Statistical Analysis Of Nix Mini 2 Color Measurement Device

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Abstract

This work provides a methodology used to perform a statistical analysis and evaluate the performance of the Nix Mini 2 color sensor device in terms of repeatability, reproducibility, and accuracy as compared to the standard device, X-Rite eXact. In this research, the values collected using the low-cost color sensors were compared to those from a standard device, X-Rite eXact. This work accepts the values collected by the X-Rite eXact as true and considers them to be accepted values for the given printed sample.

Initial analysis was performed by evaluating measurements collected from a number of printed samples and applying simple statistics to analyze ΔE* between the values obtained using the Nix Mini 2 devices and those recorded with the X-Rite eXact. As anticipated, the initial testing and data indicated statistically significant differences between the data collected using the Nix Mini 2 device and X-Rite eXact; however, due to the three-dimensional nature of color, these simple statistics do not illustrate the devices' ability to correctly specify the color measured. This work aims to discuss the devices' ability to measure and specify color when compared to a standardized device.

Introduction

Instrumental color measurement allows for objective data about color to be captured and recorded and creates a common language that supersedes the limits of human perception and defines a descriptive vocabulary that facilitates color communication between industries all around the world (Phillips, 2020). Color measurement devices can be generally categorized into the following three categories: colorimeters, which provide CIE L*a*b* values that correlate to the

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way humans perceive color, densitometers, which provide density readings that correlate to the amount of ink on a given substrate, and spectrophotometers, which capture a set of reflection values that describe the reflectance of an object across the visible spectrum (Seymour, personal communication, August 2021). As demonstrated in Table 1, these devices each have their own way of describing the same color. Colorimeters and spectrophotometers are the two most advanced color measurement instrument types, both of which use sophisticated technologies to accurately and precisely quantify and define color (Phillips, 2020).

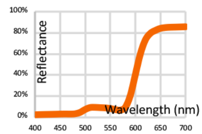
Colorimeters	Densitometers	Spectrophotometers
L* 50.62 a* 51.29 b* 49.48	C 0.26 M 1.05 Y 1.42 K 0.59	 Specular Reflectance
Colorimeters use XYZ filters to measure tri-stimulus values that are similar to the way humans perceive color.	Densitometers use RGB filters to measure CMYK densities by taking the negative log of the reflected light.	Spectrophotometers split the emitted light into thin bands and record the reflectance at 10-20nm intervals.

Table 1: *Functionality and Data Collated by Colorimeters, Densitometers, and Spectrophotometers*

These types of devices share some similarities, but their ideal applications vary quite a bit. The biggest difference is the capability of the device to measure and describe color. For this reason, these devices do not all have the same end use. When tight color control is not necessary, colorimeters may be sufficient to capture color measurements and perform basic color evaluation. As such, they are useful for calibrating monitors and specifying colors for use in graphic design. Spectrophotometers are more comprehensive in their measurement, as they measure and provide color data on the entire spectrum (What Is A Colorimeter?, n.d.). When posed with the question: “Which color instrument is right for you?”, Tim Mouw states:

> Colorimeters are a great way to capture color and do basic evaluation for applications that don’t require tight color control. Since spectrophotometers measure the entire spectrum instead of just red, green, and blue, they provide more accurate color data; making them useful for a broad range of applications in R&D, color formulation, and quality control (2019a).

The primary objective of this statistical analysis is to determine to what extent the Nix Mini 2 color sensors replicate measurements taken from standardized spectrophotometer devices. In order to better understand the limitations of such devices, further research was conducted to evaluate their performance as a color measurement tool in terms of their ability to obtain repeat measurements (repeatability and reproducibility) and their accuracy (or ability to conform to accepted values for a given printed sample) using the MCDM (mean color difference from mean) and Zc (Z-score of color) methods for evaluating color difference.

*Analyzing Color Difference in CIE L*a*b**

CIELAB is a three-dimensional color space based on the color opponent theory that is used to describe and order colors. This model describes a color in terms of its lightness (L*) and the color's hue in terms of opponents sets of red/green (a*) and yellow/blue (b*). Every color is uniquely located within the color space by its position on the L*, a* and b* axes, and can be described by a set of L*, a* and b* coordinates (Berns, 2019; Color Differences & Tolerances, 2008; Colorimetric Fundamentals, 2008). There are several methods for analyzing color difference; ΔE* is widely used in the print industry to calculate the difference in two single samples, Mean Color Difference from Mean (MCDM) is a method used to evaluate a data point when compared to the mean of the data set, and lastly, multivariate statistical methods that allow for joint analysis of inter-related variables like CIE L*a*b*.

Color difference, between any two colors in CIE L*a*b* color space, is the distance between the colors' locations and is usually expressed as ΔE* (called Delta E). ΔE* (total color difference) is calculated based on the three-dimensional change observed in L*, a*, and b* axes. Changes for each axis can be expressed as ΔL*, Δa*, and Δb*. ΔE* is calculated based on the combined differences ΔL*, Δa*, and Δb* and represents the distance of a line between the two colors (Gordon, 2022).

There are multiple ΔE* formulas that can be used to calculate color difference. The ΔE*ab formula is a sum of squares equation developed by the International Commission on Illumination (CIE) in 1976 to describe the Euclidean distance between two unique points within the CIE L*a*b* color space (Berns, 2019; Schuessler, n.d.).

In many applications, the use of L*a*b* in conjunction with the ΔE*ab formula is limited by the non-uniformity of the color space. To address the fact that the desired perceptual uniformity of L*a*b* color space has not been realized, alternative ΔE* formulas were developed (Color Differences & Tolerances, 2008). For example, ΔE*94 was created to take into account certain weighting factors for each lightness, chroma, and hue value (Schuessler, n.d.). The weighting factors presented in ΔE*94 did not adequately resolve the perceptual uniformity issue; therefore, the ΔE*00 formula was developed to include an additional five corrections (CIELAB ΔE* Color Difference, 2020). ΔE*00 is the current and most accurate color difference formula. In this research, both ΔE*ab and the ΔE*00 formulas will be used.

Mean Color Difference from Mean

Mean Color Difference from Mean (MCDM) is explained thoroughly in Billmeyer and Satltzman's Principles of Color Technology (Berns, 2019). MCDM is a metric used to compare the mean ΔE* of a group of CIE L*a*b* data points. To calculate the MCDM, mean L*a*b* values are obtained from the sample set. Then the distance, in ΔE, between each measurement and the mean for the sample set is obtained. The MCDM is then calculated by taking the mean of all ΔE* values obtained throughout this process. This method can be applied to any of the ΔE* color difference formulas. If the L*a*b* data within the sample set are normally distributed and uncorrelated, and they have the same standard deviation, the distribution in three-dimensional color space appears as a sphere where the value calculated for MCDM is the radius. However, if significantly different standard deviations within L*a*b* are observed, the MCDM will average the worst case and provide an exaggerated view of the precision of the data set (Nadal et al., 2011). Limitations for using this method as a measure of variability include poor approximation of elongated ellipsoids and the tendency for color differences to have a non-normal distribution (Berns, 2019). The MCDM method will be used in this research to evaluate the Nix device in terms of repeatability, the devices' ability to repeat identical measurements over short or long periods of time, and reproducibility, the devices' ability to obtain identical measurements when external variables are changed, such as the operator.

Multivariate Statistical Methods

According to Roy Berns in *Satltzman's Principles of Color Technology*, despite the limitations of using the MCDM, it is reasonable to continue to use MCDM as a measure of variability. However, alternative methods for evaluating color difference distributions are outlined by Nadal, Miller, and Fairman to evaluate multi-valued measurements like specular reflectance or tri-stimulus values without reducing the data to a single-valued parameter (color difference). In *Statistical Methods for Analyzing Color Difference Distributions*, data was analyzed using a Chi-Square Distribution, Hoteling T^2 analysis, and a Resampling approach (using Bootstrap). The research concluded that the MCMD approach did provide an "optimistic" evaluation of the results due to the naturally skewed distribution of color difference values and proposed that the resampling method should be used for multi-valued measurements.

Research on statistical process control of color by John Seymour poses that color difference (ΔE) and the MCDM process is inappropriate for statistical process control (2018). His paper details the deficiencies of using color difference for evaluating process control and introduces a method called "ellipsification" which is used to quantify a set of data points within a three-dimensional color space and allow for a Z-score (*Zc*) to describe the relationship of a group of values to the mean, or a target value. The *Zc* method that Seymour proposes is similar to the Hotelling's T^2 statistic. Both methods allow for multi-dimensional analysis and will lead to the same statistical conclusion. The major difference between the T^2 and the *Zc* is that the *Zc* results in linear units while the T^2 is in squared units (Seymour, 2018). As both methods will result in the same statistical inference, the *Zc* method will be used in this research to evaluate the accuracy of the Nix device or its ability to collect values that conform to "accepted" values for a given sample. Accepted values would traditionally be collected in a high-accuracy laboratory such as the National Metrological Institute. However, in this research, values collected with the X-Rite eXact will be considered "accepted" values.

This study focuses on determining what the low-cost sensor can do and to what extent. To improve understanding of the color sensor ability, replicate measurements taken using standardized devices. The goal is for the low-cost sensors to present similar outcomes when contrasted to the X-Rite eXact. However, it is hypothesized that these devices will not provide sufficient accuracy to meet industry standards for color evaluation in the field.

Methodology

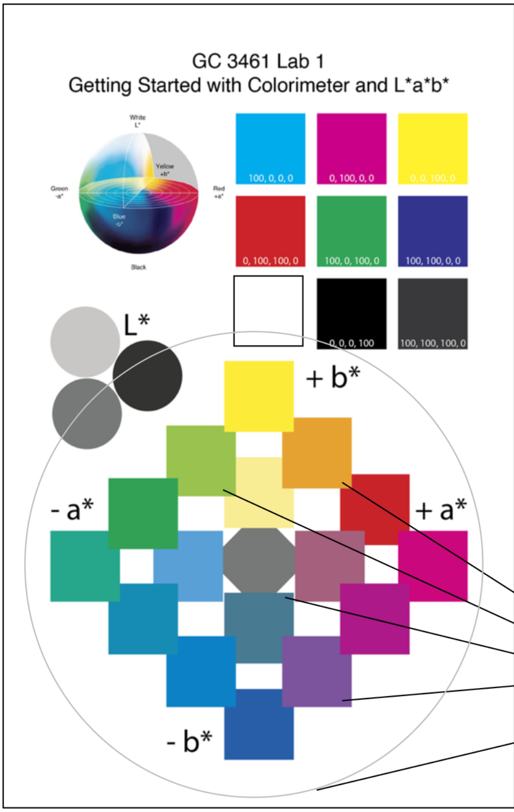
In order to obtain results that were compatible across the devices tested, the flowing settings were used when recording the measurements evaluated in this study: both devices have an Optical Geometry of 45°/0°, Illuminants of D50, and the 2° Observer Function. Therefore, these settings were used as the standards in this research. One major difference among the devices is the size of the apertures. The Nix Mini 2 device has a 15mm aperture while the eXact devices used in this study have a 4mm aperture meaning measurements taken with the Nix sample a much larger area than measurements obtained with the eXact. The other key difference between the device specifications is the measurement condition, as the eXact's measurement conditions are set to CIE standards M0 or M1, whereas the Nix Mini 2 uses an approximation "Similar to M2" according to the manufacturers' published technical specifications.

When studying data collected in this study, it is important to understand that each device specifies fractional data to a different degree. The Nix and eXact measure and report a different number of digits. Data collected with the eXact was measured using a tethered device, DataCatcher, and Microsoft Excel (2019, 2022). This data collection process allowed for data to the ten-thousandths place (four digits) to be seamlessly collected without user intervention or human error recording the values. At this time, there is no software solution that would remove user intervention or alleviate human error when using Nix Device. Data collected with these devices was obtained by pairing the Bluetooth color sensor device to the users' smartphone and measuring the sample with the appropriate smartphone app (Nix Digital, 2022). Nix devices report values rounded to the nearest ones place or the nearest whole number. Values displayed within the app to the user were then input manually into Excel.

Data Collection and Outlier Identification

To evaluate the repeatability and reproducibility, measurements were taken on both the white and black areas of a Leneta 3NT-31 sheet. Three users used the same device to take 20 sequential measurements on the black portion of a Leneta card without repositioning the device. The users then moved the device to the white portion of the Leneta card and took an additional 20 (sequential) measurements of the white area. To minimize the chance of imperfection or damage of the card impacting the data collection process, the first card was removed/discarded from the Leneta pad, and the second sheet was measured. Leneta 3NT-31 sheets are not 100% opaque. To minimize the impacts of unwanted background colorants, the sheet was measured on top of the remaining sheets in the pad.

When measuring the values used to assess the device's accuracy, each of the 10 devices measured 10 sheets of the test target shown in Figure 1. 15 measurements were taken for each of the 10 sheets. All printed samples were produced on a Konica Minolta AccurioPress C3080 on the same paper stock in one run. Leneta 3NT-31 sheets were affixed to the reverse side to ensure the background color would not be captured during the measurement process. When not in use, the printed samples were stored in a single stack inside a file folder made of black paper. To reduce the chance of inks being exposed to light and color changing during the data collection phase of this project. Color samples were measured in the following order: paper, cyan, magenta, yellow, red, green, blue, black, light (grey), medium (grey), dark (grey), orange, purple, slate, and lime for sheets 1 through 10 sequentially. As previously mentioned, Nix data was collected (to the nearest whole number) using Nix Digital, the accompanying smartphone app, and eXact Data was collected (to the fourth decimal place) using DataCatcher and Excel. Data was manually transferred from the Nix Digital app into Excel.



	C	M	Y	K
Cyan	100	0	0	0
Magenta	0	100	0	0
Yellow	0	0	100	0
Red	0	100	100	0
Green	100	0	100	0
Blue	100	100	0	0
Paper White	0	0	0	0
Black	0	0	0	100
Process Black	100	100	100	0
Light Grey	20	17	18	0
Medium Grey	55	46	46	11
Dark Grey	70	64	63	61
Orange	0	41	100	0
Lime	53	0	100	0
Slate	84	36	29	10
Purple	53	8	0	0

Pseudo-CIE $L^*a^*b^*$ cross-section

Figure 1

After collecting the data, statistical parameters including sample size (*n*), population mean (μ), standard deviation (σ), minimum/maximum value and range were computed using simple functions in Excal. Additionally, the QUARTILE function was used to determine the first (Q1) and third (Q3) quartiles, and the difference (Q3-Q1) was taken to provide the interquartile range (IQR). Outliers are values that stray an abnormal distance from other values in the dataset. The L* a* and b* values were evaluated as independent datasets and outliers were identified and highlighted using conditional formatting. Data points were considered to be outliers if they were < *Q1 - (1.5*IQR)* or > *Q3 + (1.5*IRQ)* for L*, a*, and b* independently. Numerous outliers were identified and considered but were ultimately included as part of the data set in hopes of representing the true behavior of the devices. When evaluating the color data captured with the Nix Mini 2 devices, the Nix Device 2 (id: 763F) was determined to be dysfunctional because 191 of the 450 values (or 42.44% of the data points) collected with that specific device were considered to be outliers of the population collected with the Nix devices as a whole. Data collected with Device 2 was retained but excluded from further calculations. Another trend that became evident during the process of identifying outliers within the data was discrepancies in print variation of Test Target Sheet 9. These discrepancies were not evident within the dataset collected with the Nix but became apparent in the measurements collected with the eXact. All data collected for sheet nine was retained but removed from both the Nix and eXact datasets moving forward.

Mean Color Difference from Mean (MCDM)

When evaluating the data using the MCDM method, the mean value of L*, a* and b* coordinates were obtained separately. The MCDM Formula (Formula 1) was then applied to obtain a MCDM value for each device as compared to the mean value collected by that device and the mean value collected by all of the Nix devices, where the subscript *i* represents the i^{th} measurement, $\overline{L}^*$, $\overline{a}^*$, and $\overline{b}^*$ are the average CIE L*, a*, and b* coordinates of the data set, and N in the number of samples (Berns, 2019; Nadal et al., 2011).

$$MCDM\ \Delta E^*_{ab} = \frac{\sum_i \sqrt{(L^*_i - \overline{L}^*)^2 + (a^*_i - \overline{a}^*)^2 + (b^*_i - \overline{b}^*)^2}}{n}$$

Formula 1: *Mean Color Difference from Mean (MCDM)*

Zc Multivariate Statistics

To statistically evaluate the accuracy of the Nix device, an Excel template provided by John Seymour was employed to obtain the Zc scores used to determine the probability that the device will be able to capture the "accepted" values collected with the X-Rite eXact for each color. The template accepts a set of CIE L*a*b* coordinates, calculates the mean L*, a*, and b* values ($\overline{L}^*$, $\overline{a}^*$, and $\overline{b}^*$), and determines ΔL*, Δa*, and Δb* for each measurement compared to the mean of the data set using Formulas 2-4 (Seymour, personal communication, July 2020). The template then calculates a covariance matrix that describes the covariance between each pair of elements of a given random vector and an inverse covariance matrix which is used to calculate the Zc of each datapoint. The Zc scores describe the number of three-dimensional standard deviations between the datapoint and the mean datapoint. The Zc scores are then used to identify outliers or datapoints that do not belong within the data set. Data points with Zc scores ≥ 4 were removed from the data set for further calculations as a Zc ≥ 4 indicates a probability (P(Zc)) of .99 that the data point falls within the data set. Lastly, the template accepts a target CIE L*a*b* value and calculates a Zc score that describes the probability that the target value lies within the dataset being evaluated.

$$\Delta L^* = L^*_1 - L^*_0$$

Formula 2: *Change in* L^*

$$\Delta a^* = a^*_1 - a^*_0$$

Formula 3: *Change in* a^*

$$\Delta b^* = b^*_1 - b^*_0$$

Formula 4: *Change in* b^*

Results and Discussion

In hopes of better understating the how the Nix device functions, statistical evaluation was performed in hopes of providing quantifiable data to evaluate the devices' precision in terms of repeatability and reproducibility using the MCDM method and the accuracy the device provides using the Zc method.

Repeatability

Repeatability is a term used to describe the device's ability to repeat multiple identical measurements over a given period of time. In other words, it describes to what extent the device can replicate the measurements it takes, or its ability to make consistent measurements over time. Repeatability is often quantified in terms of short (seconds or minutes), medium (hours), or long periods (days, weeks or longer) of time between measurements (Berns, 2019). The data collected in this research was taken over a short period of time. The MCDM values found in this study are shown in Table 2. They are all very low and desirable, however this may be misleading primarily due to the fact that the device reports only whole numbers. The rounding that occurs when using the Nix device can potentially over or underestimate the variability of the dataset. For example, you may notice that all of the black Nix readings for users two and three were the same resulting in a mean value that is identical to every data point collected within the data set and a MCDM of 0. This would likely not be the case if the device was reporting to even the first decimal place. The data presented in Table 2 shows that the repeatability of the eXact is superior to that of the Nix with an average MCDM of .03 ΔE^*_{ab} for black vs the .19 ΔE^*_{ab} obtained with the Nix. Measurements taken on the white sample area also support this trend with MCDM values of .04 ΔE^*_{ab} and .13 ΔE^*_{ab} for eXact and Nix, respectively.

User	Black		White	
	Nix MCDM	**eXact MCDM**	**Nix MCDM**	**eXact MCDM**
1	.56	.03	0	.03
2	0	.02	.38	.03
3	0	.04	0	.05
Mean	**.19**	**.03**	**.13**	**.04**

Table 2: *Repeatability MCDM values (in ΔE^*_{ab}) for CIE L* a* b* Taken by Three Users on One Device*

Reproducibility

Reproducibility is a term used to describe a device's ability to take consistent readings when some aspect of the measurement condition has changed. Reproducibility is often tested by changing the operator or instrument. In other words, reproducibility describes the device's ability to repeat identical measurements when conditions do not remain the same (Berns, 2019). The same 60 measurements utilized to examine repeatability are used to obtain the device reproducibility. However, at this point, the MCDM is calculated using each data point and the mean value of the entire data set (comprised of measurements taken by all three users). Table 3 presents the data collected to gauge the reproducibility amongst various (3) users. The data shows once again that the eXact exhibits better performance in terms of being able to reproduce identical measurements provided a change in user has occurred. The values presented here are once again impacted due to the measurement reporting limitations of the Nix device. The MCDM values posed by the Nix would presumably increase if the device reported more significant figures. The values shown in Table 3 illustrate the advantage of using the eXact over the Nix. When changing the user in a measurement condition, the eXact was able to reproduce measurements within a 0.18 ΔE^*_{ab} for black samples and 0.10 ΔE^*_{ab} for white samples, while the Nix measurements varied in 1.23 ΔE^*_{ab} for black and 0.67 ΔE^*_{ab} for white. The Nix reproducibility values are of concern because they indicate that the same exact device when used by different users could produce two distinct values with color differences greater than one ΔE^*_{ab}.

User	**Black**		**White**	
	Nix MCDM	**eXact MCDM**	**Nix MCDM**	**eXact MCDM**
1	1.87	.23	.67	.08
2	.97	.24	.81	.13
3	1.13	.06	.53	.08
Mean	**1.32**	**.18**	**.67**	**.10**

Table 3: *Reproducibility MCDM values (in ΔE^*_{ab}) for CIE L* a* b* taken by three users on one device*

Accuracy

When examining the accuracy of the Nix device, the Zc (Z-score of color) method developed by John Seymour was employed. Similar to the traditional Z score, the Zc is a measure that describes the relationship between a data point and the mean of a group of values. More specifically, *Zc* represents the normalized three-dimensional standard deviation between two values, or between a set of values and a target value. The null hypothesis in this type of multivariant analysis states that the target value can be found within the dataset. Similar to a traditional Z score, Zc can be used with a set of significance levels used to understand the probability that the value in question belongs in the dataset, assuming that the dataset has a trivariate normal variation the Zc score will have a chi distribution with three degrees of freedom (Seymour, 2018).

Before applying the Zc to evaluate the set of 100 Nix values relative to the mean value obtained with the eXact, a Zc score was calculated using each of the Nix data points and the mean value of the data set. Single data points were removed if the Zc was > 4 when compared to the mean value, as a Zc greater than four indicates a 0.10% chance of observing that value within the sample population.

Table 4 presents the data used to evaluate the Nix's ability to capture accepted values. Please note that outliers were removed from the color patches labeled with an asterisk. When looking at the data in the Zc column, it is clear the mean value collected with the eXact varies from the values collected in the Nix data set. The Zc values listed describe the number of standard deviations the target value differs from the mean values of the data set. The P(Zc) values in Table 4 represent the probability that the target value belongs to a population that is statistically different from that of the Nix data set, while the values found in the chance column describe the chance of attaining the target value within the data set.

Color Sample	eXact Mean (Target)			Nix Mean			Standard Deviation			Zc	P(Zc)	Chance
	$\bar{L}^*$	$\bar{a}^*$	$\bar{b}^*$	$\bar{L}^*$	$\bar{a}^*$	$\bar{b}^*$	σL^*	σa^*	σb^*			
Paper	94.69	0.69	-1.57	93.1	-0.2	2.1	1.15	0.58	1.49	4.64	> 0.999	< 0.1%
Black	15.80	-0.32	-0.28	12.2	2.3	-1.7	1.85	3.35	1.90	2.84	0.98	2.0%
Light*	78.83	3.48	0.39	77.5	2.8	3.1	0.89	0.81	1.34	3.25	0.99	1.0%
Medium	50.31	2.74	-1.19	48.8	2.8	0.0	0.79	1.30	1.01	3.18	0.99	1.0%
Dark	25.07	2.65	-0.89	22.6	4.4	-1.4	1.04	2.08	1.44	3.76	1.00	0.2%
Cyan	52.12	-33.35	-47.13	51.0	-32.1	-47.8	0.55	1.80	1.09	3.00	0.98	2.0%
Magenta	47.13	73.29	-0.08	45.9	74.5	1.3	0.64	1.71	1.26	2.27	0.90	10.0%
Yellow	87.54	-4.72	82.16	86.1	-4.0	85.2	0.97	1.18	2.29	2.92	0.98	2.0%
Red	47.10	67.05	42.58	46.0	68.7	43.9	0.62	2.48	3.62	2.09	0.90	10.0%
Green	50.31	-63.32	19.80	49.4	-61.8	22.1	0.68	4.16	1.89	3.00	0.98	2.0%
Blue*	25.09	21.18	-44.03	23.4	23.9	-45.8	1.31	1.13	1.22	2.47	0.90	10.0%
Orange	70.33	22.96	61.91	69.0	24.0	64.9	0.83	1.66	2.60	2.52	0.95	5.0%
Purple*	40.85	39.08	-25.78	39.1	39.8	-25.4	0.84	1.45	0.77	2.38	0.90	10.0%
Slate*	43.75	-19.41	-26.64	42.5	-19.2	-26.7	0.66	1.70	0.64	2.35	0.90	10.0%
Lime	67.74	-32.86	50.88	66.6	-32.03	-54.05	0.75	1.88	1.94	3.44	0.99	0.5%
Mean										**2.94**		**>2%** **<5%**

Table 4: *Accuracy Zc Scores Probability and Chance for 15 CIE L* a* b* Color Samples*

While some of the color samples evaluated in this research perform better than others, we see that in the best case scenario (for magenta, red, blue, purple, and slate), there is a 10% chance that the data cloud of Nix data will contain the accepted target value obtained with the eXact; meaning there is a 90% chance that that value belongs in a statistically different population. In other words, the user would have to take 10 measurements before the Nix would report the accepted value for a particular color sample. Based on the Zc scores, probability, and chance observed in this research, the Nix devices have been found to provide statistically different CIE L* a* b* values. The Nix devices do not provide the accuracy needed to conform to the accepted values attained with the eXact in this research.

Conclusion

The work presented here supported the hypothesis that low-cost sensors do not function with the precision needed to be implemented in an industry setting where tight color tolerance is needed. Previous research found that color sensors like the Nix Mini 2 can provide reasonable and consistent outcomes to support basic concept illustration and can be suitable for teaching basic concepts within graphic communication curricula. However, when statistically evaluated using the MCDM method and Zc scores to evaluate the devices in terms of repeatability, reproducibility, and accuracy, the Nix does not perform with the precision that is necessary in most color measurement environments outside the classroom. When high sensitivity is called for, the Nix becomes ineffective in recording accepted values and showing subtle differences in the prints, as it lacks the precision that standardized devices like the eXact provide. In conclusion, low-cost color sensor devices such as the Nix Mini 2 can be utilized as a teaching tool, but they should not be used for practical color evaluation or process control.

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