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RESEARCH ARTICLE

TOWARDS A COMPUTER MODEL OF ATTENTION FATIGUE

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ABSTRACT

The exact mechanism of mental fatigue is still not well understood even with the long history of neuroscience and psychology. It is said a human being undergoes mental fatigue when he or she just had a prolonged session of focusing on particular sustained attention task and this could particularly dangerous for certain tasks such as driving. Directed Attention Fatigue (DAF) is caused by an identified mechanic and was described a tug of war between bottom up attention mode and top down attention mode where DAF will cause decrease focus on the task on hand. By using an eye tracker to obtain human data, this project aimed to study eye gaze pattern's relationship with DAF. The obtained human data can be modeled into existing visual attention model which hopes to reproduce the human results. The model had to have the capability to reproduce human perception, recognition and also decision making to achieve the objective of this project. Itti and Koch Model (IKM) will be used as the base model of this project. The model overall gave reasonable results that provided certain insights into the gaze characteristics of DAF.

INTRODUCTION

Human beings will need to go through various tasks in life on daily basis and these tasks require concentration. People could classify these tasks as trivial but tasks such as driving would be severely dangerous if one is not concentrating. Various tasks require the use of sustained concentration overtime and the task's performance often degrades over time with factors such as motivation greatly affecting the rate of degradation. The duration of sustained concentration is still limited by the human mind even with infinite motivation, which will have produced negative outcomes such as tiredness and decreased performance on task which may prove fatal. One of the key aspects of human perception is known as attention which is the mechanism underlying concentration. It means be emphasized that a failure of attention is a failure of concentration. Attention in the visual modality is the main concern of this project where attention directs eye gaze, and poor results of a particular task is caused by the failure to attend to the task at hand. From reviews, there is two modes of attention which is distinguished by effort and purpose (Theeuwes, 2010). One of the modes where eye gazes are drawn to points of high saliency in terms of visual property given a particular scene is known as the bottom up mode (Itti, 2001). The other mode described as an active mode where the human consciously directs the eye gazes to points that we want to look at and usually with accordance with a specific task which can override bottom up stimulus and is known as top down mode (Desimone and Duncan, 1995). The competition between these two modes will cause the inhibition of bottom up stimulus and inhibition requires mental resources which are limited (Navalpakkam, 2005). After some time of continuous inhibition of bottom up cues and focusing on top down cues, a state known as Directed Attention Fatigue (DAF) (Berto, ?; Hartig and Staats, 2005; Hartig *et al.*, 2003) will appear. Degradation of performance due to the inability to inhibit bottom up stimulus is one of the symptoms of DAF (Kaplan and Berman, 2005). The underlying mechanics of DAF is still not well understood. More knowledge of DAF can be obtained with the help of computer models and this knowledge will help us design tasks better or even produce countermeasures for DAF. Re-designing tasks and performance strategies to reduce fatigue and therefore improve performance and safety can be aided by a computer model that undergo DAF and fatigue overtime. Without the need human subjects, the computer model can produce results of a specific task with the advantage of speed and flexibility. A variety of computational models of visual attention have being developed. Yet, no current attention model fatigues over time.

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A model of DAF will developed in this project via methods of high novelty by substantially extending the influential bottom-up attention model of Itti and Koch (IKM) (Kaplan and Berman, 2005) to model sustained task performance with the inclusion of modules such as foveation, object recognition, decision making. A sustained task will be used to induce DAF on human participants in order to collect human data by using an eye tracker and custom software. The human data collected will be used to both guide and validate the model. Predicting the measurable gaze characteristics and deterioration in performance associated with DAF will the main focus of the model. The emergent behaviour of interacting functional and biologically-inspired processes and not a trivial product of the data will be the key features of the model. It is intended that human data collection will yield insights into the gaze characteristics of DAF and that these can be successfully predicted and explained by the model developed here.

Literature Review

Visual Perception and Attention

Various research done on human vision and its computational modelling has shown that vision is a challenging problem especially when dealing with realistic data and viewing conditions (Szeliski, 2010). Attention and visual perception are closely related as it is impossible to attend to things that we can't see due to the structure of the eyes (Gershenfeld, 1998). This gives birth to the concept of fovea vision due to the distribution of rod and cone receptor cells in the human eye (refer figure 1). The fovea vision gives an important note to attention as our eyes' perception is generally blurry except at the point of gaze. The foveal vision is necessary for activities where visual detail is of primary importance, such as reading and driving. Although some degree of perception is possible using peripheral vision, for tasks involving fine discrimination, failure to direct gaze towards targets is likely to lead to failure of the task at hand.

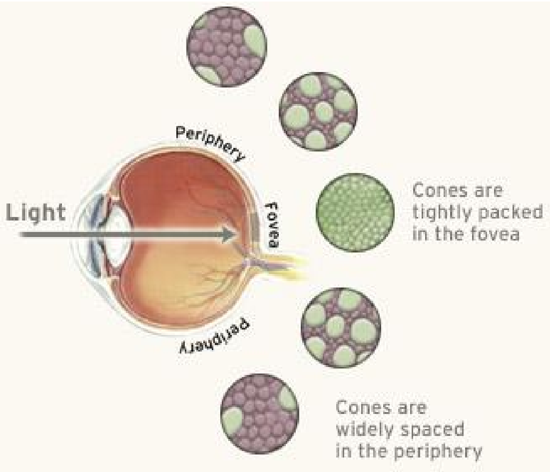


Figure 1. Structure of the eye for cones and rods density placement

Top down and bottom up influences both acts as a function of gaze control. William James (1892) stated that Attention is said to have a voluntary and involuntary aspect and this theory is widely recognised by modern cognitive science and computational modelling (Itti, 2003). The concept of salience is used to describe those properties of visual stimuli that attract our attention in bottom-up fashion. Local differences in visual properties such as intensity, orientation, and colour are main concept of salience. In computational modelling of attention, saliency based models has been high influential, especially on the model developed by Itti and Koch which is extended in this present work.

Directed Attention Fatigue

Many tasks require attention guided visual perception to complete. Different tasks will have different mental demands but most of them require sustained focus over time. With sustained effort in the performance of a demanding mental task, fatigue may set in. This will lead to potentially devastating consequences; as the matter of fact, the issue of mental fatigue is surprisingly poorly-defined and not well understood, especially in its relation to attention. Objective task performance deteriorates over time and is often accompanied by negative subjective effects. The objective task performance deterioration can be seen as a failure of basic ability and "is distinguished from the effects of sleepiness, motivation, learning, and physical fatigue" (Leonard J. Trejo *et al.*, 2005). However, there are still questions lingering about as to what exactly is fatigue and what is it's mechanism. It could be the human cognitive process disrupted by mental fatigue and affects also the mood, or the human brain just purely shut downs in a bid to save resources therefore affecting general performance and capability? Mental fatigue, cognitive fatigue and more recently, directed attention fatigue (DAF) have been identified as the negative effect of sustained mental work.

Environmental psychologists developed the concept of DAF in the study of what are known as "restorative environments". Kaplan's (1995) Attention Restoration Theory (ART) is the theory discussed earlier where a struggle between voluntary (top-down) and involuntary (bottom up) modes of attention. Little effort is required for the involuntary mode and it is driven bottom-up by inherently fascinating features of the scene being perceived (Kaplan, 1995). Voluntary attention on the other hand often requires focusing on stimuli of less inherent interest and therefore suppression of attention to stimuli not relevant to the task at hand. The common symptoms of DAF are as follows irritability, an inability to plan, a reduced sensitivity to interpersonal cues and increased likelihood of errors in performance (Maarten *et al.*, 2005). A normal human being daily life often makes heavy demands on directed attention and he or she may need the experience of a restorative environment that facilitates a switch to involuntary attention in order to recover.

DAF has been induced (and subsequently restored by natural environments) in a number of studies using challenging mental tests (Berto, ?; Hartig and Staats, 2005; Hartig *et al.*, 2003). One test especially relevant to this project is the Sustained Attention Response Test (SART) used by Berto (2005). Sustained Attention to Response Test (SART) (Manly, Robertson, Galloway, & Hawkins, 1999) consists of 24 randomised sequences of the digits 0-9 shown on a screen's center and subjects were instructed to press a button following any digit except the target value '3'. A new digit was presented every 1125ms, and remained on screen for only 250ms. Significant decrease in performance has been found in SART by Berto after 10 minutes into the test and this shows that SART has the capability to fatigue the human participants in a short while. However, SART lacks any kind of orienting component therefore gazes may not play a part in this test at all. Attention may not be fully measured in this test and modifications has to be done in order to use it for this project.
However, even with the success of DAF work so far, there has been little study done in understanding the underlying mechanism of DAF. In principle, the brain consist of areas for visual perception, attention, cognition and hence the decrease in activity over time in these areas, as determined by PET or fMRI might settle the question (Gazzaniga *et al.*, 2013). Eye tracking technology can also be used to detect gaze patterns since DAF, manifested as a failure to attend to task relevant locations. So far, this has not yet been done and the studies done by Trejo and Boksem used EEG methods which are incapable of cortical localisation which neither captured gaze data. DAF studies have also done nothing either. This project will make a first, small, attempt to address these issues. It will work on the plausible assumption that performance degradation in tasks with a substantial orienting component is due to DAF.

Gaze tracking will be carried out to answer this question and our model will have to predict this behaviour.

Computational Modeling of Attention

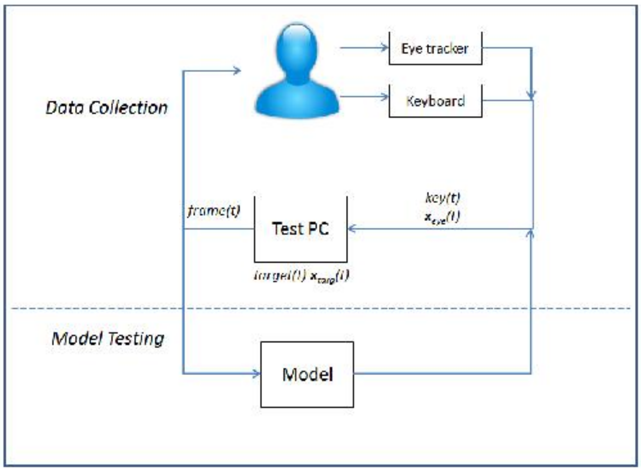
It is said that modelling can use to prediction(8). At a superficial level, a predictive model may be expressed as a mathematical equation directly relating external variables; data are collected and patterns are found that allow prediction. Therefore, a model with fatigue capability based on human data can set the base line in understanding DAF but yet no model has implemented fatigue into account because of various reasons. Modelling sustained task performance requires all our perceptual and cognitive faculties to some extent, and the objective is highly challenging as perceptual capability such as foveal vision and decision making are features needed to be taken into account. There are already around 65 models of visual attention developed over the years and the models have been classified within an organizational taxonomy (Borji, 2013). Different vision models have been classified based on their modelling strategies. It is important to keep in mind that not all models were developed with the same goals and that modelers do not always follow only one strategy only and may combine both taxonomy to try to get the best of both worlds. IKM is one of the models developed for this propose and is using the concept of the biologically inspired saliency map. Saliency map is created by calculating the difference between a center point with its surrounding in terms of basic visual features such as color, orientation and intensity. This allows IKM to recreate human gaze patterns in a free viewing or bottom up mode as we know it. Extended work was also done to include task based capability to the original model (Navalpakkam, 2005). Overall, this made the IKM suitable as the baseline in this project as it is also freely available.

Eye Tracker Related Research

Eye tracker technology has being used in many research fields especially in neuroscience and cognitive science. The movement of the eyes can be said to be closely related to many medical conditions such as dyslexia, ADHD (Haseloff, 2015) and Parkinson's disease (Marx *et al.*, 2012). Other than that, there is research in eye gaze patterns of alcohol induced participants where all of these researches found great correlation between eye gaze patterns with their specific conditions (Freeth *et al.*, 2011; Friese *et al.*, 2010). In the context of mental fatigue, eye tracker has being used to evaluate task performance and eye activity. Lavine did a test on 30 minutes vigilance task where sound burst will occur time to time in order to keep participants vigilant and found that the participants' accuracy and fixations on target decreased as time went by (Lavine *et al.*, 2002). Cazzoli claimed that eye movement is a reliable indicator of fatigue due to sleep deprivation or time spends on cognitive tasks (Cazzoli *et al.*, 2014). Based on the literature review done, the number of participants used for testing purposes range from 20 to as low as 6 person (Haseloff, 2015; Marx *et al.*, 2012; Lavine *et al.*, 2002; Cazzoli *et al.*, 2014). An average of 10 person as test group is very common and usually can produce healthy results.

MATERIALS AND METHODS

On the general scale, the human data was first collected from 10 participants when doing a sustained attention task. Data collected were task performance, reaction time, and distance from target (positive stimuli). The data collected was analyzed and modeled into equations to be integrated into the model. The newly integrated model would also be simulated with the same sustained attention task to provide equal similar output in order to be compared with the human data. The comparison would allow fair evaluation of the model's performance with respect to the human data. Below is the overall flow of the project:



Flow of the Methodology

Participants

10 healthy participants (5 males and 5 females), between 21 to 26 years of age, were recruited from the university population. They had normal vision or corrected to normal vision. None of the subjects used prescription medication of sorts.

Eye Tracking

To obtain eye gaze data in real time, Mirametrix S2 was used to fulfill this purpose. The S2 is eye tracker that was placed under the monitor with a portable tripod and it utilized the reflection of eye glint with infrared reflection to detect the eye gaze. The S2 comes with an API that Java compatible and also with readymade calibration software. Basic raw data of the S2 is the x, y coordinates and timing of the eye gazes with respect to the screen. The S2 has accuracy of 0.5 to 1% range with data rate of 60Hz which is suited for this project.

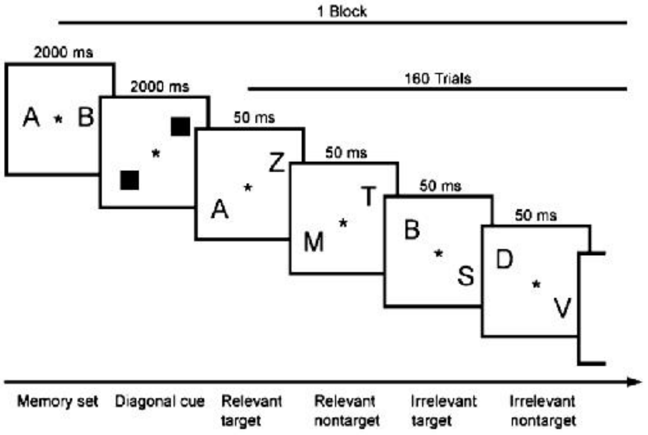
Software Used

To administer the SAT test, Java was used to collect the human data in terms of performance and eye tracking because of the convenience in instrument interfacing. While Java was used to administer the test, the material of the test was created using MATLAB because of the capability to perform operations on images with more ease. The customized model too was programmed in MATLAB environment alongside with any data processing work.

Pilot Study

Boksem's Test

Boksem's test was used in conjunction with event related potential (ERP) in order to learn about brain activity and mental fatigue(2). The test originally administer with duration of 3 hours without rest. However, with this project, the test was shorten to 1 hour only with constrains such as physical discomfort because of the eye tracker. The goal of the test is memorized the correct cues and respond to Relevant Targets only. The flow of the test is as below:

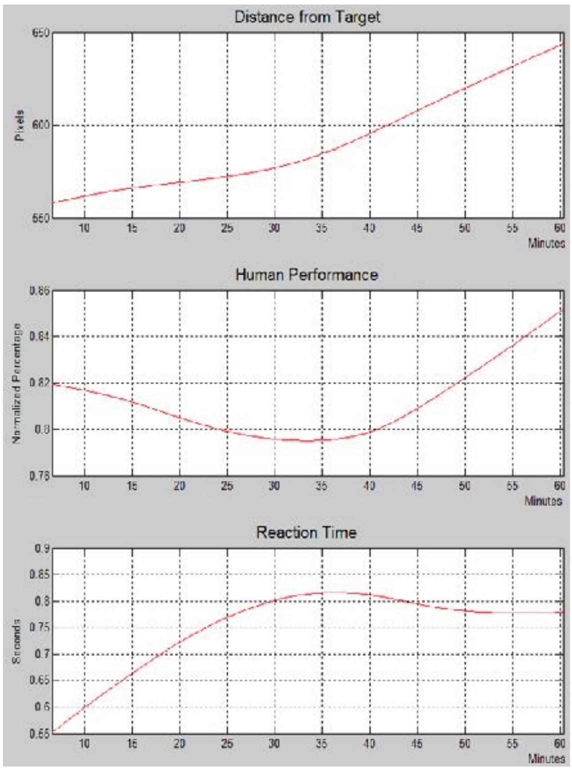


Flow of Boksem's Test (3)

Success on answering the correct target yields a true positive, β while wrong responds will earn the participants a false positive, α. The performance of the test is decided by this equation:

$$\text{Performance } \% = \beta / (\beta + \alpha) \quad \ldots\ldots\ldots\ldots\ldots.. (1)$$

Results from Boksem's test as collected from human participants is shown in Figure 4.

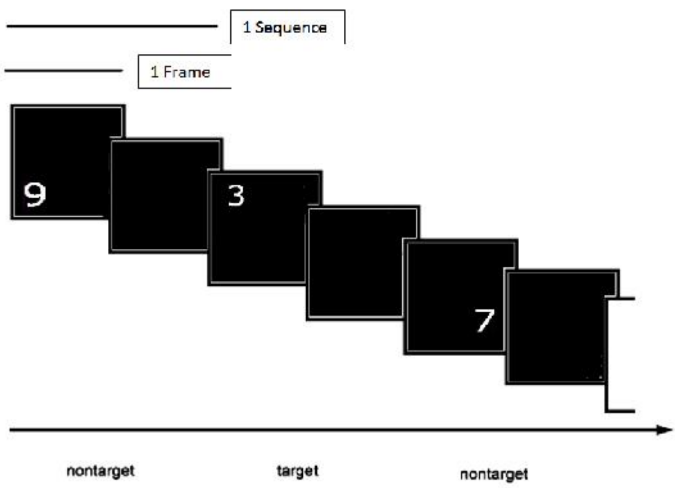


Results from Boksem's Test

The results obtained from all the participants were averaged out and the data were also split into 9 time intervals where all the data in 1 time interval were averaged out for every participant respectively. This was done in order to see the big picture and obtain an overall trend of the results as shown below with smooth curve fitting. In overall point of view, this test shows promising results in reaction time and distance from target however with failure of the terms of accuracy. Reactions time gradual increase overtime which meaning the participants were getting slower over time because of DAF. The accuracy of participants changed little over time and this was related to the distance over time which also related to the strategy used by the participants. Participants' explained that for this test that, it is possible to maximize accuracy without sacrificing too much mental resource. Due to the nature of the test, a strategy was utilized by most of the participants by looking only at the one of the cued point as there were only 2 cued points in this test. By doing so, they can focus less while still having good performance with the true positives. The main culprit would be due to the predictable location of the targets as participants know where to orient around.

Predictive Model using Spatial SART

From the failure of Boksem's test, it was learned that the state of DAF would be quite tough to produce on the human participants. To resolve this issue, a more brutal and forgiving test was needed. To do this, SART was introduced into the equation with a certain twist. The SART test as stated in the literature review has been effective in producing results whereby the participants' were performance in the test were reduced over a short period of time (usually 4 to 5 minutes). However, to fit our purpose of research, SART has to be modified with spatial aspect. With randomly generating the position of numbers on the screen instead of just center point of fixation, we will be able to use the eye tracker to study the effect of fatigue related to the human gaze and participants' performance in the test. By adding the spatial element into SART, it is believed the task becomes more challenging and requires more mental attention than before therefore several justified tunings were made. The first change would be the duration of SART which was tripled to 12 minutes of total test time instead of the usual 4 minutes. This is done because SART is now more active and requires participants to be more active in their senses.



Flow of Spatial SART

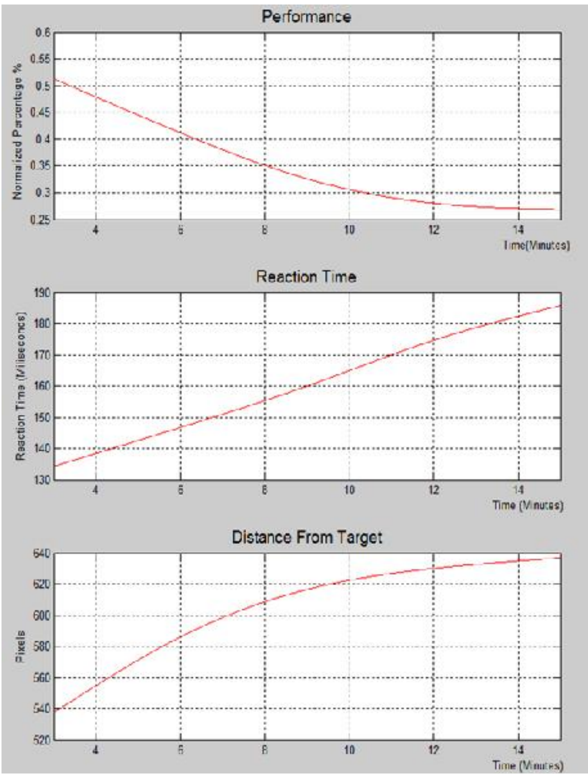
The traditional SART draws flak from motivational issues whereby criticism about the mundane and routine course of SART bored the participants out instead of fatiguing them. The spatial SART eliminates this problem by forcing participants to be more alert and have to actually move their eyes to find the numbers in order to get the correct answer in place. With motivational issues eliminated, it was fit to make the test longer in order to truly induce mental fatigue into the participants. The flow of the new test can be seen from below.

Human Results of Spatial SART

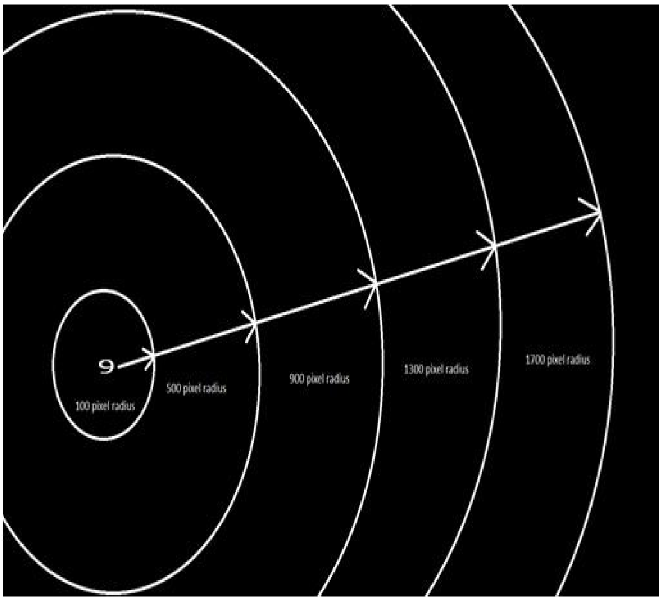
Like the previous test, the results obtained from all the participants were averaged out and the data were also split into 5 time intervals where all the data in 1 time interval were averaged out for every participant respectively. This was done in order to see the big picture and obtain an overall trend of the results as shown below with smooth curve fitting. The human results of Spatial SART are as shown below.

From the graphs, it can be seen there were drastic changes over time in all 3 variables. Reaction time increases which fit the findings of other authors (Itti *et al.*, 1998; Itti *et al.*, 2003). Performance graph showed a drastic drop in performance which shows a reduction of around 30% over the course of the test and increase in overall distance to target. This shows that the participants managed to be under the influence of DAF after a certain point during the test. To analysis deeper for modelling purposes, a more detail analysis was done on the distance to target but breaking down it down to specific distance as average value doesn't provide the critical information needed. The breaking down was done as the following illustration to obtain a probability model that can be integrated into IKM:

Illustration of the Breaking Down of Proability Distribution Model

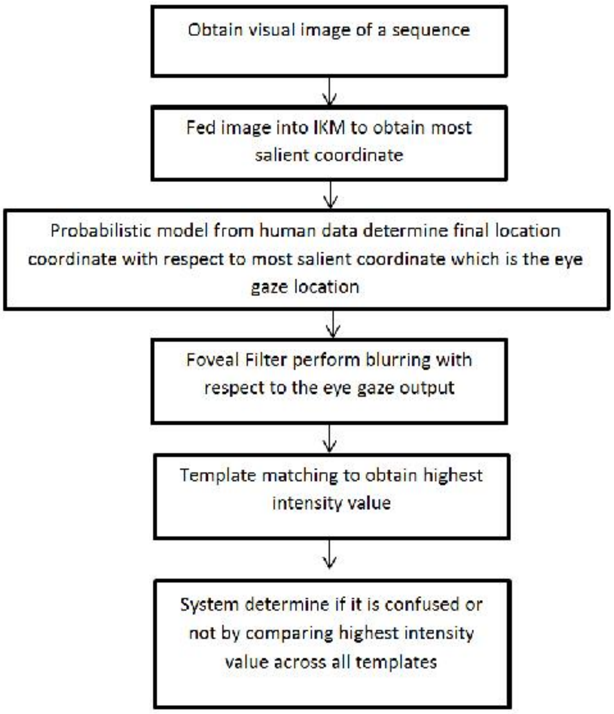


Human Results from Spatial SART



Modeling and Model Results

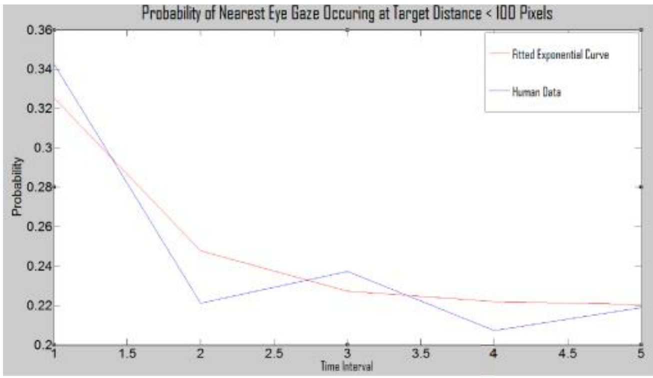
The flow of the model can be summarized as below:



Flow of the Model

Location Probability

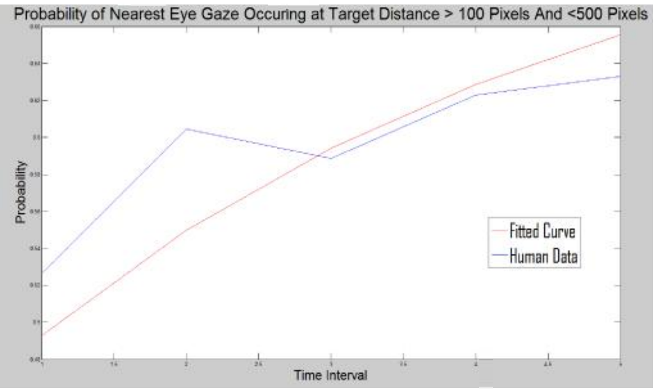
From the probability mass function obtained from the human data, it is possible to set the location of IKM points of attention to as the human data's. Due to the fact humans are individually different, average values were taken from all the participants and therefore a probabilistic approach is used to generalize the model to a general human response. Based on the human data result, it is possible to attempt to fit the data to a probabilistic model that changes with both time and distance where the equation in general can be denoted as $p(t, D)$ where t is time in seconds and D is distance interval that can take 5 numbers, $\{1,2\ldots5\}$. As from previous section, the human results were in depth analyzed and simplified by using probability of nearest eye gaze and the nearest distance is broken up into 5 sections. However, results showed that are actually 3 sections of interest, which is <100 pixels (represented by section 1), between 100 pixels to 500 pixels (represented by section 2), and between 500 pixels to 1700 pixels (represented by section 3). Below illustrations shows the range of distance the probability model can take and the results of each sections in table form. Below is the example of probability distribution when D = 1 and D = 2 which is the first section and second section respectively.



Probability of Gaze Position Given D = 1

From the figure, it seems that the data could be easily fed into an exponential curve with only small deviations. Exponential function for this distance is given by:

$$p_1 = 0.3426(e^{-t/1500})$$



Probability of Gaze Position Given D = 2

From the figure, it seems that the data could be easily fed into an exponential curve with only small deviations. Exponential function for this distance is given by:

$$p_2 = (0.52 - 0.63)(e^{-t/167.4}) + 0.52$$

For $D > 3$, the results obtained were negligible due to low probability count in all 3 sections.

Implementation of Foveal Filter

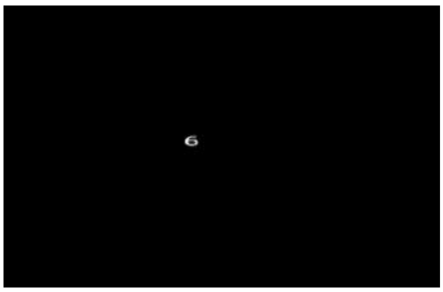
The results of the model will be compared to human data in order to obtain a measure on the accuracy of the model. The foveal filter used was derived from the work of Geisler and Perry. where the original purpose is to compress video images for a low bandwidth video communication while still keeping the important information in good condition via point of gaze location. The gist of the filter is to do a spatial resolution reduction across the image with respect to the point of gaze. The further away from the gaze, the more blurry the image will be. The main mechanism of the foveal filter is the implementation of multi resolution pyramid which generally is a spatial low pass filter. Examples of the foveal filter can as seen from Figure 11 and Figure 12.

Original Image, where the circle represents the location of gaze

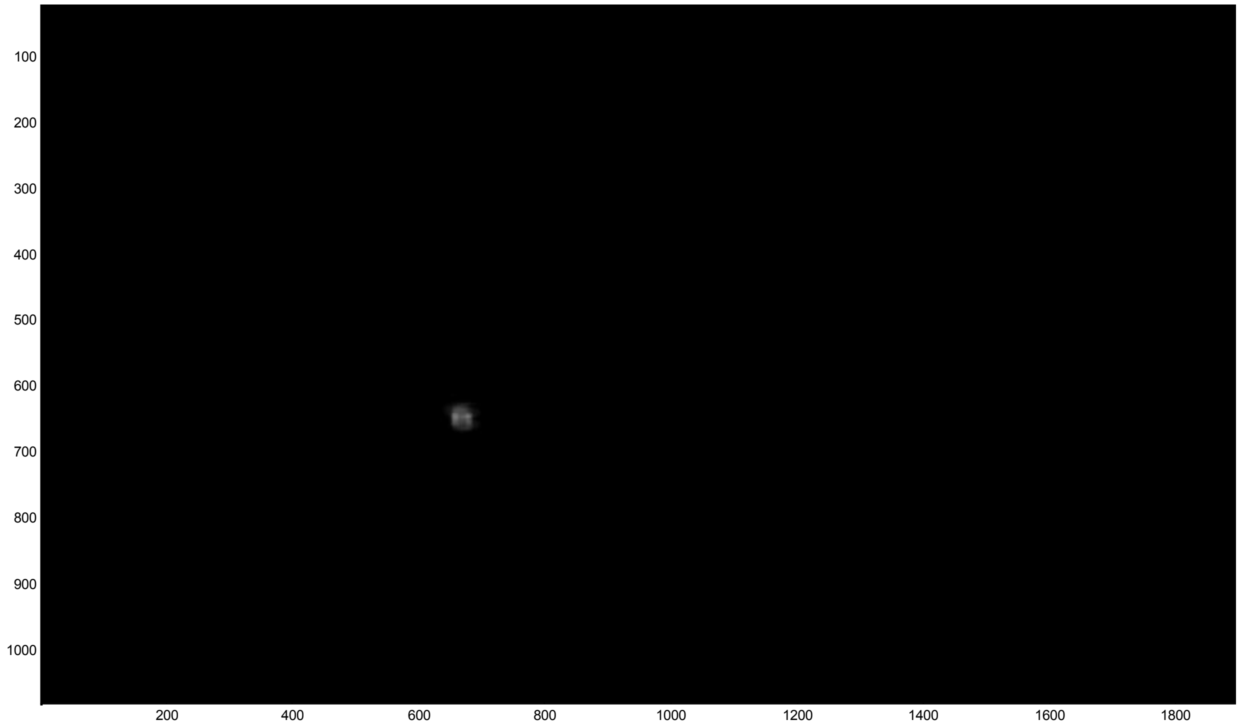
Image after the foveal filter

Recognition via Template Matching

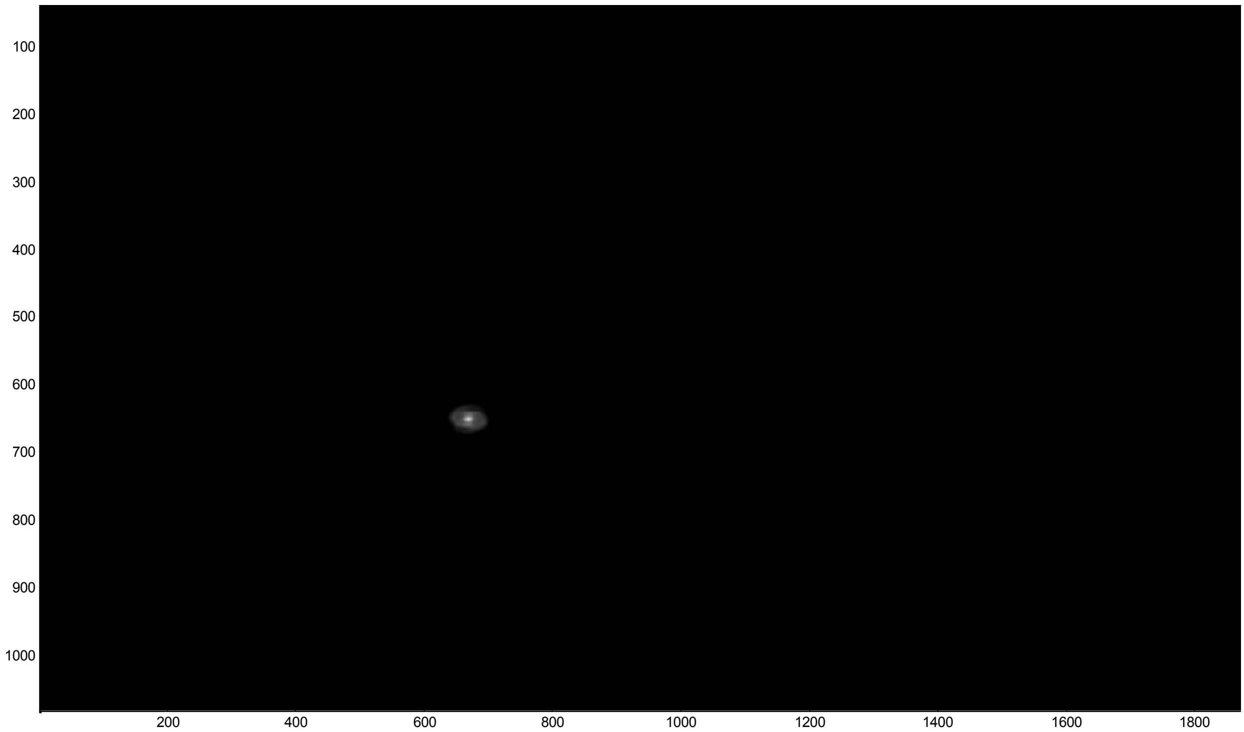
For the recognition model, a simple template matching process was proposed it is fast and efficient. This is due to the fact the spatial SART requires fast recognition and process, so therefore it was seen fit to introduce something that has the same feature. Same goes for the decision making part, fast reaction and thinking was need in the test; Hence, a system that represents this must be fast and robust also. The template matching in this model is based on cross correlation using Fast Fourier Transform (FFT). Template Matching is computer recognition technique to detect objects and also perform object comparison by using the basis of signal processing. Fast Fourier Transform (FFT) is a signal processing method and is a commonly used method to perform template matching. The templates needed to be known and preloaded into the system and matched with any input image. Cross-correlation can be done in any number of dimensions, and for this project, a 2D cross-correlation is used as images can be seen actually as 2D signals. The following Figures show the effects of the template matching with same input image but differing templates:



Original Input Image



Matched with Template of the number “1”. Highest point of intensity value: 124



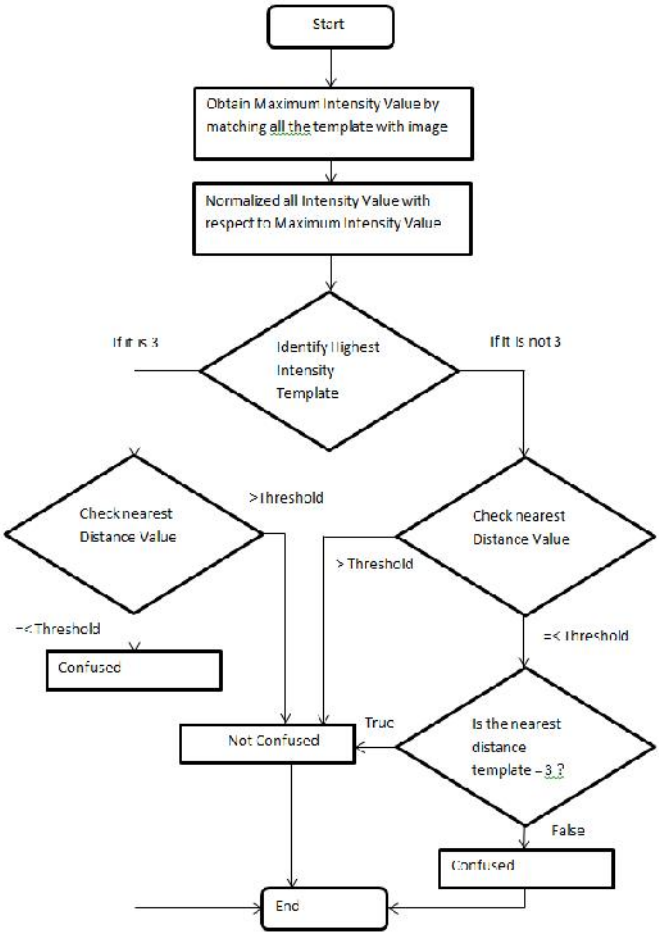
Matched with Template of the number “6”. Highest point of intensity value 232

As seen from the images above, note that if a matching template is used, a point of higher intensity can be obtained. The whole goal of doing template matching is to obtain a measure of sort that can be used in decision making and this would be the highest point of intensity.

Decision Making

Decision making here involves a human like response from the system.

The decision to create this part of the system is based on the observation of the human participants and also their personal feedback. A quick and fast response would be required led the human participants to have specific mindset on dealing with the test. Since the target number is “3”, the human participant will response in a way that they will press the spacebar as long it is not “3”. In other words, as long there is no confusion between “3” with the other numbers, the participants can be very sure of their answer and control themselves to not press the space bar. The goal here is achieve confusion for the decision making, and with the template matching alone confusion cannot be achieved as template matching always give the best results. However, with the addition of the foveal filter and IKM, the input image will be blurred depending on the gaze location. This allows the opportunity for the system to be confused just like its human counterpart instead of getting everything with top accuracy just like a machine would. Without blurring, a matched template will have a very much higher maximum intensity value which is distinct from the other templates value. With blurring, the maximum intensity value of a matched template will still be the highest compared to the other non-matched templates but their value differences will be greatly reduced. Given the information, can flow chart can be written as shown in the Figure 16.

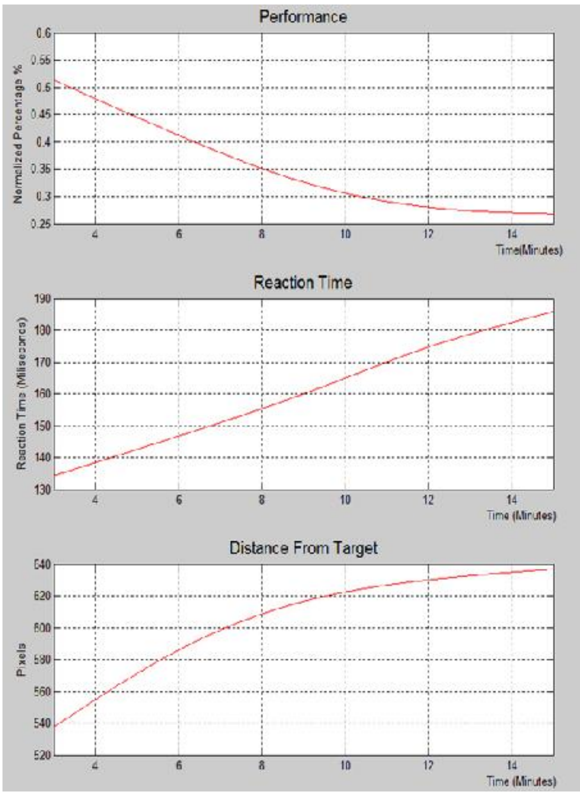


Flow Chart of the Decision Making Process

Spatial SART Model Results

he experiment was done on workstation with Intel(R) Xeon(R) CPU E5-1650 @ 3.2 GHz and 16 GB Ram. One experiment approximately takes 6 hours to complete which the raw data has 13 minutes in terms of duration. As recalled previously, 2 variable which was the reaction time (RT) and performance were obtained from human data. The reaction time was not included because RT is dependent not only human recognition and decision making, but also dependent on the motor skills which the model cannot replicate.

Therefore, only the performance between the model and the human data was compared. On the hand, the eye tracker results will be compared with the model's eye gaze position result in terms of average minimum distance from target and the probabilistic model. A total of 10 trials of the model were done to mirror the 10 human participants for spatial SART. Every results would be different because the model was based on probability. The results of the model was similarly analyzed using the method the human data where the results were averaged and split into 6 time intervals with 5 data points as seen the Figure 17. Overall, the result from the model matches very well the human data in terms of trend. However, it must be noted that the model performance is weaker compared to the human data in general while the distance from target isn't perfect either.



Results of the predictive model

To measure how much deviation of the model result to the human data, Mean Square Percentage Error (MSPE) was used.

$$MSPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{D-Z_i}{D}\right)^2 100\%$$

Where D is the desired average distance, n is the number of data points and Z is average score for each time interval. Based on the formula, MSPE for the model's on average distance from target has 1.01% deviation from the collected human data with the highest square percentage error occuring on first 3 minutes which is 4.23%.

Conclusion

This project has done research in a significant and novel area and managed to create visual attention model that can undergo fatigue. It has to be stressed that no model of visual attention has capability to undergo performance deterioration under the effects known as DAF and research done on this area will provide significant impact on the literature itself. In order to model human behaviour under DAF, the human data must be collected which is also tied to one of the objectives of this project. To collect human data, instrument such as eye tracker was used and coding in Java needed to be done to implement the implementation of the test. A new SAT have been devised by extending original SART in order to collect the relevant human data for modelling. In other words, the human data in terms of performance and eye gaze behavior has been collected successfully. To implement human behaviour from the collected data into a computational model, a base model known as IKM model was chosen as the target implementation. The IKM model in the MATLAB Saliency Toolbox was thoroughly analysed and extended with various modules such as foveation, top down control, object recognition and behavior in order to achieve the objective in creating model that will fatigue over time. The modules were created with substantial amount of coding in MATLAB environment and integrated the knowledge from human data. From this, a working computational models of DAF were developed with the show of promising results. The results obtained from the models were compared to their human counterpart where huge similarities were found in certain parts. However, this model lacked the top down versus bottom up mechanism as described by the reviewed literature. Hence, the exploration continues by trying to incorporate the mechanism into the IKM as future work.

REFERENCES

Borji, A., Itti, L. 2013. State-of-the-art in visual attention modeling. Pattern Analysis and Machine Intelligence, IEEE Transactions, Volume 35, Issue 1, Pages 185-207.

Cazzoli, D., Antoniades, C. A.,Kennard, C., Nyffeler, T., Bassetti, C.L., Muri, R.M., 2014. Eye movements discriminate fatigue due to chronotypical factors and time spend on task—a double dissociation. PLoS One. 2014 Jan 22;9(1):e87146. Doi: 10.1371/journal.pone.0087146.eCollection 2014.

Desimone, R. & Duncan J. 1995. Neural mechanisms of selective visual attention. Annual Review of Neuroscience 18:193-222.

Freeth, M., Foulsham, T., & Chapman, P. 2011. The influence of visual saliency on fixation patterns in individuals with Autism Spectrum Disorders. *Neuropsychologia*, *49*(1), 156–160. doi:10.1016/j.neuropsychologia.2010.11.012

Friese, M., Bargas-Avila, J., Hofmann, W., & Wiers, R. W. 2010. Here's Looking at You, Bud Alcohol-Related Memory Structures Predict Eye Movements for Social Drinkers With Low Executive Control.*Social Psychological and Personality Science*, *1*(2), 143–151.

Gazzaniga, M.S., Ivry, R., & Mangun, G.R. 2013. Cognitive Neuroscience: The Biology of the Mind. W.W. Norton, New York, (IV Edition).

Gershenfeld, N. (1998). The nature of mathematical modelling. Cambridge University Press.

Hartig, T. and Staats, H. 2005. Linking preference for environments with their restorative quality. In B. Tress, G. Tress, G. Fry and P. Opdam. (Eds.). From Landscape Research to Landscape Planning. Aspects of Integration, Education and Application. Dordrecht: Springer: 279-292.

Hartig, T., Evans, G.W., Jamner, L.J., Davis, D.S., Gärling, T. 2003. Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, 23:109-123.

Haseloff A. 2015, Dyslexia, ADHD, and Eye Tracking. Taken from http://docslide.us/education/eye-tracking-testing-dyslexia-and-adhd.html on 23th August 2015.

Itti, L., Koch, C. 2001. Computational modelling of visual attention. Nature reviews neuroscience, Volume 2, Issue 3, Pg. 194-203.

Itti, L., Rees, G., Tsotsos, J.K. (Eds) 2005. Neurobiology of Attention. Academic Press.

Kaplan, S. 1995. The Restorative Benefits of Nature: Toward an Integrative Framework. *Journal of Environmental Psychology* 15: 169-182.

Kaplan,S. Berman, M. G. 2005. Directed Attention as a Common Resource for Executive Functioning and Self-Regulation. Perspectives on Psychological Science.

L. Itti, C. Koch, E. Niebur, A Model of Saliency-Based Visual Attention for Rapid Scene Analysis, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 20, No. 11, pp. 1254-1259, Nov 1998.

Itti, L., N. Dhavale, F. Pighin, 2003. Realistic Avatar Eye and Head Animation Using a Neurobiological Model of Visual Attention, In: Proc. SPIE 48th Annual International Symposium on Optical Science and Technology, (B. Bosacchi, D. B. Fogel, J. C. Bezdek Ed.), Vol. 5200, pp. 64-78, Bellingham, WA:SPIE Press, Aug.

Lavine, R. A., Sibert, J. L., Gokturk, M., Dickens, B. 2002. Eye-tracking measures and human performance in a vigilance task. Aviat Space Environ Med. Apr; 73(4):367-72.

Leonard J. Trejo; Rebekah Kochavi, Karla Kubitz, Leslie D. 2005. Montgomery; Roman Rosipal; Bryan Matthews, "Measures and models for predicting cognitive fatigue" in Proc. SPIE 5797, Biomonitoring for Physiological and Cognitive Performance during Military Operations, (23 May 2005).

Maarten, A.S. Boksem, Theo F. Meijman, Monicque M. Lorist, 2005. "Effects of mental fatigue on attention: An ERP study" in Cognitive Brain Research 25 107 – 116.

Marx, S., Respondek, G., Stamelou, M., et al. 2012. Validation of mobile eye-tracking as novel and efficient means for differentiating progressive supranuclear palsy from Parkinson's disease. *Frontiers in Behavioral Neuroscience*. 6:88. doi:10.3389/fnbeh.2012.00088.

Berto, R. ?. "Exposure to restorative environments helps restore attentional capacity," in *Journal of Environmental Psychology*

Szeliski, R. 2010. Computer Vision: Algorithms and Applications. Springer Texts in Computer Science.

Theeuwes, J. 2010. Top–down and bottom–up control of visual selection. Acta Psychologica, Volume 135, Issue 2, Pages 77-99

Navalpakkam, V., L. Itti, 2005. Modeling the influence of task on attention, Vision Research, Vol. 45, No. 2, pp. 205-231, Jan.

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