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FACTORS THAT CONTRIBUTE TO DISAGREEMENTS DUE TO VARIATIONS IN COLOUR OBSERVERS' DECISIONS IN VISUAL COLOUR ASSESSMENT IN TEXTILE INDUSTRY

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ABSTRACT

Colour assessment is a process where the colour of a manufactured textile is validated against the same of a pre-defined product for acceptance purposes. Therefore, colour assessment is identified as a quality assurance technique. A growing dialogue has been in focus on the reliability of the visual colour assessment through manual, people dependent techniques and its appropriateness for today's context. To meet today's demand, digital colour management processes have been developed and many manufacturers believe that these techniques have enhanced reliability and the level of acceptance and thus identified as a way for brands to achieve strategic advantages. Nevertheless, many textile and garment manufacturers have become reluctant to switch to digital colour management systems because they still believe in traditional practices. Therefore, this study focuses on the accuracy and reliability of traditional visual colour assessment process. Visual colour decisions are made by both highly trained colourists in the industry and colour assessors who often have little or no colour assessment training. A carefully constructed questionnaire was the key in the methodology of this study. The general information of the participants mainly consisted of their knowledge, readiness to adhere to standard operating procedures, use of equipment, having colour vision tests etc. The results were statistically analysed and graphically represented to identify factors that significantly contribute to different colour decisions and disagreements i.e. customer understanding, colouristic experience of supplier and colour vision protocol. The study concluded with recommendations to colour assessors who are relying on conventional colour assessment techniques on how variations and disagreements can be reduced.

***Keywords**: Visual Colour Assessment, Colour Management, Colour Decision*

INTRODUCTION

Colouration of textiles is found in two major processes of textile manufacturing i.e. dyeing and printing. In both of these processes colour assessment becomes a prime activity thereby creating the necessity of an effective colour management throughout. At customer's end, the colour gives the first impression of quality of the product before any other textile property does. Consequently, there is more possibility for the product to get rejected if the customer is not happy with the colour, despite all the other quality parameters achieved on it. In today's context of business, customer expectations have gone much higher with more focus on the speed of the process and the quality of the product. Therefore, achieving the expected colour on the specified fabric quality within the agreed timeline is a challenging task for a fabric manufacturer.

On the whole, the total colour management i.e. managing colour in all colour related activities from design stage to the finished product is of paramount importance for a fast textile supply chain. A rejection of product for colour entails inevitably reprocessing because the colour has to be improved until the customer is satisfied. There is a possibility for such rejections of colour to result in delays of bulk production that causes late deliveries of finished products and even go to the extent of not only order cancellation but also losing of business relationships between the manufacturer and the customer. Therefore, many benefits can be derived from total colour management such as consistency of colour, maximizing profit, higher sales, protection of reputation and minimizing costs of re-work. This suggests that making the right decision, on the right colour, at the right time would nullify possible financial and time implications of poor or late decisions and thereby boost the business relationships between the fabric manufacturer and the customer.

Every effort is put in colour matching process in order to produce the colour of the customer standard on a lab dip sample, the best and the soonest possible. The rate of first-time customer approvals of these lab dips which is called the 'Lab Dip Hit Rate' is considered as a measure of success of colour matching. Thus, this lab dip hit rate reflects the degree of consensus between the customer and the fabric supplier, over colour decisions. Therefore, analysing the contributing factors towards a

poor lab dip hit rate and taking possible measures to avoid the same would help to minimize disagreements that occur between the two parties.

Colour assessment can be conducted in two ways, visually and instrumentally. Instrumental colour assessment is done by means of Spectrophotometer' where as visual colour assessment the 'demands a skilful colourist. In case of instrumental assessment, both colour standard and the lab dip which are to be assessed for colour are measured by the spectrophotometer and it identifies the two colours based on their spectral values i.e. the amount of light energy reflected from each sample at several intervals along the visible spectrum. Then, how close the colour of the lab dip is to that of the customer colour standard is confirmed by means of a "Pass/Fail" report generated by the spectrophotometer.

In contrast, visual colour assessment is identified as a more people dependent technique in which three main areas are to be focussed – the quality and intensity of the light source, how samples are prepared and presented for viewing and colour vision protocol of the observer. The perception and interpretation of colour can be highly subjective and this fact can lead to disagreements on colour decisions. Therefore, many retailers insist on having instrumental colour assessment in which colours are objectively communicated as numeric values and for quality control aspects, pass/fail tolerances are set up. Despite this preference for instrumental colour assessment, the "Pass/Fail" report generated by the spectrophotometer is generally reviewed by carrying out a visual assessment too, in real working environment. This is in practice because there could be cases where the decision on the report may not be much in agreement with the visual perception of the observer due to variety of reasons.

In the case of instrumental colour assessment, there are standard operating procedures to be followed to ensure the accuracy of measurements and results. Similarly, to mitigate effects of subjectivity in visual colour assessment, there are standard practices and protocols to be adhered into. However, out of these two methods, practically the visual colour assessment is the most common method that is being used to assess colour across the supply chain. Therefore, it is worth to investigate the factors that contribute to disagreements on colour decisions in visual assessment so as attempts can be made to prevent those and assist a fast textile supply chain.

By all means, the supply chain would be benefitted if the Lab Dip Hit Rate can be improved through a concerted effort of all colour-decision makers. In the textile manufacturing industry of Sri Lanka, this figure falls in between the range of 75% - 85% according to the information received from the internal sources of major fabric manufacturing mills. This suggests that approximately 15% - 25% of chance is there for a submitted lab dip to get rejected in the first round itself. Figure 1 depicts the Lab Dip Hit Rate of five major fabric manufacturers in Sri Lanka whose real names have not been disclosed to protect their privacy.

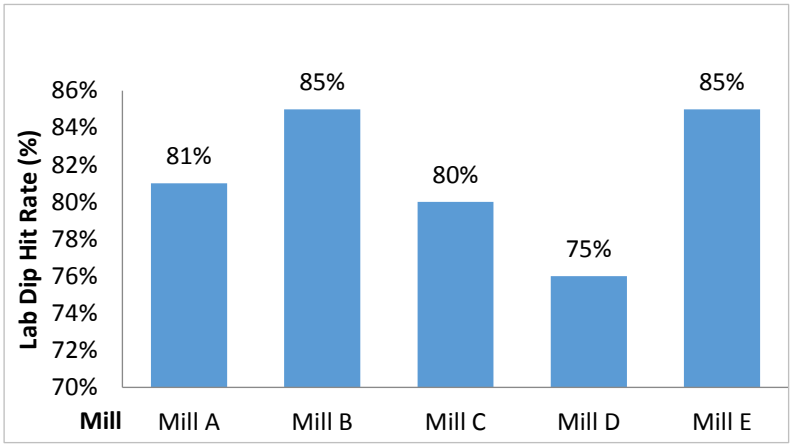


Figure 1: Lab Dip Hit Rates of Five Major Fabric Manufacturers in Sri Lanka
[Source: Internal Sources of Respective Mills]

Therefore, it is a timely industrial concern to investigate the major contributing factors in visual colour assessment that lead a customer to disagree with the fabric supplier over a colour decision. In this paper the extent to which the standard methods of visual colour measurement are adhered to is analysed whilst highlighting the most influential non-conformances that occur in current practice. In addition, it also addresses the ways of minimizing such non-conformances of visual colour assessment in order to reduce disagreements between the supplier and the customer.

CRITICAL LITERATURE REVIEW

When scientifically defined, colour is a variation in the spectral power distribution of light as discriminated by the human visual system; it is a qualitative perception of light (Hanson, 2012). The spectral power distributions, as explained by Datacolor (2013), result from both sources of light and objects that modify the light. Upon a reliable estimate, Judd and Wyszecki (1975 cited in Hanson, 2012) claim that ten million colours can be distinguished by human observers. The longitudinal studies show

that the human visual system mainly contains the eye and brain; the eye receives physical stimuli in the form of light and sends those stimuli as electrical signals to the brain, which interprets the signals as images. Chrisment (1998) states that colour is not a physical reality; it is an interpretation, by the cortex, of sensations detected by the eye and this interpretation could vary from one person to the next. In his seminal article on colour vision, Gouras (2011) states "colour vision is an illusion created by the interactions of billions of neurons in our brain. There is no colour in the external world; it is created by neural programs and projected onto the outer world we see".

Hofer et al. (2005) as cited in Rizzi and Bonanomi (2012) claims that recent studies have proven that cone distribution in the retina highly changes (up to 40 %) among different people. When cone cells fail to function normally, colour vision defects occur (Sakamoto, 2013). As stated by Hanson (2012) even the left and the right eyes of a person can perceive colours slightly differently. Further, in their scholarly article, Salvi et al. (2006) explain how colour vision changes with age; lens in our eye absorbs more blue light because of accumulation of yellow pigments in the lens causing a relative "blue blindness". Thus, colour vision deficiency can occur in both congenital and acquired forms and its prevalence can be as high as 8% in males and 0.5% in females (Simunovic, 2009). Colour deficiencies can be quickly identified by the Ishihara Colour Test while Munsel 100 Hue test can identify the aptitude to discern small colour differences that are just perceptible (Best, 2012); but, Hanson (2012) points out that for various reasons, even simple colour tests generate wide ranges of responses from the same observer at different times. Because colour perception is a result of an interaction of three elements i.e. the light source, the object and the observer (Chrisment, 1998), with these observer differences, different people can see colours differently.

Park (2011) shows that visual colour assessment can be influenced by factors such as colour illuminants, viewing geometry, size of specimen, the age, sex, and colour discrimination of the observer together with the consistency of observers. Further, "The use of a panel of three observers gives more consistent results. Individual observers make at least 17% of wrong decisions." (Park, 2011) Due to the inherent subjectivity of visual colour assessment, the textile industry has resorted to instrumental colour assessment as an attempt to improve the quality of colour matching, in terms of accuracy, consistency and reproducibility. Yet, Hanson (2012) states that being a human sense of intangible nature, colour is very hard to replicate in a software or robotic hardware and Datacolor (2013) too emphasizes that colour is an aspect of visual perception which is not easy to define or measure. In their scholarly article on the colour difference formula, CIE94, McDonald and Smith (1995, p.376) comments, "Quality control of colour matching by instrumental pass/fail evaluations is one of the most important objectives and applications of colour measurement in industry, but it is not without its problems. Chief of these has always been the derivation of reliable relationships between the reflectance data provided by colour measuring instruments and the judgements of visual observers".

Even today, some of our most expensive brands still rely on the human sense of colour perception to ensure "Agreement" with measurement by instruments (Narich, 2016). Instrumental and visual colour approval programmes would complement each other (Laidlaw, 2009) if they are used with a clear understanding of the process. In her investigation into colour tolerancing, Laidlaw (2009, p.7) concludes, "Neither visual, nor instrumental, nor a combination should be expected to prevent every wrong decision, but the number of such errors may be reduced to the point of diminishing cost effectiveness".

RESEARCH METHODOLOGY

To investigate the major contributing factors in visual colour assessment that lead to disagreements between the fabric manufacturer and the customer, the following conceptual framework (Figure 2) was constructed.

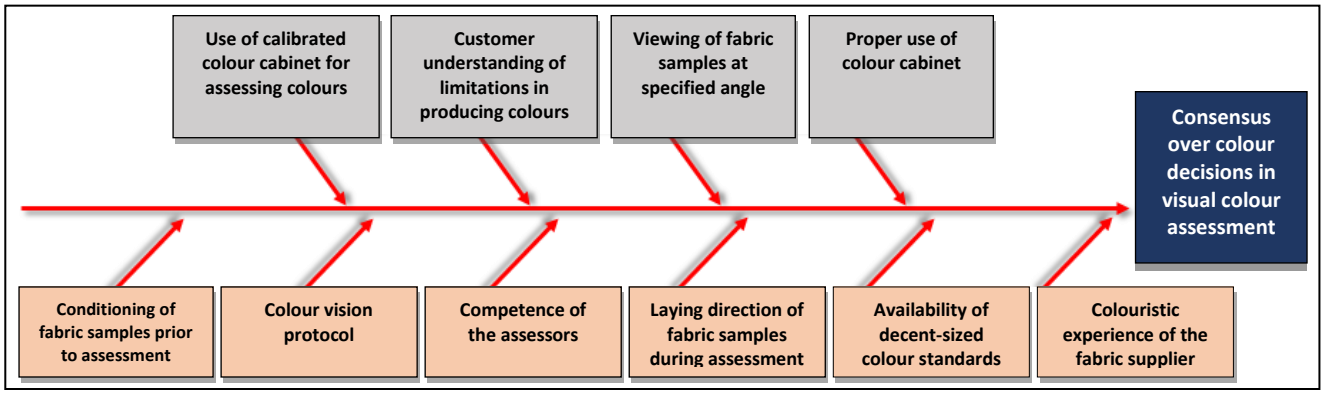


Figure 2: Conceptual Model

Ten independent variables were identified as per the 'Colour Matching Norms'. Out of ten variables, four variables were carefully selected based on the assumption and the literature based understanding that the rest of the factors could be controlled by strictly adhering to visual colour assessment protocol with basic colour skills. Thereafter, these were logically related to identify sub variables of the dependent variable, 'Consensus over colour decisions in visual colour assessment'.

The research was based on quantitative data and being a correlational study, it helped to find the answer for the focus of the research. The target population for this research was all the colour assessors of Sri Lanka who work in textile factories, garment factories and buying offices. Under nonprobability sampling design, judgment sampling was selected because the desired information could be obtained only from a specific target group which is the colour assessors. The sample size was decided to be 80 by the researcher.

The questionnaire for this research was carefully formatted in such a manner that it could draw data on the general information of the participant such as the sector he or she works for, the working experience, the eligibility for assessing colours in terms of colour vision, how professional his or her working environment is to meet the standards of colour protocol and so on. In addition, direct questions were prepared to get an understanding of the current practices relating to colour assessments. Several open ended questions were added last to gather opinions of the colour assessors over their current practices, past experience relating to colour approvals and suggestions for improvements hoping that such data elicited would reveal insights as to how improvements can be made to establish better colour protocol in the textile industry. Primary data that were collected were analysed according to Pearson's correlation method at the confidence level of 95 % and confidence interval (margin of error) of 5, by means of SPSS and Microsoft Excel.

DATA ANALYSIS

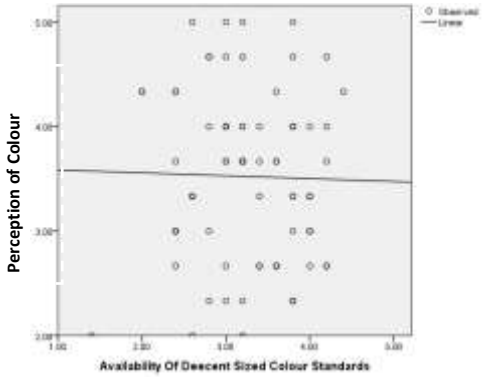
The expected number of responses was 80 and 74 of respondents sent their feedback, thus, the response rate turned out to be 92.5 %. With the collected data following findings were extracted. 42% of the respondents agreed that colour standards are provided in correct size (minimum 4 cm^2) all the time. 66% agreed that colour standards become sub-sized due to the short supply of those by retailers. 50% understand the difficulty in colour matching in such case. 44% agreed that if available, spectral data is provided then, if not, 53% would resort to specifying another colour reference (e.g. Pantone).

In the assessment of the customer understanding of limitations in producing colours, 58% of the respondents agreed that possible issues are discussed at pre-production meetings. If required, 69% would grant time extensions to hit difficult shades and 77% would speak to the retailer over commercial tolerances. 65% agreed that the customer and the fabric supplier work as a team on colour issues. In addition to the above the effect of the colouristic experience of the fabric supplier was investigated through the questionnaire and more than 80% of the respondents agreed that the colouristic experience of the supplier is indispensable because then they can communicate better over colour matching issues, hit the right shade in few attempts, understand customer needs and maintain an effective dialogue all along.

Another aspect which was attempted to measure through the questionnaire was adherence to the colour vision protocol and 83% of the respondents confirmed that colour vision of assessors is tested before recruitment. 74% agreed that this testing is done at least once a year. 62% agreed that colours are not assessed when feeling unwell. 74% confirmed that during assessing, tinted glasses or contact lenses are not worn while 71% take regular short breaks every 20 minutes. Following were obtained through the correlation analysis done on major variables. The first was on the size of the sample used to assess the colour.

The Effect of Availability of Decent-Sized Colour Standards

A weak negative relationship was discovered between the "Availability of Decent-Sized Colour Standards" and the "Perceptions of Colour" with a negative correlation of 0.069. Further, the significant two tailed value is above 0.05 which means that there is no significant correlation between the two variables (Figure 3) and thus the requirement of decent sized samples breaks.



(a)

		Availability of Decent- sized	Perception of Colour
Availability of Decent-sized Colour Standard	Pearson Correlation	1	-0.069
	Sig. (2-tailed)		0.561
	N	74	74
Perception of Colour	Pearson Correlation	-0.069	1
	Sig. (2-tailed)	0.561	
	N	74	74

*. Correlation is significant at the 0.05 level (2-tailed).

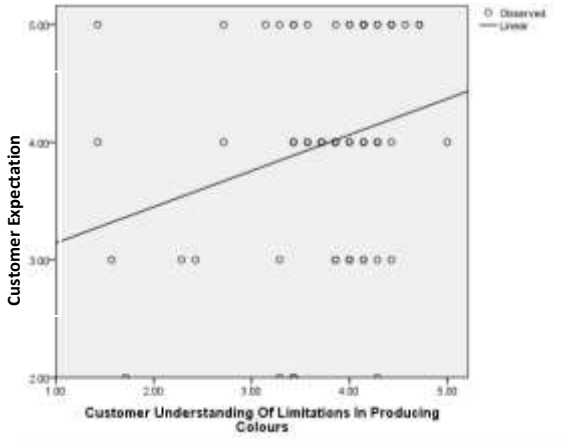
(b)

Figure 3: The Effect of Availability of Decent-Sized Colour Standards

The influence of the sub-sized standards on the perception of colour seems to have been ignored due to the fact that alternative measures are taken in such cases (e.g. use of Pantone references) as shown by the research findings. Thus, the contribution of sub-sized standards towards the consensus between the customer and the supplier over colour approvals seems to be insignificant.

The Effect of Customer Understanding of Limitations in Producing Colours

As seen in Figure 4, the results indicate that there is a weak positive relationship between the "Customer Understanding of Limitations in Producing Colours" and the "Customer Expectations" with a correlation of 0.244. Further, there is a statistically significant linear relationship between the two variables as the Sig. (2-tailed) value is less than 0.05. Thus, it proves that "Customer Understanding of Limitations in Producing Colours" causes a considerable impact on "Customer Expectations".



(a)

		Customer Understanding of Limitations in Producing Colours	Customer Expectation
Customer Understanding of Limitations in Producing Colours	Pearson Correlation	1	0.244*
	Sig. (2-tailed)		0.036
	N	74	74
Customer Expectation	Pearson Correlation	0.244*	1
	Sig. (2-tailed)	0.036	
	N	74	74

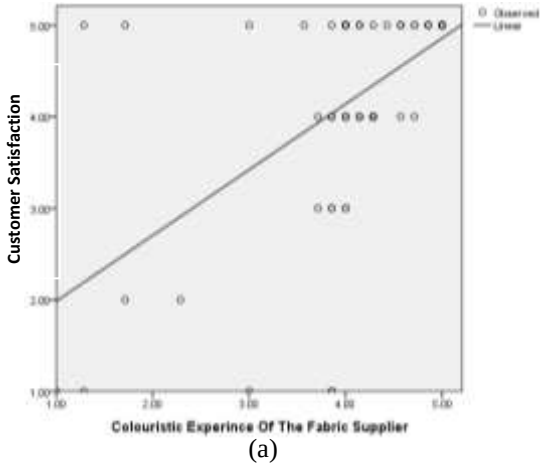
*. Correlation is significant at the 0.05 level (2-tailed).

(b)

Figure 4: The Effect of Customer Understanding of Limitations in Producing Colours

The Effect of Colouristic Experience of the Fabric Supplier

As presented in Figure 5, there is a positive, moderately strong relationship between the "Colouristic Experience of the Fabric Supplier" and the "Customer Satisfaction" with a correlation of 0.566. This indicates that an approximate linear relationship exists between the "Colouristic Experience of the Fabric Supplier" and the "Customer Satisfaction". The feedback of the respondents provides sufficient facts to discern the result. Thus, "Colouristic Experience of the Fabric Supplier" seems to cause a considerable impact on ultimate "Customer Satisfaction".



(a)

		Colouristic Experience of the Fabric Supplier	Customer Satisfaction
Colouristic Experience of the Fabric Supplier	Pearson Correlation	1	0.566**
	Sig. (2-tailed)		0
	N	74	74
Customer Satisfaction	Pearson Correlation	0.566**	1
	Sig. (2-tailed)	0	
	N	74	74

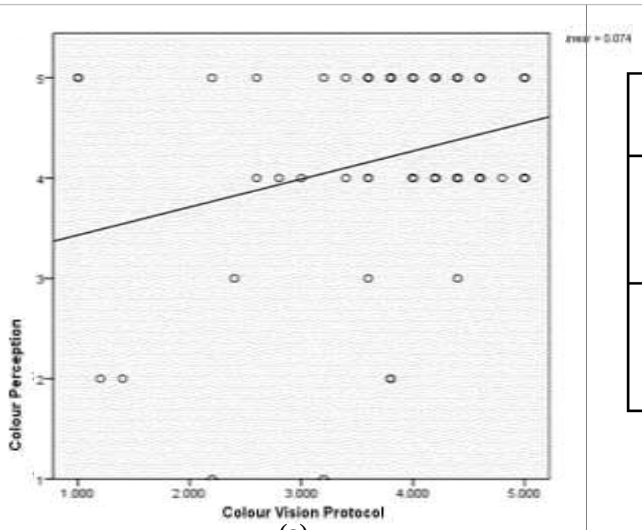
*. Correlation s significant at the 0.05 level (2-taed).

(b)

Figure 5: The Effect of Colouristic Experience of the Fabric Supplier

The Effect of Colour Vision Protocol

As seen in Figure 6, there is a weak positive relationship between the "Colour Vision Protocol" of the assessor and the "Perception of Colour" with a correlation of 0.268. Further, the significant two tailed value is less than 0.05 which means that there is a significant correlation between the two variables. Thus, it indicates that adherence to "Colour Vision Protocol" contributes fairly well for consensus between the customer and the supplier over colour approvals.



(a)

		Colour Vision Protocol	Colour Perception
Colour Vision Protocol	Pearson Correlation	1	0.268*
	Sig. (2-tailed)		0.021
	N	74	74
Colour Perception	Pearson Correlation	0.268*	1
	Sig. (2-tailed)	0.021	
	N	74	74

*. Correlation is significant at the 0.05 level (2-tailed).

(b)

Figure 6: The Effect of Colour Vision Protocol

DISCUSSION

Because of the growing trend for a focus on a fast textile supply chain which is believed not to be optimum yet (Hinks et. al., 2007), the effectiveness of the visual colour assessment itself is getting to be controversial day by day and many attempts are being made to establish the instrumental colour measurement instead and to make it popular along the supply chain. Despite such efforts, many colour assessors including some brands as found in the Literature Review, still tend to make the final decision on a colour match visually even when it passes within the agreed instrumental colour tolerance. This fact was proved in this research because 76% respondents agree that they follow this practice in real working environment. Thus, most colour evaluations are made visually (Datacolor, 2013) with difficulties that may arise when colour tolerances need to be considered. As Gangakhedkar (2012) points out, the practical approach is, to use acceptable tolerances defined by statistical analysis, correlated with visual acceptable matches. Further, the tolerances can only be determined from experience – pragmatically, the correct pass/fail limit is such that all pairs of samples with a colour difference less than this limit will be accepted by the customer (Gangakhedkar, 2012). To create such tolerances, a good correlation needs to be established between visual assessment and instrumental assessment by collecting data of acceptable and unacceptable samples, therefore, both instrumental and visual colour assessment methods do need to exist practically and they are complementary.

The visual colour assessment, the seemingly most prevalent assessment method despite its inherent subjectivity, may lead to more disagreements on colour decisions if the standard operating procedure is not followed as highlighted in the Literature Review. In addition, through this research, an attempt is made to identify most contributing factors that lead to disagreements i.e. size of the standards, customer understanding of limitations in producing colour, colouristic experience of the supplier and adherence to colour vision protocol. Except the size of the standard, all factors show their contributions towards the consensus between the customer and the supplier over colour decisions. The size of the standard may not show much influence on the consensus because the majority of the respondents take alternative measures such as referring a colour guide (eg. Pantone) when colour standards are sub-sized.

Best (2012) points out that in commercial working environments, complying with every guideline is a challenge, yet, the more elements that could be implemented and controlled, the better the consistency and quality in making decisions on colour. In this research, many respondents agree that at their workplaces, visual colour assessment protocols are in practice; for example, 95% of the respondents agree upon correct use of colour viewing cabinets while 73% agree with adherence to colour vision protocol. However, Park (2011) shows that even when the factors that influence colour assessment are standardised and the Standard Operating Procedure is followed, visual methods of colour matching can be haphazard and unreliable for various reasons. Further, as found in the Literature Review, the use of a panel of three observers gives more consistent results than individual observers. Interestingly, this research finds that 80 %, of the respondents tend to take a second opinion, whenever they have any doubt in their perception. But, all in all, only 74% would change one's own decision being influenced by a different opinion of the second assessor. The 26% of the rest would stick to their own perception showing somewhat rigidity. This finding would have been further investigated because Park (2011) states that it has been found that wrong decisions are likely to exceed 20% of assessments, with trained colourists reversing their decisions in a similar proportion if given the opportunity to re-assess standard and batch pair.

The study also reveals that 22% of the respondents, who follow standard procedures for using the colour viewing cabinet, tend to use a substituted light source when the specified light source is not available at the workplace. This kind of situations can be easily prevented by ensuring that the colour assessors are provided required tools and equipment while conducting awareness programmes over the adverse effects of malpractices and frequent audits. Best (2012) emphasizes, "Being proficient in the execution of colour assessment procedures is essential, but equally important is the knowledge of why guidelines are in place and the associated risks of taking what can seem like unimportant shortcuts".

According to Best (2012), the most frequent problems that would be found in the colour approval process are not highly technical, but administrative and procedural; therefore, they can be easily avoided. This premise is underpinned by the results of this research because it has given some insights into the current practices in visual colour assessment process and suggestions of colour assessors for implementations of new practices at their workplaces such as having regular correlation among colourists, arranging team discussions and peer evaluations etc.

The study reveals that adherence to visual colour assessment guidelines by senior colour assessors of Sri Lanka is at a satisfactory level. Yet, based on the responses received on the statements with regard to the adherence to the colour vision protocol, it is observed that there is room for further improvement because there is an average disagreeing percentage of 14%, over the five statements that have been structured to gather data on the same. These non-compliances need to be prevented completely because of their great impact on the colour perception as found in the Literature Review and should not be compromised under any circumstances.

This research could have been conducted better with deeper analyses, covering a wider range of colour assessors, at various levels. In such case, the questionnaire would need to be prepared in the mother tongue too, for the low educational level. Further, if two questionnaires had been prepared separately, one for the garment sector and buying offices and the other for the textile sector, more effective feedback would have been received. Having one questionnaire for all the three sectors reduces the weightage of the answers; because some questions may relate more to one particular sector while they would not be rightly comprehended by a respondent of a different sector.

The research would have been further improved if colour assessors could be interviewed in their own working environment, with less structured questions and more open ended questions, in order to gather more accurate information at the convenience of the respondents.

CONCLUSION

The results of the study reveal that visual colour assessment is still the prevalent and preferred colour assessment method in the Sri Lankan textile industry. Out of the four factors that were identified as majorly contributing to disagreements over colour decisions in visual assessment, only three were found to be considerably influential, according to the results i.e. the customer understanding of limitations of producing colours, colouristic experience of the supplier and the colour vision protocol. The other factor, the size of the standard, did not prove to be making any influence on the consensus among the observers over colour decisions. It can be concluded that a supplier who has colouristic skills and experience can render a service to the satisfaction of customer while his effective communication would help the customer to understand the limitations of producing colours and reconcile high customer expectations to a moderate level. Finally, the findings of this research can be utilized for a pragmatic approach to strengthening cordial business relationships along the textile supply chain where disagreements over colour decisions can cause disastrous consequences.

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REFERENCES

Best, J. (2012). Colour specification and visual approval methods for textiles. In: Best, J. ed. *Colour design: Theories and applications*. Cambridge: Woodhead Publishing, pp. 271-294.

Chrisment, A. (1998). *Color & colorimetry.* Paris: Editions 3C Conseil, pp. 1-30.

Datacolor (2013). *Colour differences and tolerances- Commercial Colour Acceptability* [online]. Available at: http://industrial.datacolor.com/support/wp-content/uploads/2013/01/Color-Differences-Tolerances.pdf [Accessed 20 February 2017].

Datacolor (2013). *Colourimetric Fundamentals, Part I* [online]. Availabale at: http://industrial.datacolor.com/support/wp-content/uploads/2013/01/Color-Fundamentals-Part-I.pdf [Accessed 20 February 2017].

Datacolor (2013). *Colourimetric Fundamentals, Part II* [online]. Availabale at: http://industrial.datacolor.com/support/wp-content/uploads/2013/01/Color-Fundamentals-Part-II.pdf [Accessed 20 February 2017].

Gangakhedkar, N. (2012). Color match: Visual versus numerical pass/fail. *Chromatic note: Understanding science and technology of color*. [blog]. Available at: https://drnsg.wordpress.com/2012/08/08/color-match-visual-versus-numerical-passfail/ [Accessed 13 March 2017].

Gouras, P. (2013). *Color vision.* [online]. Available at: http://webvision.med.utah.edu/book/part-vii-color-vision/color-vision/ [Accessed 10 September 2013].

Hanson, A. R. (2012). Colour and colour perception. In: Best, J. ed. *Colour design: Theories and applications*. Cambridge: Woodhead Publishing, pp. 2-23.

Hinks, D. et al. (2006). *Optimizing color control throughout the supply chain*. [online]. Available at: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=DA71A05D6E471CCF8F1ADBBA66C22C5C?doi=10.1.1.125.4471&rep=rep1&type=pdf [Accessed 10 September 2013].

Laidlaw, A. (2009). The Black and White Line for Colour Tolerancing. In: AATCC (American Association of Textile Chemists and Colourists), *AATCC 2009 International conference.* South Carolina, USA, 10-12 Mach 2009, Omnipress: Wisconsin

McDonald, R. and Smith, K. J. (1995). CIE94- a new colour-difference formula*. *Journal of the Society of Dyers and Colourists*, 111 (December 1995), pp. 376-379.

Narich Creative Innovation (2016). *Visual Colour Assessment*. [online]. Available at: https://www.narich.co.za/visual-colour-assesment/ [Accessed 13 March 2017].

Park, J. (2011) *Visual v Instrumental Colour Assessment*. [online]. Available at: http://www.textiletoday.com.bd/visual-v-instrumental-colour-assessment/ [Accessed 27 February 2017].

Rizzi, A. and Bonanomi. (2012). Colour illusion and the human visual system. In: Best, J. ed. *Colour design: Theories and applications*. Cambridge: Woodhead Publishing, pp. 83-104.

Sakamoto, T. (2013). Colour Space to Express Colour Attributes of Dichromatism: A Trial Study. In: AIC (International Colour Association), *AIC2013: Bringing Colour to Life.* Newcastle Upon Tyne, England, .8-12 July 2013, The Colour Group (Great Britain): United Kingdom

Salvi, S. M., Akhtar, S. and Currie, Z. (2006). Ageing changes in the eye. *Postgraduate Medical Journal*. [online]. 82(971), pp.581-587. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2585730/ [Accessed 01 March 2017].

Simunovic, M.P. (2010) Colour vision deficiency. *Eye.* [online]. 24**,** pp.747–755. Available at: http://www.nature.com/eye/journal/v24/n5/full/eye2009251a.html [Accessed 12 September 2013].