Pastels: a colour guide for artists and manufacturers

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To bring some order to the plethora of pastel colours, samples and measurements were made of 3154 artist's chalk pastels, comprising the complete lines of eight brands (Rembrandt, Unison, Sennelier, Schmincke, Girault, Blue Earth, Mount Vision, and Great American). Munsell specifications, calculated from the measurements, are presented; another file lists which pastels are closest to standard Munsell colours. Artists can use these resources to organise and choose pastels. The pastel measurements were also analysed to provide recommendations for manufacturers. About 300 pairs of pastels (with both pastels from the same brand) differ by a DE00 of 2 or less. Likewise, many pastel sets contain overly finely gradated colour series. Removing these redundancies would simplify pastel sets without compromising colour offerings. Many pastel names convey no colour information; labelling each pastel stick with its Munsell specification would allow pastellists to make informed purchasing decisions without relying on questionable colour reproductions.

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Introduction

Though not as common as oil or acrylic paints, pastels have been a standard painting medium since the 18th century [1]. By using a minimum of binders, pastels achieve higher pigment loads, and more saturated colours, than other painting media. Artists usually mix oils or acrylics on a palette, to produce a wide gamut of colours from a handful of base paints. Since pastels, by contrast, cannot be mixed on a palette, a single pastel manufacturer typically produces a few hundred pastels, with many fine colour gradations. As a result, pastels can quickly become unmanageable: Figure 1 shows some (but not all) of the author's personal collection, acquired over a decade. This paper aims to bring some order to the abundance of pastel offerings, for the benefit of both artists and manufacturers.

Figure 1: Most of the author's pastel collection.

The tools of colour science were used to this end. A spectrophotometer was employed to measure 3154 pastels, comprising the complete lines of eight brands: Rembrandt, Unison, Sennelier, Schmincke, Girault, Blue Earth, Mount Vision, and Great American. To express pastel colours in terms that are natural to artists, the measurements were converted to Munsell specifications [2-3]. Painters, manufacturers, and researchers are welcome to use this data, which is presented as both text files and spreadsheets. Though this paper is believed to present the first publicly available pastel measurements, mention should be made of previous work by Marie Meyer, who measured an even larger set of pastels to produce her *Multi-Brand Color Chart: Pastels* [4], displaying the pastels in terms of the Munsell system. Personal communications, however, reveal that her measurements have been lost.

In terms of methodology, this paper applies exploratory data analysis to spectrophotometric measurements of pastels, with the aim of producing some practical recommendations for two difficulties that pastellists face. The first difficulty is the confusion that results from the sheer number and variety of pastels. The second difficulty is making purchasing decisions on the basis of questionable colour reproductions.

The analysis shows some ways to simplify pastel offerings and reduce confusion. For example, 304 near-duplicate pairs of pastels were found. Two pastels are considered near-duplicates if they are from the same brand, and their colour difference (denoted DE00, or just DE) is 2 or less. The DE is a scientifically standardised [5-6] measure of colour difference. The more similar two colours are, the smaller their DE. Along the same lines, most pastel brands contain many colour series, typically going in sequence from a dark version of a hue to a light version. Visual inspection reveals that the colour steps in a series, though they might not fall below a particular DE threshold, are often overly finely gradated. Eliminating one pastel from each near-duplicate pair, and paring down some series, would reduce pastel offerings by nearly 10 percent, without compromising their gamut.

Labelling each pastel stick with its Munsell specification would greatly mitigate the second diffculty. Most pastel names, which are more often numbers, provide little or no colour information. Pastellists often cannot physically see what they are buying; instead, they must rely on questionable colour reproductions in printed or online catalogues. The Munsell specification, on the other hand, defines colour unambiguously, so a Munsell naming system would allow a painter to look up a pastel in a Munsell book, for a much better idea of its colour. The Munsell system was designed to be intuitive for visual artists, so its specifications are helpful even without a Munsell book.

This paper also provides a sort of reverse Munsell table, to help pastellists find particular colours. For each standard Munsell colour, such as 7.5GY 8/6, the table lists the pastels whose colours are closest. In this case, pastel 824 by Mount Vision is a good match for 7.5GY 8/6, since the DE between them is 0.8, while pastel E6B by Blue Earth is another good match, with a DE of 1.7. An artist would likely achieve better colour control, and make better purchasing decisions, by using the reverse table than by consulting reproductions in paper or online catalogs. In addition, the table provides information from multiple brands simultaneously, rather than requiring an artist to look through each brand's offerings individually.

This paper is organised as follows. First, the pastel samples and measurements are described, along with the Munsell system. Next, data files and spreadsheets are presented, with some recommendations for use. Then, data analysis identifies near-duplicate pastels, which are two pastels, from the same brand, with practically identical colours. Finally, the analysis suggests some practical recommendations (using Munsell specifications for pastel names, and paring down pastel offerings). The paper ends with a brief summary.

Samples and measurements

Description of samples

This study measured samples of the complete line of chalk pastels from eight different brands: Rembrandt, Unison, Sennelier, Schmincke, Girault, Blue Earth, Mount Vision, and Great American. *Chalk pastels or soft pastels* are just traditional pastels, which typically use gum tragacanth [1] as a binder. They differ from oil pastels, which use oils or waxes as binders. In addition, some manufacturers speak of hard pastels, which are chalk pastels which contain clay or other additives, to make the pastel firmer and less manipulable. Pastel pencils, for instance, are thin cylindrical hard pastels, with a wooden casing like a pencil. The terms *hard* and *soft* are extremes on a continuum, and the degree of hardness is not precisely defined. Though all the pastels in this study are considered soft pastels, the Rembrandt and Girault pastels are harder than the other manufacturers'.

Table 1 lists the number of pastels by brand. In all, 3154 pastels were measured. The largest set was Great American, with 546 pastels, and the smallest set was Rembrandt, with 218 pastels. Samples were made or obtained for each of the 3154 pastels. A sample is an area of pastel, between half an inch and an inch square, applied to white paper that was manufactured especially for pastels or related media. Figure 2 shows some examples for Rembrandt pastels. To make the pastels, the samples were applied as thickly and smoothly as possible, usually being rubbed by a finger; ideally the sample would be opaque, covering the paper completely. The papers used were commonly available white pastel papers, with minimal tooth. The Rembrandt samples were made by the author on Canson Mi-Teintes paper. The Unison samples were kindly provided by Unison (based in Northumberland, England), on unidentified paper. The rest of the samples were provided by Dakota Pastels (based in Seattle, USA), on Somerset Radiant White paper. No fixative was used on any of the samples.

Brand	Number of Pastels
Great American	546
Sennelier	525
Unison	422
Mount Vision	407
Schmincke	400
Blue Earth	336
Girault	300
Rembrandt	218
Total	3154

Table 1: Measured pastel samples.

Figure 2: Some Samples of Rembrandt pastels.

Each pastel brand has its own naming system, usually not very informative, for individual pastels. Since pastels often contain a mixture of pigments, the traditional artist's nomenclature of pigment names like *cadmium yellow* or *viridian green* cannot be used. Some manufacturers, like Girault and Sennelier, simply assign numbers, not always consecutive, to their pastels. Rembrandt divides its set into hue series, assigning each pastel one number for its series, and a second number for its position in the series. The position numbers vary from 2 to 12, with numbers above 5 indicating tints and numbers below 5 indicating shades. For example, the Rembrandt pastel 626,10 is a light green. Other manufacturers use letters as modifiers. Schmincke, for example, uses D and H to indicate dark and light versions of a colour (D and H stand for *dunkel* and *hell*, the German words for dark and light). Unison divides its pastels into series such as Yellow Green Earth. Table 2 lists the series, along with abbreviations used in this paper. The pastels in each series are then numbered, so Yellow Green Earth 7 is the seventh pastel in that series. This paper will refer to a pastel by its brand name, plus the manufacturer's identifier for that particular pastel. For example, the two pastels mentioned in this paragraph would be Rembrandt 626,10 and Unison YGE7.

Series	Abbreviation
Additional	A
Blue Green	BG
Blue Green Earth	BGE
Blue Violet	BV
Brown Earth	BE
Dark	Dark
Green	G
Grey	Grey
John's Set	J
Light	Light
Natural Earth	NE
Orange	O
Portrait	P
Red	R
Red Earth	RE
Special Collection	SC
Turquoise	T
Yellow	Y
Yellow Green Earth	YGE

Table 2: Unison pastel series.

While most pastels contain only pigment and binders, some manufacturers have introduced additives to give special effects, such as mica flakes for iridescence. Sennelier 800 through 825 are examples. These additives affect a pastel's appearance rather than its colour *per se*. Since the number of effect pastels is small, and since they have definite colours, they were included in this analysis alongside the standard pastels.

A pastel's shelf life is effectively unlimited, and decades-old pastels are still usable. Although reputable manufacturers use lightfast pigments to prevent colour changes, there is always the possibility of fading. Over a long enough time, furthermore, a manufacturer might change a pastel's name or formulation. Because of such situations, two pastels with the same name can differ. Figure 3 shows a particularly bad example, in which two pastels, both Rembrandt 331,9, produce very different colours. Another possible cause of colour variation is manufacturing inconsistency. Slight pigment discrepancies from batch to batch, or fluctuations in the relative proportions of ingredients, can cause colour irregularities. While colour consistency was not analysed, Figure 4 shows that it could be significant when it occurs. The figure reproduces two samples, each made with a pastel labelled Sennelier 303. Though close, the two samples' colours are also slightly but definitely different. The sample on the left tends toward orange when compared with the sample on the right, which tends more toward red. While the extreme difference in Figure 3 almost certainly results from a renaming or reformulation, the difference in Figure 4 could result just as plausibly from manufacturing variability. An interesting further study would be to quantify pastel manufacturing consistency.

Fortunately, the differences in Figures 3 and 4 seem the exception rather than the rule, so no attempt was made to identify or correct for them. Instead, samples were taken from any convenient source. The Rembrandt samples shown in Figure 2, for example, were taken from the artist's personal collection, borrowed from friends' collections, or, if necessary, purchased. The pastel samples from all the brands were assembled over a year and a half, from late 2013 to mid 2015.

Figure 3: Two different colours for Rembrandt 331,9.

Figure 4: Two samples, each made with Sennelier 303.

Description of measurements

Spectrophotometric measurements of the pastel samples provided the data which was analysed to produce the recommendations in this paper. Measuring pastels is difficult, not only because of their dusty surface, but also because of difficulties in controlling application. As a result, measurements are more variable than we would like, and the DEs calculated from them should be taken as guides rather than gospel: they indicate possible issues, to be followed up by visual inspections before any decisions are made. This section discusses possible sources of variability when measuring pastels.

Each sample was measured with an X-Rite i1Pro2 handheld spectrophotometer, as shown in Figure 5. More technical details of the pastel measurements can be found in Centore (2016) [7]. Each sample was actually measured three times, with replacement, and the median was taken as the final measurement. A pastel sample's dusty surface makes measurement difficult, and the mean colour difference from the mean [8] (MCDM) was about 1 [9]. For comparison, the MCDM for printed inkjet samples, measured with the same i1Pro2, was typically between 0.2 and 0.3. The MCDM is expressed as a DE (calculated for these samples with respect to Illuminant C, for compatibility with the Munsell standard), so the perceived DE between two measurements of the same sample could easily be 1. While using the median reduces variability somewhat, the calculated DE between two different samples still inherits the uncertainty of the individual samples' measurements, so a DE between two different pastels might not be as accurate as desired. Despite their less-than-ideal accuracy, the instances examined will show that DEs between pastels are reliable enough to help humans make colour decisions.

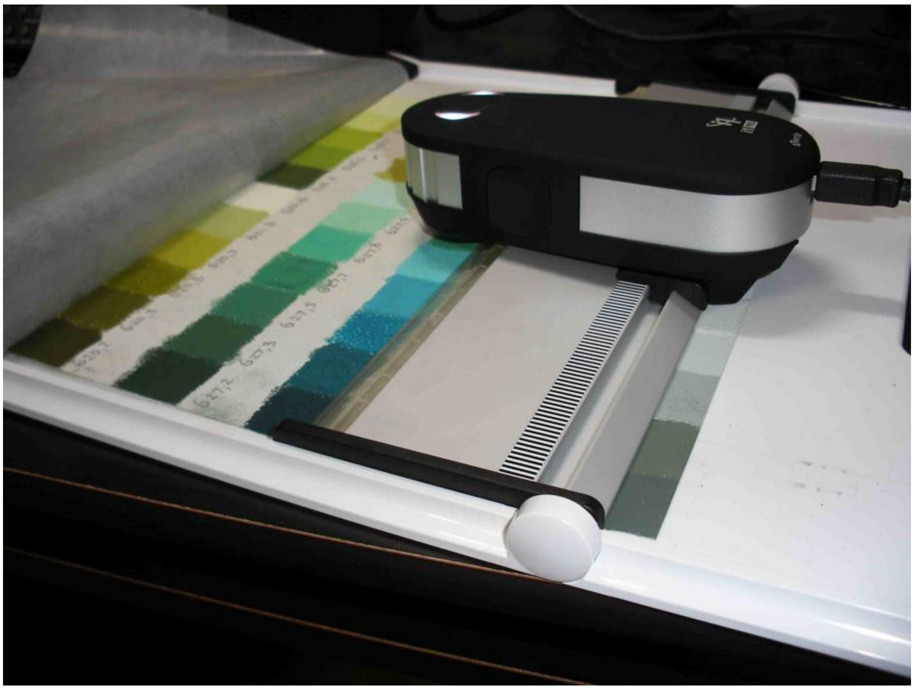

Figure 5: The X-Rite i1Pro2 spectrophotometer, used for measuring pastels.

Consistency was also a concern, since samples were made on different kinds of paper, and by different people. The difference in paper is likely not of concern, since six of the eight brands used the same kind of paper. In theory, an opaque sample's colour is independent of substrate; in practice, of course, samples are usually not quite opaque. Since the papers are all white and don't have much texture, however, the substrate influences all the colour samples similarly. Sample preparation was another source of variability, because pastels were applied to paper manually–in the literal sense, with pastels being rubbed by fingers. Manual application, of course, is hard to standardise. Though the samples were checked visually for smoothness and coverage, there is no simple objective way to eliminate this source of variability. Fortunately, the analysis in this paper focuses on comparisons, such as finding the DE between two Mount Vision pastels or analysing a Girault colour series, in which pastels *from the same brand* were applied to the same paper, and likely by the same person. Such intra-brand comparisons therefore avoid these consistency concerns.

A more indirect measurement problem is clerical error. Most samples were prepared by third parties; the author himself received samples of pastels, but not the actual pastels. Since a single set contains hundreds of pastels, of finely gradated colours, it is easy to select the wrong pastel occasionally, or fill in the wrong square on the page of samples. The author came across several of these mistakes in the course of analysis, and corrected them. Given the large number of pastels, though, likely other clerical errors have slipped through.

The Munsell system

Analysing pastel colours, or colours in general, requires a systematic language. At the start of the 20th century, Albert Munsell developed such a system, using terms that are natural to artists. The system classifies surface colours by three perceptual attributes that are basic to painting: hue, value and chroma.

Hue is universally understood. It says whether a colour is red, yellow, purple, etc. Munsell designates 10 basic hues: R (red), YR (yellow-red, or orange), Y (yellow), GY (green-yellow), G (green), BG (blue-green), B (blue), PB (purple-blue), P (purple), and RP (red-purple). Each basic hue is further subdivided into 4 steps, denoted with a prefix. For example, the four greens are denoted 2.5G, 5G, 7.5G, and 10G. 2.5G is a yellower green, that is closer to GY than it is to BG. 10G is a bluer green, that is closer to BG than it is to GY. In all, then, the Munsell system specifies 40 hues (4 steps for each of the 10 basic hues). These 40 hues are equally spaced perceptually. One could interpolate any desired amount between two adjacent hues. For example, the hue 6GY is a yellowish green that is between 5GY and 7.5GY, but perceptually more similar to 5GY. White, black, and greys are not considered hues in the Munsell system. Rather, they are designated N, for “neutral”.

Many different colours can have the same hue. Figure 6, for example, shows the “hue leaf” for 6GY, a set of colours all of which have hue 6GY. The different colours within a hue leaf are specified further by value and chroma. The empty boxes indicate colours that are in the Munsell system, but that are beyond the gamut of the printing process used to produce the figure. The hue leaf shades smoothly into the neutral axis, consisting of greys, shown on the left.

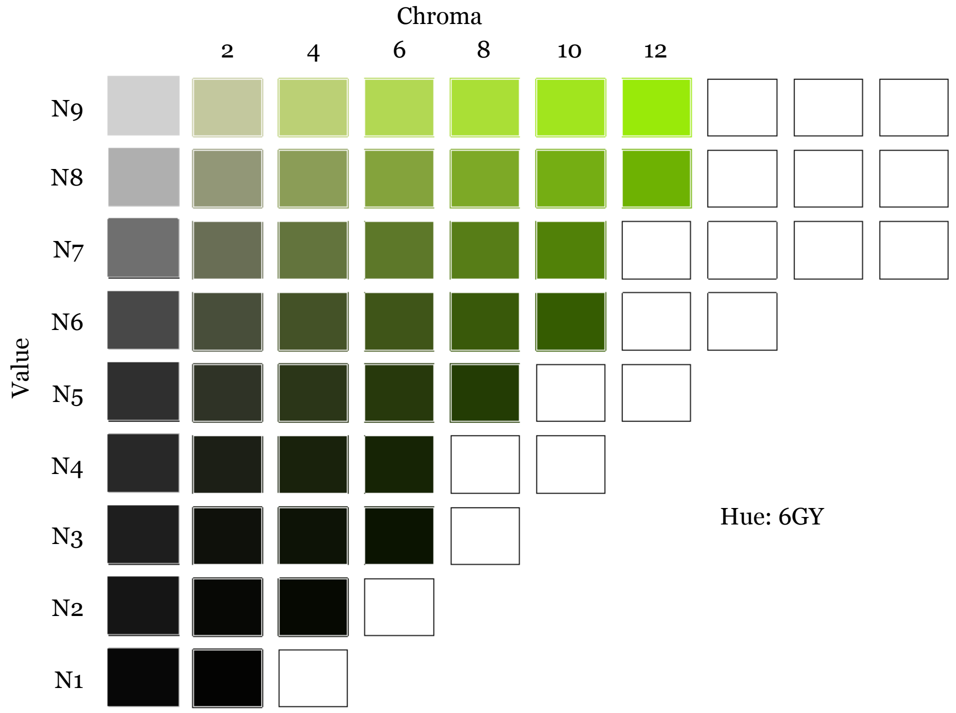

Figure 6: The hue leaf for 6GY in the Munsell system.

Munsell value designates how light or dark a colour is. The theoretically darkest black has a value of 0, and is denoted N0. The theoretically lightest white has a value of 10, and is denoted N10. Between N0 and N10 are 9 progressively lighter greys, denoted N1 through N9. The spacing between the greys is perceptually equal. All colours have a Munsell value, not just the neutrals. For example, there are light blues and dark blues. A blue with value 8.5 has the same lightness as N8.5.

Munsell chroma refers to how intense, or saturated, a colour is. For example, a lemon is an intense yellow, while masking tape is a dull yellow. A dull colour is closer to a neutral grey than an intense colour. The Munsell system denotes chroma numerically. Greys have chroma 0. A colour with a chroma of 10 or higher is generally perceived as saturated. Colours of low chroma, say 4 or less, are perceived as subdued, with a high grey content.

The Munsell notation for a colour takes the form H V/C, where H stands for hue, V stands for value, and C stands for chroma. For example, the colour 10R 9/6 would be a very light (V is 9), moderately intense (C is 6), orangish red (H is 10R). A colour with chroma 0 is a neutral grey, which is denoted NV, where V stands for value. For example, N5 is a grey that is midway between white and black.

Early versions of the Munsell system were collections of intuitively chosen hand-painted swatches, which served as physical standards for judging other colours. The 1943 Munsell renotation [2], which is the standard today, defined the system scientifically. The renotation used thousands of visual assessments of paint samples, by 41 human observers, to provide a firm empirical basis for the system. In addition, the renotation specified a set of 2745 Munsell colours quantitatively, in terms of a scientific coordinate system developed by the Commission Internationale de l'Ėclairage (CIE). By interpolating between the 2745 specified Munsell colours, CIE coordinates can be found for any other Munsell expressions. While the renotation calculates CIE coordinates from Munsell coordinates, it is also possible to invert [3] the renotation, so that one can calculate a Munsell specification from a set of CIE coordinates.

CIE coordinates can be calculated from measurements provided by the i1Pro2 spectrophotometer, allowing us to find Munsell specifications for all 3154 pastels. As a result, we have an intuitive, yet still objective, description for each pastel's colour.

Pastel data files and spreadsheets

To allow painters easy access to the Munsell data for pastels, some downloadable text files have been posted online, at http://www.aic-color.org/journal/v15.htm. Each text file contains tab-delimited, human-readable text, in a matrix format. The first line is a header row, that describes the contents of the rows beneath. The files can be easily opened in spreadsheet programs such as Microsoft Excel. For convenience, two workbooks, one in Microsoft Excel .xls format and one in NeoOffice .ods format, have also been provided. The text files appear as spreadsheets in these two workbooks.

The following files have been provided:

1. **MunsellDataForPastels.txt.** Each row of this text file gives the Munsell coordinates for one pastel. In addition to the complete Munsell specification, columns give particular parts of the Munsell specification. For example, there are columns for value and chroma.
2. **MunsellToPastel.txt.** This file is a kind of inverse to MunsellDataForPastels.txt. Given a Munsell specification from the renotation, the file lists those pastels that are the best match for it.

3. **NearDuplicatesForPastels.txt.** This file lists all pairs of pastels that are produced by the same manufacturer, and whose colours are very similar. Such near-duplicates will be discussed in detail later.
4. **PastelData.ods and PastelData.xls.** Each of the preceding files appears as one spreadsheet in these two workbooks.

The spreadsheet “Munsell” presents the most basic data. Table 3 shows the first few lines. Given a particular pastel, an artist can find its Munsell specification directly beside it.

The spreadsheet “MunsellToPastel” presents a sort of inverse table, which helps find a pastel that is a good match for a desired colour. Suppose a pastellist wants a certain colour, such as 7.5RP 5/8. Then the row, shown in Table 4, for 7.5RP 5/8 in “MunsellToPastel” gives the closest available pastel as Girault 328, whose DE from 7.5RP 5/8 is 1.6, a good match. The next best match is Schmincke 034O, with a DE of 3.9. Three other possible matches, with their DEs, are also given.

This inverse table is particularly useful when ordering pastels online or through printed catalogs, where the colour reproductions are not very reliable. An added help is that an artist can search through multiple brands at once. Without such an aggregated table, an artist would have to search through each brand individually to find the best match in that brand, and then compare all the brands' best matches.

The spreadsheets can be easily manipulated to provide interesting information. Suppose, for example, that one wants to find the most saturated pastels. Then open PastelData.ods or PastelData.xls to the spreadsheet “Munsell”, whose first few lines appear in Table 3. Saturation corresponds to chroma, which occurs in the final column. Highlight all the columns that contain entries. Click on Data, on the upper bar of the spreadsheet. A drop-down menu will appear, from which the option Sort should be selected. This option leaves individual rows untouched, but reorders them so that the entries of a user-specified column are sorted. Choose the column labeled Chroma, and specify that the order is Descending, to make the highest chromas appear first.

Brand	Identifier	Munsell specification	Total hue	Hue prefix	Hue letter(s)	ASTM hue	Value	Chroma
Blue Earth	B1A	6.82PB 3.14/9.34	6.82PB	6.82	PB	76.82	3.14	9.34
Blue Earth	B1B	6.55PB 3.20/7.35	6.55PB	6.55	PB	76.55	3.20	7.35
Blue Earth	B1C	6.75PB 2.35/2.57	6.75PB	6.75	PB	76.75	2.35	2.57
…	…	…	…	…	…	…	…	…

Table 3: The spreadsheet “Munsell” in the file PastelData.ods.

Munsell	…	1. Brand	1. Identifier	1. DE00	2. Brand	2. Identifier	2. DE00	…
7.5RP 5/8	…	Girault	328	1.6	Schmincke	034O	3.9	…

Table 4: Best pastel matches for 7.5RP 5/8, from the spreadsheet “MunsellToPastel”.

Table 5 shows the first few lines of the newly ordered data, with the most saturated pastels at the top. The rightmost column shows the highest chromas achieved, over the entire data set of 3154 pastels. The most intense pastels therefore reach Munsell chromas of about 17. The bottom of the file would show the dullest pastels, those that are nearest to neutral. By selecting Ascending rather than Descending order, the dullest pastels would appear at the top of the list, and the most saturated pastels at the bottom. The sorting technique is very versatile. For example, one could sort on Hue Letter, then on Hue Prefix, to find all the pastels in the hue range from 6BG to 8BG.

Brand	Identifier	Munsell specification	Total hue	Hue prefix	Hue letter(s)	ASTM hue	Value	Chroma
Schmincke	008D	7.89Y 9.15/17.42	7.89Y	7.89	Y	27.89	9.15	17.42
Sennelier	389	6.98PB 3.90/16.89	6.98PB	6.98	PB	76.98	3.90	16.89
Sennelier	930	0.13YR 5.54/16.85	0.13YR	0.13	YR	10.13	5.54	16.85
Great American	340.0	7.19PB 4.35/16.46	7.19PB	7.19	PB	77.19	4.35	16.46
…	…	…	…	…	…	…	…	…

Table 5: The spreadsheet "Munsell", ordered from highest chroma to lowest.

Analysis and recommendations

A major difficulty with pastels is their sheer numbers: painters and manufacturers must somehow make sense of hundreds of pastel sticks. This section first presents some analysis of the spectrophotometric pastel measurements, showing that most manufacturers produce near-duplicates, in which two pastels have almost identical colours. This analysis, and the previous Munsell analysis, lead to two practical suggestions for making pastels more understandable. First, near-duplicate or unnecessary colours can be eliminated. Second, pastels' names could be their Munsell specifications. This section discusses each suggestion in turn.

Eliminating near-duplicates

When a manufacturer produces several hundred pastel colours, making them all distinct is a challenge. This section discusses the finding that all the brands offered some duplicates or near-duplicates, that is, two pastels (from the same brand) whose colours were nearly identical. An exhaustive calculation determined near-duplicates, by evaluating the colour difference (DE) for all pairs of pastels of the same brand. Two pastels were considered near-duplicates if their DE was 2 or less. For example, the DE between the pair Blue Earth C1C and Blue Earth B2C was only 0.2; these colours would be considered identical in most practical settings. A few of the comparisons were not quite appropriate, for example when one pastel was an iridescent version of another; in that case, the pastels could have the same colour, but a significant difference in appearance. Sennelier, for instance, had five such near-duplicate pairs. Overall, however, the small number of effect pastels did not distort the results significantly, so they were included in the near-duplicate analysis.

Table 6 lists the number of near-duplicates by brand. Sennelier has 90 near-duplicate pairs, the largest of any brand. Rembrandt has only 11 pairs, the smallest of any brand. Sennelier, however, offers more than twice as many pastels as Rembrandt. As a rule of thumb, the table shows that larger sets have more near-duplicates. While not unexpected, this result does suggest that manufacturers are not systematically checking for repeated colours. This lack of checking is perhaps understandable because the sheer number of pastels makes identifying duplicates surprisingly time-consuming. A visual check requires setting a sample of each pastel directly against a sample of every other pastel. Even a small set like Rembrandt would require nearly 50,000 comparisons. A spectrophotometric analysis, of course, will readily identify pastels of similar colours, but it is unclear to what extent pastel manufacturers use colour-measuring equipment. (Many pastel companies function more like cottage industries than instrumented factories. Unison, for example, consists of less than a dozen employees, making pastels in an old rectory in Northumberland.)

Brand	Number of near-duplicates	Number of pastels
Sennelier	90	525
Great American	62	546
Schmincke	47	400
Girault	32	300
Blue Earth	22	336
Unison	20	422
Mount Vision	20	407
Rembrandt	11	218
Total	304	3154

Table 6: Number of near-duplicate pairs of pastels (each pair is from the same brand).

Since spectrophotometric measurements have an MCDM of 1, causing some uncertainty in the DEs when two pastels are compared, an ersatz duplication could occur solely because of measurement error. A colour shift due to manufacturing inconsistency, such as appears in Figure 4, could also create an ersatz duplication. Given this general uncertainty, the DEs should be used mainly as indicators of likely colour duplication, which must then be visually inspected.

As an example, Figure 7 shows the 11 near-duplicate Rembrandt pairs. Two samples have been made for each pair, and placed side-by-side. This method of comparison is the most demanding, as it heightens even small differences. While the photographic and electronic reproduction involved in Figure 7 distorts colours for the reader, a visual check of the physical samples shows that slight colour discrepancies between most of the pairs are perceptible, though just barely. One conclusion from this fact is that, despite the measurement variability, the DEs for pastels correlate reasonably well with human judgement.

Rather than taking the DE too literally, the practical implications should be considered, and in a practical setting these side-by-side discrepancies are not of much concern. Suppose that, while working on a half-finished portrait, an artist decides he would like to use the colour produced by Rembrandt 231,9 in Figure 7. By accident, he picks up Rembrandt 234,10 and applies it instead of Rembrandt 231,9. These two colours are so similar that, in this situation, the difference between them is negligible: it really makes no difference which of the two pastels he uses. If pastel 231,9 were in a box a foot from the painting surface, it would likely appear identical to pastel 234,10, when applied to the painting surface.

Since the distinction between them is of no practical import, one of them could be discarded, or better still, not produced by the manufacturer in the first place. Eliminating one of each of the 304 pairs in Table 6 would on average reduce the size of pastel sets by nearly 10 percent, without reducing the colour gamut or the fineness of colour gradation. A manufacturer could then either produce a smaller set, or replace the eliminated pastels with pastels of new colours, after checking that those new colours are significantly different from all the old colours. Either way, artists would benefit, by receiving more colours for dollar spent.

The DE cutoff for duplicates can be extended considerably. Rather than a DE of 2, one could profitably make visual comparisons for DEs up to 3, or even 4 or 5. Suppose two pastels, say of DE 4, were indistinguishable when six inches apart. This situation could occur, for example, if they were in different sections of one of the pastel boxes in Figure 1. Then even if they were clearly different when viewed side by side as in Figure 7, a painter would not have much reason to prefer one over the other in practice, so one could be discarded. Rather than setting a hard and fast rule, the DE cutoff and level of acceptable colour similarity could, and likely should, be determined by human judgement applied to particular cases.

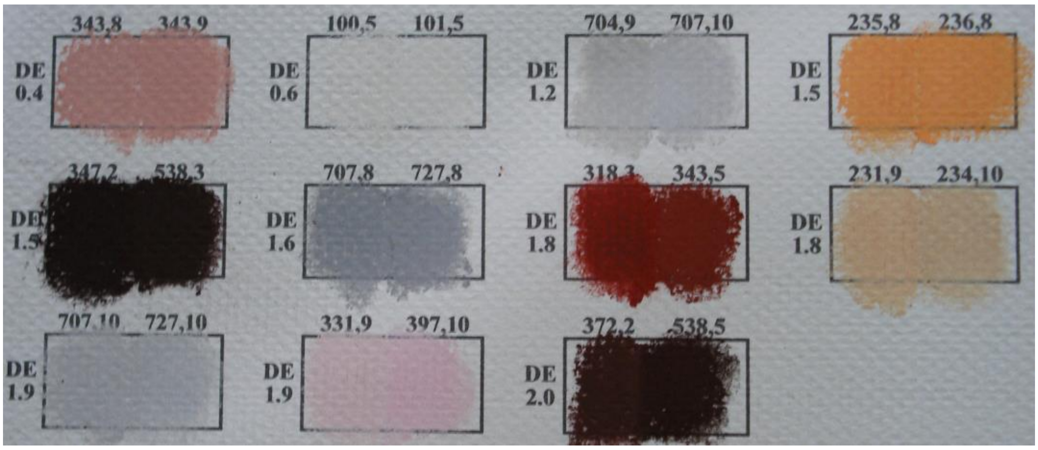

Figure 7: Side-by-side comparison of near-duplicate Rembrandt pastels.

Refining colour series

Along the same lines, a colour series is sometimes gradated more finely than needed. Figure 8, for instance, shows a series of Naples Yellow samples from the Girault line. Upon visual inspection, the difference from one colour to the next seems insignificant. The DE between 99 and 100 is only 1.2, which for most purposes is an excellent match. The DE between 97 and 98, however, is only 2.5, while the difference between 98 and 99 is 2.7. These differences can be noticed on close inspection, but would likely be overlooked at a quick glance. The remaining DEs are slightly higher: the DE is 5.1 between 100 and 101, and 4.0 between 101 and 102. These differences are more noticeable, but not immediately striking. The DE between the two pastels at the ends, 97 and 102, is definitely significant, at 13.4, and also clearly visible. Suppose three pastels were removed from the set, reducing the Naples Yellow series to 97-100-102. Then the gradations would still be fine enough for practical use, and the gamut would be just as large. Many series in many of the sets could be similarly simplified, without sacrificing any colour range.

As with near-duplicates, DEs provide helpful indications, but decisions about simplifying and refining series are best made by human observers, after visual inspection.

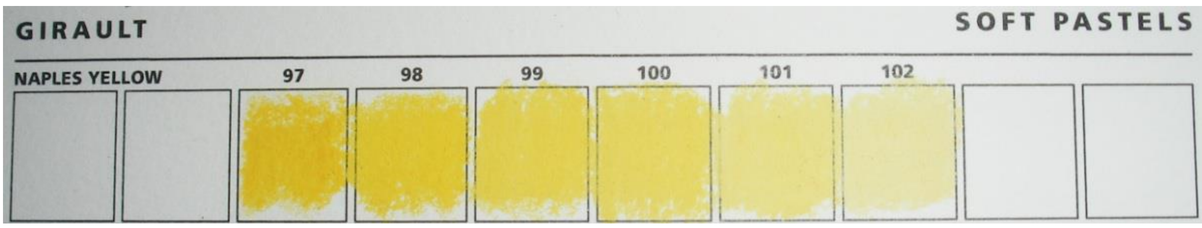

Figure 8: Girault's Naples Yellow series (reproduced from a Dakota Pastels chart).

Informative pastel names

As mentioned earlier, most pastel names (or more often, numbers) convey little information to an artist. The name Girault 97, for instance, gives no indication that the pastel is a yellow, nor that it is light and fairly saturated. Two brands, Unison and Blue Earth, give some indication of hue, and two others, Rembrandt and Schmincke, give at least a relative indication of lightness. It is recommended instead that each pastel be labelled with its Munsell specification. The name itself would then provide at least an approximate idea of the colour, and a painter could consult a Munsell book, interpolating visually if needed, for a more accurate idea.

In fact, the Munsell system can be helpful even without a book. For example, the Munsell value of Caucasian skin is about 7, so when painting a portrait, colours with Munsell value 7 would likely be used for skin in full light. Taking this idea further, shadows in portraits or figure work would be given a Munsell value of 4 if moderate light-dark contrast is desired, and a Munsell value of 2 for strong light-dark contrast. As another example, an artist who has some pastels of chroma 4, and recognises them as being subdued but still of easily distinguishable hue, knows that other pastels of about that chroma are similarly saturated. Hue markings, of course, are self-explanatory, even without a printed reference. By considering the three Munsell attributes in this way, a painter could select pastels without consulting a Munsell book.

Munsell identifiers would eliminate a difficulty that pastellists face: buying pastels without first seeing their colours. Since art supply stores that display open stock pastels for many brands, or even one brand, are few and far between, purchasers must rely on printed or electronic colour reproductions. Since these reproductions are usually inaccurate, many purchases involve a fair bit of guesswork. Using Munsell specifications as names would mitigate this guesswork.

Summary

This paper has presented Munsell specifications for 3154 artist's pastels, calculated from original spectrophotometric measurements. A sort of inverse table was also calculated, that identifies which pastels are closest to a standard Munsell colour. Artists can use this data when choosing, organising, or purchasing pastels, to avoid relying on questionable colour reproductions. The pastels' measurements have all been posted along with this paper, as both text files and spreadsheets. Other researchers are free to use this data for further analysis, and to combine it with data of their own.

Measurement analysis revealed many near-duplicates, in which two pastels from the same brand have very similar colours. The analysis also suggested some practical improvements, such as using Munsell specifications as pastel names and eliminating duplicate or unnecessary pastels, to make pastel offerings more tractable for both artists and manufacturers.

This work aims to bring some order to the plethora of commercially available pastel colours. Many painters, not to mention manufacturers, undoubtedly find the large number of pastels unnecessarily confusing. It is hoped that the results presented here will lead to simple, practical improvements that make pastel use easier and more effective.

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