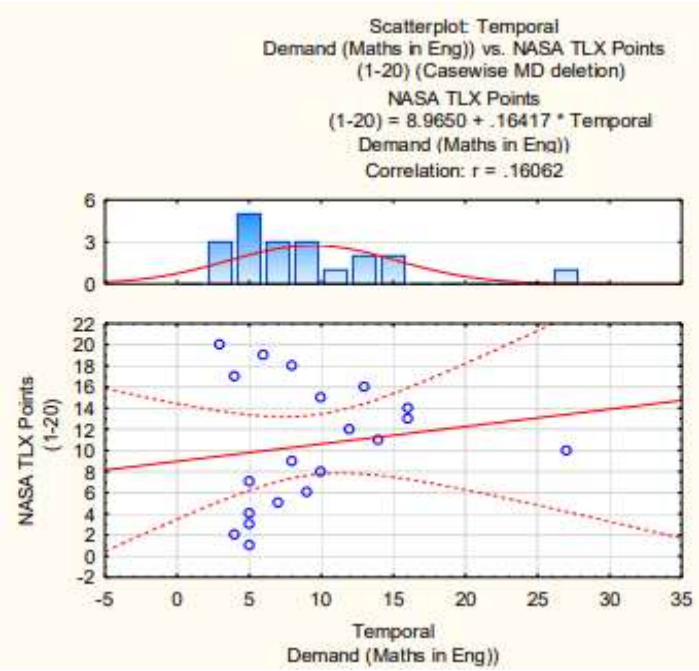


Figure 9. **Graph between NASA-TLX Points and Frequencies of Temporal Demand when Children solved Mathematics test in English Language**. The temporal demand correlation (r) = 0.16062, when children solved mathematics test in English language. Children required more temporal demand while solving the Mathematics test in English language.

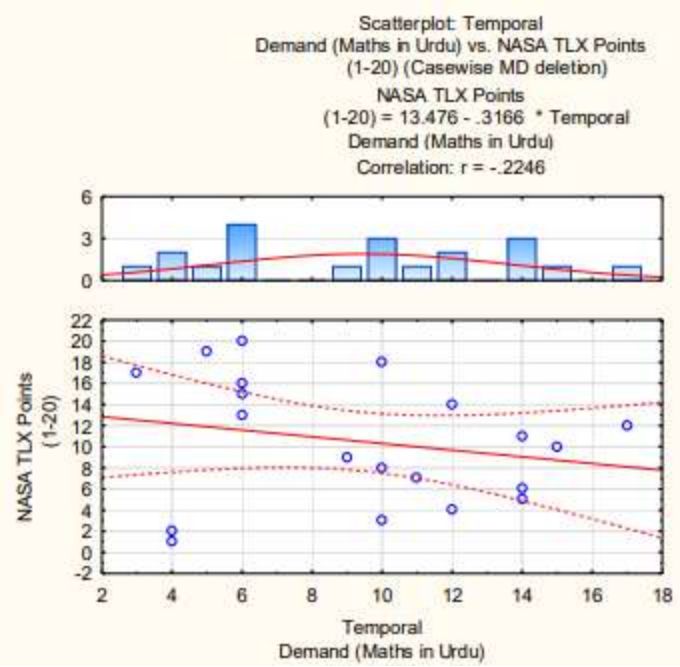


Figure 10. **Graph between NASA-TLX Points and Frequencies of Temporal Demand when Children solved Mathematics test in Urdu Language.** The temporal demand correlation (r) = -0.2246, when children solved mathematics test in Urdu language. Children required less temporal demand while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Temporal Demand (Maths in Eng))	0.160616
Temporal Demand (Maths in Urdu)	-0.224648

Figure 11. **Comparison of Correlations of Temporal Demand of Two Groups of Children solved Mathematics test in English and Urdu Language.** The temporal demand correlation (r) = 0.16062, when children solved mathematics test in English language. The temporal correlation (r) = -0.22465, when children solved mathematics test in Urdu language. As the correlation (r) = 0.16062 is positive, which shows that children take more time when they solved the test in English language, and correlation (r) = -0.2246 is negative, which shows that children take less time when they solved the task in Urdu language.

3.5 Performance

The correlation (r) = 0.589736 of performance, when children solved the mathematics test in English language, and (r) = 0.802373 when children solved the test in Urdu language. Results shows that both performance correlation values are significant but results of correlation of Mathematics task in English language is more significant. As the performance marking is done by children themselves, so they marked as their well performance in both comparison tests. As performance results are very complex, after deep analysis of the data and the graph of performance, we came to the point that children performed good and more effectively when they solve the test in Urdu language as compared to English language.

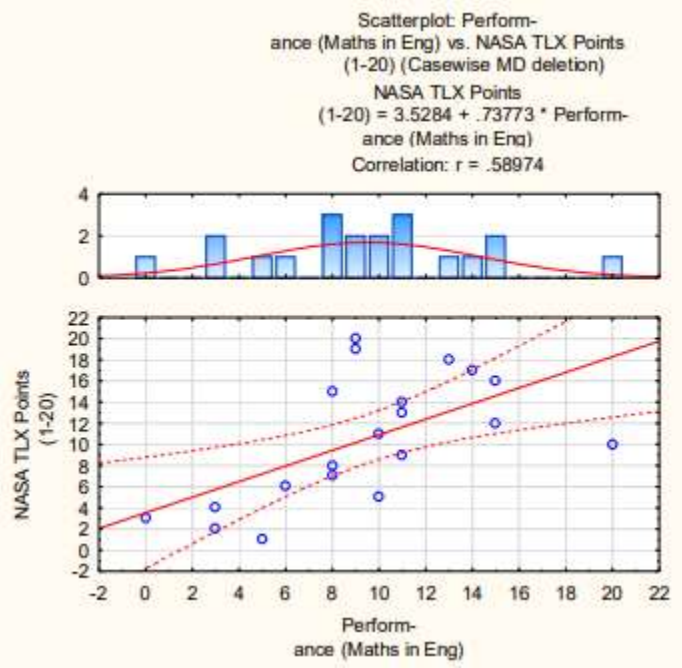


Figure 12. **Graph between NASA-TLX Points and Frequencies of Performance when Children solved Mathematics test in English Language**. The performance correlation (r) = 0.58974, when children solved mathematics test in English language. Children performed good while solving the Mathematics test in English language.

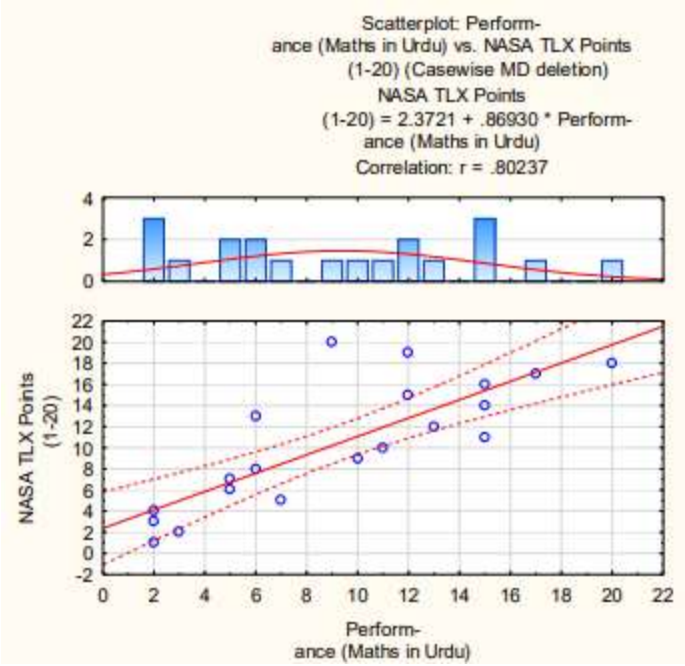


Figure 13. **Graph between NASA-TLX Points and Frequencies of Performance when Children solved Mathematics test in Urdu Language**. The performance correlation (r) = 0.80237, when children solved mathematics test in Urdu language. Children performed good and more effectively while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Perform-ance (Maths in Eng)	0.589736
Perform-ance (Maths in Urdu)	0.802373

Figure 14. **Comparison of Correlations of Performance of Two Groups of Children solved Mathematics test in English and Urdu Language.** The performance correlation (r) = 0.589736, when children solved mathematics test in English language. The performance correlation (r) = 0.802373, when children solved mathematics test in Urdu language. As the performance correlation results are very complex, both the correlation results are significant, deep data analysis shows that children performed well when they solved test in English language, and they performed good and more effectively when they solved the test in Urdu language.

3.6 Effort

Effort Correlation (r) = 0.481969 when children solved the test in English language, (r) = 0.759960 when children solved the test in Urdu language. Results shows that both effort correlation values are significant, but correlation of effort in Mathematics task in English language is more significant. Effort correlation results are complex, after deep analysis of the data and the graph of effort, we came to the point that children done great effort while solving the test in English language, and done less effort while solving the same task in Urdu language in comparison of Experiment 1 and 2. So, we can say that children required more effort when they solved Mathematic task in English language and less effort when they solved task in Urdu language.

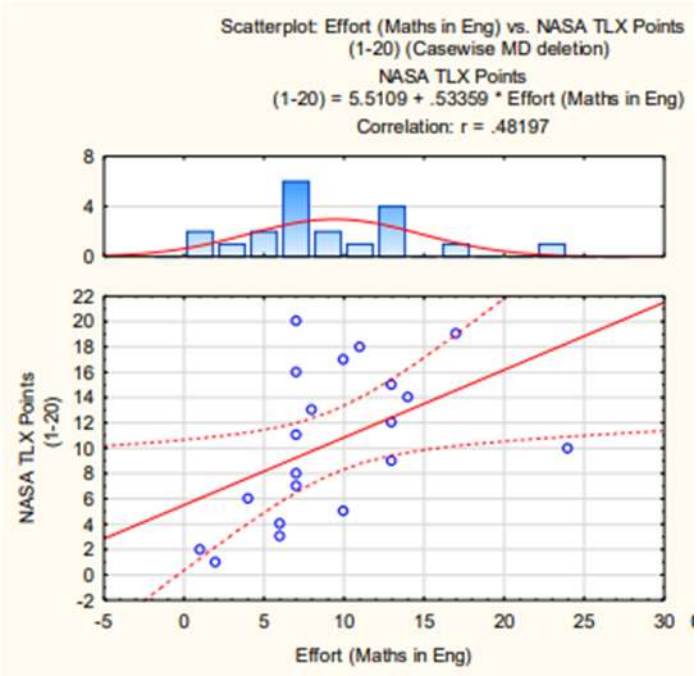


Figure 15. **Graph between NASA-TLX Points and Frequencies of Effort when Children solved Mathematics test in English Language**. The effort correlation (r) = 0.48197, when children solved mathematics test in English language. Children required great effort while solving the Mathematics test in English language.

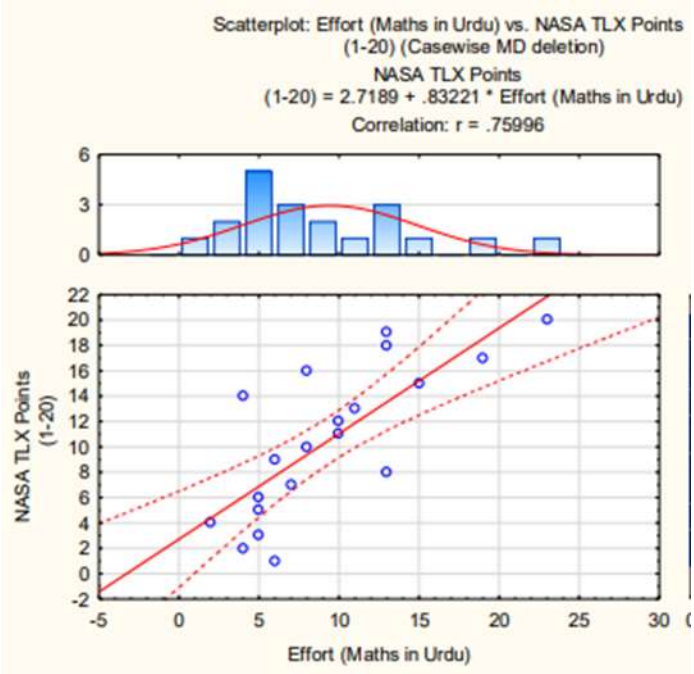


Figure 16. **Graph between NASA-TLX Points and Frequencies of Effort when Children solved Mathematics test in Urdu Language.** The effort correlation (r) = 0.75996, when children solved mathematics test in Urdu language. Children required less effort while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Effort (Maths in Urdu)	0.759960
Effort (Maths in Eng)	0.481968

Figure 17. **Comparison of Correlations of Effort of Two Groups of Children solved Mathematics test in English and Urdu Language.** The effort correlation (r) = 0.75996, when children solved mathematics test in English language. The effort correlation (r) = 0.481968, when children solved mathematics test in Urdu language. As both correlation results are significant, but the correlation (r) = 0.48197 is more significant, which shows that children required more effort when they solved the test in English language, and they required less effort when they solved test in English language.

3.7 Frustration

Frustration correlation (r) = -0.359582 when children solved the test in English language, and (r) = -0.716815 when children solved the test in Urdu language. As both the correlation values are negative, but frustration correlation (r) = -0.7168 in Mathematics task in Urdu language is significant. After deep analysis of the data and the graph, we came to the point that when children solved mathematics test in English language, they showed more frustration as compared to when they solved test in Urdu language. More number of children were less frustrated when they solved Mathematics task in Urdu language

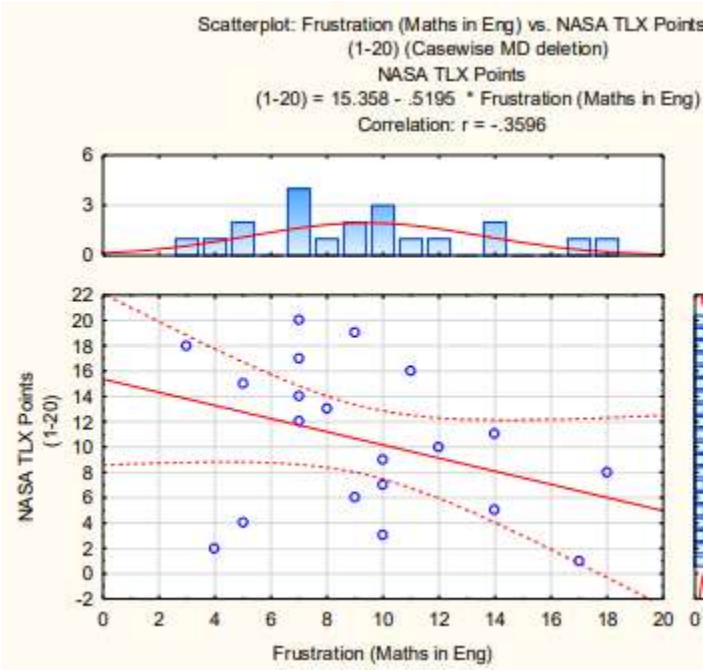


Figure 18. **Graph between NASA-TLX Points and Frequencies of Frustration when Children solved Mathematics test in English Language**. The frustration correlation (r) = -0.3596, when children solved mathematics test in English language. Children face more frustration while solving the Mathematics test in English language.

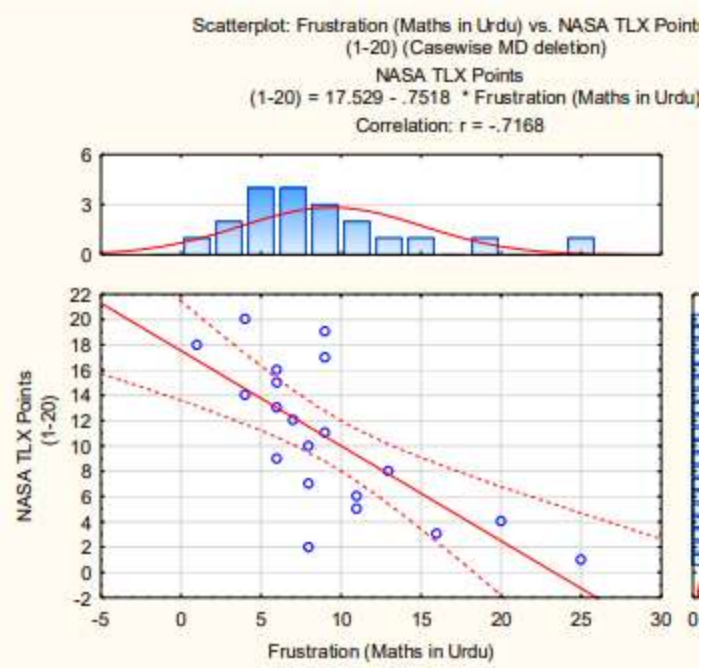


Figure 19. **Graph between NASA-TLX Points and Frequencies of Frustration when Children solved Mathematics test in Urdu Language**. The frustration correlation (r) = -0.7168, when children solved mathematics test in Urdu language. Children face less frustration while solving the Mathematics test in Urdu language.

Variable	Correlations (NASA TLX Data) Marked correlations are significant at p < .05000 N=20 (Casewise deletion of missing data) NASA TLX Points (1-20)
Frustration (Maths in Eng)	-0.359582
Frustration (Maths in Urdu)	-0.716815

Figure 20. **Comparison of Correlations of Frustration of Two Groups of Children solved Mathematics test in English and Urdu Language.** The frustration correlation (r) = -0.359582, when children solved mathematics test in English language. The frustration correlation (r) = -0.716815, when children solved mathematics test in Urdu language. As both the correlation values are negative, but frustration correlation (r) = -0.7168 in Mathematics task in Urdu language is significant which shows that children feel more frustration when they solved the test in English language and feel less frustration when they solved test in Urdu language.

3.8 English Grammar

We tested 187 children from the English Grammar test, so that we can check the state of students on English Grammar. The purpose of this test is that children should learn English in the schools for learning it as an international language but not the medium to convey the concepts of other subjects like Mathematics, Science, and Social Studies etc. There is common opinion of linguistic expert, educationists, and psychologists that the native or the mother language of a child is the only suitable language of learning.

3.9 Discussion

187x3 NASA-TLX rating sheets were collected. The data of rating sheets were analyzed deeply and keenly. The data and graphs were analyzed on the basis of numerical data of workload the children experienced when children were subjected in three tasks of experiment setup (Laurie-Rose, et al., 2014). Figure 3, 4, and 5 indicates the increased mental workload in Mathematics task in English language and decreased mental workload in Urdu task. Figure 6, 7, and 8 indicates the increased physical demand in Mathematics task in English language and decreased physical demand in Mathematics task in Urdu language. Figure 9, 10, and 11 indicates the increased temporal demand in Mathematics task in English language and decreased temporal demand in Mathematics task in Urdu language. Figure 12, 13, and 14 indicates the well performance in Mathematics task in English language and good, efficient, and effective performance in Mathematics task in Urdu language. Figure 15, 16, and 17 indicates the great and increased effort in Mathematics task in English language and less requirement of effort in Mathematics task in Urdu language. Figure 18, 19, and 20 indicates the increased frustration in Mathematics task in English language and decreased frustration in Mathematics task in Urdu language (Laurie-Rose, et al., 2017). As all figures in results illustrated that mental demand is major part of this study and other parts are considered as minor workload subjects in this cognitive study. Significant difference was found between the results of mental demand. The mental demand correlation (r) = 0.10487, when children solved mathematics test in English language. The mental demand correlation (r) = -0.2807, when children solved mathematics test in Urdu language. As the correlation (r) = 0.10487 is positive in task in English language, which shows that children face more mental workload when they solved the test in English language,

and (r) = -0.2807 is negative which shows that children face less mental workload when they solved the test in Urdu language (Khanum & Trivedi, 2013).

CHAPTER 4: CONCLUSION

The main objective of this study is to explore the mental workload experienced by the children studying in multilingual environment. As subject books e.g. Mathematics, Science, Social studies, and Islamiyat are in English language, their subject teachers give instructions and help in English language, while their home languages are other than English e.g. Urdu, Punjabi, Saraiki, Pushto etc. They speak in mother language with their parents, siblings, relatives, and friends, and they watch television in Urdu or native language. However, children feel more workload when subjects are taught in English language and their whole Environment is multilingual. For measuring the workload, we use the NASA-TLX test, so that we can do the workload study in numerical and graphical form. Workload is the capacity of a person to do a task. Workload is comprises of 6 subjects; mental demand, physical demand, temporal demand, performance, effort, and frustration. In cognitive tasks and activities, a person need more mental demand, so our main concern is with mental demand of children required in task solved in English language and same task solved in Urdu language. We have designed 3 sets of Experiment to measure the difference between mental workload when children solved the Mathematics task in English, same task in Urdu language, and English Grammar task to test the level of study of English Grammar in schools. For this complete study, we have designed the home language survey, three tasks questionnaires, and simplified definitions of NASA-TLX workload subscales, and comfortable rating sheet for children. Home language survey has 9 questions, asking about the language in which teachers give them the classroom instructions about subjects, in which language children are more comfortable to learn the concepts of books, in which language they speak to their parents, in which language their parents speak to them, in which language they speak to their friends, which language they can understand most, in which language they watch television and cartoons. We make the Mathematics task in English language from latest KS2 SAT 2022 Mathematics papers. We picked the 10 word problem questions for grade 7 which every child is able to do. We have authenticated those questions from subject specific teachers so that children of grade 7 can do that task. Then we translated the same Mathematics task in Urdu language. We made 3rd task of English Grammar from latest KS2 SAT 2022 English Grammar papers. We simplified the definitions of NASA-TLX workload subscales for children, so that children could understand them easily. We made the comfortable NASA-

TLX rating sheet for the children, so that they can marked it correctly. Workload has six subscales, each subscale rating is divide into 20 equal parts, in other words the subscales rating is from 0-20 points and there is difference of only 1-point in every rating. 0-point is minimum level and 0%, 10 is mid-point and 50% of subscale rating, and 20-point is maximum level and 100% of each subscale's rating. For more convenience for children, we also translated the NASA-TLX rating scale into Urdu. We visited well reputable 3 public and 2 private schools of Rawalpindi, Pakistan. The sample size is 187, 112 girls, and 75 boys of age 11-14 years. We take the permission from the schools authority to take the tests from children of class 7 of their school. Children tested for 3 experiments in morning and peaceful environment. We used the paper and pencil version of NASA-TLX test for this study and initial data and results are present on hard sheets. After that we made results data and graphs from Statistica software application. As Mathematics task is a cognitive activity, which required more mental demand as compared to all other factors of workload. Results showed that, children required more mental demand while solving Mathematics task in English language and less mental demand is required while solving same Mathematics task in Urdu language. Other workload subject's results also show that children required more physical, temporal demand, and effort while solving the Mathematics task in English language and less physical demand, temporal demand, and effort for solving same test in Urdu language. Children marked well performance when they solved test in English language, while they performed good and more efficiently, when they solved the task in Urdu language. They feel more frustration, when they solved the test in English language, and feel less frustration when they solved test in Urdu language. We performed the Experiment 3 to check the mental state of children and level of learning the English Grammar. From the results, we can conclude that subject's relevant instructions given to the student should be given in national language, so that children studying in school feel less workload. In cognitive tasks, mental workload is main component of workload, which should be more considerable for children studying in schools. Books e.g. Mathematics, Science, Social Studies, and Islamiyat should be in Urdu language. While making the books, this concept should be considered by educationists that whole book should be in national language, and if they are compiling the material of specific topic, it should be written in national language, then the main headings of the topics should be written in English language in brackets. Children feel more comfortable in their natural environment, as language is also a part of environment, when they read whole topic in their

national language, this will feel less mental stress and fatigue, they can grasp the whole concept of subject, and by learning the main headings of the topics in English in respective subject class and English Grammar, translations and meanings etc. in English class will help them to convey their message to whole world in International language. Teachers should give the class instructions in Urdu language, so that students feel less mental workload. English should be the international language to convey the message to whole world but not the medium to convey the concepts of subjects to children in primary and secondary level in schools. This study will help in improving the educational ergonomics for children in school settings.

Future Perspectives

This study can help to work on gender studies in education sector. Further, work on timetable setting for children studying in schools and students studying in university can be assessed by workload assessment tests.

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