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Detection of eye strain due to usage of electronic devices: A machine learning based approach

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***Abstract*---**The development of ICT has led to a mobile revolution. Mobile phones, internet, social networking, emails, video conferencing and much more has changed the way we work, learn and communicate (Bian M, 2015). Technology brings with itself certain challenges with respect to the harmful impact of prolonged usage of digital devices on the users' health. People who excessively use electronic devices develop musculoskeletal syndromes. Eyes, shoulder and neck muscles, arm, and wrist are most affected with prolonged usage of digital devices. The aim of this research is to study and list the problems associated with eyes due to the prolonged usage of electronic gadgets with screen. For this purpose, 350 people (170 females, 180 males) from different ages and jobs were asked about eye health with the help of a questionnaire. The factors to detect eye strain and fatigue were collected from literature as well as through a set of interviews. The factors act as the variables for the factor analysis and random forest method has been used for classification. The results of this study implicates the factors that can be used to detect eye strain and fatigue in the users of digital devices. The results can be useful for people to take precautionary and remedial measures in case of eye strain due to prolonged screen time.

***Keywords*---**eye strain, electronic devices, machine learning.

Introduction

The usage of electronic devices has become a common practice in people from all sectors. The last two years have seen the maximum rise in the usage of electronic

devices for work, education, entertainment and communication. The development in the field of electronics and communication has led to this scenario where almost all people have access to some form of electronic device. The usage of devices like mobile phones, computers and other screen devices has made the tasks like online education, work from home, online shopping, etc. very common. (Arora, March 2021) The development of internet and communication technologies has brought the world together and there is no limit to the kind of uses these technologies have been put through (Kharb, Oct-20).

The widespread use of digital devices with screen has given rise to the term "Computer vision syndrome (CVS)" (Aggarwal, 2021)It is defined by a range of eye and vision related problems arising from prolonged screen time and has been a known health problem since many years (Portello JK, 2012). Visual fatigue (VF) and digital eye strain (DES) also refer to such conditions of digital devices with screen being linked to potential eye problems. These digital devices with screen include devices such as tablets and smartphones along with computers and laptops (M., 2016). Ease of availability and purchase of internet and mobile data has led to the massive growth of digital device usage in recent years. Millions of individuals from all age groups have access to digital devices and hence are at risk of CVS (eMarketer. Digital set to take majority share in UK time spent with media in 2016., 2016).

Literature Review

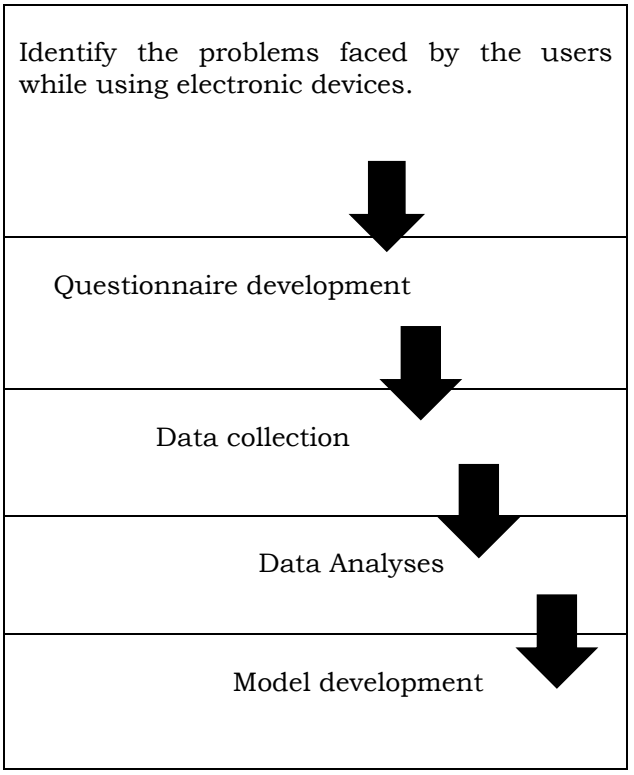
Developments in communication and internet Technology has enabled the people to have remote access to resources and information and enables them to work and study from anywhere and anytime. The usage of technology brings certain usage challenges especially for the eyes of people having long hours of screen exposure. The term used to describe eye fatigue is called asthenopia. It consists of complaints by the patients related to discomfort in the eye (Gowrisankaran S, 2012). Asthenopia refers to the complaints such as eye discomfort, watering of eyes, dry eyes, blurred vision, and difficulty in focusing, feeling of foreign body in eye (Neugebauer A, 1992). It is very important to understand this condition as it impacts the users of digital devices in terms of attention and may influence the job as well as academic performance of the users. In our age, the use of digital devices is increasing, depending on the technological developments. The period from 2019 onwards which is the time when the world faced the wrath of COVID 19, the use of electronic devices increased more than ever. People depend on these digital devices for various tasks such as job, education, communication and entertainment. As a result, the risk of eye strain due to prolonged screen time has increased more than ever. Prolonged usage of screen, increased work and study using digital devices, using computer and other devices with screen can affect the eye fatigue complaints in users (Agarwal, 2013); (Ostrovsky A, 2012).

As per American Optometric Association, a variety of eye and vision-related problems can develop with even 2 hours per day of continuous screen time and is referred to as digital eye strain (DES) or (Computer vision syndrome (CVS).) (Dr. Archana B Saxena, 2021). A range of various eye strain related symptoms is evident with use of the digital devices with screen which is grouped under 'computer vision syndrome', (Blehm C, 2005) (Yan Z, 2008) including eyestrain,

watering eyes, headache, tired eyes, burning sensation, red eyes, irritation, dry eye, foreign body sensation, blurred vision at near and double vision (Maducdoc MM, 2017) (Titiyal JS, 2018). Moreover, musculoskeletal symptoms such as shoulder pain, neck pain, back pain and wrist pain are also prevalent in users with prolonged screen time (Ichhpujani P, 2019).

Research Methodology

Eye strain and fatigue is a common problem faced by the people using electronic devices with screen (Khanna RC, 2020). Repetitive strain injury is a chronic condition that develops because of repetitive, forceful, or awkward hand movements for prolonged periods leading to damage to muscles, tendons, and nerves of the neck, shoulder, forearm, and hand, which can cause pain, weakness, numbness, or impairment of motor control. The objective of this paper is to identify the factors causing eye strain due to the usage of electronic devices. The methodology followed is:



We have focused our research to factors affecting the eyes of the users when they use electronic devices with screen. To identify the problems related to prolonged screen usage, we identified a set of users and conducted interviews to get feedback on usage related aspects.

Conduct of Interviews

We conducted interviews with users from different age groups and professions to understand the issues related to eye strain. The questions comprised of the following:
How much is the screen time per day?
What is the purpose of using devices?
What kind of devices are being used?
What kind of problems are being faced related to eyes?
The responses collected from the interviews are summarised under:

AGE GROUP	NUMBER OF PARTICIPANTS	USAGE PURPOSE	DEVICES USED	AVERAGE SCREEN TIME PER DAY	PROBLEMS FACED
5 – 15 years	4	Online classes, gaming, movies	Smartphone, tablet, laptop, PC	5-6 HOURS	Itching of eyes, Watering of eyes, Eye pain, Burning of eyes, Redness of eyes
15 – 20 years	4	Online classes, gaming, movies, surfing, social media	Smartphone, tablet, laptop, PC	6-8 HOURS	Headache, Eye pain, Dryness in eyes, Burning of eyes
20 – 30 years	4	Online classes, gaming, surfing, movies, social media, job, online shopping	Smartphone, tablet, laptop, PC	>8 HOURS	Eye pain, Tiredness of eyes, Dryness in eyes, Redness of eyes
30 – 45 years	5	movies, surfing, social media, job, online shopping	Smartphone, tablet, laptop, PC	>8 HOURS	Headache, Tiredness of eyes, Shoulder & neck pain
>45 years	5	movies, surfing, social media, job, online shopping	Smartphone, tablet, laptop, PC	>8 HOURS	Eye pain, Tiredness of eyes, Shoulder & neck pain, Blurred Vision

After the interviews, we were able to understand the issues faced by the users while using electronic devices and we developed a questionnaire on the basis of the responses.
The following factors are used in the design of questionnaire to detect eye strain in the users:

Itching of eyes
Watering of eyes
Headache
Eye pain
Tiredness of eyes
Dryness in eyes
Burning of eyes
Redness of eyes
Blurred Vision
Excessive Blinking of eyes

The questionnaire was distributed through email and whatsapp to 350 people out of which 335 responded. The data was then collected and analysed.
Data Demographics
Total number of respondents: 335

Gender		Male		Female	
		196		139	
Age Group	5 – 15 years	15 – 20 years	20 – 30 years	30 – 45 years	>45 years
	21	35	150	106	23
Usage time/ Screen time		1 - 3 hours	3 - 6 hours	6 - 8 hours	> 8 hours
		10	75	200	50

Observations

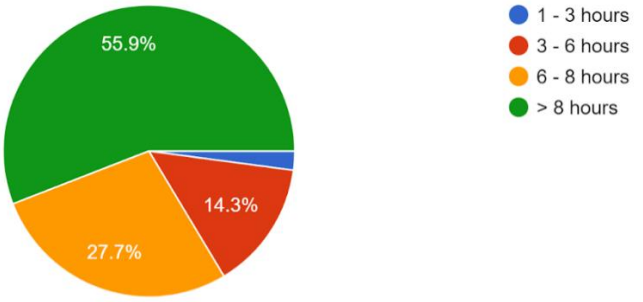


Fig. 1: Usage duration of digital devices

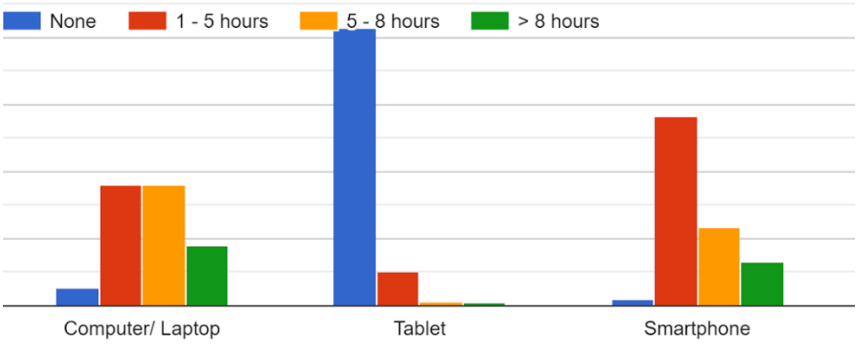


Fig. 2: Usage of screen devices

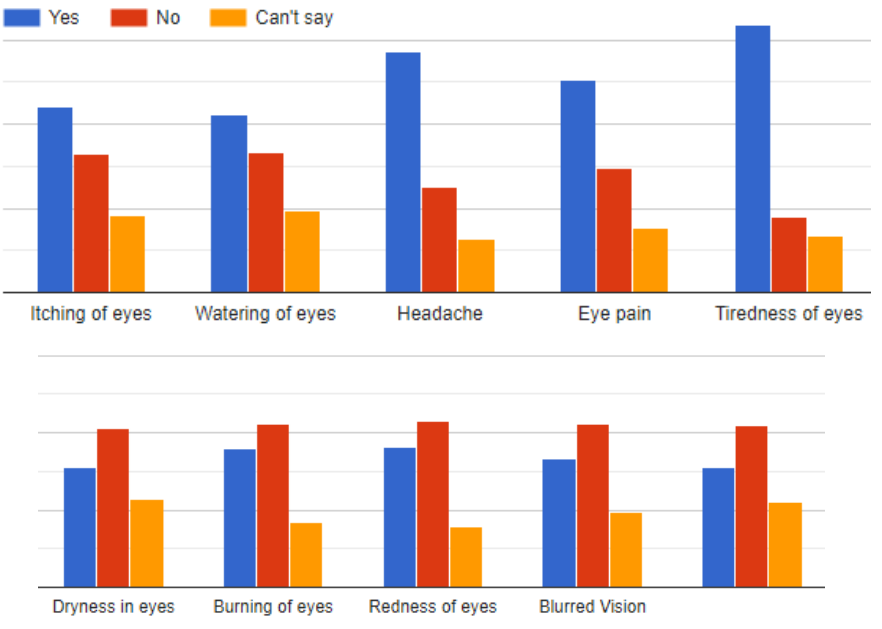


Fig. 3: Problems faced by users during screen usage

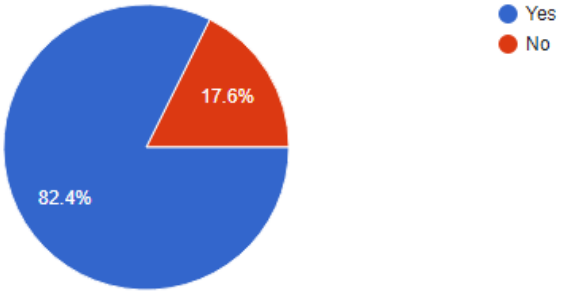
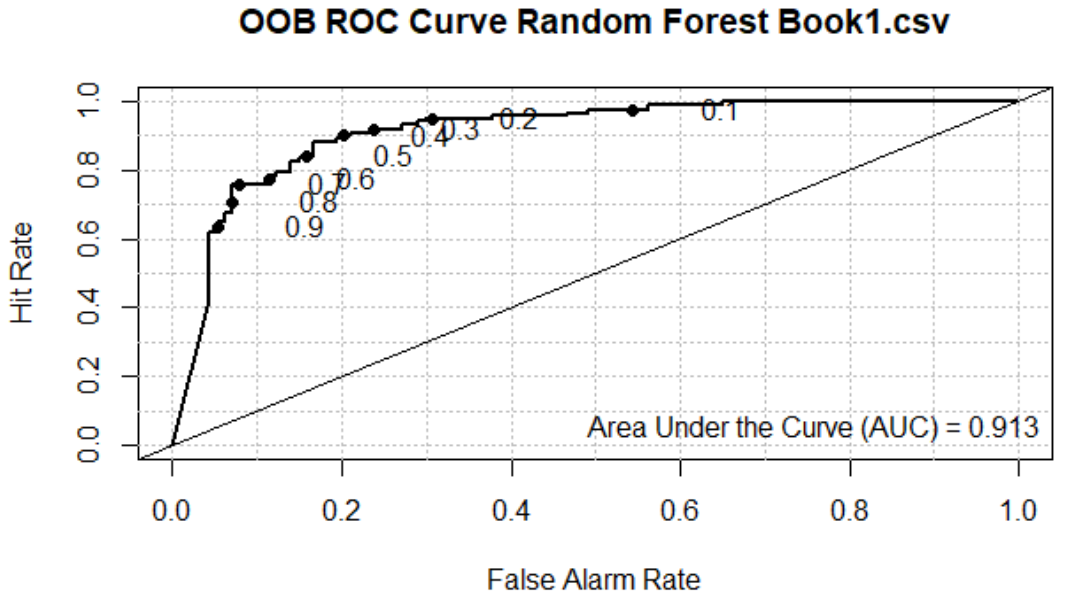


Fig. 4: Development of eye strain and fatigue during pandemic

Random Forest Model

Random Forest is a learning method for classification based on generating a large number of decision trees where each tree is constructed using a different subset of our training dataset. These subsets are usually selected by sampling data at random with replacement from the original data set. The decision trees are then used to identify a classification consensus by selecting the most common output.
ROC Curve or Receiver Operating Characteristic Curve is a method for visualizing the capability of a binary classification model to diagnose or predict correctly. The ROC Curve plots the true positive rate against the false positive rate at various thresholds.

Our target for the ROC Curve is that the true positive rate is 100% and the false positive rate is 0%. That curve would fall in the top left corner of the plot. AUC is intended to determine the degree of separability, or the ability to correct predict class. The higher the AUC the better. 1 would be perfect, and .5 would be random.



Analysis of the Area Under the Curve (AUC)
==========
Call:
roc.default(response = crsrfy, predictor = as.numeric(crsrfpredicted))
Data: as.numeric(crsrfpredicted) in 114 controls (crsrfy No) < 120 cases (crsrfy Yes).
Area under the curve: 0.8419
95% CI: 0.7949-0.8888 (DeLong)

11204

Summary of the Random Forest Model
==========
Number of observations used to build the model: 234
Missing value imputation is active.
Call:

```
randomForest(formula = eye.strain.and.fatigue1 ~ .,
data = crs$dataset[crs$train, c(crs$input, crs$target)],
ntree = 500, mtry = 3, importance = TRUE, replace = FALSE, na.action =
randomForest::na.roughfix)
```

Type of random forest: classification
Number of trees: 500
No. of variables tried at each split: 3
OOB estimate of error rate: 15.81%

Confusion matrix

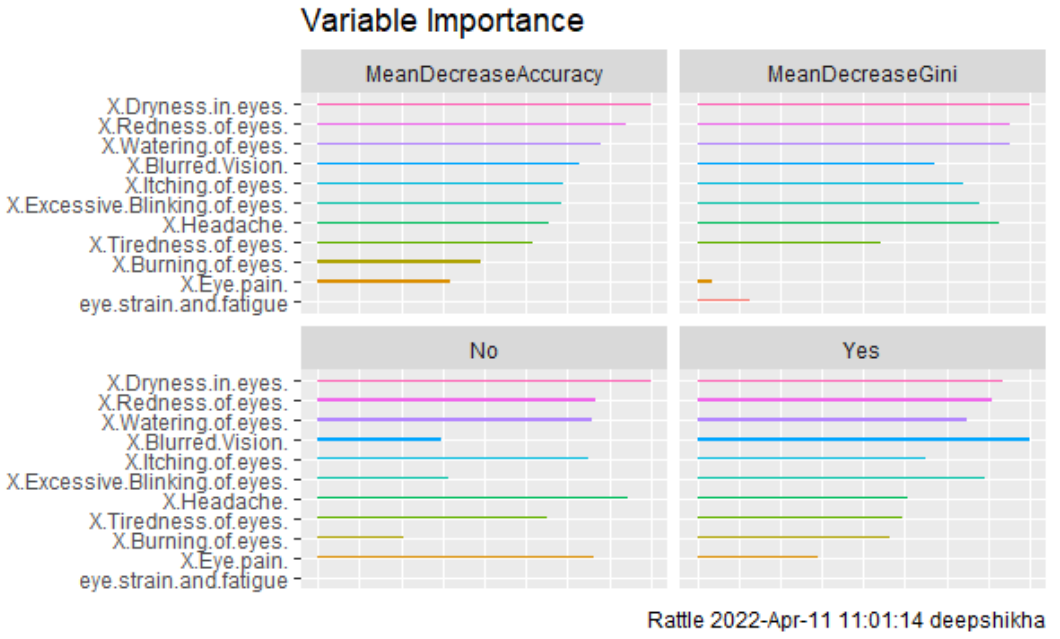
A confusion matrix is a tool for summarizing the performance of a classification algorithm. A confusion matrix will give us a clear picture of classification model performance and the types of errors produced by the model. It gives us a summary of correct and incorrect predictions broken down by each category. The summary is represented in a tabular form.
Four types of outcomes are possible while evaluating a classification model performance. These four outcomes are described below:-
True Positives (TP) – True Positives occur when we predict an observation belongs to a certain class and the observation actually belongs to that class.
True Negatives (TN) – True Negatives occur when we predict an observation does not belong to a certain class and the observation actually does not belong to that class.
False Positives (FP) – False Positives occur when we predict an observation belongs to a certain class but the observation actually does not belong to that class. This type of error is called **Type I error.**
False Negatives (FN) – False Negatives occur when we predict an observation does not belong to a certain class but the observation actually belongs to that class. This is a very serious error and it is called **Type II error.**

These four outcomes are summarized in a confusion matrix given below.

	No	Yes	class.error
No	96	18	0.1578947
Yes	19	101	0.1583333

Variable Importance

	No	Yes	MeanDecrease Accuracy	Mean Decrease Gini
eye.strain.and.fatigue	22.80	42.55	41.92	9.10
X.Eye.pain.	8.34	25.97	26.97	10.07
X.Burning.of.eyes.	18.29	16.16	23.49	10.48
X.Tiredness.of.eyes.	10.80	14.51	17.76	5.70
X.Headache.	6.53	13.75	15.90	2.59
X.Excessive.Blinking.of.eyes.	15.97	3.09	14.37	3.10
X.Itching.of.eyes.	8.61	11.31	14.22	3.54
X.Blurred.Vision.	16.34	-2.97	12.43	4.30
X.Watering.of.eyes.	8.41	5.61	10.09	2.31
X.Redness.of.eyes.	8.27	2.05	7.27	2.32
X.Dryness.in.eyes.	5.37	0.69	4.40	1.81



Each features' importance is assessed based on two criteria:

- Mean Decrease Accuracy: gives a rough estimate of the loss in prediction performance when that particular variable is omitted from the training set.

Limitation: if two variables are somewhat redundant, then omitting one of them may not lead to massive gains in prediction performance, but would make the second variable more important.

- Mean Decrease Gini: GINI is a measure of node impurity. Think of it like this, if you use this feature to split the data, how pure will the nodes be? Highest purity means that each node contains only elements of a single class. Assessing the decrease in GINI when that feature is omitted leads to an understanding of how important that feature is to split the data correctly.

Conclusion

Computer vision syndrome is the term used to describe eye strain that result from prolonged exposure to devices such as computer, tablet, cell phone, etc. Many people experience eye discomfort and vision problems when exposed to digital screens for long hours. The level of strain and fatigue may increase with the time spent in using amount of digital screen. While conducting this research, we found that people spend longer amount of time with digital screens during covid 19 and post covid 19 situation as compared to pre-pandemic situation. The respondents of the interviews and questionnaire were are performing various digital activities like online classes, work from home, shopping, entertainment, etc. on multiple devices during lockdown. The research indicated that majority of people in the respondent group are using digital devices for more than 8 h/day. Eye strain and fatigue related symptoms such Itching of eyes, Watering of eyes, Eye pain, Tiredness of eyes, Dryness in eyes, Burning of eyes, Redness of eyes, Blurred Vision and Excessive Blinking of eyes with systemic symptoms including shoulder pain, back pain and headache have been faced by the respondents during lockdown with increase in digital device usage.

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