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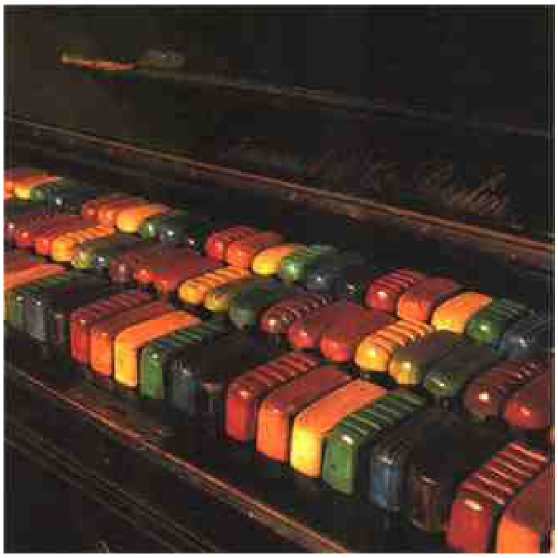
Investigation of the correspondence between musical notes and colours.

Report by Robert Bray and Sebastián Griz, August 2011



In his talk on creativity and style, Sebastián Griz told us about **Xul Solar** (http://en.wikipedia.org/wiki/Xul_Solar), an Argentine artist and philosopher, who found a correspondence between the frequencies of musical notes and the colours of the visible spectrum, and devised a piano with keys coloured according to this relationship.

Intrigued by this idea, Sebastián and I set about creating a table of the frequencies of musical notes that would extend through enough octaves to reach the frequencies of visible light.

Sebastián had a table of the frequencies (to two decimal places) of the 12 notes of the western tonal system for the octave C4 (middle C) to B4. We created an Excel spreadsheet that would double the frequencies of these notes as many times as required.

It turned out that the frequencies had to be doubled 40 times to get into the range of the frequencies of visible light. Theoretically, you would need a piano with 444 extra keys to reach the first C whose frequency would correspond with a colour of the spectrum. Here is a section of the spreadsheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	octave no.	**C**	**C#**	**D**	**D#**	**E**	**F**	**F#**	**G**	**G#**	**A**	**A#**	**B**
2	4	**261.63**	**277.18**	**293.66**	**311.13**	**329.63**	**349.23**	**369.99**	**392.00**	**415.30**	**440.00**	**466.16**	**493.88**
3	5	5.23E+02	5.54E+02	5.87E+02	6.22E+02	6.59E+02	6.98E+02	7.40E+02	7.84E+02	8.31E+02	8.80E+02	9.32E+02	9.88E+02
4	6	1.05E+03	1.11E+03	1.17E+03	1.24E+03	1.32E+03	1.40E+03	1.48E+03	1.57E+03	1.66E+03	1.76E+03	1.86E+03	1.98E+03
5	7	**2093.00**	**2217.46**	**2349.32**	**2489.02**	**2637.02**	**2793.83**	**2959.96**	**3135.96**	**3322.44**	**3520.00**	**3729.31**	**3951.07**
6	8	4.19E+03	4.43E+03	4.70E+03	4.98E+03	5.27E+03	5.59E+03	5.92E+03	6.27E+03	6.64E+03	7.04E+03	7.46E+03	7.90E+03
7	9	8.37E+03	8.87E+03	9.40E+03	9.96E+03	1.05E+04	1.12E+04	1.18E+04	1.25E+04	1.33E+04	1.41E+04	1.49E+04	1.58E+04
8	10	1.67E+04	1.77E+04	1.88E+04	1.99E+04	2.11E+04	2.24E+04	2.37E+04	2.51E+04	2.66E+04	2.82E+04	2.98E+04	3.16E+04
9	11	3.35E+04	3.55E+04	3.76E+04	3.98E+04	4.22E+04	4.47E+04	4.74E+04	5.02E+04	5.32E+04	5.63E+04	5.97E+04	6.32E+04
10	12	6.70E+04	7.10E+04	7.52E+04	7.96E+04	8.44E+04	8.94E+04	9.47E+04	1.00E+05	1.06E+05	1.13E+05	1.19E+05	1.26E+05

The notes on an 88 key piano range in frequency from 27.5Hz (A0) to 4186.01Hz (C8). That is to say they vibrate the air from around 27 times per second to just over 4000 times per second.

The frequency of the light in the visible spectrum ranges from 400THz (lower limit of red) to 789THz (upper limit of violet). That is to say that the electric and magnetic vectors of the light oscillate from around 400 million million times per second to 789 million million times per second. (Notice that this is almost a doubling, which is why we get a correspondence of one octave of musical notes to the range of colours in the visible spectrum in the table below.)

Here's the section of the spreadsheet that gets up to those frequencies.

40	42	7.19E+13	7.62E+13	8.07E+13	8.55E+13	9.06E+13	9.60E+13	1.02E+14	1.08E+14	1.14E+14	1.21E+14	1.28E+14	1.36E+14
41	43	1.44E+14	1.52E+14	1.61E+14	1.71E+14	1.81E+14	1.92E+14	2.03E+14	2.16E+14	2.28E+14	2.42E+14	2.56E+14	2.72E+14
42	44	2.88E+14	3.05E+14	3.23E+14	3.42E+14	3.62E+14	3.84E+14	**4.07E+14**	**4.31E+14**	**4.57E+14**	**4.84E+14**	**5.13E+14**	**5.43E+14**
43	45	**5.75E+14**	**6.10E+14**	**6.46E+14**	**6.84E+14**	**7.25E+14**	**7.68E+14**	8.14E+14	8.62E+14	9.13E+14	9.68E+14	1.03E+15	1.09E+15
44													
45		**C**	**C#**	**D**	**D#**	**E**	**F**	**F#**	**G**	**G#**	**A**	**A#**	**B**

I used a table that shows the frequency ranges of the seven main colours of the visible spectrum to get approximate colours for the notes. We're grateful to Laura Cabral for providing the following table of RGB values for our light frequencies.

NOTES	RED	GREEN	BLUE
F#	27	0	0
G	131	0	0
G#	229	19	0
A	255	143	67
A#	255	177	67
B	139	255	67
C	67	182	91
C#	41	97	127
D	29	71	127
D#	67	0	137
E	29	0	47
F	11	0	17

These values produce the following set of colours.

Descriptions of these colours are:

F#: **dark redish brown**
G: **mahogany**
G#: **red slightly orange**
A: **orange pink**
A#: **yellowish/orange pink**
B: **yellow green**
C: **bluish green**
C#: **bluegreen**
D: **blue**
D#: **red purple**
E: **deep purple**
F: **black purple**

Robert's reservations

Sound waves are mechanical waves: a vibration of the air (or other medium) in which they travel. Light waves are electromagnetic waves and although they have properties that correspond to the properties of sound waves (frequency, wavelength, speed, etc.), they are a very different phenomenon. Therefore any relationship that might be found between the frequencies of musical notes and colours can be for the purpose of intellectual entertainment only! For a soundwave with a frequency in the range of hundreds of THz to have an amplitude of only thousandths of a millimetre, the molecules of the medium in which it is travelling would need to be moving at around the speed of light. This would introduce relativistic effects that would effectively prevent such a wave from existing.

However, there have been plenty of other investigations carried out into the relationship between notes and colours, and there's no shortage of adherents to the belief that such correspondences are meaningful. Music and colours both have strong emotional effects on people, and psychological research can find ways to relate the two. But whether they're connected in the same way for all people, or in any absolute, objective, physical way is another question.

Sebastián's additional thoughts

We have to remember that our eyes don't have a linear response, so some frequencies have got less or more brightness than others. I'm also surprised by something... the red component proportion starts to increase again at the end of table; may we have to consider low ultraviolet as the first red's harmonic, as it doubles its frequency? It's not unreasonable to think that this has an effect which excites the red-perceiving cones, just as the harmonics excite not only the strings tuned to the fundamental note, but also their multiples...

As to whether the correspondance is meaningful, or intellectual entertainment only, I think that depends on the purpose we are using this information for. In art, this correspondance can be used in the same way that metaphor is, and even can be expanded to other equivalent features: tone-note, saturation-harmonic purity, brightness-volume…

Sometimes there are other more useful ways of thinking than science, specially (but not exclusively) in art. As Don Juan said, "it's not what you know what matters, it's what you do with that".

My only reservation is that, even being visual animals, our vision has a handicap… we basically see in three colors (red, green & blue), and by combining these three we have an approximate perception of all the spectrum. Even when each pure color have its own wavelength, in the way we perceive, different combinations of light wavelengths can produce the same colour. Imagine if we could only hear three notes (e.g. G#, B & D), and blending them in different volume combinations could make us hear all the notes of the octave…

Regarding Xul Solar's piano: as you can see, there are 3 slightly different red colours in the keyboard of Xul Solar... it's reasonable to think they are **F#, G, & G#**, so in this keyboard I deduced this correspondance:

F#: red
G: scarlet
G#: reddish orange
A: orange
A#: yellowish orange
B: yellow
C: yellowish green
C#: green
D: bluish green
D#: blue
E: purple
F: deep purple

I heard that this piano had quarter-tones, but I don't understand why it has 18 notes in each octave… and the ones above equal to the ones below. I believe it's more reasonable to think that it's for convenience, so you have the same organization starting in any note (you can play up/down with the same figure in any note, using the 1st & 2nd or the 2nd & 3rd rows). And did you note every Major 3rd there are rough keys? Maybe some indication for the fingers?

It's a beautiful and easy to remember correspondance, but if we want to be accurate, the correspondence between the notes and colours has to be as we've presented above using RGB values that correspond to the light frequencies.

Further reading

http://www.endolith.com/wordpress/2010/09/15/a-mapping-between-musical-notes-and-colors/

(This shows similar but less precise results to ours.