Adaptation and Validation of the Tamil (Sri Lanka) Version of the Montreal Cognitive Assessment (MOCA)

P.A.D. Coonghe¹, P. Fonseka², S. Sivayokan³, A. Kesavaraja⁴, R. Malhotra⁵, and T. Ostbye⁶

Abstract

The study aimed to develop the Tamil (Sri Lanka) version of the Montreal Cognitive Assessment (MoCA) and investigate its reliability and validity as a brief screening tool for mild cognitive impairment (MCI). Tamil-speaking Sri Lankan older adults with normal cognition and MCI were recruited from a neurology clinic. Adaptation of the English MoCA to the Tamil (Sri Lanka) involved context-specific content modification and translation. The content validity, reliability, sensitivity, and specificity of the tool were evaluated. Study participants were 184 older adults, comprising 85 with normal cognition and 99 neurologist-diagnosed MCI. The tool had high internal consistency (Cronbach’s alpha=0.83). ROC curve analyses showed an area under the curve of 0.87 (95% CI 0.83-0.91) for detecting MCI. The optimal cut-off score for detection of MCI was 23/24, yielded a sensitivity and specificity of 84.7% and 76.4%, respectively. The Tamil (Sri Lankan) version of the MoCA maintains its core diagnostic properties rendering

¹ Department of Community and Family Medicine, Faculty of Medicine, University of Jaffna, Sri Lanka, padcoonghe@univ.jfn.ac.lk
² No. 26 D 1/1, Rosmed Place, Colombo 7, Sri Lanka.
³ Psychiatry Unit, Teaching Hospital, Jaffna, Sri Lanka.
⁴ Neurology Unit, Teaching Hospital, Jaffna, Sri Lanka.
⁵ Duke-National University of Singapore (NUS) Medical School No.8, College Road, Singapore 169857.
⁶ Duke Global Health Institute, No.310, Trent Drive, Durham NC USA, 27710.

Date Received: 22nd October 2018
Date Accepted: 19th December 2019
it a valid and reliable tool for screening of MCI among Tamil speaking Sri Lankan older adults.

Key Words: Elderly, Jaffna, MCI, MoCA, Screening, Sri Lanka, Tamil

Introduction

Mild cognitive impairment (MCI) refers to an intermediate transitional cognitive phase between cognition of normal aging and mild dementia. Individuals with MCI carry a high risk of deterioration to Alzheimer's disease (AD) and other dementias relative to cognitively normal individuals. In 2005, the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) was reported to be a better screening test for MCI than the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) among English and French-speaking persons. While the MoCA had a sensitivity and specificity of 90% and 87%, respectively for detecting MCI, the MMSE, which is widely used by primary care physicians to screen for dementia, had a sensitivity of only 18% for MCI (Nasreddine et al., 2005). Consequently, the use of the MoCA for screening for MCI has become pervasive in many countries. At the same time translation and validation studies of the MoCA have confirmed its validity as a screening test for MCI in several countries, including South Korea, China and Sri Lanka (Lee et al., 2008, Yeung et al, 2014, Karunaratne et al, 2011).

In Sri Lanka, except for Sinhala language version of the MoCA (Karunaratne et al., 2011) the Tamil language version has not been validated.

Sri Lanka has a population of about 21 million (Department of Census and Statistics, 2012). Sinhala and Tamil are the major languages spoken in the country with Tamil being spoken by about 5 million individuals. Globally, Tamil is spoken by 75.8 million people, an official language in three countries (India, Sri Lanka, and Singapore) and is also common in Australia, Canada, Malaysia, Mauritius, and Burma. At the same time, many dialects of the spoken Tamil language, which vary from each other, are used in different geographical regions of the world (Simons & Fennig, 2018). Such variations exist across regions in close geographical proximity; for instance, the vocabulary and grammar used by the
speech rates in Sri Lanka vary substantially from that used by the Tamil speakers in India. For this reason, the Tamil version of the MoCA developed in India is not directly applicable to Sri Lanka. Further, details on the validity of the Tamil (India) version of the MoCA are not available. And, given the difference in literacy rates of the two countries (Sri Lanka: 92.6% and India: 72.1%) (UNESCO, 2013), and that educational level impacts the MoCA cut-off score for the detection of MCI, the Tamil (India) version of the MoCA (Nasreddine et al 2005 retrieved from http://www.mocatest.org) may not be applicable to the Tamil-speaking population of older Sri Lankans. Thus, a culturally appropriate Sri Lankan Tamil version of the MoCA with acceptable psychometric properties is required to provide efficient and accurate screening of Tamil-speaking Sri Lankan older adults for MCI. The present study therefore aims to develop the Sri Lankan Tamil version of the MoCA and investigate its reliability and validity as a brief screening tool for MCI among Tamil-speaking Sri Lankan older adults.

Methods

Participants

This was a cross-sectional study of ambulatory, community-dwelling, Tamil-speaking Sri Lankan older adults recruited from the Neurology Clinic of the Teaching Hospital, Jaffna in Northern Sri Lanka. The approval of the research protocol from the Institutional Review Board (IRB), at the University of Jaffna was obtained. Written informed consent was obtained from all participants. All the MCI patients were able to give their consent without any difficulties. Based on the calculated sample size—a total of 184 older adults, comprising 85 with normal cognition and 99 neurologist-diagnosed MCI were recruited. For all participants, the inclusion criteria included age 60 years or older and the availability of an informant (i.e. a caregiver). The exclusion criteria included those with: cancer within 5 years, active infection, end-stage renal or other organ failure, non-ambulatory, depression by Diagnostic and Statistical Manual of Mental Disorders - fourth edition (DSM-IV, 2000) criteria, deafness, and other communication barriers.
Instrument

The MoCA is a one-page instrument. It measures eight cognitive domains with 10 items, and includes tests on short-term memory recall, visuospatial abilities, multiple aspects of executive functions, phonemic verbal fluency, abstraction, attention, concentration and working memory, language function, and time and place orientation (http://www.mocatetest.org). The MoCA can usually be completed in 10 minutes. In the original English and French MoCA version, one point is added for individuals with 12 or fewer years of education. The highest possible score is 30 points, and a higher score is indicative of better cognitive status.

We obtained permission to use the MoCA from its developer (Nasreddine et al., 2005). The original English version of the MoCA was first translated into (Sri Lanka) Tamil by three bilingual Tamil-speaking Sri Lankan medical professionals (Community Physician, Psychiatrist and Neurologist) separately, and the final version was approved with the consensus of all the experts who participated in the translation. Subsequently, this version was back-translated into English by a native Tamil speaker who was unfamiliar with the English version of the MoCA.

Finalizing the Sri Lanka Tamil version of MoCA, the following linguistic and cultural adaptations were made.

(1) Trail making test: The first five letters of the English alphabet were replaced with the first five letters of the Tamil Alphabet.

(2) Naming test: Pictures of a rhinoceros, and a camel were replaced with pictures of an elephant and a cow as the local community is more familiar with the latter animals than the former.

(3) Memory test: While two (face and red) of the five original words were retained, the rest (velvet, church, and daisy) were replaced. ‘Velvet’ was replaced with the Tamil word for ‘Silk’ as silk is a commonly used cloth material. ‘Church’ was replaced by the Tamil word for ‘Temple’ because most Tamil-speaking Sri Lankans are Hindus. And instead of ‘Daisy’, ‘Jasmine’, was selected.
(4) Test of attention for letters: The English alphabet was replaced with Tamil letters that have a corresponding sound.

(5) Language repetition: The English version of MoCA has two sentences. The first sentence was translated to retain the same meaning and the same number of words. But the name ‘John’ was replaced with ‘Kannan’. The second sentence was translated to retain the same number of words and also the same meaning without any corrections.

(6) Verbal fluency test: In the original tool, this test involves naming a maximum number of words beginning with the letter ‘F’. The corresponding Tamil ‘F’ is not used commonly. Therefore, it was replaced with the letter ‘P’.

(7) Test for abstraction: This was included identification of similarity of three pairs. In the original tool, these pairs were ‘Banana-Orange’, ‘Train- Bicycle’, and ‘Watch –Ruler’. During the process of adaptation, ‘Banana- Orange’ was retained without any change. But ‘Train' was replaced by ‘Bus’ because the majority of the people in Northern Sri Lanka are unfamiliar with the train and bus as common public mode of travel. Similarly, ‘Watch’ was replaced with ‘Balance’ because among older adults only a few use a watch and a weighing balance is a common measuring item that people are likely to have experienced.

The MoCA interviewer guide which has comprehensive instructions for administration of MoCA was also translated to Tamil. Necessary changes were made in MoCA-Tamil (Sri Lanka) adaptation. Then the translated guide was reviewed by a panel of experts who were involved in the translation into MoCA-Tamil (Sri Lanka) of the original MoCA tool. The adopted tool and guide were pre tested among ten patents from a medical clinic for chronic diseases at the Teaching Hospital, Jaffna and few corrections were made.

Clinical diagnosis

Older adults attending the Neurology Clinic of Teaching Hospital, Jaffna were subjected to full physical and neurological examination by a neurologist to classify
them as having normal cognition or having MCI. Those deemed as having “normal” cognition were without any cognitive complaint or impairment on assessment and did not have dementia as per the DSM-IV criteria nor MCI. Those deemed as having MCI were classified so based on the criteria Winblad et al. (2004) i.e., the presence of memory complaint (corroborated by an informant), impaired memory function for age and education (delayed word recall score <1 SD below normal age- and education-matched mean for Sri Lankan older adults), intact activities of daily living and no dementia as per DSM-IV criteria. Every willing older adult (n=184; classified as either having normal cognition or having MCI) then underwent a detailed clinical and cognitive assessment, lasting for approximately 90 minutes. The results of the gold standard was blinded to the MOCA- Tamil (Sri Lanka) administration. Socio-demographic data, history on cognitive symptoms and coexisting diseases were collected and the MoCA-Tamil (Sri Lanka) was administered. Then, after 4 weeks, a total of 20 older adults (10 with normal cognition and 10 with MCI), selected from the 184 study participants were assessed for test–retest reliability of the MoCA by the same data collector. We also evaluated interrater reliability by inviting another subgroup of 20 participants (10 with normal cognition and 10 with MCI), who were rated twice by two independent raters with the MoCA-Tamil (Sri Lanka).

Statistical analysis

The Original MoCA tool developers have suggested an additional item be added to persons with 12 years of education or less to minimize errors related to education. Therefore, in this study, an additional item was added to MoCA-Tamil (Sri Lanka) scores for those who had education for 12 years or less (if MoCA-Tamil (Sri Lanka) score < 30). Demographic characteristics across those with normal cognition and MCI were compared using the chi-squared test (for categorical variables) or the student ‘t’ test (for continuous variables). Internal consistency reliability of the MoCA-Tamil (Sri Lanka) was assessed using Cronbach's alpha. Test-retest reliability of the MoCA-Tamil (Sri Lanka) was assessed using intra-class correlation coefficients (ICCs) for baseline and 4 weeks retest scores. ROC curve analysis was performed to determine sensitivity and
specificity for detecting MCI. All tests considered two-sided hypotheses and a 5% level of significance. SPSS for Windows (version 21.0 SPSS; SPSS, Chicago, IL, USA) was used for the analyses.

Result

Study sample

Study participants were 184 older adults, comprising 85 with “normal” cognition and 99 neurologist-diagnosed MCI. The mean age was 69.7 (SD 4.8) years. There was no statistically significant difference in the mean age or sex between normal cognitive and MCI participants but, a significant difference was observed in years of education between the two categories of participants (Table 1).

Table 2 shows the education-adjusted mean MoCA-Tamil (Sri Lanka) scores of “normal” cognitive and MCI participants. The mean MoCA-Tamil (Sri Lanka) score discriminated the two diagnostic categories of the study participants (p<0.001).

Table 1. Demographic characteristics of the Study Participants by cognitive status (N=184)

| Demographic characteristics | Normal cognition | MCI | p-value |
|-----------------------------|------------------|-----|---------|
| Age, in years; Mean (SD)    | 69.1 (± 4.5)     | 70.2 (± 5.0) | \( p^\delta = 0.12 \) |
| Years of education; Mean (SD)| 9.2 (±2.7)       | 8.1 (±2.9)   | \( p^\delta = 0.01 \) |
| Male (%)                    | 41(48.2)         | 52(52.5)     | \( p^* = 0.56 \) |
| Female (%)                  | 44(51.8)         | 47(47.5)     |         |

\( ^\delta p \text{ value derived by student 't' test} \)
\( ^* p \text{ value derived by chi-square test} \)
Table 2 Summary of Group Differences of MoCA-Tamil (Sri Lanka) scores

| MoCA-Tamil (Sri Lanka) Score | P value |
|-----------------------------|---------|
| Normal Cognition (N =85)    |         |
| Mean score                  | 26.4    | 21.2    | p< 0.01 |
| (95% CI)                    | (26.0 - 26.8) | (20.7 - 21.7) |
| Median                      | 26.0    | 21.0    |
| Inter Quartile              | 25-28   | 19-23   |
| Range                       |         |
| Skewness                    | 0.30    | -0.09   |

Reliability of MoCA-Tamil (Sri Lanka)

Test – retest reliability data were collected from a subsample of 20 participants (Normal cognition and MCI) tested, on average, 28± 1.5 days apart. The mean change in MoCA-Tamil (Sri Lanka) scores from the first to second evaluation was 0.8 ± 1.8 points, and the correlation between the two evaluations was high (correlation coefficient = 0.93, p< 0.001) and suggesting good stability over time.

Internal consistency of MoCA-Tamil (Sri Lanka)

Internal consistency of the scale was assessed using Cronbach's alpha. An alpha value of 0.7-0.9 was considered as evidence to support good internal consistency of the instrument (Streiner, 1993). The internal consistency of the MoCA-Tamil (Sri Lanka) was moderate to high, yielding a Cronbach's alpha of 0.831. This indicated good internal consistency.
Table 3. Item Total Statistics Analysis of MoCA Tamil (Sri Lanka)

| Item                  | Scale mean if item deleted | Correlated item-total correlation | Cronbach’s alpha if item removed |
|-----------------------|----------------------------|-----------------------------------|---------------------------------|
| Trail making          | 19.1304                    | 0.525                             | 0.782                           |
| Copy cube             | 19.2536                    | 0.404                             | 0.790                           |
| Clock drawing         | 17.5145                    | 0.688                             | 0.751                           |
| Naming                | 16.5870                    | 0.214                             | 0.798                           |
| Digit span            | 18.2681                    | 0.560                             | 0.773                           |
| Sustained attention   | 18.8841                    | 0.659                             | 0.774                           |
| Serial 7 calculation  | 17.3333                    | 0.551                             | 0.770                           |
| Sentence repetition   | 18.3949                    | 0.442                             | 0.784                           |
| Phonemic fluency      | 19.3370                    | 0.325                             | 0.794                           |
| Abstraction           | 17.8913                    | 0.575                             | 0.774                           |
| Delayed recall        | 17.3623                    | 0.378                             | 0.819                           |
| Orientation           | 14.2246                    | 0.563                             | 0.769                           |
| Scale statistics      | 19.4710                    | 0.831                             |                                  |

**Inter-observer reliability**

The inter-observer reliability was assessed through the application of the test on the first ten patients in the study by two independent blinded evaluators. A correlation of coefficient and concordance of 0.91 was obtained with a 95% CI of (0.77, 0.99). This correlation and concordance coefficient are considered almost perfect.

According to Table 3, which shows item test statistics, the correlated item-total correlations are basically the correlation between the particular item and a composite score of all the other remaining items. In addition, if the corrected item-total correlation is >0.30, it indicates homogeneity between each item and total inventory score. Values <0.30 indicate that a particular item correlates poorly with the overall scale (Abdollahimohhammad & Ja’afar, 2014). In this tool, all the items
except Naming have higher than expected corrected item-total correlation. ‘Cronbach's Alpha, if item removed; is a measure of examining the relationship between the individual item and the total scale. This is the value of Cronbach’s alpha for the remaining items if the given item is not included in the scale. So, in this scale, all the subscales 'Cronbach's Alpha if item removed' are lower than overall scale’s Cronbach's alpha (0.831).

Table 4. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the MoCA-Tamil (Sri Lanka) for detection of normal cognitive and MCI patients

| Cutoff | Sensitivity | Specificity | PPV (%) | NPV (%) |
|--------|-------------|-------------|---------|---------|
| ≥ 21   | 52.4        | 100.0       | 100.0   | 48.32   |
| ≥ 22   | 58.6        | 100.0       | 100.0   | 51.80   |
| ≥ 23   | 68.1        | 97.6        | 98.45   | 57.60   |
| ≥ 24   | **84.7**    | **76.4**    | **88.90** | **68.40** |
| ≥ 25   | 87.7        | 64.7        | 84.80   | 70.00   |
| ≥ 26   | 90.6        | 44.7        | 78.60   | 67.9    |
| ≥ 27   | 94.8        | 28.2        | 76.70   | 70.79   |
| ≥ 28   | 97.4        | 16.5        | 72.38   | 73.85   |
| ≥ 29   | 100.0       | 7.1         | 58.30   | 100.00  |
| ≥ 30   | 100.0       | 0.0         | 69.2    | Not applicable |

Bold values indicate cutoff point used in the study with values of sensitivity and specificity.

**Predictive validation**

With the use of a cut-off of 26 points (suggested in the literature as the ideal MoCA cut-off score to detect MCI), the MoCA-Tamil (Sri Lanka) detected 90.6% of MCI cases, but specificity was reduced to 44.7% (Table 4). With the use of the cut-off of 24 points, the MoCA-Tamil (Sri Lanka) exhibited high sensitivity (84.7%) and
specificity (76.4%). Therefore, 24 points seemed to provide the best balance between sensitivity and specificity (any score of ≤23 was considered to be the abnormal result).

The area under the ROC curve (AUC) of the MoCA-Tamil (Sri Lanka) for the identification of MCI was 0.87 (95% CI 0.83-0.91) (Fig.1)

Discussion

The objective of this study was to develop the Tamil (Sri Lanka) version of the MoCA and investigate its reliability and validity as a brief screening tool for MCI among Tamil-speaking Sri Lankan older adults. In Sri Lanka the majority of the population is rapidly ageing. The validation of the MoCA in Tamil (Sri Lanka) will be very useful for the clinicians and especially for the primary care physicians in detecting MCI in order to enhance the provision of appropriate care in time.

The results of this study seem to be in line with previous validation studies using the MoCA. First, the MoCA Tamil (Sri Lanka) mean scores for the diagnostic groups were similar to the ones presented in the original study (Nasreddine et al., 2005). Second, the MoCA-Tamil (Sri Lanka) demonstrated adequate test-retest
reliability and high internal consistency and these were similar to the studies of MoCA validation by Nasreddine et al., 2005; Gil, Vega, Ruiz de Sanchez, & Burgos, 2013; Karunaratne et al., 2011; Yu et al., 2012.

As shown in Table 3. ‘Cronbach's Alpha if item removed' is a measure of examining the relationship between individual item and the total scale. This is the value of Cronbach's alpha for the remaining items if the given item is not included in the scale. So, in this scale all the subscales 'Cronbach's Alpha if item removed' are lower than overall scale's Cronbach's alpha (0.831). It means, all the items are needed for the scale in terms of reliability. Karunaratne et al., (2011) found that Cronbach's alpha increased when the item naming was removed and they concluded that the contribution of the item 'Naming' to the scale was poor.

Sensitivity and specificity of a tool were determined based on the cutoff point decided with the help of ROC curve. A score which yields the best balance between sensitivity and specificity for the MCI participants was decided as the cutoff score. As described in Table 4 the cutoff score of ≥ 24 discriminate NC from MCI participants with the sensitivity of 84.7% and specificity of 76.4%. This cutoff score provides the positive predictive value (PPV) as 88.9% and negative predictive value (NPV) as 68.4%. When increasing the cut-off value to 26 as recommended by the authors of the original MoCA tool the sensitivity decreased to 68.1% but specificity increased to 97.6%. Because of this reason, it was decided that a score of ≥ 24 was the cut-off value to detect NC from the MCI participants.

The Spanish version of the MoCA validation used scores of ≥23 with the optimal sensitivity (89%) and specificity (79.8%) (Gil et al., 2013). In the Beijing version of the Chinese MoCA validation, the cut-off score for the optimal sensitivity and specificity to detect MCI appeared to be ≥22 for the MoCA-BJ, at which the sensitivity and specificity were 68.7% and 63.9% respectively (Yu et al., 2012).

Some limitations of this study should be mentioned. This tool cannot be applied to illiterate elders, and therefore they were excluded from the study. Another limitation is the fact that the MCI group was heterogeneous, as different MCI

12
subtypes were included in the sample. In addition, this was not a community study, as the sample was hospital based.

**Conclusion**

The Validated Tamil (Sri Lanka) MoCA is a reliable and an acceptable tool to assess MCI in the community setting with a cut-off value of $\geq 24$. It had 84.7% sensitivity and 76.4% Specificity. The reliability and internal consistency of the tool were higher than the expected level.

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Intelligent Traffic Light Controlling System According to the Traffic Area

Randima Fernando¹ and Anusha Jayasiri²

Abstract

Traffic congestion is a significant problem in recent years because of the ever-increasing number of vehicles in the roads and the poor management of traffic. Traffic congestions are not constant throughout the day. They are changing from time to time. Present traffic controllers have fixed time intervals for red, yellow and green signal lights and therefore, cannot provide a better solution for the dynamic traffic congestion during the day. Computer vision technology can be used to create an intelligent traffic controlling system which can adapt its time intervals according to the real traffic. In the existing traffic controlling systems, a wastage of the green signal duration occurs as fixed green signal duration assigned for a phase is sometimes larger than the actual requirement. Hence, the other roads at the intersection have to wait, in vain, with more traffic, until that fixed green time period is over. In the proposed method, real time traffic image sequences are analyzed by using image processing in order to obtain the actual traffic area. Then, time for green light is assigned according to that traffic area. Hence, the wastage of green signal duration is eliminated by the proposed method since it allocates time for the green signal that is sufficient for the actual traffic

¹ Department of Statistics and Computer Science, University of Kelaniya, Sri Lanka, randi.fernando111@gmail.com.
² Information Technology Centre, University of the Visual and Performing Arts, Sri Lanka, anusha.j@vpa.ac.lk

Date Received: 02nd November 2018
Date Accepted: 14th November 2019
present on the road to the pass. The results reveal that the green signal duration that needs to pass the traffic is proportional to the road area covered by traffic at that time.

**Keywords** — Traffic area, Image processing, Intelligent controlling of traffic, Green signal duration

**Introduction**

Traffic congestion has become a major problem in recent years. It causes many problems such as air pollution, sound pollution, stress and, time and energy wastage. The reasons behind this problem are the insufficiency of the resources provided by the current infrastructure for transportation to meet the ever increasing number of vehicles on the road and the improper controlling of traffic creating traffic jams (Agrawal D. and Sahu A., 2015). These traffic jams not only affect the human routine but also lead to a rise in the cost of transportation.

Traffic congestion in urban areas especially in Colombo is a major problem which needs to be urgently solved. The traffic congestion during a day is dynamic. The current system of fixed time sequenced signal lights cannot adapt its time intervals according to the changing traffic.

There are situations in cross way intersections such as heavy incoming traffic available only from several sides of the intersection while the rest are relatively empty. In this case, people on the heavily - occupied side have to wait for a longer time while the road containing low traffic displays a green signal without having vehicles to move. The allocation of fixed green light time for all sides, leads to a wastage of green signal duration as well as creating more traffic in other roads thereby increasing the average waiting time of every person in the traffic.

The government officials set these timers according to the proportionate amount of traffic present on different sides of the intersection using some statistical data. However, this can never be so flexible to control dynamic traffic throughout the day because some areas of high traffic may receive scanty traffic at some point of the day and some low traffic volume areas might get congested.
Hence, there is a dire need for a smart system that can adjust the timing of these lights based on the real time traffic present on the road. Because of this, there is an interest in developing intelligent traffic controllers using various technologies such as Magnetic Loop Detectors, Inductive loop detectors, light beams of infrared rays and LASER, and also using image processing. (Choudekar P. et al, 2011) Using image processing operations to develop a self-adaptive, intelligent system which can help in better traffic management is cost effective as cameras are cheaper and affordable devices compared to any other devices such as sensors. (Joshi A. A. and Mishra D., 2015)

Several researches have been done for controlling traffic using different techniques of image processing. They are mainly based on vehicle counting methods (Aher C. and Shaikh S., 2015), (Abbas N., et al, 2013) (Niksaz P., 2012) and image comparison methods. (Choudekar P. et al, 2011)

The aim of this research is to identify a technologically advanced, intelligent traffic controlling method by recognizing the actual area of the traffic which is presented on a road thereby providing an adequate amount of time for the traffic to pass by dynamically changing traffic light timers.

Moreover, the proposed method is supposed to eliminate the wastage of green signal duration by providing only a sufficient time interval rather than providing a pre-set time interval. Thus, the road with less traffic will be given the green signal for a shorter period of time, while the road with more traffic will be given a longer green signal period.

The ultimate objective of this research is to decrease the average waiting time of people in the traffic thereby saving more energy and time.
Methodology

The proposed approach to the elimination of the wastage of ‘green signal duration’ and controlling traffic is as follows: firstly, a camera was installed at the phases of an intersection to monitor the incoming traffic. After collecting image data sequences through the camera, the area covered by the vehicles in that particular road phase was quantified by processing images. Traffic signal time duration for effective green period will be dynamically set based on the current incoming traffic area from that direction. In this method, the road which is having more traffic, will be allotted a longer duration of green signal duration compared to others. Hence, it can be used to avoid the wastage of green signal duration.

Figure 1. Proposed method for calculating the green signal duration

According to Figure 1, the proposed method can be divided into four parts: the first part is the acquiring of image sequences of the traffic on the road phase by using a fixed camera. The second part is applying pre-processing techniques on image sequence to enhance the features of the image to prepare it for further analysis. This is achieved by using an OpenCV vision library. The third part is to detect the targeted area where the vehicles are actually presented on the road. The last part is allocating ‘effective green signal time’ to the phase which can be performed according to the current area of the traffic which covers the road at that particular moment. This research is done with the help of Open Source Computer Vision Library (OpenCV) version 3.2 and C++ with the use of Visual studio 2015. Traffic videos were captured by using a phone camera with 12 MP.
A. Image Acquisition

Image acquisition in image processing can be broadly defined as the action of retrieving an image from some source usually a hardware-based source which can be passed through whatever processes that need to occur afterwards. Image acquisition is the first stage of any vision system because without an image, no processing is possible. The image acquired is completely unprocessed. Therefore, after obtaining the image, various methods of image processing are applied to the image to perform many different vision tasks. However, if the image is not acquired satisfactorily, then, the intended tasks may not be achievable even with the aid of image enhancement.

In this research, image sequences were captured by using a phone camera and the camera was stationary. The camera was positioned at sufficient height in order to have a clear view of the road from the point of the traffic lights. The camera is activated a few seconds before the light turns into green. As a preliminary task, offline videos which were taken from real time videos were used to propose a method. The method that is proposed here can be directly applied to the real time videos as well.

The next stage is to extract the frames continuously from the real time video coming from the stationary camera. These frames were then pre-processed and analyzed to detect the traffic area.

B. Pre-processing

Pre-processing is a common name for operations with images at the lowest level of abstraction. In these operations, both input and output are intensity images. The aim of pre-processing is to suppress unwanted distortions and enhance image features which are important for further processing (Gaikwad O., et al, 2014). In other words, pre-processing is done to get a clear image. Since the images are extracted from real time video frames, they can be distorted, blurred, dark etc. For example, images can be blurred in rainy weather. Similarly, images can be darker when captured at night time conditions or can be too bright when it is very sunny. Therefore, different pre-processing methods are applied to the images to improve
the quality of the image that further helps in better analysis of the image and also the traffic area calculation.

Image pre-processing methods can be categorized according to the size of the pixel neighborhood that is used for the calculation of new pixel brightness. Every piece of video will need some preprocessing to some extent and the amount is wholly dependent on both the source video and the format. The following are some pre-processing techniques used in the proposed method:

1. Image cropping
2. Thresholding
3. Colour space conversion
4. Distance transformation
5. Normalization

1). **Image Cropping**: Cropping an image extracts a rectangular region of interest from the original image. This allows to zoom in on a specific portion of the image. In order to do cropping, the co-ordinates of the rectangle should be specified. In this research, the coordinate values of the road area are predefined by selecting appropriate values that can extract the whole region of the road. Since the camera is stationary, unnecessary information is fixed in every frame of the live video. Therefore, it is easier to crop the region of interest or the road in every frame.

Image cropping was done using image cropping function in OpenCV.
2). **Thresholding:** Image thresholding is a simple, yet effective way of partitioning an image into a foreground and a background. This image analysis technique is a type of image segmentation that isolates objects by converting grayscale images into binary images. Thresholding often provides an easy and convenient way to perform this segmentation on the basis of the different intensities or colours in the foreground and background regions of an image. In many vision applications, it is useful to be able to separate the regions of the image corresponding to objects. (Open Source Computer Vision, 2016)

The input to a thresholding operation is typically a grayscale or colour image. In the simplest implementation, the output is a binary image representing the segmentation.

3). **Colour Space Conversion:** The Colour of an image may contain a great deal of information which can be used for simplifying image analysis, object identification and extraction based on colour. These procedures are usually carried out by considering the pixel values in the colour space in which it is defined. To specify a colour in terms of three or more particular characteristics, there are a number of methods called colour spaces or colour models. Selecting a method out of them to represent an image is depended on the requirements of the operations to be performed because some methods are more appropriate according to the
requirements of applications, for example, in some colour spaces such as RGB, the brightness affects the three channels, a fact that could be unfavorable for some image processing operations.

There are more than 150 colour-space conversion methods available in OpenCV. The function provided by OpenCV in the imgproc module is,

```c
void cvtColor(InputArray src, OutputArray dst, int code, int dstCn=0).
```

(Open Source Computer Vision, 2016)

![Resultant image after applying color space conversion](image)

**Figure 4. Resultant image after applying color space conversion**

4). **Distance Transformation:** This section describes the distance transformation used for calculating the distance to an object. The distance transform is an operator normally only applied to binary images. The result of the transformation is a grey level image that looks similar to the input image except that the grey level intensities of points inside foreground regions are changed to show the distance to the closest boundary from each point.

There are many ways of computing the distance transformation of a binary image. One intuitive but extremely inefficient way of doing this is to perform multiple successive erosions with a suitable structuring element until all foreground regions of the image have been eroded away. Further, distance transformation can be calculated much more efficiently using clever algorithms which are based on recursive morphology. (Open Source Computer Vision, 2016)
5). **Normalization:** In image processing, normalization is a process that changes the range of pixel intensity values. Normalization is sometimes called as contrast stretching or histogram stretching. In more general fields of data processing such as digital signal processing, it is referred to as dynamic range expansion. The purpose of dynamic range expansion in the various applications is usually to bring the image or other type of signal into a range that is more familiar or normal to the senses. Hence, the term normalization.

![Resultant image after applying normalization](image1.png)

**Figure 5. Resultant image after applying distance**

![Resultant image after applying normalization](image2.png)

**Figure 6 Resultant image after applying normalization**

**C. Traffic Area Identification**

After performing pre-processing techniques described above, the resulting image is ready for further analysis in order to identify the actual area of the road that is covered by vehicles. This study was carried out for a single lane. During the
analysis stage, the value of pixels is scanned across straight lines originating from the beginning of the starting point of the traffic lights going right until the end of the road. This was achieved with the use of coordinates values of the cropped image.

While scanning each pixel lying on these lines, it is required to identify whether that pixel represents a part of a vehicle or not.

When there is lesser traffic on the road after some point along the road, the values of consecutive pixels hold a value which equals to the pixel value of the road. That is because from that point onwards no vehicle queue is presented on the road or the next vehicle might not still connect the queue as it is still coming or has some distance to pass in order to connect the queue. Hence, the queue length can be derived from the distance between the starting point of the traffic lights and the last co-ordinate of pixel of which the pixel value represents a vehicle.

A similar process was carried out across various lines on the road and then, returned to the length of the line which has the highest distance. This process was applied to all frames in the image sequence to take the highest distance of the line. This distance was used to calculate the traffic area. The traffic area identification at several traffic situations by using the proposed method of this study is illustrated by figure. 7, figure. 8 and figure.9.
Figure 7. Traffic area identification at low traffic situation

Figure 8. Traffic area identification at medium traffic situation

Figure 9. Traffic area identification at high traffic situation
### D. Determination of green time

For the time allocation, the work of N. Mokashi. (Mokashi N. 2015) was referred. Consider that the four-way intersection depicted in figure 10 shows the four phases along the directions, north (N), east (E), south (S) and west (W) respectively.

The cycle is defined as the time duration between the beginning of two consecutive green signal durations of the same signal.

Let each road along the directions of N, E, S and W have equal, maximum green signal duration $T_{\text{max}}$ and during that time period, the maximum traffic area $A_{\text{max}}$ can pass the intersection point.

Let $AN$, $AE$, $AS$ and $AW$ be the areas of traffic which are actually present at that particular moment, measured in the directions of N, E, S and W respectively.

Let $TN$, $TE$, $TS$ and $TW$ be the duration for which the signal turns green for the directions of N, E, S and W with respect to $AN$, $AE$, $AS$ and $AW$ traffic areas at a particular moment.

*Figure 10. Cross-way intersection*
Then, we can derive $TN$, $TE$, $TS$ and $TW$ as follows:

\[ TN = T_{max} \times (AN/A_{max}) \] -------(2)
\[ TE = T_{max} \times (AE/A_{max}) \] -------(3)
\[ TS = T_{max} \times (AS/A_{max}) \] -------(4)
\[ TW = T_{max} \times (AW/A_{max}) \] -------(5)

According to this method, the green time durations are determined as a portion of $T_{max}$. And also, it can be seen that at each and every cycle, the cycle time is not a constant. It also changes its value according to the area of traffic presented.

\[ Cycle \ Time \ (C) = TN + TE + TS + TW \]

\[ = \left( T_{max} \times \left( \frac{AN}{A_{max}} \right) \right) + \left( T_{max} \times \left( \frac{AE}{A_{max}} \right) \right) + \left( T_{max} \times \left( \frac{AS}{A_{max}} \right) \right) + \left( T_{max} \times \left( \frac{AW}{A_{max}} \right) \right) \]

\[ = T_{max} \times \left( \frac{AN + AE + AS + AW}{A_{max}} \right) \] -------(6)
Results

Following are the green signal duration based on the several different traffic situations: the time represented here is in seconds.

![Image](image1.png)  
*Figure 11. Time allocation at low traffic situation*

![Image](image2.png)  
*Figure 12. Time allocation at medium traffic situation*

![Image](image3.png)  
*Figure 13. Time allocation at high traffic situation*
duration for this road is 60 seconds. When there was high traffic, these 60 seconds are completely used by vehicles to pass the intersection point. But, in other traffic situations such as low traffic, some portion of this time was sufficient.

In this study, we assumed that this 60 second time is enough to pass the traffic within a maximum area of 200 * 945 pixels. After obtaining the actual traffic area (that area was also obtained in pixels) by using the method which is described above the green signal duration was determined as a portion of 60 seconds.

The following table shows some traffic area measurements and respective green time durations which were obtained using the proposed method:

| Traffic Area (Pixel²) | Effective Green Time (s) |
|-----------------------|--------------------------|
| 69000                 | 22                       |
| 70600                 | 22                       |
| 127800                | 41                       |
| 128000                | 41                       |
| 139600                | 44                       |
| 146200                | 46                       |
| 159000                | 50                       |
| 159400                | 51                       |
| 176400                | 56                       |

*Table 1. Traffic area measurements and respective green signal durations*
The following Figure 14 depicts the relationship between the traffic area and the green signal duration which was generated by using this method:

![Traffic area Vs Green signal duration](chart.png)

*Figure 14. Relationship between traffic area and green signal duration*

It is clear that the effective green light time was proportionate to the traffic area. Hence, it can be concluded that the proposed method is accurate. The proposed system optimizes the average waiting time of every person present in the traffic. It can generate the green signal duration intelligently by considering the actual traffic present on the road.

A simple analyzing method was used for analyzing the binary image in order to detect the traffic length. Moreover, a simple calculation was required to obtain the traffic area. Thus, even with less computing power, this method could work well.

The proposed system is very cost-effective compared to the other methods which are used in traffic controlling as it only needs a computer and a digital camera. Furthermore, the cost for Installation and maintenance is less than other technologies.
Discussion

Traffic congestion is becoming a serious issue day by day since it can lead to many other problems. The main reasons for traffic congestion problems are insufficient infrastructure for transportation with the ever-increasing number of vehicles and inefficient transport management systems etc.

The current traffic controlling systems have been unable to provide efficient solutions for the ever-increasing traffic congestion. The main reason behind the failure of fixed time controllers, is that they could not adapt its time intervals according to the varying traffic patterns. Therefore, the waiting time of each vehicle in the traffic queue is increasing. This study showed that the image processing is a better technique to control the traffic congestion problem. It is also more consistent in detecting vehicle presence because it uses the actual traffic frames. Since it visualizes the reality, it also functions much better than those systems that rely on the detection of vehicles using a metal detector.

The method proposed in this study is control traffic in an intelligent way. It would basically reduce the vehicle waiting time at junctions. It can identify the actual area of traffic with which the road is covered, by using simple methods and it can allocate time for green lights based on the factor of the current traffic area. Thus, a road with less traffic will be given the green signal for a shorter period of time while a road with more traffic will be given the green signal for a longer period. This system is initially developed for controlling traffic in a single lane. It can be further developed for handling traffic in a road with several lanes.

The accuracy of this method can be improved by concurrent analyzing of traffic videos from two points along the road thereby taking the mean value of the area covered by traffic. During the study, it is ascertained that the camera position is very crucial in getting accurate data. A higher camera position is necessary to detect the traffic area accurately.

It is a timely requirement to have the type of system mentioned in this study as this time saving factor will lead to efficient transporting, benefitting not only the
vehicle users but also governmental and non-governmental sectors of the country (Rane R., Pathak S., Oak A. and Khachane S., 2015). Furthermore, saving fuel would benefit the entire vehicle users since the money that would be spent on fuel will be reduced. Since the vehicles would spend lesser time at the intersections, a more eco-friendly environment will be created thereby lifting the living standards of the people.

**Conclusion**

The results show that this method has acquired its objectives by successfully eliminating the wastage of effective green time and controlling traffic in an intelligent way. This method provides an efficient solution regarding the traffic congestion problem. The proposed method is beneficial and with some improvements, it can be used to create a fully completed intelligent traffic controller which can adapt its time intervals according to real time traffic present on the road.

This work can be enhanced further by proposing a system which identifies the presence of emergency vehicles such as ambulances or fire brigades and give preference to those lanes with emergency vehicles to pass the traffic (Khanke P. and Kulkarni S., 2014).

In addition, any future work can involve further image processing that would provide better results including night time images. Through these means, traffic can be controlled in the day time as well as night time.

In addition, this work can be further expanded by implementing this technique with the real time online image sequences and can be used to create a perfect traffic controlling system.
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Sensory Perception: A Comparative Study of Western Psychology and Buddhist Psychology

Ven. Gomila Gunalankara Thero¹

Abstract

Sensory Perception (SP) is a fundamental psychological process of species for their survival, as it predominantly involves with memory and learning. In human, therefore, a spectacular system of sensory processing has developed. Every being in the world has special features of their sensory information processing systems. This study focused on exploring the Buddhist Psychological explanation of SP of human beings in comparison to the theories and models of SP in Western Psychology (WP). The study was conducted under qualitative research methods, based on textual studies. Western psychologists have introduced number of theories such as Human Information Processing Theory of Cognitive Psychology through experimental researches to understand the biological and psychological process of SP. Buddhist Psychology (BP) of SP is mainly laid on the explanations in Abhidhamma pitaka and Sutta pitaka. The special attention was, here, paid on Sabbacittasādhārana cetasika and Cittavīthi in the Abhidhamma pitaka and Madupindika sutta in Sutta pitaka. In conclusion, both WP and BP comprise of complex theories and models of SP. The two approaches are less comparable, as there are different complex explanations except certain similarities.

Key Words: Sensory Perception, Cognitive Model, Bio-psychological Model, Sabbacittasādhārana Cetasika, Cittavīthi Analysis

¹ Department of Practical Buddhist Studies, Bhiksu University of Sri Lanka, Anuradhapura, Sri Lanka, ggunalankara@busl.ac.lk

Date of Received: 02nd November 2018
Date of Acceptable: 14th November 2019
**Introduction**

Sensation and Perception are two parallel topics which are highly discussed in the field of Psychology. In the history of psychology, experimental psychologists, gestalt psychologists and cognitive psychologists have developed significant theories and models on sensation and perception based on scientific researches. The distinction between sensation and perception was developed by Thomas Reid, a Scottish philosopher, in 1765. It is defined, “Sensation is the stimulation of the sense organs and perception is the selection, organization, and interpretation of the sensory input” (Weiten, 2005, p. 91). According to the explanations of biological psychologists, sensation detects stimulations (sensory inputs) from the internal or external environment, with absorption of energy such as light and sound waves through sensory organs such as eye and ear. Thereafter, the information is transduced and transmitted to the brain through the nerves system, so that interprets into meaningful information (perception).

There are numerous theories and models developed by the Western Psychologists through experiments to explain the process of SP. Those theories and models mainly prefer the Biological and Cognitive Process of SP in relation to the functions of sense organs and the brain. Each theory and model in WP fulfills shortages of each other.

Referring to the BP, *Abhidhamma pitaka* includes an enormous analysis on human mental conditions and psychological functions. Especially, *Dhammasanganippakarana* of *Abhidhamma pitaka* can be considered as the Buddhist Psychoanalysis. In line with, the *Sutta pitaka* consist of number of teachings on the psychology of human mind and its process.

**Research Problem**

How is the Sensory Perception process analyzed in Buddhist Psychology and is it comparable to the Western Psychological Analysis?
Objective

The objective of this research is to compare the psychology of Sensory Perception analyzed in Buddhist Psychology and Western Psychology, referring to the selected theories and models from both streams.

Literature review

There are number of researches and studies conducted on sensation, perception and information processing in both Western and Buddhist Psychology. The Western Psychological theories and models of SP are very familiar to the field where as Buddhist psychological explanations of which are very rare. Prof. E.R. Sarachchandra in his ‘Buddhist Psychology of Perception’ (1958) gives a comprehensive study on SP, paying attention on teachings in Sutta pitaka and Abhidhamma pitaka. Prof. Y. Karunasada provides an explanation on seven fold Universal Mental Concomitants, under the theme of ‘Sabbacittasādhārana cetasika of Abhidhamma Psychology’ (1995) (translated by A. Thilakeratne). Even though these studies revealed BP of SP, they did not provide a comparative study with WP.

‘The Concept of Visual Perception; A Comparative Study of Buddhist and Western Psychology’ (2013) is a study conducted by Ven. Aththaragoda Piyadhamma. He, in his study, compares theories of Visual Perception in two systems. Concluding his study, he mentions that WP mainly concerns with biological process of visual perception and Gestalt psychology comes up with a cognitive view of which while BP mainly emphasizes a psychological perspective on visual perception entirely (Piyadhamma, 2013, p. 265).

Methodology

As this is a comparative review, the study was conducted under the qualitative research methods based on textual studies. Documentary sources of WP and Buddhist teachings and electronic sources such as websites were used as materials for data collection. Findings were discussed and analyzed using the content analysis method.
Findings

Western Psychology of Sensory Perception

Sensation and perception process of humans and other beings has become a major research field among scholars in the WP. Especially, experimental psychologists, gestalt psychologists, cognitive psychologists, biological psychologists, neuropsychologists have conducted scientific researches on this area and have developed number of theories, models and principles explaining the process of SP.

Gestalt psychologists have introduced several principles of SP such as grouping with similarity or proximity, figure-ground relationship, law of continuation, closure and concept of whole etc. These principles explain the forms of vision, how the brain organizes the visual patterns and certain cognitive functions. But these principles are merely to explain the visual perception.

Human Information Processing (HIP) model of Cognitive Psychology is one of the major theories on SP in WP. The HIP model explains what occurs during the stages (attention, perception, short-term memory etc.) of processing information (Reed, 2004, p.03). The HIP model depicts several stages of the process, including Input (information from external or internal environment), Sensory store, Filter, Pattern recognition, Selection, Short Term Memory (STM), Response, and Long Term Memory (LTM).

Collecting and processing information in every second is an active function of all living beings. Primarily, information from external or internal environment receives through the sense organs which is containing short sensory store. “Sensory store provides a short storage of information in its original sensory form. It is a part of the memory that holds analyzed sensory information for a fraction of a second, providing an opportunity for additional analysis following the physical termination of a stimulus. Filter is a part of attention in which some perceptual information is filtered out and not recognized, while other information receives attention and recognized. Pattern recognition is the stage of perception during which a stimulus is identified” (Reed, 2004, p.03).
Within that process, recognized, perceived and selected information is transmitted into the Short Term Memory (STM) where information holds only about 20-30 seconds. Most important and necessary information is, thereafter, stored in the Long Term Memory (LTM) which has no capacity limits and lasts from minutes to entire lifetime. The information can flow in both directions, within sensory store and LTM. An earlier stage can, therefore, be influenced by information in a later stage, and the other side is also the same (Reed, 2004, p.03).

Bio-psychological model in WP gives a comprehensive explanation on what occurs during the SP process on the basis of biology. It is mainly based on the functions of the nervous system related to the particular sense organ and the process of the brain. According to the bio-psychological explanations, each sensory organ is particularly adapted to detect stimulus from the environment as energies (e.g. light, sound, chemical). There are five sense organs specialized for visual perception, auditory perception, olfactory perception, gustatory perception, somatosensory perception particularly. Sensory receptors in each sensory organ convert the detected stimulus into electrical impulse and transmitted to the particular region of the brain through sensory nerves so that to recognize, organize, interpret and store (the process of perception).

For instance, the eye is specialized to detect light from the external environment. Every moment when the eye is open, light energy enters into the eye passing through the cornea, pupil and the lens, and falls on the retina where the image of the object reflects upside down. Cones and Rods located on the innermost layer of the retina are specialized in daylight vision, colour vision and night vision. The photoreceptors stimulated by the light trigger neural impulse. The visual information converted into a neural impulse travels to the brain through the optic nerve and processes in the visual cortex of the occipital lobe of the brain where the visual input is perceived, analyzed, interpreted and stored etc. The process in the brain is called the perception. As shown in the above example, each SP is based on each biological function.
Buddhist Psychology of Sensory Perception

Buddhist psychological explanation on SP is mainly found in the Abhidhamma piṭaka and in several discourses of the Sutta pitaka. In the Abhidhamma piṭaka, the analysis of Sabbacittasādhārana Cetasika and Cittavīthi are two teachings that are significant in explaining the process SP.

The universal mental states (sabbacittasādhārana cetasika) compiled in the Dhammasanganippakarana and elaborated in the Abhidhammatthasangaha is a very important category of Abhidhamma on information processing. It includes seven mental concomitants, namely; Phassa (Contact/mental impression), Vedanā (Feeling), Saññā (Perception), Cetanā (Volition), Ekaggatā (one-pointedness/concentration), Jīvitindriya (Psychic life/vitality) and Manasikāra (Attention/advertence). These seven mental concomitants are common to every consciousness (89 or 121 citta-s), with no distinction of both kusala and akusala citta, hence, it is called Sabbacittasādhārana (universal). According to the Abhidhammic analysis, even though these mental concomitants are commonly arisen with every consciousness (citta), they do not run on gradual process and arise simultaneously with a particular citta. The Phassa is described in Abhidhamma as a non-material relationship between the sense organs and their objects (Sarathchandra, 1958, p.28).

However, ‘Phassa’ is here mentioned as the first factor. The Madupindika sutta in Majjhimanikāya explains clearly how the phassa arises, and what, thereafter, occurs in the process. Considering the eye, for instance, “the visual consciousness (cakkhu viññāna) arises because of the eye and material shapes; the meeting of the three is sensory impingement (contact/phassa); feelings (vedanā) are because of sensory impingement (phassa); what one feels one perceives (saññā/ sañjānāti); what one perceives one reasons about (vitakketi); what one reasons about one obsesses (papañceti); what obsesses one is the origin of number of concepts and obsessions (papañcasaññasankārā samudacaranti) which assail a man in regard to material shapes cognizable by the eye” (Silva, 1979, p 24). According to this explanation there are several stages before the perception; cakkhu viññāna, phassa
and vedanā. After perception, the person reasons about, thinks about and obsesses about the stimulus. That is considered the beginning of number of concepts, ideas, obsessions etc. Mrs. Rhys Davids mentioned in her *Buddhist Psychology* (1914) “The most notable example of it is important formula of natural causation as exemplified in the process of life being bound up with dukkha... Sense and feeling stirred by sense are converted into motor presentations; as desire, etc. But, we meet with no closer analysis of intellectual process, of what has, in our own psychology being called representative and re-representative cognition or ideation.” (Davids, 1914, p. 88). According to her clarification, SP is analyzed in Buddhism as a cognitive process which is causally conditioned and it is, further, connected with the human suffering (*dukkha*). This Buddhist psychological explanation is somewhat different from the stereotyped theories and models of SP in the WP.

One of the other important explanations on SP is the analysis of *Cittavīthi* (Thought Process) in *Abhidhamma pitaka*. The duration of one Thought Moment (*cittakkhana*) consists of three steps; genesis, static and dissolution. One Thought Process includes seventeen Thought Moments. According to the sense doors, six thought processes are analyzed in the *Abhidhammatthasangaha*, as follows.

1. The thought process connected with the eye-door.
2. The thought process connected with the ear-door.
3. The thought process connected with the nose-door.
4. The thought process connected with the tongue-door.
5. The thought process connected with the body-door.
6. The thought process connected with the mind-door. (Nārada, 1980, p.206)

When an object is presented to the mind-consciousness through one of the five doors (eye-body), a Thought Process runs as follows (Table 01). That is called the *pancadwārāwajjana cittavīthi*. The thought process connected with mind (*manodwārāwajjana cittavīthi*) is deferent from it.
| No. | Process                                      |
|-----|---------------------------------------------|
| 17  | Tadālambana (Registering Consciousness)     |
| 16  | Tadālambana (Registering Consciousness)     |
| 15  | Javana (Impression)                         |
| 14  | Javana (Impression)                         |
| 13  | Javana (Impression)                         |
| 12  | Javana (Impression)                         |
| 11  | Javana (Impression)                         |
| 10  | Javana (Impression)                         |
| 9   | Javana (Impression)                         |
| 8   | Votthapana (Determining Consciousness)      |
| 7   | Santirana (Investigating Consciousness)     |
| 6   | Sampaticcana (Receiving Consciousness)       |
| 5   | Cakku Viññāna (eye - One of Five Sense - Consciousness) |
| 4   | Pañcadvārāvajjana (Sense-door Consciousness) |
| 3   | Bhavaṅgapaccheda (Arrest Bhavaṅga)          |
| 2   | Bhavaṅga Calana (Vibration Bhavaṅga)        |
| 1   | Atiṭa Bhavaṅga (Past Bhavaṅga)              |

(Nārada, 1980, p.34)

Table 01. Thought Procedure Connected with Five Doors

According to the table depicts, the thought process connected with eye door (cakkhudvārika atimahanthārammana cittavīthi) runs as follows. “A visible object which has passed one instant enters the avenue of eye. Then, the Bhavaṅga (1) vibrates for one thought moment and perishes (2), arresting the Bhavaṅga stream (3). Subsequently, the five-door apprehending consciousness (4) arises and ceases apprehending that very visible object. Thereafter, thought moment of eye consciousness sees the very form (5), of recipient consciousness receives (6) it, of investigating consciousness investigates (7) it and of determining consciousness determines (8) it. Then, one of the twenty nine kinds of sense-sphere Javanas causally conditioned runs for seven thought moments (9-15) and two retentive
resultants (16-17) arise accordingly. Finally comes the subsidence into the "Bhavaṅga" (Nārada, 1980, Pp. 207-208). Each thought moment is causally conditioned and run in a gradual process. Similarly, different thought processes are illustrated in *Abhidhammatthasangaha*, according to the sense-door, the kind of person and the plane of existence etc.

**Discussion**

According to the BP, human receives information from the external environment at every moment through five doors; eye, ear, nose, tongue and body (skin). Each of this information meets just mind called *viññāna* (consciousness) at very first and then *phassa* (contact) arises. In seven fold mental concomitants, *phassa* is the first mental factor. According to the *Madupindika sutta* in *Majjhimanikāya*, consciousness (*viññāna*) arises because of the biological factor (sense organ) and external information. Considering the eye, for instance, the visual consciousness (*cakkhu viññāna*) arises because of the eye and material shapes. The meeting of these three; sense organ (eg. *cakkhu*), external information (eg. *rupa*) and consciousness (eg. *cakkhu viññāna*), is the *phassa* (contact/ sensory impingement).

In line with, *Mahāhatthipadopama sutta* in *Majjhimanikāya* emphasizes that there should be a healthy sense organ (*Ajjhattikam cakkhum aparibhinnam hōti*) as a basic factor for a complete SP. Here, *Ajjhattikam cakkhum* means the biological strength of the eye or ability to see. Thus, the BP emphasizes the biological factor as the first of SP process, as shown in the Bio-psychological model in WP. After this basic process, the BP explains deep affective and cognitive processes of SP from feeling (*vedanā*) to the origin of number of concepts and obsessions (*papañcasaññasankārā samudacaranti*) which assail a man in regard to information cognizable by the sense organ.

Seventeen thought moments which are causally conditioned in a *cittavīthi* is very complex analysis, as it starts from the very first drop of the point where the information processing is begun, at the vibration of *bhavanga citta* (inner psychological alert), which cannot be seen in the western psychological
explanations. For a complete perception of a physical object through any sense door of five, the mind needs to pass seventeen thought moments. The rapidity of the process is as such as number of thought moments geneses and cease within the duration of one millisecond, and then again, a new thought process is taken place.

However, Sense-door Consciousness (eg. cakkhu viññāna) which was explained before arises at the fourth and fifth thought moment of the stream of thought process. Before that, another complex inner psychological process on received information comes to pass. The cognitive process is taken place after that and the thought moments of Javana (Impression) play a significant role in processing the perceived information.

Conclusions

Both WP and BP provide theories, models and principles with complex explanations on SP. Therefore, the two approaches are less comparable, as there are different complex explanations, except certain similarities in the process.

As a common factor, the both systems agree that the SP is a process of the combination of biological and cognitive functions. The Bio-psychological model emphasizes the biological factors of SP whereas cognitive psychologists pay much attention on cognitive process of information processing. In line with, the gestalt psychologists explains how the brain organizes the visual patterns and certain cognitive function. As same as in western psychological theories, Madupindika sutta, sabbacittasādhārana cetasika and cittavīthi in BP emphasize the importance of biological factor and cognitive factor.

Each theory or model or principle of WP explains and emphasizes one aspect of SP process; biological or cognitive. However, the Buddhist psychological explanation on SP can be seen as a combination of all these factors; affective, biological, cognitive and inner mental process. The Cittavīthi analysis in BP is absolutely a psychological process and it can be considered as beyond the Western psychological theories, models and principles of SP. In conclusion, BP of SP can be identified as ‘Affective-biological-cognitive model of SP’.
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English Vocabulary Learning Strategies of Engineering Science Students

M.A.S.P. Manchanayaka¹

Abstract

This study investigated the use of vocabulary learning strategies by the students of engineering sciences. It focused on the frequency of use of strategy by them in learning technical terms and investigated the strategies related to success and failure of learning technical terms in the target language, English. In brief, this study enumerated the most frequently used strategies and least frequently used strategies by the participants. A comparison was also made between the highly proficient and less proficient learners in the least and most frequently used vocabulary learning strategies. The results of this study showed that learners prefer to use written repetition, verbal repetition, and bilingual dictionary strategies. A significant use of learning strategies among successful learners was found and the findings showed that proficient learners used a variety of strategies while less proficient learners used a comparatively smaller number of strategies. Neither the proficient learners nor the low proficient learners are good at employing social strategies to discover the meaning of new technical terms.

Keywords: Terms, strategy, cognitive, metacognitive, proficient.

Introduction

There has been a shift in the field of language learning and teaching with the emphasis being placed on learners and learning rather than on teachers and their teaching. In parallel to this new shift in interest, how learners process new

¹ University of Kelaniya, Sri Lanka, susil_manchanayaka@yahoo.com

Date of Received: 19th September 2018
Date of Accepted: 19th December 2019
information and what types of strategies they employ to understand, learn or remember information has been a primary concern of the vocabulary researchers. According to Wedding and Gylys (1983), technical terminology is a specific terminology used to achieve the purpose of communication in the engineering sciences. Technical terminology has two characteristics. First, most technical terms are made of roots and affixes (Yang, 2005). Any single engineering sciences term has at least one root determining its meaning and one or more bound morphemes to change the part of speech or change the meaning of the word. Schmitt (2000) argues that when learners use word parts as an initial word-guessing strategy, they must be careful to check the surrounding linguistic context to see if their guess makes sense or not. Haynes and Baker (1993) also reported that learners sometimes made an incorrect guess about what an unknown word meant in a given text, and then stuck with that erroneous meaning in other contexts even though the surrounding context made clear that it makes no sense. Second, technical terminology is an open set with a number of low-frequency words and newly coined terms.

Since teaching and learning all the words of any language is a hard task, teaching learners vocabulary learning strategies to infer the meaning of unfamiliar terms is more efficient than teaching every vocabulary item they encounter. As Nation (1994) suggested, teaching learners strategies is particularly important when it comes to dealing with low-frequency words. Following Nation, Schmitt (1997) also suggested that high-frequency words should be taught, whereas learning low-frequency words will still require strategies for inferring their meaning.

**Background of language learning strategies**

In most of the studies on language learning strategies, the primary concern has been on "identifying what good language learners report they do to learn a second or foreign language, or, in some cases, are observed doing while learning a second or foreign language." (Rubin and Wenden 1987). The findings of Fan's (2003) study showed that the learners used the strategies for reviewing and consolidating their knowledge of known words and perceived them as useful and that they
preferred dictionary strategies. The most proficient learners depended more on sources, guessing and dictionary than the less proficient learners. Regarding the discrepancies between the frequency of use and perceived usefulness in learning L2 vocabulary, the findings revealed the complexity in strategy use.

Schmitt (1997) also reported that the learners used more repetition and dictionary strategies and considered them more useful than other strategies listed in the Vocabulary Learning Strategy Inventory in which 57 strategies have been listed. The strategies of semantic grouping and imagery were less used and regarded as the least useful. There was also some evidence that advanced learners tended to use more complex and meaning-focus strategies than less proficient learners. A number of studies have examined the effectiveness of some specific strategies for learning technical terminology (Fang, 1985; Troutt, 1987; Dunkle, 1983).

Fang and Troutt studied the effectiveness of two strategies, but, two learning strategies alone are not enough for us to see the whole picture of how learners learn technical terms effectively. To gain a general picture of the optimal use of learning strategies for learning technical terms, studies that deal with all the strategies as a group are a supplement to Fang’s and Troutt's empirical research.

**Language learning strategies: definition**

Many vocabulary research experts defined the term 'language learning strategy'. Wenden and Rubin (1987) define learning strategies as "... any sets of operations, steps, plans or routines used by the learner to facilitate the obtaining, storage, retrieval, and use of information". According to Richards and Platt (1992), learning strategies are "intentional behaviour and thoughts used by learners during learning so as to better help them understand, learn, or remember new information". Faerch et. al. (1983) stress that a learning strategy is "an attempt to develop linguistic and sociolinguistic competence in the target language". According to Stern (1992), "The concept of learning strategy is dependent on the assumption that learners consciously engage in activities to achieve certain goals and learning strategies may be regarded as broadly conceived intentional directions and learning techniques". All language learners use language learning
strategies either consciously or subconsciously when they process new information and perform tasks in the classroom. Since the classroom is like a problem-solving environment in which language learners are likely to face new input and difficult tasks given by their instructors, learners’ attempts to find the easiest way to do what is required, that is, using language learning strategies is an inescapable task.

Could learners use appropriate learning strategies based on the characteristics of technical terms such as guessing from linguistic context and analyzing morphemes when they learn technical terms? Chamot and Kupper (1989) reported that high-proficiency language learners know how to use the correct strategies to achieve their goals. Oxford (1985) asserted that successful learners use a range of strategies which are appropriate for their learning tasks. Do high proficiency learners use different strategy patterns from those used by low proficiency learners as found in the studies mentioned above? To have further insight on the use of learning strategies of successful learners, the strategy patterns used by successful and unsuccessful learners may be studied and the attention of the present study was also directed to it.

The purpose of this study was to explore the strategies used by learners to learn technical terms. This study measured the frequency of use of strategy by students of engineering sciences in learning technical terminology and to identify the strategies related to success and failure in learning the terms. In brief, this study attempted to evaluate the most used strategies and the least frequently used strategies by the participants. A comparison was also made between high and low proficient learners. Students of engineering sciences are required to take the course ‘Academic English’ as a complementary component of the orientation course to begin academic work in English. In order to help teachers to overcome the challenge of teaching technical terms and help engineering sciences students learn technical terms effectively, this study was conducted to explore the strategies used in learning technical terms.
Methodology

Some related literature was reviewed and the gap in current knowledge was established. After reviewing the related literature, a questionnaire was developed. This questionnaire was pilot tested for its consistency. After the pilot testing process, the questionnaire was administered to the sample of 100 participants at the University of Moratuwa and they represent middle-income and high-income social strata. However, only 88 questionnaires were used to analyze data as 12 of the administered questionnaires were incomplete. Once the data were collected, they were tabulated and simple statistical analyses were run on the data. The introduction, background to the research problem, review of literature and definition of language learning strategies were written followed by the analysis and interpretation of data. After the analysis and interpretation of data, the discussion and final conclusion was written.

Sample

Participants in the current study were 88 students of engineering sciences in the first year of their study. They all have done their Advanced Level Examination in the mathematics stream. They specialize in engineering sciences. The sample consisted of male and female participants aged 21-22 years. The participants have passed the English Language as a subject at the Ordinary and General English at the Advanced Level Examination.

Instrumentation

The instrument used to collect data on strategies is the questionnaire designed by incorporating the Vocabulary Learning Strategy Inventory of Schmitt (1997). The categories of terminology were based on Schmitt's (1997) taxonomy for studying Vocabulary Learning Strategies. In it, social, determination, memory and metacognitive strategies have been listed. The participants were required to answer questions on their strategy use. The questionnaire was made of two sections. Part one collected such background information as participants’ English proficiency. The second part included 63 items grouped into categories of
terminology learning strategies.

**Analysis and interpretation of data**

The data were gathered in class by the researcher. A structured questionnaire was used to gather data. Before the questionnaire was administered, a brief explanation of the purpose of the study was provided to the participants. Strategies were categorized according to the VLS Inventory of Schmitt (1997). Each participant’s responses were recorded. See the analysis of data and results presented below.

**Results**

Most and least used strategies by all participants

| Item | Rank | Category        | Strategy                                      | Mean  |
|------|------|-----------------|-----------------------------------------------|-------|
| 28   | 1    | Cognitive       | Written repetition                            | 4.22  |
| 29   | 2    | Cognitive       | Verbal repetition                             | 4.01  |
| 07   | 3    | Determination   | Bilingual dictionary                          | 3.79  |
| 21   | 4    | Cognitive       | Vocabulary section in textbook                | 3.12  |
| 31   | 5    | Cognitive       | Take notes in class                           | 3.01  |
| 4    | 38   | Social (consolidating) | Ask the teacher for a synonym                  | 1.49  |
| 34   | 39   | Cognitive       | Put technical terms on physical objects       | 1.41  |
| 08   | 40   | Social (discovery) | Discover new meaning from group activity      | 1.33  |
| 34   | 41   | Cognitive       | Listen to the tape of a list of words         | 1.21  |
| 12   | 42   | Social (discovery) | Ask the teacher for a new sentence including the new technical term | 1.08  |

*Table 1:*

The table indicates that item 28 (4.21, written repetition) has the highest average frequency, and next is item 29 (4.01, verbal repetition), followed by item 7 (3.79,
using a bilingual dictionary), item 21 (3.22, vocabulary section in the textbook). The least preferred strategies are item 12 (1.08, ask the teacher for a new sentence including the new term), and next is item 34 (1.21, listen to tape of word lists), followed by item 8 (1.33, discover new meaning from group activity), item 34 (1.42, label physical objects), item 4 (1.49, ask teacher for synonym of new term).

Most and Least Used Strategies by Highly¹ Proficient Learners

| Item | Rank | Category          | Strategy                                      | Mean  |
|------|------|-------------------|-----------------------------------------------|-------|
| 21   | 1    | Cognitive         | Use of vocabulary section in the textbook     | 4.34  |
| 31   | 2    | Cognitive         | Take notes in the classroom                   | 4.20  |
| 07   | 3    | Determination     | Use a bilingual dictionary                    | 4.30  |
| 29   | 4    | Cognitive         | Verbal repetition                             | 4.10  |
| 28   | 5    | Cognitive         | Written repetition                            | 4.01  |
| 34   | 38   | Cognitive         | Label physical objects                        | 1.30  |
| 38   | 39   | Cognitive         | Listen to the tape of the word list           | 1.29  |
| 08   | 40   | Social (consolidating) | Discover new meaning from group activity | 1.20  |
| 12   | 41   | Social (discovery) | Ask the teacher for a sentence with the word  | 1.09  |
| 23   | 42   | Social (consolidating) | Interact with foreigners                      | 1.09  |

*Table: 2*

The data in table 2 shows that the most preferred strategies for high proficiency learners are item 21 (4.34, vocabulary section in the textbook), item 31 (4.20, take notes in class), item 7 (4.30, using a bilingual dictionary), item 29 (4.10, verbal repetition), and item 28 (4.01, written repetition). The least preferred strategies are

¹ The pre-test administered indicated the level of proficiency the participants had.
item 23 (1.09, interact with foreigners), item 12 (1.09, ask the teacher for a sentence including the new term), item 8 (1.20, discover new meaning from a group activity), item 38 (1.29, listen to a tape of word lists), and item 34 (1.30, label physical objects).

Most and Least Used Strategies by Low Proficient Learners

| Item | Rank | Category               | Strategy                                              | Mean |
|------|------|------------------------|-------------------------------------------------------|------|
| 28   | 1    | Cognitive              | Written repetition                                     | 4.7  |
| 29   | 2    | Cognitive              | Verbal repetition                                      | 3.65 |
| 16   | 3    | Social (consolidating) | Ask classmates for meaning                            | 3.41 |
| 21   | 4    | Determination          | Guess from linguistic context                         | 3.27 |
| 07   | 5    | Determination          | Use a bilingual dictionary                            | 3.27 |
| 34   | 38   | Cognitive              | Label physical objects                                | 1.49 |
| 03   | 39   | Memory                 | Use the new term in a sentence                        | 1.49 |
| 38   | 40   | Cognitive              | Listen to the tape of word lists                     | 1.30 |
| 12   | 41   | Social (discovery)     | Ask the teacher for a sentence including the word    | 1.10 |
| 23   | 42   | Social (consolidating) | Interact with foreigners                              | 1.07 |

*Table: 3*

The most preferred strategy for low proficiency learners is, as revealed in table 3, item 28 (4.7, written repetition), item 29 (3.65, verbal repetition), item 16 (3.41, ask classmates for meaning), item 21 (3.41, guess from linguistic context); and item 7 (3.27, use a bilingual dictionary). The least preferred strategies are item 23 (1.07, interact with foreigners), item 12 (1.10, ask the teacher for a sentence including the new term), item 38 (1.30, listen to tape of word lists), item 3 (1.49, use new word in sentences), item 34 (1.49, label physical objects).
Discussion

Research into the vocabulary learning strategies revealed a number of positive strategies used by high proficiency learners so that such strategies could also be used by low proficiency learners trying to become successful in language learning. However, there is always the possibility that low proficiency learners can also use the same good learning strategies while becoming unsuccessful owing to other reasons. At this point, it should be emphasized that using the same good language learning strategies does not guarantee that low proficiency learners will also become successful in language learning since other factors may also play a role in successful learning.

The results indicated that there exist major differences in the patterns of learning strategy used by learners of two proficiency levels. High proficiency learners are better at gaining knowledge of a new term. They remember effectively, control, and evaluate their own vocabulary learning strategies better than low proficiency learners do. However, both groups are poor at utilizing social strategies to discover new meanings of the terms they find. Social strategies involve asking for clarification or verification, cooperating with peers, and interacting with native speakers of the target language being learnt.

The lack of use of item 9 (Asking the teacher for a sentence with the word) by the learners has also been influenced by the same factor i.e. educational system and cultural background learners are born into. One study done in China reported that 'Many learners prefer to ask the teacher after the class in order to minimize the loss of face if the question seems unwise' (Scarcella, 1990). In addition, learners do not have enough chances to communicate with native English speakers, so that the item 'interact with foreigners' is relatively unemployed by both proficiency level learners.

Comparing the strategies used by high proficiency learners to those used by low proficiency learners, it was noted that written verbal repetitions were the most and the second most popular strategies among both levels. This finding is in accordance with Schmitt's (1997) and Yang's (2005) study which showed that the
repetition of a word's written form was used frequently in a Japanese context. This can be attributable to the learning styles encouraged by teachers. Learners are usually required to memorize vocabulary and grammar through repetition. According to Sheridan (1981), the practice of modelling and repetition is usually applied in some classrooms so as to assist learners to develop particular language skills.

None of the textbooks or materials taught to the participants included an audiotape or CD on which lists of words had been recorded to improve pronunciation and aural understanding of the words. This is why item 34 (listen to the tape of word lists) is one of the least used strategies by participants in the study. This finding is consistent with Yang and Su's study (2003), which presents the view that the main difficulty learners encountered in speaking is their poor pronunciation.

**Conclusion**

Language learning strategies, being specific actions, behaviours, tactics or techniques facilitate the learning of the target language. All language learners, it is needless to say, use language-learning strategies. The study indicated that students of engineering sciences, in general, prefer to use written repetition, verbal repetition, and bilingual dictionary strategies. In contrast, asking the teacher for a new sentence including the new term, listening to a tape of word lists, and discovering new meaning from group activity are the strategies least used by the learners. In general, neither low proficient nor high proficient learners use social strategies to learn the meaning of new terms. The study revealed a significant overall use of learning strategies among high proficient learners. Considering Cohen and Aphek (1985), teachers can teach strategies however, they should raise awareness of learners, recognize the most appropriate strategies for every situation and suggest, for example, learners a range of strategies and let learners decide which strategies are good for them.
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New cosmological model including inflation, deceleration, acceleration and deceleration again

P.V.N.M.C. Perera¹, K.D.W.J. Katugampala²

Abstract

Since Perlmutter and A.G. Riess (Reiss, Adam G., 1998) observed that the Universe expands with an acceleration, many models involving dark energy have been proposed to explain this phenomenon. (Perlmutter, S., 1997), (Reiss, Adam G., 1998). A family of cosmological models with both acceleration and deceleration is presented in this research study. According to Einstein’s field equations, in general, relativity is in the form,

$$R^\mu_\nu - \frac{1}{2} R g^\mu_\nu = k T^\mu_\nu - \Lambda g^\mu_\nu$$

The Einstein’s field equations are modified in this research study. We consider $A$ a parameter of cosmic time. The assumptions of a homogeneous and isotropic universe are based on the Mach’s principle. We started with the Robertson-Walker metric in spherical polar coordinates. We found the Christoffel symbols to define the Ricci tensor, the curvature scalar and the energy-momentum tensor using the Robertson-Walker metric. The modified Einstein’s field equations for scalar factor $R(t)$ which is called ‘radius of the universe’ is solved using the Robertson-Walker metric and Energy momentum tensor. The solution of $R(t)$ can be introduced in the following form, so that it shows the inflation at the beginning.

¹ Department of Mathematics, Faculty of Engineering, The General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka, niroshmcperera@gmail.com
² Department of Mathematics, University of Kelaniya, Sri Lanka, wasantha@kln.ac.lk

Date of Received: 02nd November 2018
Date of Accepted: 14th November 2019
\[ R(t) = b\sqrt{(1 -\cos^2 \omega t)} \]

A solution is assumed for the universe which results in inflation, deceleration, acceleration and deceleration again. Taking the present value of the cosmic time \( t \) as 13.7 billion years we find the density of the inflationary universe is \( 2.0211 \times 10^{-28} \text{Kg m}^{-3} \) and deceleration of the universe is \( 9.1822 \times 10^3 \text{ms}^{-2} \) which agree with the observations. We discussed the redshift of light from extragalactic sources, which arises from the Robertson-Walker metric. This redshift is a measure of the expansion of the universe in a given period of time. The redshift is the ratio of the value of the scalar factor of the universe at present epoch to that at the epoch of emission of light from the extragalactic sources which is observed at present. The scalar factor is increasing with time \( t \) at present. However, there could be epochs where the scalar factor is decreasing.

**Keywords**: cosmological model, scalar factor, Einstein’s field equation, inflation.

**Introduction**

In 1997 Perlmutter and his group, and in 1998 Reiss and his group from the observations of Type 1A supernovae concluded that the universe is not only expanding but expanding with an acceleration. (Perlmutter, S., 1997), (Reiss, Adam G.,1998). This came as a surprise as the standard model had been well established for some time which explained the big bang microwave background radiation and other important observations. According to the standard model the universe has been expanding with a deceleration after an initial inflation as postulated by Alan Guth though without a proper mechanism (Reiss, Adam G.,1998).

Various theories have been proposed to explain the expansion of the universe with acceleration and it has been generally believed that this acceleration is due to what is called, “dark energy”. However, the problem has been to identify the dark energy. The vacuum energy had been one of the candidates and there were many who identified vacuum energy with the cosmological constant. (Weinberg S., 1989) However, there was a problem as the cosmological term was very small and
the vacuum energy was very large, and the difference being of order 150. However, there were others who had referred to the cosmological constant and vacuum energy separately while some invoked quintessence to explain the so-called dark energy. (Sato, K., 1981)

**Methodology**

In order to explain dark energy, we modified Einstein’s field equations and considered the cosmological constant giving rise to an energy field and included the cosmological term on the right hand side of the field equations instead of on the left hand side. The terms on the left hand side of the equations referred to the geometry while the terms on the right hand side represent matter radiation and energy. Thus the cosmological term was transferred from being a term representing geometry of the space time to that representing energy and it is also considered a parameter of cosmic time, and not a constant as was done originally by Einstein.

\[
R^\mu_\nu - \frac{1}{2} R g^\mu_\nu = \kappa T^\mu_\nu - \Lambda g^\mu_\nu
\]  

(1)

Next we consider the Robertson-Walker metric,

\[
d s^2 = c^2 d t^2 - R^2(t) \left[ \frac{d u^2 + u^2 (d \theta^2 + \sin^2 \theta \, d \phi^2)}{1 + \frac{\kappa u^2}{4}} \right]
\]  

(2)

and evaluate non-vanishing Christoffel symbols of Robertson-Walker metric.

The \( \Lambda \) term introduced by Einstein himself gives rise to a field that repels particles and objects rather than to one that attracts them. For the different values of \( \mu \) and \( \nu \) in equation (1), we obtained following two independent equations with four unknown variables \( R, \rho, \Lambda \) and \( p \).

\[
\frac{\kappa \rho}{R^2} = \Lambda - \frac{3 \dot{R}^2}{R^2 c^2} - \frac{3 \kappa}{R^2}
\]  

(3)
\[
\frac{\kappa p}{c^2} = -\Lambda + \left[ \frac{\kappa}{R^2} + \frac{\dot{R}^2 + 2R\ddot{R}}{R^2 c^2} \right]
\]  
\text{(4)}

In order to use the Robertson-Walker metric we should decide which value of the three possible values \( \kappa = -1, 0, +1 \) would give an appropriate solution. We write the equations (3) and (4) as

\[
\frac{8\pi G}{c^2} \left( \rho + \frac{p}{c^2} \right) = 2 \left( \frac{\kappa c^2 + \dot{R}^2 - R\ddot{R}}{R^2 c^2} \right)
\]  
\text{(5)}

Physical quantities pressure and density should remain positive and this implies that the left hand side of (5) should be positive. Then the only possible value of \( \kappa \) is +1

The universe is believed to have expanded with an inflation. To support this inflation we selected the following form of equation, therefore the inflation could be accommodated.

We assume that a family of solutions of above equations for \( R \) can be written in the form,

\[
R(t) = b \sqrt{1 - \cos^3 \omega t}
\]  
\text{(6)}

using the following boundary conditions,

- \( R = 0 \) at \( t = 0 \),
- \( \dot{R} = 0 \), \( \ddot{R} = 0 \) at \( \omega t = \frac{\pi}{2} \), (point of inflection),
- The present value of rate of expansion of universe is \( 7.43 \times 10^4 ms^{-1} \)

where \( b \) and \( \omega \) are unknown constants.

Recent observations have led to the approximate value \( \frac{2}{3} \) for the ratio of dark energy \( \left( \Lambda' = \frac{\Lambda c^2}{6\pi G} \right) \) to matter density \( \left( \rho \right) \), \( \left[ \frac{\Lambda'}{\rho} \right] \) and to the value 1.6, for the redshift \( \left[ \frac{R|_{\omega t = \omega t_0}}{R|_{\omega t = \frac{\pi}{T}}} \right] \), at the onset of acceleration. Taking this redshift to be a constant, a family of solutions can be found for different ratios of dark energy to
matter density. Similarly, keeping the ratio of dark energy to matter density as $\frac{7}{3}$, we found that a family of solutions can be obtained for different values for the above redshift. Though there is no solution when the redshift is 1.6, there is a solution when its value is 1.3, which is good enough considering the uncertainties associated with measurements.

**Results and discussion**

The age of the universe is estimated to be 13.7 billion years. Taking the present value of the cosmic time $t$ as 13.7 billion years we find, $b = 4.4168 \times 10^{20} m$, $\omega = 6.8 \times 10^{-16} rad \ s^{-1}$ when the above redshift is 1.3. The variation of $R(t)$ with $t$ is given in Figure(1). It is seen that, the “radius of the universe”, $R(t)$ increases in the first phase with both acceleration and deceleration.

![Radius of the universe](image)

*Figure 1. Radius of the Universe with respect to the solution $R(t) = \frac{b}{A} \sqrt{(1 - \cos^3 \omega t)}*
The Figure 1 shows that the universe expands and contracts in cycles after the big bang. It is now in its expansion phase of the first cycle. The universe expands during phase AB with an acceleration then in BC with deceleration. At C it undergoes a point of inflection and starts acceleration again in phase CD following a deceleration in phase DE. After E the universe starts contraction. The acceleration observed by Perlmutter could correspond to the phase CD and the deceleration claimed by Schaefer could be represented by the phase DE.

Taking the present value of the cosmic time $t$ as 13.7 billion years, we find the density of the inflationary universe is $2.0211 \times 10^{-28} \text{Kgm}^{-3}$ and deceleration of the universe is $9.1822 \times 10^3 \text{ms}^{-2}$ which agree with recent observations (Weinberg S., 1989).

**Conclusion**

In this research we postulated that the cosmological term arises out of the space time energy and the term is a measure of the space time energy. Writing down of the cosmological term on the right hand side of the field equations made the tensor $kT^{\mu\nu} - \Lambda g^{\mu\nu}$ divergenceless, and hence what is conserved is not the energy due to matter and radiation, but energy due to matter, radiation and space – time.

This is a new result in itself as it makes not only space time a form of energy but a form of energy that could be converted to other forms of energy and vice versa. Until Einstein formulated his Theory of general relativity space – time was the arena in which matter and radiation moved without changing the space – time itself. Einstein revolutionized this concept and said that matter and radiation changed the space – time as well. In other words according to Einstein, space – time is determined by matter and radiation. Einstein wanted to incorporate Mach’s Principle that implied that there was no space – time in the absence of matter or radiation. However, Einstein did not succeed in his attempt to incorporate Mach’s Principle into his general theory of relativity.

In this work we have gone a step further by taking space – time as a form of energy that could be converted into other forms of energy and vice versa, thus not only
that matter and energy determine space–time but could get converted into space–time. In a sense, Mach’s Principle becomes superfluous as when space–time exists it implies that matter or radiation exists.

With the modification of the field equations and interpretation of space time as a form of energy we attempted to find solutions of the modified field equations. We imposed certain boundary conditions and our strategy was to assume a family of equations with certain arbitrary constants and find those constants using the boundary conditions. The field equations reduced to two independent equations and we had to solve them for four variables, the scalar factor $R$, the density $\rho$, the pressure $p$ and the cosmological Parameter $\Lambda$.

We found a family of solutions that satisfied the boundary conditions imposed and agreed with many of the observations by the cosmologists. The model accounted for the inflation at the beginning and the model predicted a universe that started with initial zero velocity but with an acceleration.

In this work, we attempted to propose a model for the universe which contained an expansion with both acceleration and deceleration. We have been able to show that our model agrees with the recent observations.

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