Technical Brief

Use of Colour in
Data Display

Contents

1 Introduction

Colour evokes feelings and is emotional. It creates visual impact and is eye-catching, makes you look. Colour can also sort and clump to indicate what goes with what.

If colour is used well, it can enhance and clarify a presentation: the right colour can help persuade and motivate and can be the difference between boring and inspiring. Colour used poorly will obscure, muddle and confuse…. While there is a strong aesthetic component to colour, using colour well in information display is essentially about function: what information are you trying to convey, and how (or whether) colour can enhance it. Also, too many or too intense colours may overwhelm your data. People's focus is to be on the data, not its decoration.

The most important use of colour in information presentation is to distinguish one element from another, a function Edward Tufte calls "to label". A colour change in any chart signifies a change in information, or an added layer of data. But the use of colour as a label goes beyond distinguishing data. Colour is also used to define the background, draw the grid and axes, and label the chart. All visible parts of a presentation must be some colour, all of which must work together to be effective.

The aim of this technical brief is to inspire humanitarian data analysts and enhance their capacity to communicate their findings through effective charts and graphs. Too often poor choice of colour hides important data and clutters valuable information behind the noise. We cannot emphasize enough that designing appropriate charts demands as much attention as ensuring the validity and reliability of the collected data. This document is the first of a series of ACAPS technical briefs on data visualization and is divided into thematic sections of generally no more than one page, each one addressing a particular aspect of the use of colour in visual display.

Graphs included in this document have been created using Tableau software, Excel default charting options and the Excel add-in Chart tamer from the greatly missed company Bonavista Systems. Most figures are based on real data from past humanitarian assessments or crises.

It is strongly recommended to print this document in colour.

2   The colour wheel

All colours are made up of three **primaries**: red, blue and yellow. When you combine the primaries, you get the three **secondary colours**: orange, purple and green. When you combine each secondary colour with its neighbouring primary, you get six **tertiary colours**: yellow-orange, yellow-green, blue-green, blue-purple, red-purple, red-orange.

Cold colours have a high proportion of blue in their make-up, such as violet blue and some greens, having a calming effect. **Warm colours** have more red and yellow in their make-up. They are energising. When used together, warm colours appear to come forward and cool colours recede.

Complementary colours are opposite one another on the colour wheel, e.g., blue and orange, yellow and purple, red and green. When a pair of high **intensity** is placed side by side, they seem to vibrate and draw attention to the element.
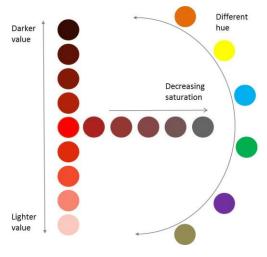
Grey lies at the centre of the colour wheel and is a neutral hue that goes with any colour. It reflects hints of the contrasting complement of any colour you pair it with.
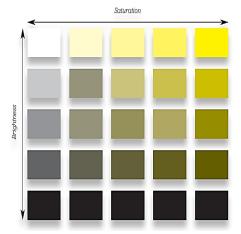
3   Colour attributes

Colours have three main attributes:

Hue refers to a specific tone of colour and is how we normally describe colour such as red, green and blue. Shade and tint are terms that refer to a variation of a hue.

Value (luminance, brightness, lightness) is how light or dark a colour is and refers to how much white, or black, is contained within a colour. Hues with a high content of white have a higher value. A darker shade of a colour can be achieved by adding black ink. Tint is a hue produced by the addition of white.
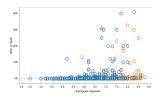
Saturation (chroma, colourfulness) refers to the purity or intensity of a colour in relation to grey. A colour with higher saturation is more intense, vivid in the same hue. I.e. a yellow becomes more intense yellow as the saturation increases.

Decreasing saturation turns the colours into shades of grey, increasing brightness turns the hue lighter but without making it grey. At maximum saturation (100%), a colour would contain no grey at all. At minimum saturation (0%), a colour would contain mostly grey and be muted.
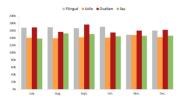
4   Colour and visual perception

"Laws" of visual perception

What we see is constantly and unconsciously organised in particular ways in an effort to make sense of our environment. As designers of tables and graphs, we should understand how to use the attributes of visual perception to clearly communicate their affordances and support their fast interpretation. The following is a list of key points, derived from the visual perception theory, that are of particular interest when using colours in visual displays.

Similarity: German psychologists developing the Gestalt theory in the 1920s observed that items that are similar tend to be grouped together. We often assume there is a relationship between items of the same colour. Through repetition of colour (but also size, orientation, texture, font, shape, etc.), we can design elements that appear related.

Salience: Attention is drawn to large perceptible differences. The most visually striking aspect of a display will draw attention to them, hence they should signal the most important information. Larger differences will be noticed first, so ensure that the most important wedge, object, or segment stands out the most. If no one element is more important, all should be equally salient. Adjustment of brightness and saturation until colours are easily distinguished or no colour predominates is a common way of creating/avoiding salience.

Dominance: When creating dominance, you design visual weights that command attention and prevail over other elements and hence create a visual hierarchy in your design. From the primary dominant element (the element given the most visual weight and placed in the foreground), design flow can be achieved to help the eye from one part of your design to the next (sub dominants-middle ground and subordinate-background) elements. A lack of dominance between elements leads to competition between them. Dominance relies on contrast, since without contrast everything would be the same. Hue, value and whitespace (but also size and density) can be used to add more visual weight to elements of your visual display.

Ask yourself:

- Which information is most important to the user?
- What are the user's priorities when your presentation starts or when they open your report?
- What does the user want or need to do first, second, third, and so on?
- Will the order of information support or hamper the user's progression through the sequence of visual displays?
- What should the user see on the screen/page first, second, third, etc?

Discriminability: To ensure that the reader detects the important data in your design, visual properties for each element must differ by a large enough proportion or the reader will not be able to tell that they are different, and hence cannot pay attention to one vs. the others.

Readability and visibility are corollary of this principle: elements and marks must be distinct enough to be noticed (i.e. distinguished from the background).

Influence of background colour

Our visual senses are not designed to perceive absolute values but rather differences in values. Our sense of brightness will depend on the context. We understand colour only in relation to its environment. For instance, four copies of this grey square are placed at various locations in a large rectangle, which varies in colour from white to black along a progressive gradient of grey. The square looks very different at each location.

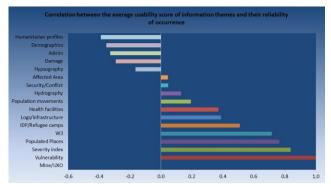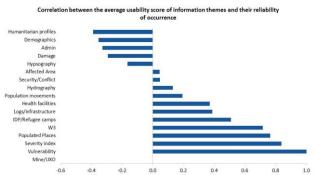Nothing has been done to alter the colour of the small rectangle. They are perceived as different from one another, because each is immediately surrounded by different shade of grey. When surrounded by light grey on the left, the small rectangle appears darker than it does when surrounded by dark grey on the right. An object's colour is perceived in contrast to the one or more colours that surround it.
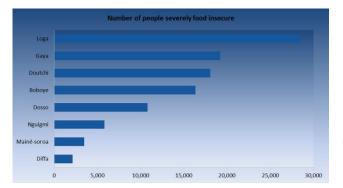
If you want different objects of the same colour in a table or graph to look the same, make sure that the background is consistent. Avoid using gradients of colour in the background or varying the background colour in any other way.
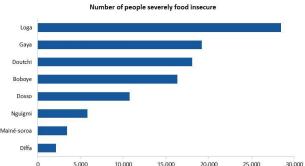
If you want objects in a table or graph to stand out, use a background colour that contrasts with the object. Choose colours carefully, always make sure that they are easy to see and that they serve the purpose for which they are intended.

Don't   **Do**

Colour, types and background

As mentioned before, some combinations of differing attributes of a visual object and its context work well to highlight, and some make it harder to perceive. This is specially the case when type is used with coloured background.

Don't forget about the readability/legibility/visibility when combining colour with type. The contrast between the type colour and the background colour must be considerable to ensure that the type remains visible.

Pair colours with care: as much as you can, stick with dark-on-light or light-on-dark combos.

POPS	Consider readability as well as visibility, the means by which viewers can see clearly. Either way you need contrast. Colours shift relative to their backgrounds: For instance, a green looks more yellow on blue and more blue on yellow. Similar colours next to each other will have soft edges that blur. Saturated complementary colours next to each other will have hard edges that vibrate.	**VIBRATES**
POPS		**VIBRATES**
POPS		**VIBRATES**
POPS		**NO CONTRAST**

Black provides the highest contrast. It is most effective to use black type on a light background. Colour type is hard to read even for readers with normal colour vision. It doesn't mean that colour and type don't mix. Pay attention to the relative values and saturation of colours when a background colour interacts with coloured type. The contrast between type and background diminishes when their brightness move closer to each other, and the type becomes less legible.

Ambient and reflected light alters colour perception. If you will be presenting in a dark room, then a dark background (dark blue, grey, etc.) with white or grey text will work fine. But if you plan to keep most of the lights on (which is highly advisable) then a white background with black or dark text works much better. In rooms with a good deal of ambient light, a screen image with a dark background and light text tends to washout, but dark text on a light background will maintain its visual intensity a bit better.

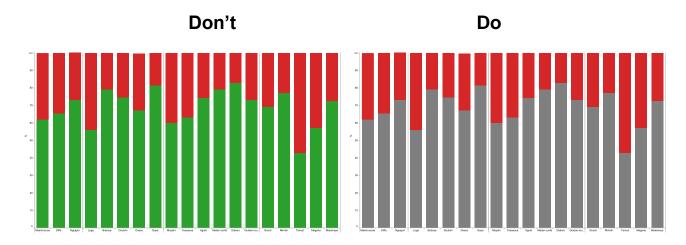| **Light room**	**Dark room**
This text color is black, which is easy to read because the light that hits each word and letter isn't reflected, but absorbed.	This text color is white, which is harder to read because the light that hits each word reflect and scatters into each other.
This text color is black on a light grey background which is easier to read than on a white background because less light is reflected behind the words.	This text color is grey, which is easier to read than white text on a dark background because less light is reflected on the words

Deficiencies in colour perception

"Colour blindness" or "colour vision deficiency" is the inability or decreased ability to see colour, or perceive colour differences, under normal lighting conditions.

About 8% of males and 0.5% of females are colour-blind in a different manner. People can have deficiencies in perceiving one colour, a colour combination or have another mutation. More than 95% of all variations in human colour vision involve the red and green receptors in male eyes. The other most common form is difficulty to distinguish between blue and yellow. It is very rare for males or females to be "blind" to the blue end of the spectrum.

To guarantee that most people who are colour-blind can distinguish different groups of data or data items that are colour coded, it is important to keep in mind the following key principle:

Select colour schemes that can be easily identified by people with all types of colour vision, taking into account actual lighting conditions and usage environment.

In choosing colours to represent data, avoid pure and combinations of red and green in the same display, as well as colour combinations in which the colours differ only in their red or green component (for example, blue and violet, because adding red to blue makes violet).

Don't	Do

No one is simply red-blue, green-blue, yellow-green, or yellow-red colour-blind. The next table includes most common colour blindness combinations. The high and medium categories are the most prevalent type and should be avoided.
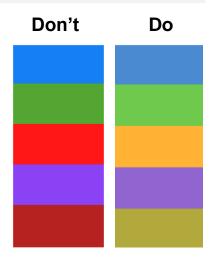
High prevalence	Medium prevalence	Low prevalence
Green and Red	Light Green and	Blue and Yellow
Green and Brown	Yellow	Yellow and Violet
Blue and Purple	Blue and Grey	Dark blue and Black
Green and Blue	Green and Grey	
	Green and Black	

A good substitute for distinguishing positive and negative values (instead of the ever popular "red means bad" and "green means good" system) is blue and red, rather than green and red.

Different hues, same value

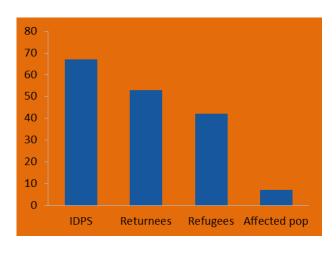Make adjacent colours have sufficiently different brightness.

Colour combinations such as red/green, yellow/violet or blue/orange are on opposite sides of the colour wheel and are considered complementary colours. Such colours intensify each other and are extremely eye-catching and vibrant. When used inappropriately, the colour intensity overpowers the underlying data and becomes aggressive. Our visual systems have difficulty registering a boundary that is defined by two colours that are of the same brightness, as in the "don't" figure (green/red pair). Used in large quantities, these colour combinations vibrate and are even distracting for readers with normal colour vision. The lack of contrast in lightness makes it virtually unreadable for colour blind users.
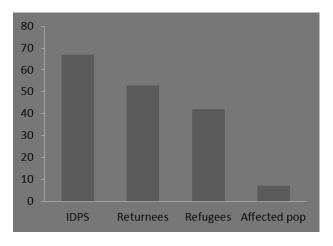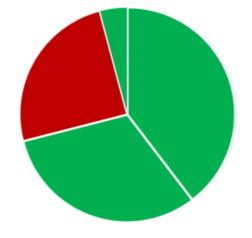
Don't   **Do**

Complimentary colour hues are very different but they can be similar in value or brightness. In the following graphs, the choice of blue/orange and red/green complementary colours for the graph design shows a lack of contrast when converted to black and white (e.g. when brightness is reduced).
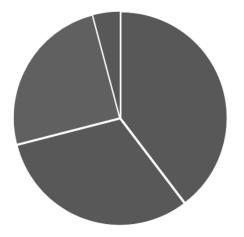
Different hue…   **…same value**

5 Key Principles on use of colour in data display

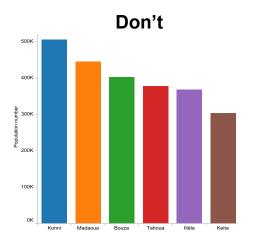### Use colour meaningfully and with restraint

Colours play an important role in enhancing, clarifying a presentation and in drawing the reader's attention, but if they are not used wisely, they can only confuse and distract from a clear understanding of the data. Appropriate use of colour requires restraint. Whenever you are tempted to add colour to a data display, ask yourself what purpose the colour serves, will it serve this purpose effectively and is there anything else other than (this particular) colour that can serve this purpose better?
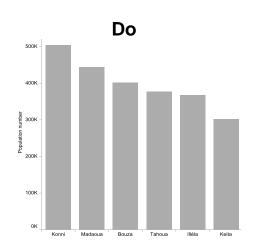
Use colour only when needed to serve a particular communication goal and to make your message clearer. Use different colours only when they correspond to differences in meaning in the data, when you need to highlight particular data, to group items or encode quantitative values.

Don't use multiple colours to represent the same kind of data or variable so the reader can focus on comparing the data.

Limit your colours. Communication is most effective when neither too much nor little information is presented.

Avoid the use of pure primary colours, except when highlighting significant data. In general, use lighter or darker shades of primary colours. Keep it simple.

Consciously or not, when people look at data display and see visual differences, they try to understand the meaning of those differences. In the above graph, colours do not mean anything, but the mind will still seek to identify different meanings of the colours, deriving attention from what really matters. The labels along the X axis already tell us what the bars represent.
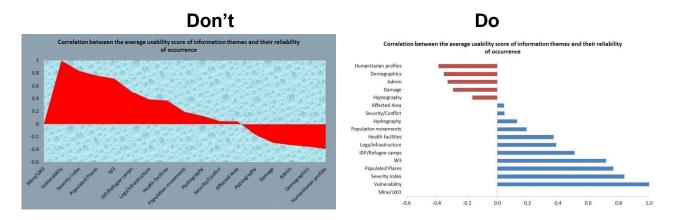
Different colours are not only unnecessary in this graph, but they also make it more difficult to see the six bars as a single related data set and discern the relationships among the bars as they range from the largest value to the smallest. In the right graph, less distraction allows to concentrate on the comparison of magnitude of each bar.

Choose the best colours for each component of your graph

Don't use colour to decorate a graph in a way that undermines its ability to present data clearly: Reduce the non-data-ink, enhance the data-ink.

In his 1983 book, *The Visual Display of Quantitative Data*, Edward Tufte succinctly stated the goal: "Above all else show the data." He introduced the concept of "data-ink ratio", the proportion of ink that is used to present actual data, without redundancy, compared to the total amount of ink used in the entire display, such as in a table or graph. The goal is to design a display that has the highest possible data-ink ratio, without eliminating something that is necessary for effective communication.

Everything that communicates actual data in a graph is data-ink. In the below example, the bars, the numeric values along the vertical axis, the labels along the horizontal axis, the labels, and the titles are all data. Despite the many data components, however, the graph on the left falls far short of an optimal data-ink ratio, specifically for the unnecessary abuse of colour.

Non-data components of tables and graphs should be displayed just visibly enough to perform their role, but no more so, as excessive salience could cause them to distract attention from the data.

In graphs, the most common non-data objects are axis lines (excluding tick marks and labels, which do encode data), background fill colours, and borders (for example, around the plot area or legend). The colours we use to display non-data components should usually be light, so they carry little visual weight. On the opposite, we want data components to dominate the landscape and be easily seen. Here are a few suggestions for a good set of default colours:
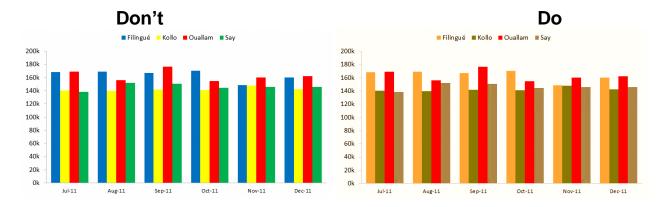
Non-data Component	Default colour	Data Component	Default colour
Axis line	Use thin grey lines of medium intensity	Bars	Use a distinct hue of medium intensity for each data series
Borders	Whether around the graph as a whole, its plot area, or a legend, if borders are needed (usually they are not), use thin grey lines of medium intensity	Lines	For thin lines, use a distinct hue of fairly high intensity for each; otherwise, use distinct hues of medium intensity
Background	Use white (or in Excel select "None" for colour)	Data points	For small points, use a distinct hue of fairly high intensity for each; otherwise, use distinct hues of medium intensity

Use soft colours, except when highlighting or distinguishing data

Use bright and/or dark colours to highlight information that requires greater attention; use lighter, soft, natural contrasting colours for the rest of the data.

Contrast and analogy are the principles that define colour design. Contrasting colours are different, analogous colours are similar. Contrast draws attention, analogy groups.
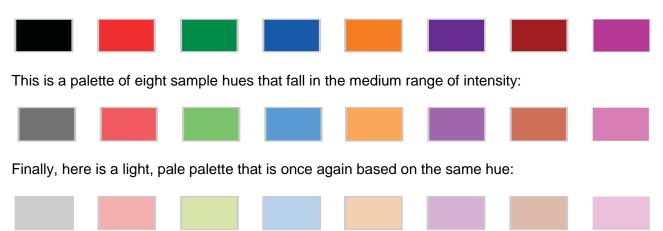
We tend to overuse intense colours, while we should use them only if we want to draw the reader's attention about something important or if it is needed to serve a particular communication goal. By using intense colours (principle of salience), we can leverage the attention-getting power of intense colours, which doesn't work if everything is intense.

In this figure, the colour intensity distracts the reader from the data. The red bar clearly stands out in the graph on the right but not in the one on the left, despite the fact that it is the same colour on both.

Below is a collection of hues that are as distant from one another as possible along the colour spectrum, but similar in intensity (that is, from light to dark and pale to bright). Using colours that are darker and greyer, or more pastel (closer to white), has many benefits. The result looks less garish and more sophisticated, is easier to duplicate in print, and allows the use of saturated colours for highlighting.

This is a bright, dark palette of the same hue (technically, black is not a hue, but the complete absence of colour), which could be used to highlight data:

This is a palette of eight sample hues that fall in the medium range of intensity:

Finally, here is a light, pale palette that is once again based on the same hue:

Notice that these colours are not only easy to distinguish, they are also well balanced. No colour pops out more than the others.
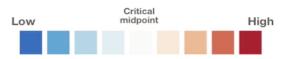
Use palettes appropriately

Categorical/qualitative palettes include colours that are distinctly different from each other. They are most successfully used to represent categorical data, when data falls into distinct groups (e.g. provinces)

Sequential palettes will typically be a single hue that ranges either from neutral to bright or from light to dark. They are used successfully with ordinal or interval data, when ordering values from low to high. Any measure that shows a continuous range of values can be "mapped" with a colour gradient.

Diverging palettes are basically two sequential palettes that meet in the middle with a neutral colour. They allow you to have two anchors, such as "agree and disagr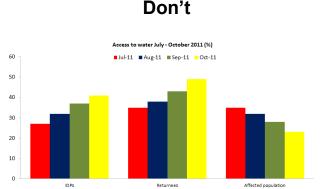ee" in a likert scale, and easily distinguish by colour. They are also used successfully with ordinal or interval data. The midpoint and end points should be meaningful (for instance zero).

Cynthia Brewer provides different colour palettes combination for reference at www.colorbrewer2.org/. While designed for thematic maps, her colors are also useful for charts, graphs, and other data presentation displays.

Try to use no more than two colour palettes in a same presentation. Make sure to use non-overlapping colour scales when displaying different views.
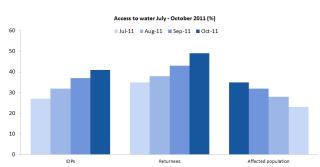
Avoid adding colour encodings with more than 12 distinct values. Once you choose a palette, stay with it for the entire presentation so all visuals look coordinated. Make sure it is reproducible in black and white or photocopy-able.

When using colour to encode an ordered range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colours for low values to increasingly darker and brighter colours for high values.
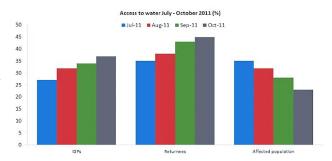
Don't

Use graduating shapes (lighter or darker) of one colour to signify a change in data (top right graph).

If you want to show magnitude instead of trend, use colours on the same side of the colour wheel to keep a multiple bar chart clean and crisp (downright graph).
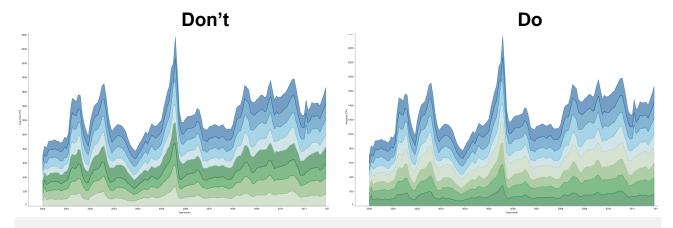
Do

Avoid setting the scale with alternating light and dark colours in the middle of the scale. The eyes can't draw meaningful comparison jumping between light and dark shades
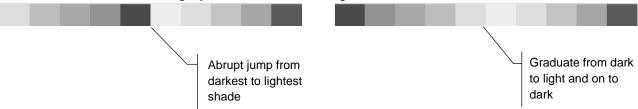
A colour scale should graduate from lightest to darkest or vice versa, regardless of the colour.
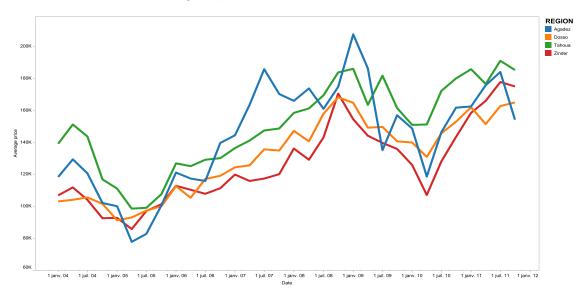
Don't	**Do**

A simple test is to convert the colour scale to black and white and check for smooth progression from light to dark
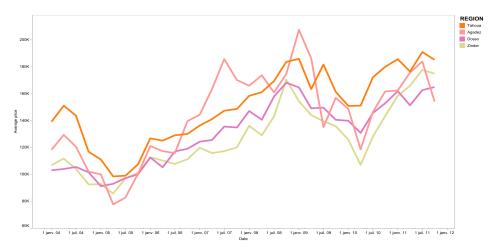
Used colour scale:

Convert the colour scale to grey scale to test for the gradation:

Abrupt jump from darkest to lightest shade
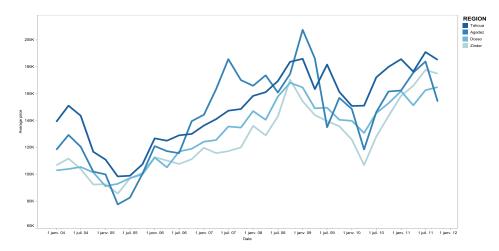
Graduate from dark to light and on to dark

Below are some more practical examples of different palettes applied to the same data to see how different choices affect the emphasis and message. The following is a line graph, showing average price of a cow in different regions of Niger between 2004 and 2011. Each region is labelled a distinctive colour of similar value. In this graph, colours are approximately equally spaced around the colour wheel to create the largest possible hue difference.
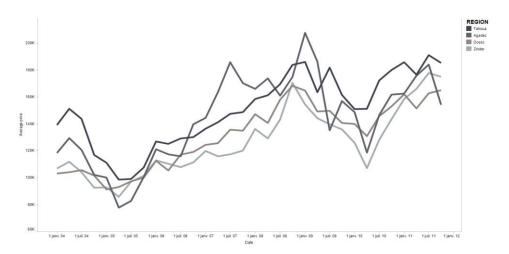
It is not necessary, however, to make the hues so different. The next graph is an example that spans only a segment of the colour wheel, yet still creates distinctly different colours. Which to use can be chosen to comply with a pre-defined category or simply by aesthetic preference.

The same approach can be used to render the image entirely in shades of grey, as shown below. Shades of grey will be adequate for many needs. It is also most cost-effective to print and easy to duplicate.
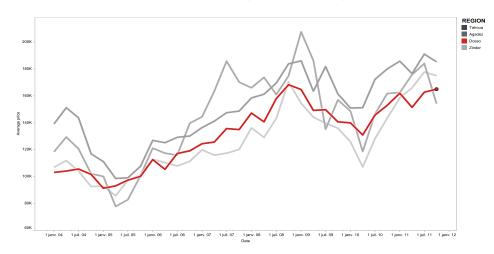

Another approach is to use a common hue that varies in Chroma and value. The next graph uses a palette of different shades of blue, ordered from light to dark. Such a progression suggests an ordered relationship and the colouring reinforces the sequential order of the data.

The following combination also provides the perfect background for highlighting with a bright colour. In this example, the focus is clearly the Dosso region, instead of all four regions equally. Use bright of dark colours such as red and black to emphasize the important line.
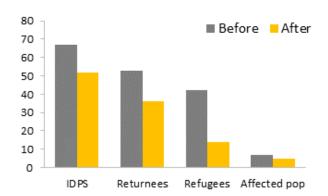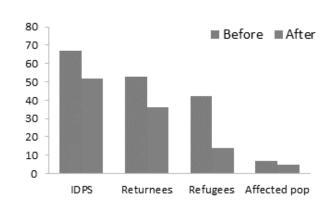
Use of legends

Avoid using colour coding or using colour contrasts alone to express information

Employ redundant visual clues such as shapes, positions, line types, font, labels and legends rather than relying on hue alone. This not only helps colour blind people, but also aids understanding by normally sighted people

A legend that relies on colour alone to convey information can be extra work for general users and possibly indecipherable for colour-blind readers. Legends are often difficult for most readers since our eyes cannot draw immediate distinction between small colour swatches, especially when there is not enough contrast in colour and brightness (see previous section). Printing in black and white may result in loosing readability.
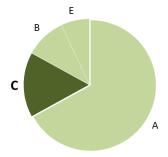
Don't

If the colour meaning isn't obvious, or your visualization does not obviously label the colour, then make sure to include a legend.
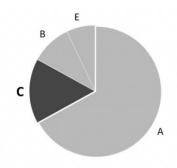
Clearly state colour names, especially when users are expected to use colour names for communication and presentation purpose

Label directly on chart elements. A darker shade or a different colour can be used to highlight the focal point or a particular segment

Direct labelling is helpful for all the readers. If you must use a legend, be sure the colours have high contrast in brightness. In addition to using darker shades to highlight a bar or a line, we can set the label in bold typeface. See segment **C** in the pie chart. This redundant means of presenting information will guarantee all information conveyed with colour is also clear without colour.

Do

Colour meaning

Be aware of context and any surrounding visual indicators that may trigger one association rather than another.

Always take into account the cultural values of your primary audience and the symbolic meanings of different colours for that audience. Choose semantically meaningful colours. Leverage common colour associations.

Colour can communicate emotion and feeling. For example, red can be associated with positive feelings like excitement and desire, but also with negative feelings of danger and alarm. One common use for colour in data visualization is using red for severity (like a lack of access) and green for a secure status.

Colour may not have a natural ordering, but it does carry a lot of cultural conventions, including many common emotional or aesthetic associations. Some of these include:

Meaning in color

Earthtones
Gentle browns, blues. Calming, sinks into the page

Unnatural colors
Alarming, unnerving, draws attention.

Cool
Soothing, restful, calm

Warm
Optimistic, active, vivid

Increasing color intensity
Increasing saturation and brightness draws the eye and means the point is more important

Red is associated with warning, danger, and warfare. It can also be associated with passion - either love or anger - and blood. In the East it is associated with good luck and prosperity.

Green is associated with nature, the earth, environmentalism and renewal. It can also be associated with permission to move ahead, clearance, etc. (as in "green light") - especially when paired with red.

Yellow is associated with happiness, sunshine, and playfulness. However, on its own or in large fields, it can be irritating. It is also associated with caution.

Blue is associated with water, coolness, and calm. Depending on the shade, it may be associated with religion or the military.

Black is associated with mourning and death, but also with luxury and sophistication.

White is associated with purity, innocence, and weddings, but also with sympathy and the afterlife (and therefore, with death).

Pink is associated with affection, imagination, and childishness. Light pink is associated with young girls, and light blue with young boys - especially when paired together.

Grey is associated with neutrality, conservatism, modesty, and maturity.

Orange is associated with fire, energy, and - in the East - spirituality. It is named for the fruit, and so can also be associated with health and vigour.

Brown is associated with dirt, leather, stone, and "earthiness." It may also be associated with animal waste.

Purple is associated with royalty (nobility) and magic (falsehood or artificiality).

Clearly, some of these associations are more desirable than others, and many colours carry associations that are radically different or even directly contrary to each other. For example black and red signifies happiness to Chinese people, and the colour white is associated with death and mourning. To know more about variations between culture and countries, it is advised to research on "colour symbolism" on the web before to present your design your graphs.
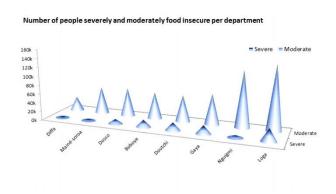
Use of visual effects
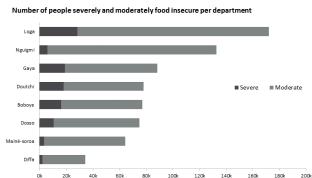
Do not use 3D charts. Use gradients appropriately.

The problem with 3-D charts isn't that they don't look pretty: They do. But effective is not the same as beautiful.
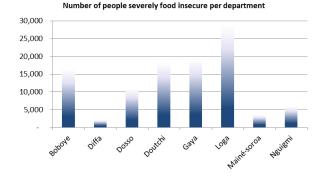
Extra dimension or illusion of depth reduces the visual precision of the chart. With a 3-D chart, you can't as easily or precisely measure or assess the plotted data. Effects (3D) introduce problems that clearly undermine the clear communication we aim for in our graphs. They add only superficial appeal, but rarely any real value. Adding a pseudo-third dimension distorts the data, emphasizing some wedges at the expense of others. Adding perspective or tilting the bar distorts the data even more.
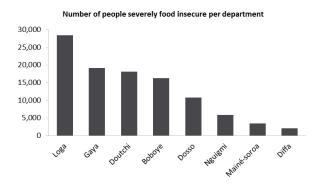
In a graph, it is important to display data as simply and clearly as possible, as in the following "Do" column.
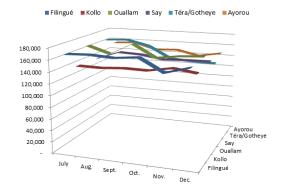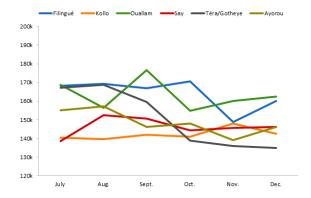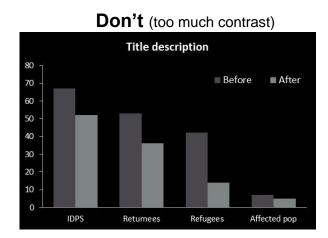
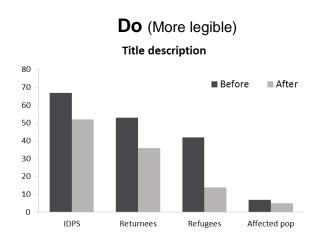| **Don't**	**Do**

Working in black and white

When designing your graphics, consider using contrasting thicknesses, tints, line styles or shapes first, before considering color.

A graphic can be colourful even in black and white. The use of different shades of black can create layers of texture and the contrast with light and dark shades can be used to emphasize the focal point. It is also a good practice to start designing visuals in black and white or monochrome first, and then add colour. It will ensure that the solution doesn't rely on colour to work, plus guarantee black and white printing or photocopying will not jeopardize all your colour encoding efforts.
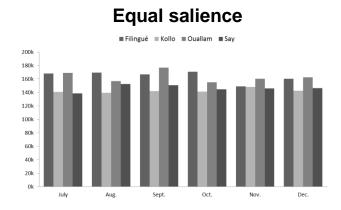
Special care to contrast

As mentioned before, black and white creates the highest contrast possible. Because black and white are not really colours, they are said to represent achromatic contrast and the human eye is more sensitive to this form of contrast than to others. It implies a constant trade-off between contrast and readability: Too little contrast makes it hard to differentiate between elements and to read, too much contrast creates so much vibration that it diminishes readability.
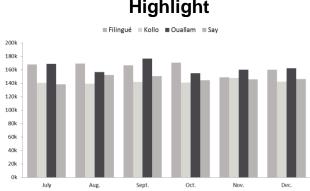
Use darker shade to emphasize/highlight the important data and lighter shade for secondary and tertiary elements.
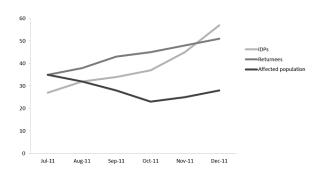
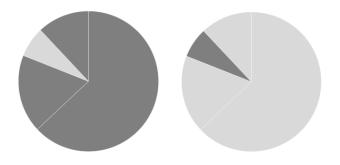Establish salience using grey colour scale.

Shades of black can be used to separate different levels of information. Sufficient contrast brings out the important message. The important line is in black.

The highlighted segment can either be a lighter shade or a darker shade.
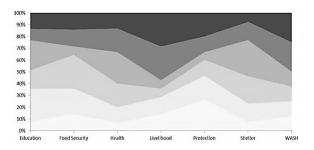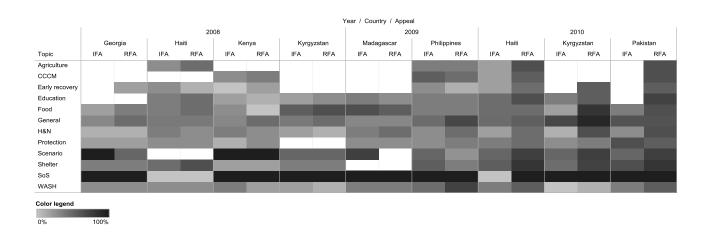

Moderate use of boldfaced type and shading can help emphasize the important data.

Market	July	Aug.	Sept.	Oct.
Filingué	168,100	169,375	**166,800**	170,500
Kollo	140,400	139,500	**141,900**	141,000
Ouallam	168,814	156,469	**176,700**	154,750
Say	138,529	152,344	**150,513**	144,375
Téra/Gotheye	167,050	168,782	**159,631**	138,709
Ayorou	155,200	157,250	**146,100**	147,875
Gouré	175,323	188,835	**191,656**	179,390

A grey scale can be used to differentiate levels of gradation.

Black and white (but also coloured) heatmaps can be used to encode multivariate data (several variables that measure different aspects of some set of entities). They are usually structured as a matrix of columns and rows. In the figure below, the % of availability of specific topics has been encoded as a continuous range of greyscale colors, ranging from the lightest for the lowest value through the darkest for the highest value. Here also, black and white color works fine to visually highlight important data across a large range of values.

Colour and other types of visuals

An **Org chart** not only displays titles but also functional and hierarchical relationship between them. In presenting any organizational chart, keep the graphical elements simple. Avoid using frames around each function or name, which add no information. Keep the chart clean so the reader can focus on the relationships. Here, the left chart displaying the core functions (red boxes) and the ad hoc functions (blue boxes) within an assessment team have been replaced in the right chart by highlighting the core function only through bold type and removing the useless frames for better visibility and readability.

Don't   **Do**

A detailed work plan helps you anticipate potential roadblocks and plan for further required resources. The following figure details activities related to joint assessment:

You can use colour to differentiate time period or assignments to different groups, individuals or to signify the importance of the tasks.

6 Conclusion

An effective design presents information in an organized manner, making it easy for the viewer to understand the roles and the relationships between the elements. Using distinct colours can be an effective way of setting apart elements and highlight or group important data/segment. **The principles** specified in the previous sections can be summarized as: assign colour according to function; use contrast to highlight and analogy to group; control brightness contrast for legibility. Soft colours should be used except when you wish to highlight specific data. Same colour should be used, except when colour differences are needed to indicate differences in the data. Last but not least, use a single, neutral background colour.

Colour use aims at:

- Conveying emotion and meaning, creating aesthetic and emotional appeal, attract the eye, signal the reader where to look first
- Organize or changing perception of space, parsing the visual field into chunks, changing apparent size
- Layering: foreground and background
- Encode quantitative values, showing similarities and differences, identify uniqueness and distinctness, creating emphasis / highlight, attracting attention
- Linking/grouping spatially separated

Using effectively colors include taking into consideration the following design principles:

Communication is most effective when **neither too much nor too little information is presented**. The first thing you need to do when beginning to prepare a graphic is to decide on exactly what message you want to convey. This is crucial because users expect to see all but only the relevant information. Presenting too little information will puzzle the user, and presenting too much will overwhelm them with needless detail and clutter your message behind the noise.

A good organizing principle is to **define categories of information**, grouped by function and ordered by importance. An effective use of colour will group related items and command attentions in proportion of importance, and all will be legible.

Don't overestimate the power of colour. The number of colours we can easily distinguish is incredibly low. For instance, it is estimated that the maximum number of categorical colours we can easily detect in a representation is around 12. Compared to other data features like position, length, size, it is visually perceived less efficiently. In addition, short term memory can't simultaneously retain the meaning of more than 9 different hues.

Always provide a colour legend. It is one of the most common mistakes in visualization: some data feature is represented with colour but then there's nothing in the interface that tells you what this colour represents. A colour legend is always needed and not only for labelling.

Use colour with extreme care and parsimony (above all, do no harm!). As colour is added to an interface, it soon becomes noise. Learn to use it with extreme care and parsimony. Realize that if colour is used to represent a data feature, it is extremely hard to use it for some other elements in the display or your document. Using colors that are darker and greyer or more pastel (closer to white) has many benefits. The result looks less garish and more sophisticated, is easier to duplicate in print, and allows the use of saturated colors for highlighting.

Use greys and grey scales. The best use one can find of colour is to understand how powerful colourless graphics are. In particular shades of greys are extremely useful in data representation and rarely "do harm", especially for segmenting the visualization space and organizing it in spaces. Begin your graph design using only tones of grey. Don't introduce any colour until the design is working in black and white. Chances are, your decisions on palette and colour will be made a lot easier because the design – or elements of the design – aren't relying on colour for their function or meaning. If your graph is already including colours, print the chart in black and white or make a copy in grey scale to test whether the contrast in values, not colours, is sufficient. The colours work if the chart holds up in black and white.

Don't represent unordered data with ordered colours. Some people use different intensities of the same "hue" to represent categories. Use distinguishable hues and, if possible, make them of the same intensity.

7   References

This technical brief was largely inspired by the work of Stephen Few and Dona M. Wong. We strongly recommend referring to their excellent work on graph and table design. Stephen Few provides a three day workshop on data visualization which is a must-do for any person interested in learning more about efficient data exploration, visualization and communication.

Practical Rules for Using Colour in Charts, Stephen Few, 2008
http://www.perceptualedge.com/articles/visual_business_intelligence/rules_for_using_colour.pdf

Effective Communication through Visual Design: *Tables and Charts,* Rebecca Carr, Mary Harrington, 2011
http://www.achievingthedreammembers.org/Portal/Modules/38ef8aeb-b8e1-4737-914a-0ddc6a0726c8.asset

Now You See It, Stephen Few, 2008

Uses and misuses of colour, Stephen Few, 2005,
http://www.perceptualedge.com/articles/dmreview/colour.pdf.

The visual display of quantitative information, 2nd Edition, Edward Tufte, 2001

Choosing Colours for Data Visualization Maureen Stone, 2006) http://www.perceptualedge.com/articles/b-eye/choosing_colours.pdf

The Wall Street Journal: Guide to Information Graphics, Dona M. Wong, 2010

An Introduction to Visual Multivariate Analysis Stephen Few, 2006
http://www.perceptualedge.com/articles/eye/visual_multivariate_analysis.pdf

The Tableau Visual Guidebook, 2012, http://mkt.tableausoftware.com/files/VisualGuidebookTabRead.pdf

Best Practices in Graphical Data Presentation, Ray Lyons 2010

Using Colour, Wolfang Aigner, 2010

Color advice for cartography, Cynthia Brewer, 2012, www.colorbrewer2.org/

Visual Expert, Basic colour and design FAQ, http://www.visualexpert.com/FAQ/cfaqhome.html

Inspirationbit, 2011, http://www.inspirationbit.com/dos-and-donts-colour/

Online colour picker, http://www.infobyip.com/htmlcolourpicker.php

DOMO, Best practices for displaying information, 2012,
http://wiki.domo.com/confluence/display/DC50/Best+Practices+for+Displaying+Information

Visuale, A list of references to learn how to use colour, 2009
http://diuf.unifr.ch/people/bertinie/visuale/2009/05/infovis_colour_theory_in_few_li.html

Designing for the web, 2011, http://designingfortheweb.co.uk/book/part4/part4_chapter17.php

White space is not your enemy, Kim Golombisky & Rebecca Hagen, 2010

ExcelChart, Perception: Gestalt laws, 2010, http://www.excelcharts.com/blog/data-visualization-excel-users/gestalt-laws/

Graph design for the eye and mind, Stephen M. Kosslyn, 2006