Red on red: a framework for the interaction of colour in the built environment

Esther Hagenlocher and Landry Smith

School of Architecture and Allied Arts, Department of Architecture, University of Oregon, USA
Emails: ehg@uoregon.edu; landrys@uoregon.edu; els@landrysmith.com

This project is based on a proposal for a temporary experimental installation for the International Garden Festival at Les Jardins de Métis in Grand-Metis, Quebec, Canada. Building upon Josef Albers's seminal primer on colour theory, *Interaction of Color*, the garden project was designed to establish a new framework for experiencing and testing colour perception and sensation in a larger field. This research examines the hypothesis, that the *Interaction of Color* is valuable architecturally, aesthetically, and in terms of performance, both in interior architecture and in architecture generally. The effect of colour can be increased without changing people's perceptions of the colour in a space by understanding the interaction of colour with the larger built environment in nature or within larger fields. The proposed research project focuses on the connection between design principles and colour interaction in order to develop understanding of how to optimise spatial efficiency, performance, and visual comfort. This research further explores through the process of testing and evaluation of experiments in various scales and media (rendering, collage, mock-up, etc.) the potential for using colours to expand, confuse, conceal, and misrepresent built three-dimensional forms.

Received 21 April 2017; revised 31 July 2017; accepted 2 August 2017

Published online: 29 September 2017

Introduction

This research project is based on a proposal for a temporary experimental installation for the International Garden Festival at Les Jardins de Métis in Grand-Metis, Quebec, Canada. Building upon Josef Albers's seminal primer on colour theory, *Interaction of Color* [1], the garden project was designed to establish a new framework for experiencing and testing colour perception and sensation in a larger field (Figure 1).

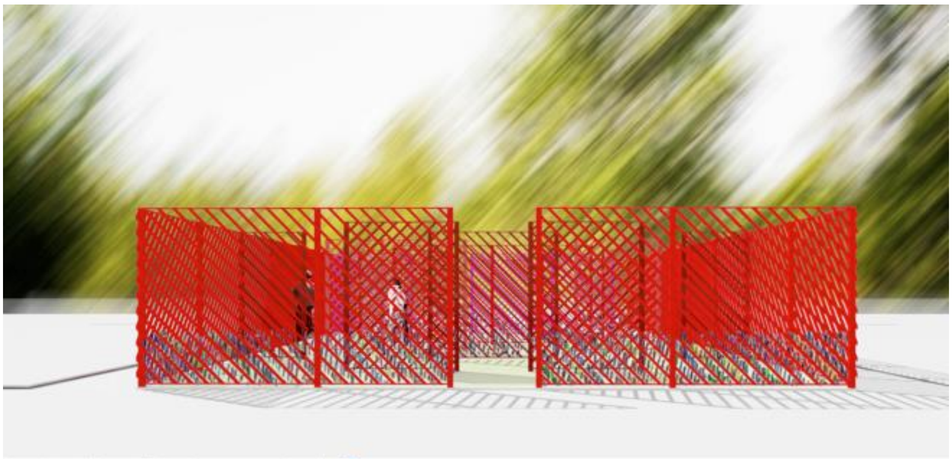


Figure 1: "Red on Red" – view towards the garden entrance elevation.

The proposed garden installation measures 10×20 metres and is surrounded by an open perimeter fence, with entrances located at the east and west ends. Inside are seven walls or fences that organise the plan into eight equal bands, each measuring 10×2.5 metres. Breaks in these interior fences delineate larger spaces and allow for numerous pathways through the enclosed garden (see Figure 2).

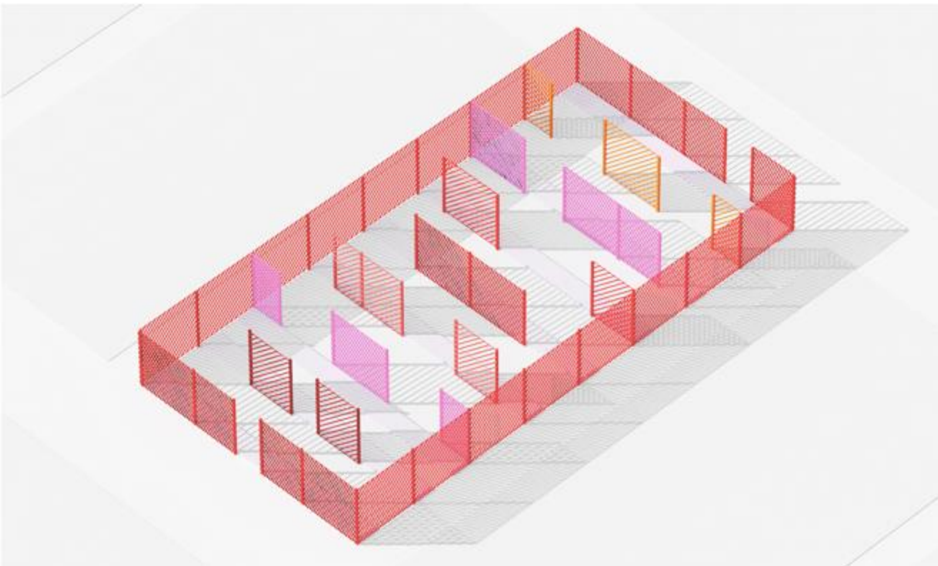


Figure 2: "Red on Red" – concept axonometric.

Countering the geometric rigor, the breaks in the fences filter visitors through the garden, loosely defining larger spaces and providing entry points on the east and west sides along the main pathways. Continuous beds of thyme are planted along the organising bands and are crossed over by visitors. All the trellis fences are made of painted wood and are characterised by fine slats oriented at ±45 degrees, alternating at each layer, resulting in a series of spaces of intensifying colour and opacity at eye level. Recalling the common wooden lattice, these diagonals establish a decidedly supergraphic element in the garden project. The tectonic expression serves to abstract the modest methods of construction and articulates a complex set of colour effects through minimal means.

The perceptional dimensions of colour were selected on the basis of contrast and interest in interaction, participation, and exchange, of both the space itself and the viewer. A range of reds was selected for high contrast with the greens of the surrounding forest and garden plantings, underscoring the contrast between natural forms and the graphic tectonic. The perimeter fence is a pure red (RAL 3001). The other fences are painted in varying red hues, some of which are tinted (white added), others toned (black added). Since colours of equal brightness but differing hues tend to assume the same spatial plane, the three-dimensional organisation of the garden is at times challenged, and an element of spatial ambiguity is introduced.

This installation was not actually built, so all the experiments and perceptions have been tested and evaluated, both manually and digitally, with models (scale 1:200) and in physical interior and exterior environments with mock-ups (scale 1:7.5 and 1:1). The specifications of the reds were based on previously conducted experiments on colour reflectivity. These experiments suggest that although our aesthetic valuing of deep colours often conflicts with the high reflectivity that is more effective for daylighting, the average reflectivity of an interior space can be increased without changing people's perceptions of the colour in the space.

Initial experiments

The initial experiments were conducted using colour models of rooms to compare subjects' perceptions of colours and reflectivity to actual measured reflectivity. These experiments will be repeated in real physical environments. Although these were preliminary experiments, the implications of the results were of sufficient interest to continue the work. Observations have been collected, and since the set-up and models can be reconstructed, the experiments provide a source of data for other colours. Multiple personal tests are now being conducted, and the number of human subjects will be increased in a larger experiment.

The hypothesis is that low reflectivity interior surface effects like rich colour can be achieved with little change to the space's overall reflectivity. In the case of rich colours, some surfaces (for example, walls) play a less important role in delivering average room reflectivity than others and are candidates for locating colour if those same surfaces are primary to the perception of the overall colour of the space. Generally speaking for the USA, Canada and Central Europe, the higher the reflectivity of a space the more evenly daylight is distributed within the space, diminishing the contrast in brightness between the window and the walls, which results in greater visual comfort. Visual comfort increases with the use of daylight, for which the human visual response is optimised, offering both physiological and psychological benefits. There is an opportunity to develop integral design early in the design process that incorporates reflective surfaces to help satisfy the genuine desire to have natural light in a room.

Experiment 1: the colourfulness of colour

A previous experiment that pertains to this project was conducted to test people's perception of colourfulness. Colourfulness and chroma are described by Fairchild as comprising one dimension of colour (the others being hue and brightness/lightness). "Colourfulness is to chroma as brightness is to lightness ... Colourfulness describes the intensity of the hue in a given colour stimulus. [5]"

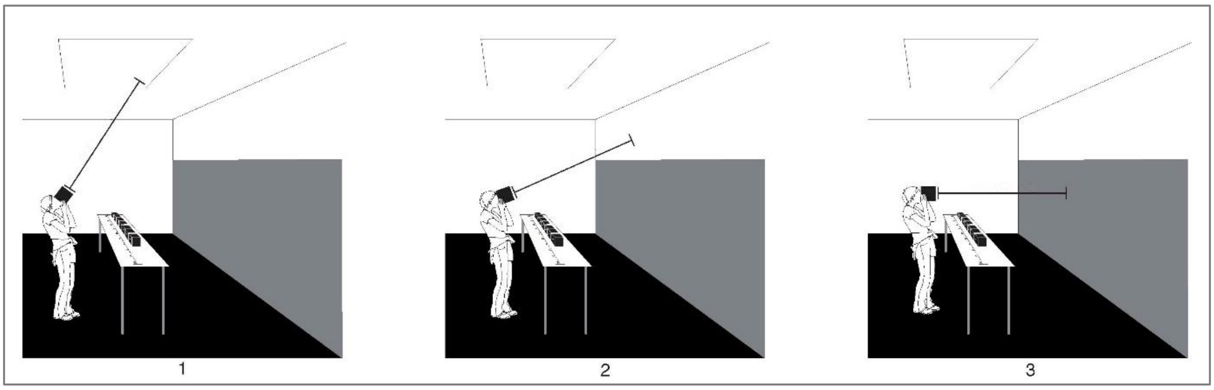
The experiment on colourfulness looked at techniques that have been used architecturally, such as reflective surfaces. We used experimental measurements to test anecdotal knowledge about the perception of colour in space (Figure 3).

The experiment followed G. Z. Brown, "It is important that the surface that first reflects the daylight be light in colour to increase the amount of light reflected into the space." [3] Brown's research is based upon findings of approximate colour reflectances by Hopinkson, "The variation of Sky Component and total Daylight Factor with distance from window” [6], to optimise the performance and perception of colour and daylight.

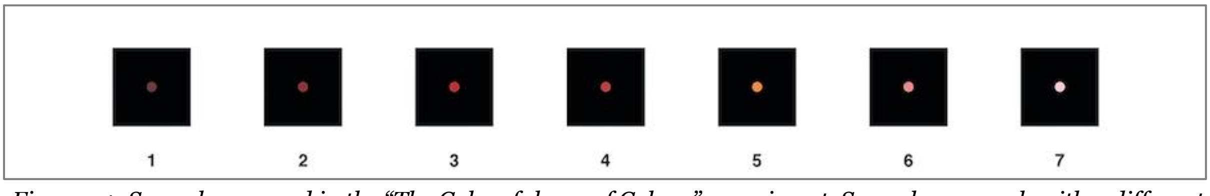
Seven identical boxes, or models, were built out of black foam board so that no light could pass through the edges (Figure 4). The insides were covered in white for high reflectivity. Each box was a cube of 20×20×20 cm. One side had a central opening: a 5 cm square aperture, called the “window.” On the opposite side was a central viewport of 12 mm diameter. The window side, or “wall,” with the 5×5 cm opening was coloured in a range of seven different commercial colours, varying in Light Reflectivity Values from 0% to 99% (Figure 5). The colours are listed, along with their LRVs (percentages): Exotic Pink (68.3%), Flamingo’s Dream (40.2%), Calypso Orange (37.8%), Strawberry Red (14.2%), Red (13.2%), Raspberry Truffle (8.5%), Chestnut (7.2%). Figure 5 shows the experiment environment.

In these experiments 50 participants were tested for their perceptions of colours. The boxes, each with different shades of red on the inside surface of the wall with the window (Figure 6), were observed in varying stages of light. Observations were made at a distance of 1.50 to 1.80 m, monocularly. In a frontal and parallel position, each human subject tested placed the box in front of her/his face, with her/his eye tight against the viewport, looked through the viewport, and described the perceptions of each colour at three different light levels: a) bright (a light source), b) not so bright (a white wall), and c) the transition between them (a grey wall).

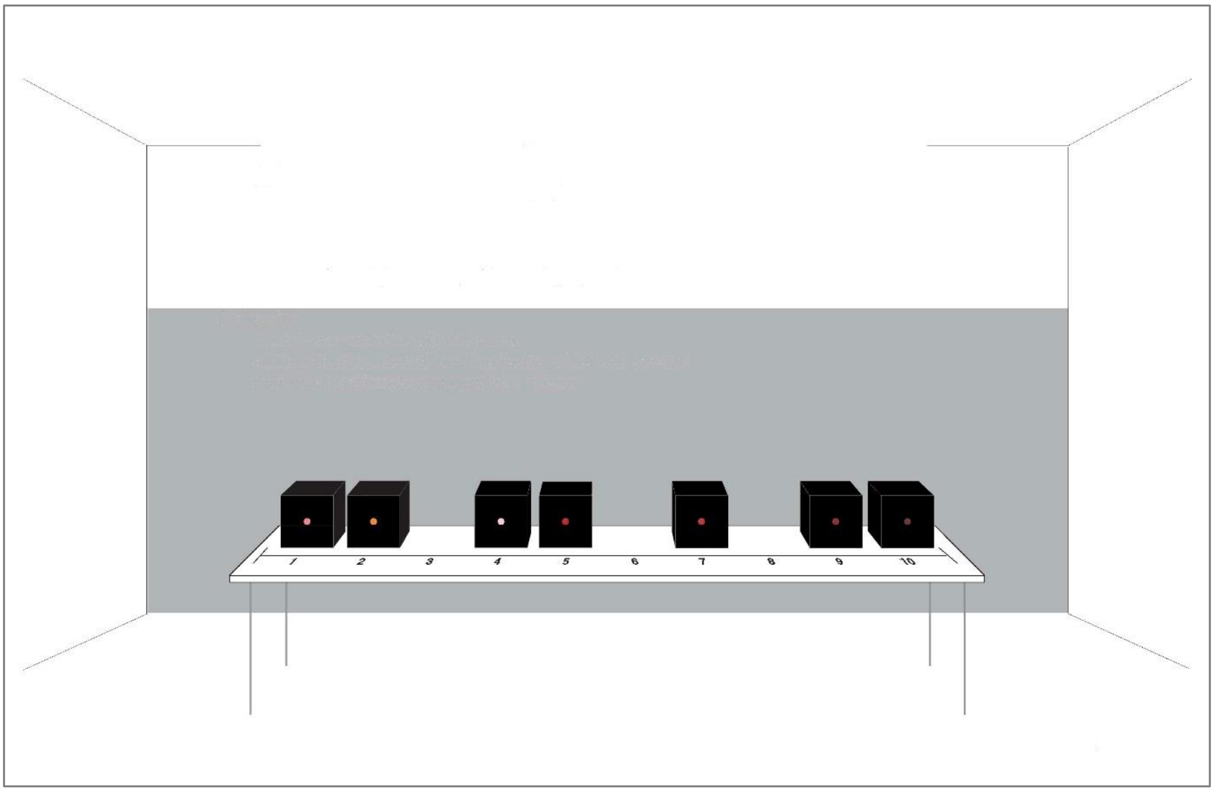
The questions asked were: Which is the most colourful wall? Which is the most colourful box? Despite the actual LRVs of the seven shades of red (listed above), the boxes with the “Flamingo’s Dream (LRV 40.2%) and Calypso Orange” (LRV 37.8%)” were perceived by most observers to be the most colourful. The results show that the most colourful colours are not necessarily the darkest ones (Figure 7).



Figures 3: Observation settings of “The Colourfulness of Colour” experiment. Observations were made at a distance of 5 to 6 feet from the specific light levels. Each person tested looked through the view ports of the boxes and described their perception of each colour at three different light levels: (1) bright – a light source, window and skylight; (2) not so bright – a white wall; and (3) the transition between them – a grey wall.



Figures 4: Seven boxes used in the “The Colourfulness of Colour” experiment. Seven boxes, each with a different shade of red on the inside surface of the wall, opposite the view hole, were observed in different light levels.



Figures 5: "The Colourfulness of Colour" experiment environment.

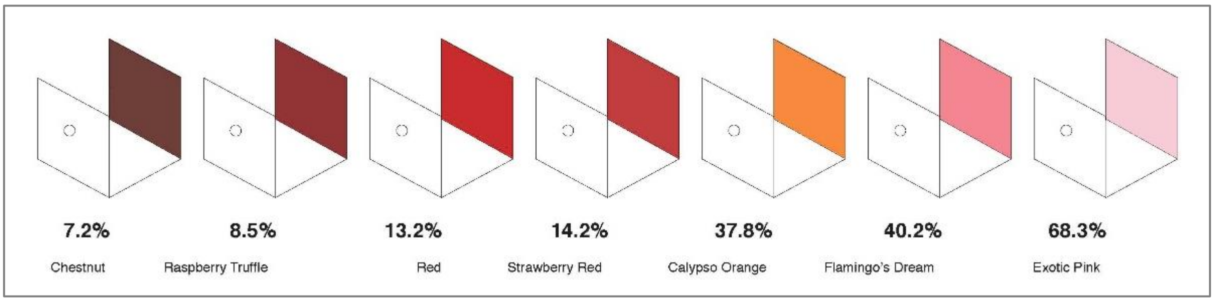


Figure 6: Reflectivity and colour of the corresponding surfaces. The coloured side, or "wall", was covered in a range of seven different commercial colours with varying in light reflectivity values from 0% to 99%.

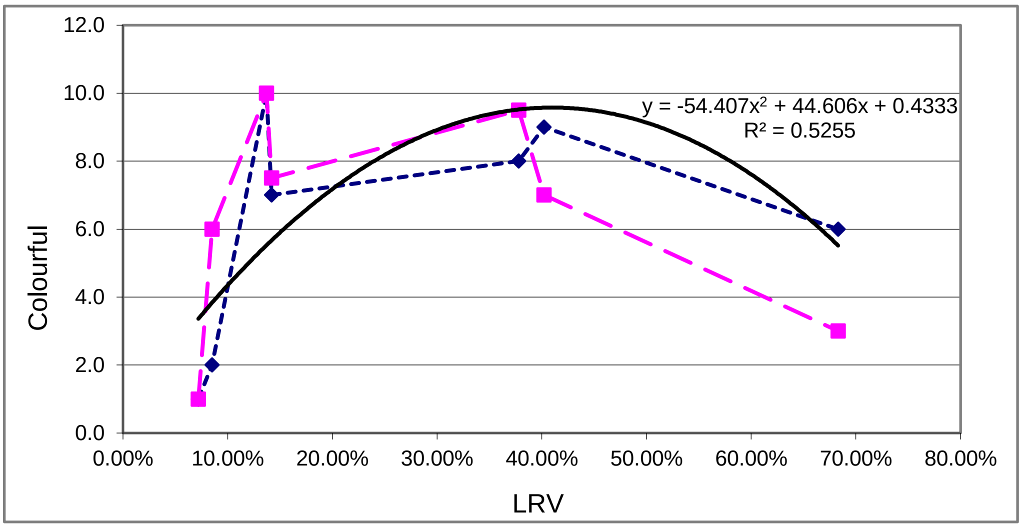


Figure 7: Observers perceived a space to be most colourful when the reflectivity of the surfaces was in the range of 30-40%.

Experiment 2: the appearance of the colour red

A follow-up experiment was conducted. Fairchild [5] writes on colour appearance terminology: "While colour is typically thought of as three-dimensional and colour matches can be specified by just three numbers, it turns out that three dimensions are not enough to completely specify colour appearance. In fact, five perceptual dimensions are required for a complete specification of colour appearance: Brightness, Lightness, Colourfulness, Chroma, Hue."

In this second experiment on the appearance of red, we built a series of boxes, or models of interior rooms, to address the question of reflectivity with changing room configurations. Each of the boxes represented a room with a window on one side, as described in the previous experiment. One set of boxes had the colour at the window side; another set of boxes had the colour on all fives sides except the window side. The project was designed to study two aspects of the relationship between the amount (visual size) of colour and the perception of it:

1. How the daylight factor changes under the same light conditions;
2. How people perceive the colour of a room interior as the amount, location and reflectivity change.

The boxes provided a limited field of view. Participants could not see the whole space, only the opposite wall with the window and a quarter of the neighbouring walls. The experiment showed that the Average Room Reflectivity (ARR) changes very little within the range of colours from an LRV of 7% to 68% if only one wall is coloured. But the ARR changes dramatically when all five walls are coloured. The question asked was: Which is the most colourful room? Each version of the boxes tested (1 wall coloured or 5 walls coloured) showed the same result, which indicates that controlling the view is a way to make a space appear colourful. These results provide a point of departure for the selection of colours for the garden project:

- That the most colourful colours are not necessarily the darkest ones.
- That rooms can appear more colourful without changing the average room reflectivity.

How do these findings translate to an exterior space?

The results of this red viewing test with 50 participants were used to determine the selection of the different reds and their positions in the garden project. This experiment showed that the eye is capable of making separate judgments describing colour appearance and perception. Therefore the same seven reds have been used for the garden project, including reds with significantly different light reflectance values, yet of the same size, texture, sample type and setup.

It was found that observers' results were similar to the predicted performance of the reds in the empirical location of the coloured fences in the garden project. The reds with a LRV 40-60% are expected to give the strongest responses in the garden project. We understand that the interaction of the painted slats, both with each other and with the colours in nature, will remain a dynamic condition. By interspersing small areas of colour through the slats, the project will highlight the relativity of colour and serve as a playful manifestation of the Bezold Effect — that a colour may appear different depending on its relation to adjacent colours. The garden is an invitation to see and celebrate that interaction on multiple fronts.

Garden project revisited and expanded

Using the initial garden proposal as a point of departure, the project will delve into the history of colour experiments on visual perception and the analysis of colour, intensity, flicker and ambience within larger fields of interaction. The objective of this research is to study and evaluate a series of complex visual effects as they occur in the built environment and in nature. The project aims to expand upon Albers's colour experiments in this larger field and to examine the potency of his discoveries outside of his regulated and abstract colour experiments.

- To what degree do the Albers experiments translate to architectural spaces — both interior and exterior?
- What are the limits of these colour effects?
- What is their potential in larger and more complex fields?

Hypothesis: Interaction of Colour is invaluable in aesthetic, architectural, and performative terms. The project focuses on the connection between design principles and colour interaction in order to develop a better understanding of how to optimise spatial efficiency, performance, and visual comfort. This research will also explore the potential for using colours to expand, confuse, conceal, and misrepresent built three-dimensional forms, because the effects of colour interaction in architecture are neither widely applied nor understood in the field. We see the potential to expand the Albers observations about colour interaction as more variables are introduced.

To test the hypothesis, the perception of colour interaction will be assessed empirically. The proposed studies will largely maintain the existing strategy and will focus on the effects of colour and reflectivity, understanding the interaction of the painted slats, both with each other and with the colours in nature, which are in a constant state of flux over the course of the day and seasons of the year. The observers will be asked questions similar to those of Albers:

- Which colours recede?
- Which colours advance?
- Which colours appear to share the same spatial plane?

We further see the potential to build upon the importance of colour in the built environment, as the architect Guenther Behnisch states, "In the North, people must have felt a need to repaint their houses in bright, fresh colours after the long dark winter, while in the South, plain white was sufficient. But this does not hold true for all and everything, and it never did. Temples, places, villas were coloured even where ordinary houses were grey or white. It seems that natural colours and materials stood for a state of affairs that people could normally accept but wanted to improve on when higher standards were called for. The better, higher world was no doubt conceived of as being bright and colourful." [3]

The study will thus seek to amplify the relativity of colour, namely that a colour may appear different depending on its relation to adjacent colours. In particular we seek to understand how colour interacts outside of Albers's two-dimensional colour experiments in three-dimensional space. We will test the interaction of colour though a series of empirical tests within a constructed exterior space. The project will develop a series of scale physical models, which will utilise a range of graphic techniques to maximise the relative appearance of a colour in relation to adjacent colours when these fields are interspersed (Figure 8).

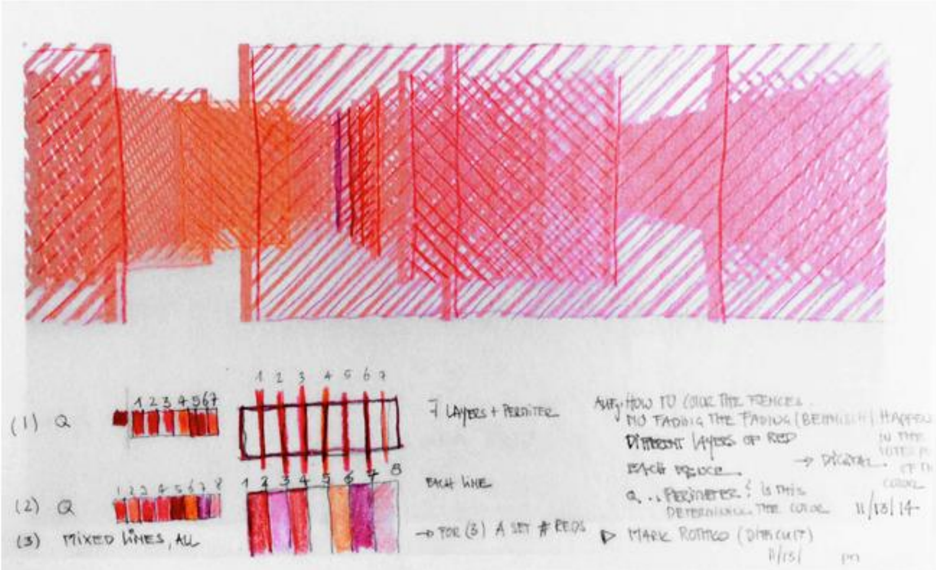


Figure 8: "Red on Red" sketch for colour interaction.

The guiding research questions for the experiments will be: (a) Can we achieve the perception of intense colours while also providing little physical colour? (b) How do we apply the Interaction of Colour to conditions that are in a constant state of flux? (c) In what ways can the use of colour alter or deny three-dimensional space? (d) How can one minimise and/or maximise the optical destruction of volumes and forms in space? (e) Can spatial composition and colour be at once independent and dependent systems?

Evaluation of Reflectivity: the experimental garden?

These effects will be investigated with a wider range of variables, including daylight, shadow, background conditions and colours (seasons and plants), and the position of the viewer. Key points of investigation will be: the definition of space through colour; the undermining of architectural space through colour application; spatial effects of colour, including compression, extension and resolution of volumes; connection and disconnection of spatial elements by colour; contrast effects of colour especially in outdoor and/or daylit spaces; testing of anecdotal knowledge about the perception of colour.

The initial proposal for the "Red on Red" Garden was an experiment designed to observe how colours interact in an outside landscape. Special attention was given to background, horizontal and vertical vantage points, and changing light conditions. Further experiments will be based on the planometric geometry of the initial garden proposal—a 10×20 metres area surrounded by an open perimeter fence and subdivided by a series of open fences into eight equal bands, each measuring 10×2.5 metres. In the experiments, several variables were introduced: colour, reflectivity, ordering, height, density of the slats, time of day, time of year, and the relative position of the various viewers.

A set of eight colours will be assigned to the garden: one colour for the perimeter condition and seven colours for the seven interior fences, whereby each plane of the project has a specific colour assignment. The colour finishes may be matte or glossy, with varying degrees of reflectivity. The assignment of colours and their sequential order could be reorganised. While the regulating plan geometry is fixed, the position and site of the openings that allow people to pass through the garden could be changed. All fences, however, will remain equally spaced at 2.5 m and be parallel with each other and perpendicular to the viewer and to the direction of movement (Figure 9).

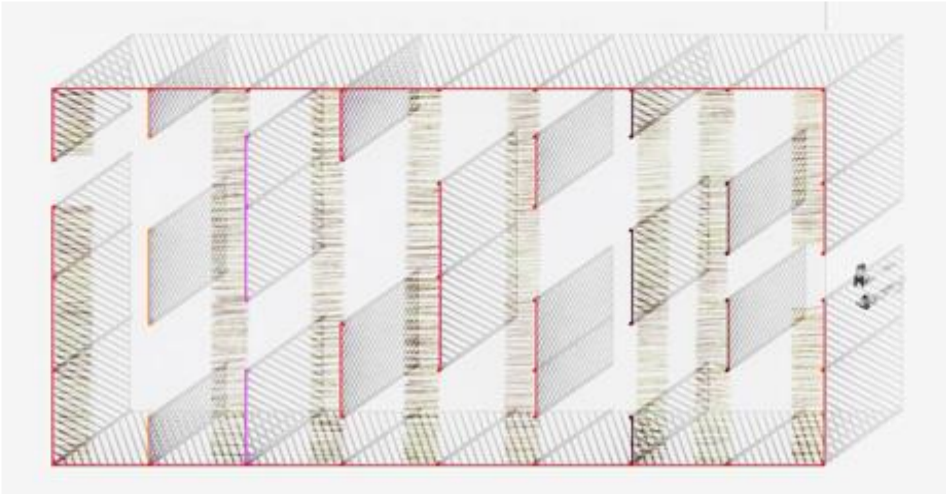


Figure 9: "Red on Red" garden plan.

The overall structural support positions will remain, but the height of the garden walls could be increased by up to +1 m or reduced by up to -0.5 m from the original 2.5 m above the ground plane. For each of the experiments the height of the fences will be constant in each configuration. Depending on the eye height of the viewer and the height of the fences, the illusion of spatial advancing or spatial receding could be reinforced. The parallel fences form a series of vertical and horizontal translucent planes. If the planes of colour generated by the fences are perceived as nested layers of colour, the spatial effects will be reduced to a minimum.

In the case of the initial garden proposal, given an average eye height of approximately 1.57 m and a fence top height of 2.5 m, the colour sequence may appear to advance counter to its planimetric organisation or the spatial ordering generated by the colours because of the larger areas of colour that appear in perspective on the lower borders. The dimensions of the individual diagonal slats that comprise the series of parallel fences will remain constant. Similar to the original garden proposal, the slats are always oriented at ±45 degrees, alternating at each layer. The spacing of these slats, however, can either be doubled or reduced to half the dimension of the original garden proposal for each wall. The visual effect produced is known as the von Bezold Spreading Effect (sometimes referred to as spatial colour mixing), which is facilitated by the alternating direction of the slats as well as the staggered positioning of the openings in the fences.

Additional variables in the experiments will be environmental and perceptual in nature. The time of day will be examined for the summer and winter solstice, as well as the autumn and spring equinox, both in direct sunlight and under a cloudy sky. The garden may at some stage be re-oriented from its original position so that one of the entries faces north. The surrounding forest, garden, and sky colour may reflect typical seasonal and daytime changes.

Cinematic studies involving a series of still images moving though the various garden compartments will be developed for each of these conditions (time of day, year). Views will be methodically recorded at eye level starting at one entry (moving south to north) and taken at each subsequent fence plane until the other entry is reached. A similar recording will be made while moving in the opposite direction (from north to south).

Depending on the colours and the order chosen, the garden at times may reinforce its own organisation, and at other times confound it. The delight in the un-known inspired by re-visiting David Batchelor's observations, "More Specifically: this purging of colour is usually accomplished in one of two ways. In the first, colour is made out to be the property of some foreign body – usually the feminine, the oriental, the primitive, the infantile, the vulgar, the queer or the pathological. In the second, colour is relegated to the realm of the superficial, the supplementary, the inessential or the cosmetic. In one, colour is regarded as alien and therefore dangerous." [2]

When colour and form are in alignment, the garden, or parts of the garden, could be regarded as functional, as a means to orient and provide three-dimensional information. However, when the viewer is moving in the opposite direction in the garden, the same colours could have the potential to take on a more de Stijl approach, especially that of Theo Van Doesburg, to confound and disrupt architectural space.

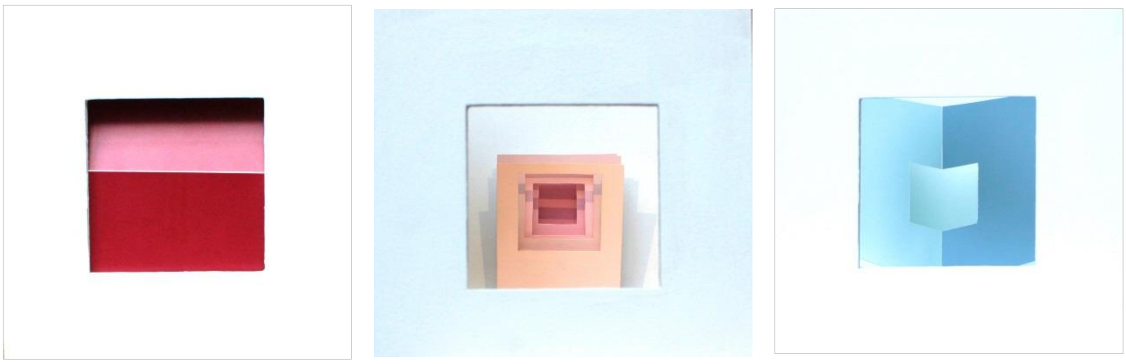
In these instances colour may refuse its typically secondary role in architectural space-making as a decorator or informant. Then it would be not so much the artist playing a subversive role in the relationship between colour and space, but rather the viewer.

Conclusions

A series of projects were conducted in the student workshop Dimensions of Colour, in collaboration with Julie Haack (Department of Chemistry) at the University of Oregon, during the Holistic Options for Planet Earth Sustainability (HOPES) conference on 15th April 2017 (Figure 10).

The results show that in *Interaction of Color*, as in Lois Swirnoff's *Dimensional Color* [7], objects and spaces may appear or disappear; however, aspects of colour and context allow spaces to re-invent themselves between spatial expression and spatial illusion, through the psychological and perceptual impact of colour in the built environment and in design.

The eye is capable of making separate judgments about the relativity of colour. *Interaction of Color* is well documented, as is the architectural role of *Dimensional Color*, but the connection between *Interaction of Color* and daylighting/reflectivity in living spaces needs to be further explored.



Figures 10: Experimental Colour-Dimension-Interaction.

Although these were preliminary experiments and results, the implications are of sufficient interest to justify further research to explain and demonstrate how colour can alter our perception of space. Multiple experiments will be conducted, and we will increase the number of human subjects. The results will be evaluated to establish rules and guidelines for the interaction of colour and for colour perception in larger fields. These guidelines will inform design applications for the use of colour in architectural spaces and other environments.

The initial experiments showed that colour is much more than a paint or a coating; rather it is a dynamic and highly subjective design element. Contrary to its often-ascribed secondary role in architecture, colour has powerful dimensional potential on a par with form itself. These experiments underscore the ongoing significance of Albers's body of work and the continuing relevance of his colour theories.

Architects and designers underestimate colours and their dimensionality in the built environment and cannot understand the special characteristics of colour combinations by looking at colours in isolation or without a larger context and field of colour interaction. The implications from the results of these experiments are that designers should not rely on their intuition but need tools to apply colour and its interactions in all kinds of spaces: interior architecture, architecture, landscape architecture and urban planning. We see many possibilities for more general research on the theme of colour and form in architecture.

References

1. Albers J (1963), *Interaction of Color*, New Haven: Yale.
2. Batchelor D (2000), *Chromophobia*, London: Reaktion, 22-23.
3. Behnisch G (1993), *Ueber das Farbliche / On Color*, Stuttgart: Hatje Cantz, 11.
4. Brown GZ (1985), *Sun, Wind & Light. Architectural Design Strategies*, New York: John Wiley, 219.
5. Fairchild MD (2005), *Color Appearance Models* (Second Edition), New York: John Wiley, 90-92.
6. Hopkinson RG, Peterbridge P and Longmore J (1966), *Daylighting*, London: Heinemann, 434.
7. Swirnoff L (1988), *Dimensional Color*, Boston: Birkhäuser, 44.