Hue, saturation, and depth in planar images

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Abstract

Poorly saturated colors are closer to a pure grey than strongly saturated hues and, therefore, appear less “colorful”. Color saturation is effectively manipulated in the visual arts for balancing conflicting sensations and moods and for inducing the perception of relative distance in the pictorial plane. While perceptual science has proven quite clearly that the luminance contrast of any hue acts as a self-sufficient cue to relative depth in visual images, the role of color saturation in such figure-ground organization has remained unclear. We presented configurations of colored inducers on grey ‘test’ backgrounds to human observers. Luminance and saturation of the inducers was uniform on each trial, but varied across trials. We ran two separate experimental tasks. In a relative background perception task, the perceptual judgments indicated whether the apparent brightness of the grey test background *contrasted* with, *assimilated* to, or appeared equal (no effect) to that of a comparison background with the same luminance contrast. Contrast polarity and its interaction with color saturation affected response proportions for *contrast*, *assimilation* and *no effect*. In a figure-ground (relative depth) perception task, perceptual judgments indicated whether the inducers appeared to lie in front of, behind, or in the same depth with the background. Strongly saturated inducers produced larger proportions of *foreground* effects indicating that these inducers stand out as *figure* against the background. Weakly saturated inducers produced significantly larger proportions of *background* effects, indicating that these inducers are perceived as lying *behind* the backgrounds. Saturation and contrast polarity interacted on *foreground* and *background* response proportions. We infer that color saturation modulates figure-ground organization, both directly by determining relative inducer depth, and indirectly, and in interaction with contrast polarity, by affecting apparent background brightness. The results point towards a hitherto undocumented functional role of color saturation in the genesis of form, and in particular figure-ground percepts in the absence of chromatic stereopsis.

Introduction

Poorly saturated colors, since they are closer to a pure grey than intense hues, appear less "colorful" than strongly saturated colors, yet, they still contain hue information. In the visual arts, color saturation is widely exploited as a measure for balancing opponent or conflicting sensations and moods. In the 19th century, at the dawn of abstract expressionism, painters such as Turner (especially in his later works) effectively used color to suggest what should be nearer or further away to the observer in the painting, relying on chromatic brightness and saturation to express and balance figure and ground, moods, and other *qualia* (Fig 1). The earlier Renaissance painters had preferentially resorted to *chiaroscuro* and geometric cues to aerial perspective using a limited chromatic range to create landscape depth and figure-ground effects. Later in the evolution of visual art, modern architects and designers like Vasarély effectively manipulated color saturation in combination with planar shape geometry to play with foreground and background effects in a complex and abstract manner (Fig 2), illustrating how chromatic luminance, saturation, and shape can be combined to elicit powerful visual sensations suggesting three-dimensional structure. While contemporary visual artists tend to share the strong belief that saturation is a key medium for creating perceptual structure, perceptual science has not yet clarified the functional contribution of color saturation to perceptual organization. Imagine the simplest possible two-dimensional image with no more than two adjacent surface regions. When there is a difference in brightness between the two adjacent regions, they can constitute a figure-ground reversible pattern, where the region seen as figure is perceived in front of the region seen as ground. This difference in perceived depth between the two regions increases as their difference in brightness increases. The observation originally stems from an experiment by Egusa (1977), who presented two different achromatic surfaces, viewed through a small aperture, on a black screen. The surface on the right was of one of three different shades of grey, and the one on the left was either white or black. Observers made judgments regarding the apparent depth of these surfaces in terms of which of the two appeared nearer. The results of this study were the first to reveal a systematic relation between perceived relative depth and brightness differences between adjacent surface regions, in that increasing the brightness difference increased the perceived depth separation in every observer. Whether the brighter or the darker of the two test surfaces appeared nearer differed from observer to observer. Subsequently, Egusa (1983) examined the effects of brightness, hue, and saturation on the perceived depth between two adjacent regions. Again, the stimuli consisted of two hemifields, either both achromatic, one achromatic the other chromatic, or of two different colors. Subjects were asked to state which hemifield appeared nearer, and to put a number on the perceived depth between (depth magnitude estimation). When both hemifields were achromatic, the perceived depth was found to increase with increasing brightness difference. Again, some subjects tended to judge the brighter side nearer, others the darker side. With the achromatic-chromatic combination, there were no differences in perceived depth among three hue conditions, whilst with the chromatic-chromatic combination the perceived depth depended on the hue combination. In terms of decreasing frequency of 'nearer' judgments, the hue order was red, green, and blue. When two chromatic hemifields differed in saturation only, the perceived depth increased with increasing difference in saturation, and whether the more saturated or the less saturated side was judged nearer depended on hue. Thus, the figure-ground differentiation between two adjacent chromatic regions in the visual field is jointly determined by brightness, hue and saturation, affecting the perceived distance of a given region from the observer.

While it is now well-established that mere luminance contrast directly determines what will be seen as nearer or further away in two-dimensional visual configurations and images (Mount *et al* 1956; Farnè, 1977; Rohaly and Wilson, 1993; O'Shea, Blackburn and Ono, 1994; Dresp, 1997; Dresp, Durand and Grossberg, 2002; Guibal and Dresp, 2004; Dresp-Langley & Reeves, 2012), observations do not cover effects of luminance and saturation on the figure-ground organization of color adjacent to, or surrounded by, achromatic fields of varying luminance intensity, or grey tones. Reasons why such effects were not actively searched for may relate to the fact that chromatic and achromatic pathways in the visual brain are widely believed to be independent (e.g. Page & Crognale, 2005) presuming no functional interaction between chromatic and achromatic neural signals.

To clarify whether or not saturation influences figure-ground perception of color patterns on achromatic backgrounds, we used stimuli from a previous study (Dresp-Langley & Reeves, 2012), which had already shown that colors of any hue could alter the perceived intensity of their achromatic backgrounds, pointing towards hitherto unsuspected interactions between color signals and achromatic contrast signals. Also, colors on grey produce depth effects that can directly be explained by variations in their luminance contrast irrespective of hue. Here, we varied the saturation levels of colors on grey in similar displays to test how these variations affect perceived background brightness and figure-ground organization.

Material and methods

Experiments were run under Windows XP on a Dell PC computer equipped with a mouse device and a high resolution color monitor (EIZO LCD 'Color Edge CG275W') with an in-built color calibration device (colorimeter), which uses the Color Navigator 5.4.5 interface for Windows. The colors of the stimuli were generated in Photoshop using selective combinations of Adobe RGB increments. The color coordinates (see Table 1) for each RGB triple are retrieved from the look-up table of the colorimeter after calibration. All luminance values for calculating the stimulus contrasts (Michelson contrasts, see Table 2) were determined on the basis of standard photometry using an external photometer and adequate interface software (Cambridge Research Instruments).

Subjects

Ten unpracticed observers, mostly graduate students in computational and/or design engineering and unaware of the hypotheses of the study, participated in the experiments. All subjects had normal or corrected-to-normal visual acuity and normal color vision (assessed on the basis of the Ishihara plates).

Stimuli

The stimuli (see Fig 3) consisted of configurations of 20 colored square-shaped surfaces, as from now called inducers, placed on a grey square-shaped surface, the background, and displayed on a black (0 cd/m^2) computer screen. The color of the inducers could be red, green, blue, yellow, or achromatic (grey). The saturation of the inducer colors was varied to produce configurations with "fully" saturated and configurations with "weakly" saturated hues (see Table 1). Inducer luminance (in cd/m^2) was 9.9, 16.7, 22.1 and 53.2 for red, 7.1, 11.5, 53.9 and 54.0 for green, 1.4, 5.1, 11.6, and 34.6 for blue and 3.2, 12.3, 58.8, and 79.00 for yellow hues. The luminance of achromatic inducers was 9.95 and 82.70 cd/m^2. The luminance of the grey backgrounds was either 2.6 or 25 cd/m^2. Color coordinates for inducer colors (X, Y, Z) are given in Table 1 as a function of color appearance and the two saturation categories ("weak" and "full"). Michelson contrasts $(L_{max}-L_{min})/(L_{max}+L_{min})$ of inducer-background configurations are given in Table 2 as a function of inducer saturation levels**.** In the task where observers had to judge relative background brightness, two background configurations were presented simultaneously: a configuration with inducers on the test background, and a plain background without inducers (comparison background). The location of test and comparison backgrounds on the screen varied randomly between left and right. A small fixation cross of low intensity was presented between trials to help subjects fixate the center of the screen. The horizontal distance between two backgrounds on the screen was 4 cm, and a given configuration on each side was 1.5 cm away from the central fixation mark that appeared between trials. The height of each background square was 9.7 cm and the width 10 cm. The smallest horizontal distance between colored inducers was 0.4 cm, the smallest vertical distance 0.5 cm. All colored inducers had identical height (0.9 cm) and width (1 cm). In the task where observers had to judge relative inducer depth, a single inducer-background configuration was displayed centrally on the screen on each trial.

Task instructions

Both experimental tasks used three-alternative forced choice to measure perceptual decisions. In the background contrast task, observers were asked to indicate whether the grey background containing inducers appeared "brighter" than, "darker" than, or the "same" as the comparison background, which contained no inducers. It was made clear that all subjects had understood that they were to compare the relative brightness of the two grey backgrounds on either side of the screen. In the relative depth or figure-ground task, observers were asked to indicate whether the colored inducer surfaces appeared to stand "in front of" or "behind" their grey background surface, or whether all surfaces appeared to lie in the "same" plane. It was made sure that all observers understood the instructions correctly before an experiment was initiated.

Procedure

Subjects were seated at a distance of 1.5m from the screen, their heads comfortably resting on a head-and-chin support. The experiments were run in a dimmed room, with blinds closed on all windows (mesopic range). Previous research had established that rod vision is not required for the generation of either apparent brightness or depth with the type of stimuli used here (Dresp-Langley & Reeves, 2012.) Five of the ten observers were run in the relative background brightness task first and then in the relative depth task, the other five were run in reverse order. In the task where observers had to judge relative background brightness, two background configurations were presented simultaneously, a test background with inducers on one side of the screen (randomly on the left or right) and a comparison background without inducers on the other side. In the task where observers had to judge relative inducer depth, a single inducer-background configuration was displayed centrally on the screen on each trial. In each task or session, the configurations were presented in random order for about one second each and each configuration was presented twice. Inter-stimulus intervals typically varied from one to three seconds and were placed under the control of the subject to allow for any after-images to vanish before the next trial was initiated. Between stimuli, subjects were exposed to a uniformly black screen, with a small, slightly brighter, fixation cross displayed in the center, which was to help them control the direction of gaze. Each individual session consisted of 72 trials per subject, of which 64 with colored inducers on the grey backgrounds and eight with achromatic inducers on the grey backgrounds.

Results and discussion

The data from each task were analyzed separately. Response proportions were determined on the basis of the frequency with which a given effect was observed in each of the two tasks. Relative background brightness (task 1) was assessed on the basis of frequencies of *contrast* effects, *assimilation* effects, and responses signaling *no effect.* Relative inducer depth or figure-ground (task 2) was assessed on the basis of frequencies of *foreground* effects (“in front”), *background* effects (“behind”), and responses signaling *no effect*.

Contrast and assimilation of the grey backgrounds

Inter-individual differences are common in this type of task (Egusa, 1977, 1983), where some observers consistently tend towards judgments in terms of assimilation, others consistently towards judgments in terms of contrast, as confirmed again more recently by Dresp-Langley & Reeves (2012). The psychophysical judgments were analyzed for each experimental condition and subject. We determined frequencies (F) of *contrast* effects reflecting responses where a test background containing brighter inducers was judged “darker” than the comparison field or a test background containing darker inducers was judged “brighter” than the comparison field. Frequencies of *assimilation* effects reflect responses where a test background containing brighter inducers was judged “brighter” than the comparison field or where a test background containing darker inducers was judged “darker” than the comparison field. Frequencies of *no effect* reflect responses where the test background appeared of the same brightness as the comparison field. These frequencies were then transformed into response proportions $P=F/N$ where N is the number of observations in a given condition.

A two-way ANOVA for a 2x4 factorial design was performed first, with two levels of the saturation factor (weak *versus* strong saturation) and the four levels of the hue factor (red, green, blue, yellow). The results of this first analysis signaled no statistically significant effects of hue on the response proportions for *contrast* ($F(1,1)=0.27$, *NS*), *assimilation* ($F(1,1)=2.29$, *NS*), or, redundantly, *no effect* ($F(1,1)=0.16$, *NS*), indicating that homogenously red, green, blue and yellow inducers influence achromatic backgrounds in the same way. This result replicates a finding from an earlier study with similar configurations and tasks (Dresp-Langley & Reeves, 2012). For further statistical analyses, the four different hues were grouped with regard to luminance (Michelson) contrast and split into two polarity groups, the eight most positive contrasts forming one group, and the remaining eight, of which most were negative, a second group. A two-way ANOVA for a 2x2 factorial design was performed with two levels of saturation (weak *versus* strong saturation) and the two levels of contrast. These statistics signaled significant effects of contrast polarity on response proportions for *contrast* ($F(1,1)=39.36$, $p<.001$), *assimilation* ($F(1,1)=66.83$, $p<.001$), and *no effect* ($F(1,1)=22.20$, $p<.001$), and statistically significant interactions between saturation and contrast polarity on these response proportions ($F(1,1)=6.18$, $p<.05$ for *contrast*, $F(1,1)=8.37$, $p<.01$ for *assimilation*, and $F(1,1)=8.29$, $p<.01$ for *no effect*).

Proportions (*P*) of *contrast*, *assimilation*, and *no effect* are plotted in Figures 4, 5 and 6 as a function of the Michelson contrast and the saturation level of the inducers. The graphs show that strongly saturated inducers have a tendency to yield higher proportions of background *contrast* than weakly saturated inducers although the main effect of saturation was not statistically significant. The significant interaction between saturation and contrast polarity is reflects several observations. Strongly saturated inducers with the highest positive luminance contrast produced the largest proportions of *contrast* effects, while the weakly saturated inducers with the highest negative luminance contrast produce the smallest proportion of *contrast* effects (Fig. 4). Although, at a first glance, weakly and strongly saturated inducers seem to produce more or less evenly distributed proportions of *assimilation* at all luminance contrasts, the largest proportion of *assimilation* effects is observed with the weakly saturated inducers of the highest negative Michelson contrast (Fig. 5), while the smallest proportion of *assimilation* arises from the strongly saturated inducers with the highest positive Michelson contrast, a significant effect here because the standard error in this comparison is relatively small.

Proportions of *contrast* and *assimilation* are summarized as a function of four contrast polarity categories are given in Figure 7, where each data point reflects the mean of two or more observations. The response proportions for trials with the achromatic inducers are included in this graph for comparison. Achromatic and colored inducers induce markedly asymmetrical *contrast* effects on their backgrounds. The strongest *contrast* effects are generated by fully saturated colored inducers with positive contrast polarity. Inducers with negative contrast sign produce very little. No marked asymmetry is found in the *assimilation* effects, which are rather weak compared with the *contrast* effects, bearing in mind that small proportions of both *contrast* and *assimilation* imply a large response proportion for *no effect*. Comparison of the achromatic data with the data from the colored inducers leads to the conclusion that the effects of either chromatic contrast or luminance contrast on the apparent brightness of achromatic backgrounds depend critically on contrast polarity. Simple explanations or models in terms of summative effects of differences in contrast, where brightness would be a fixed weighted sum of these latter (e.g. Burns, Smith, Pokorny, & Elsner, 1982), do not hold in the light of the marked asymmetry between effects from positive and negative polarities observed here.

Figure-ground organization

We computed individual frequencies (*F*) of responses signaling *figure* and *ground*, reflecting observations where inducers were judged as standing “in front” or “behind” the grey background. Frequencies of responses signaling *no effect* reflect individual observations where the inducers were judged to lie in the “same” plane as their grey background. The subjects' responses were analyzed for each experimental condition and individual. The responses frequencies (*F*) were transformed into response proportions $P=F/N$ where N is the number of observations in a given condition.

The first statistical analysis, using two-way ANOVA for a 2x2 factorial design with two levels of the saturation factor (weak *versus* strong saturation) and four levels of the hue factor (red, green, blue, yellow) signaled no significant effects for hue (see also Dresp-Langley & Reeves, 2012). The effects of saturation on response proportions for *foreground* effects, *background effects* and *no effect* were all statistically significant ($F(1,1)=7.49$, $p<.05$ for “in front”, $F(1,1)= 4.761$, $p<.05$ for “behind”. ANOVA for a 2x2 factorial design with the two levels of the saturation factor and two levels of the luminance (Michelson) contrast factor was run. As before, hues were grouped with regard to luminance (Michelson) contrast and split into two polarity groups, the eight most positive contrasts forming one group, and the remaining eight, of which most were negative, a second group. In addition to the significant effects of saturation, this analysis revealed a significant effect of contrast polarity on the proportion of responses signaling *foreground* effects ($F(1,1)=62.20$, $p<.001$), *background* effects ($F(1,1)= 14.90$, $p<.01$), and *no effect* ($F(1,1)=32.21$, $p<.001$). A significant interaction between saturation and contrast polarity was found to influence the response proportions for *background* effects ($F(1,2)=18.33$, $p<.001$).

Response proportions for *figure* and *ground*, expressed in terms of *foreground* effects (“in front”) and *background* effects (“behind”), and response proportions relative to *no effect* are given in Figures 8, 9, and 10 as a function of the inducers’ Michelson contrast and saturation levels. Strongly saturated inducers produce larger response proportions for *foreground* effects than weakly saturated inducers. Strongly saturated inducers with the strongest positive luminance contrasts produce the largest response proportions relative to *foreground* effects, where the inducers are seen as standing in front of the configuration. Weakly saturated inducers yield larger response proportions for *background* effects than strongly saturated ones. These *background* effects, where the inducers are seen as standing behind the configuration, are shown to markedly depend on the polarity of the inducers' luminance contrast.

Response proportions for *figure* and *ground* in terms of *foreground* and *background* effects are summarized as a function of four contrast polarity categories in Figure 11, where each data point reflects the mean of two or more observations. The response proportions for trials with the achromatic inducers are included in this graph for comparison. Achromatic inducers with the strongest negative luminance contrast and weakly saturated colored inducers with (here medium) negative polarity yield the largest response proportion (approaching 1) of *background* effects, while achromatic and fully saturated colored inducers with the strongest positive luminance contrast yield the largest response proportion (also approaching 1) of *foreground* effects. Proportions of *foreground* effects indicating that inducers are seen as figure tend to increase between strong negative and strong positive contrast polarities, while *background* effects indicating that inducers are seen as ground tend to decrease. Strong contrasts of either sign contribute to resolving figure-ground ambiguity, in particular when associated with an achromatic luminance or a fully saturated color contrast. The data show quite clearly that fully saturated and weakly saturated inducers of similar luminance contrast produce markedly different effects within a given polarity range.

Conclusions

Color saturation contributes to the figure-ground organization of two-dimensional configurations of colored inducer surfaces on achromatic backgrounds. In the light of the response proportions from the relative background brightness task (task 1), we conclude that strongly saturated surface colors associated with a positive luminance contrast are the most likely to promote background *contrast* induction and *foreground* effects. Weakly saturated surface colors associated with a negative luminance contrast have a tendency to induce background *assimilation* or *no effect* at all. They are the most likely to generate *background* effects, i.e. to be seen as standing behind their achromatic backgrounds. The figure ground organization of colored surfaces on achromatic backgrounds tends to be more ambiguous compared with configurations of achromatic inducers on achromatic backgrounds. This seems to hold especially in the range of relatively strong negative luminance contrasts, where achromatic inducers engender clear foreground percepts while colored inducer produce more ambiguous percepts. This may be one of the deeper reasons why renaissance painters tended to exploit *chiaroscuro* and geometric cues to pictorial depth using preferably achromatic contrasts and resorting to color only within a very limited chromatic range.

The results here suggest that induction polarity (*assimilation /contrast*) and depth order (*foreground/ background*) cannot be linked by any straightforward causal explanation. While color saturation systematically and significantly determines depth order, this is not so for the case of induction polarity. Also, one cannot conclude that variables which support contrast systematically bring a contrasted surface to the foreground. In the case of colored inducers, it all depends on their saturation and contrast polarity and in the case of achromatic inducers, on their contrast polarity. This is consistent with conclusions from earlier studies (e.g. Egusa, 1977, 1983; Guibal and Dresp, 2004; Dresp-Langley & Reeves, 2012) and contradicts the intuition that perceived pictorial depth may be directly linked to subjective brightness effects and color appearance (e.g. Katz, 1911, Long & Purves, 2003). In a review chapter, we (Dresp-Langley & Reeves, 2013) discussed the possibility that a probability based selection of neural signals may drive perceptual grouping (see also Dresp & Langley, 2005), or *Gestalt* formation (see also Pinna, 2011), and guide the brain in working out the most likely hypothesis of visual structure from elementary characteristics of current visual input. At some stage, bottom-up attention becomes critically important as some input characteristics readily attract attention away from others in the visual field. Image parts with a stronger and more salient contrast or color may benefit from selection for attention when presented together with objects of a less salient contrast or color. Color saturation may have a decisive influence here.

Data from recent visual studies indeed suggest that feature-based selection for attention can be based on any aspect of color contrast. Hue alone may be used independently of lightness in displays with multiple colors, and saturation may be used in displays where color is held constant (Stuart, Barsdell, & Day, 2014), as was the case in our displays here.

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Figures and Tables

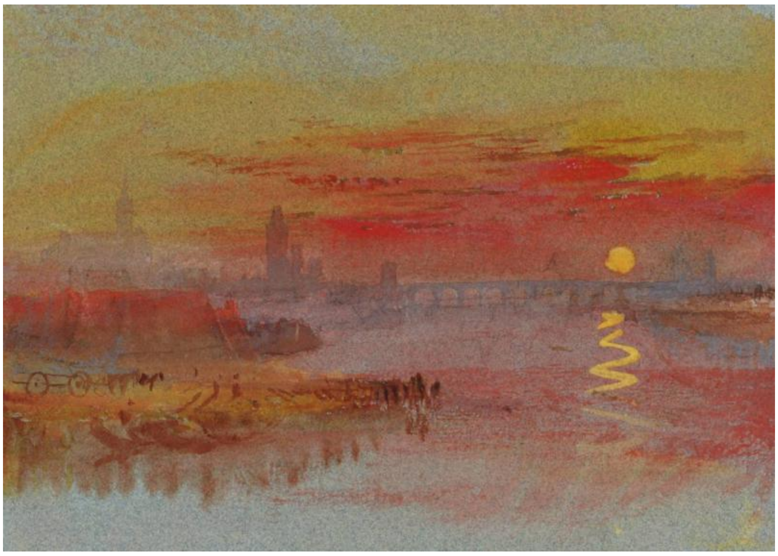


Figure 1

In the 19th century, painters like Turner effectively exploited color, saturation, and luminance effects to suggest figure and ground, as here in *"Sunset on Rouen"*.

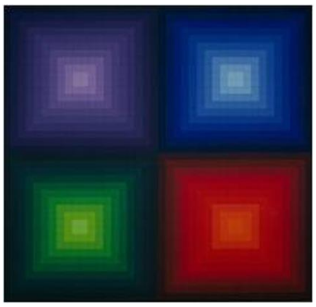


Figure 2

In the 20th century, designers like Vasarély, as here in *"Arcturus II"*, demonstrated how the manipulation of color, saturation, and luminance, combined with planar shape geometry, permits creating compelling figure-ground effects.

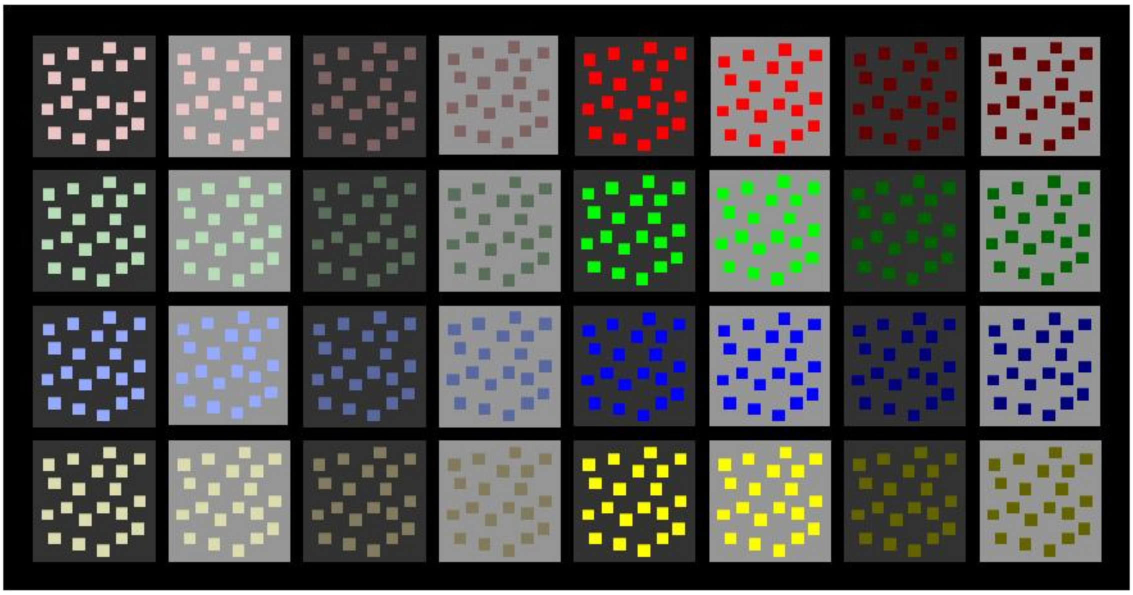


Figure 3

Variations in luminance contrast and saturation of colored inducers presented on grey backgrounds. In a relative background brightness task, observers had to judge the relative brightness (*brighter*, *darker* or *same*) of a grey test background with inducers (as shown here) in comparison with a simultaneously presented background field of identical luminance without inducers (not shown here). In a relative depth task, observers had to indicate whether they perceived the inducers of a given configuration as standing *in front* or *behind* the grey background or whether inducers and background appeared to lie in the *same* plane.

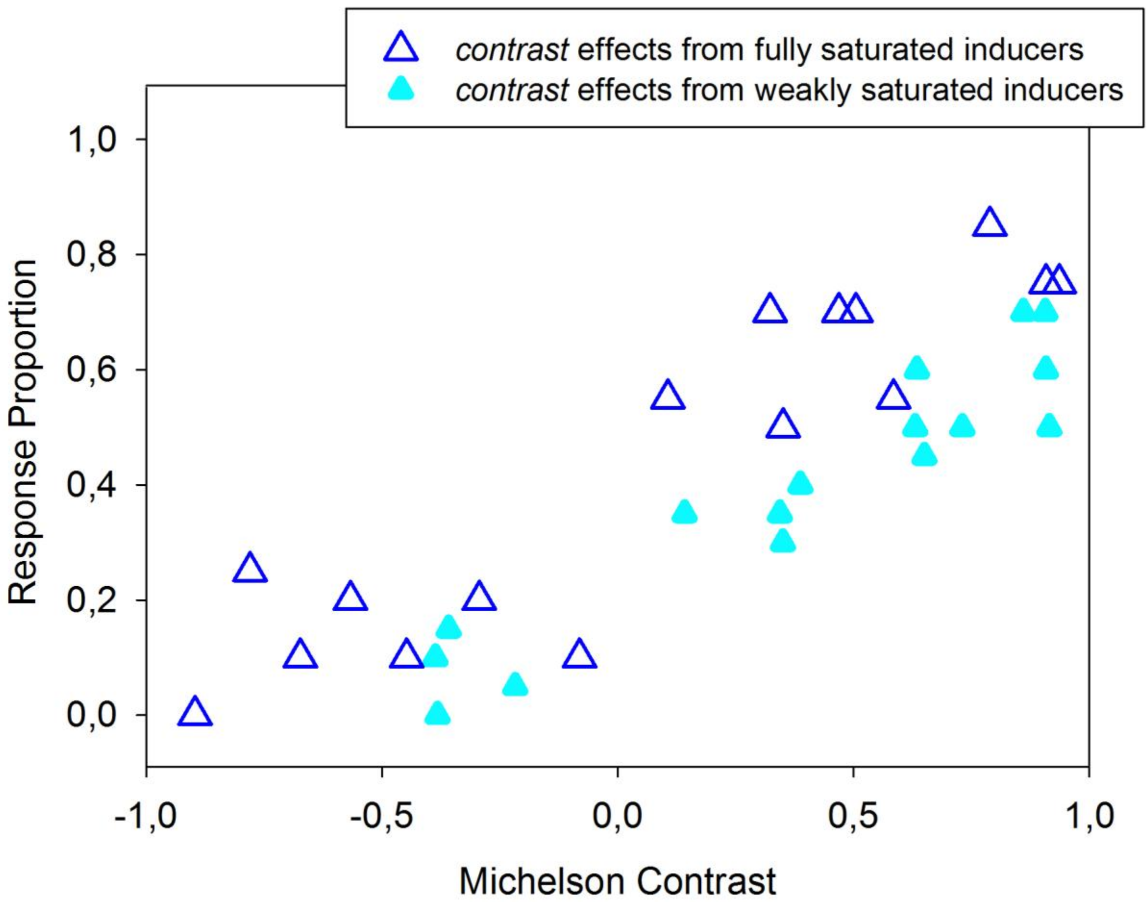


Figure 4

Response proportions for *contrast* effects as a function of the Michelson contrast and saturation level of colored inducers.

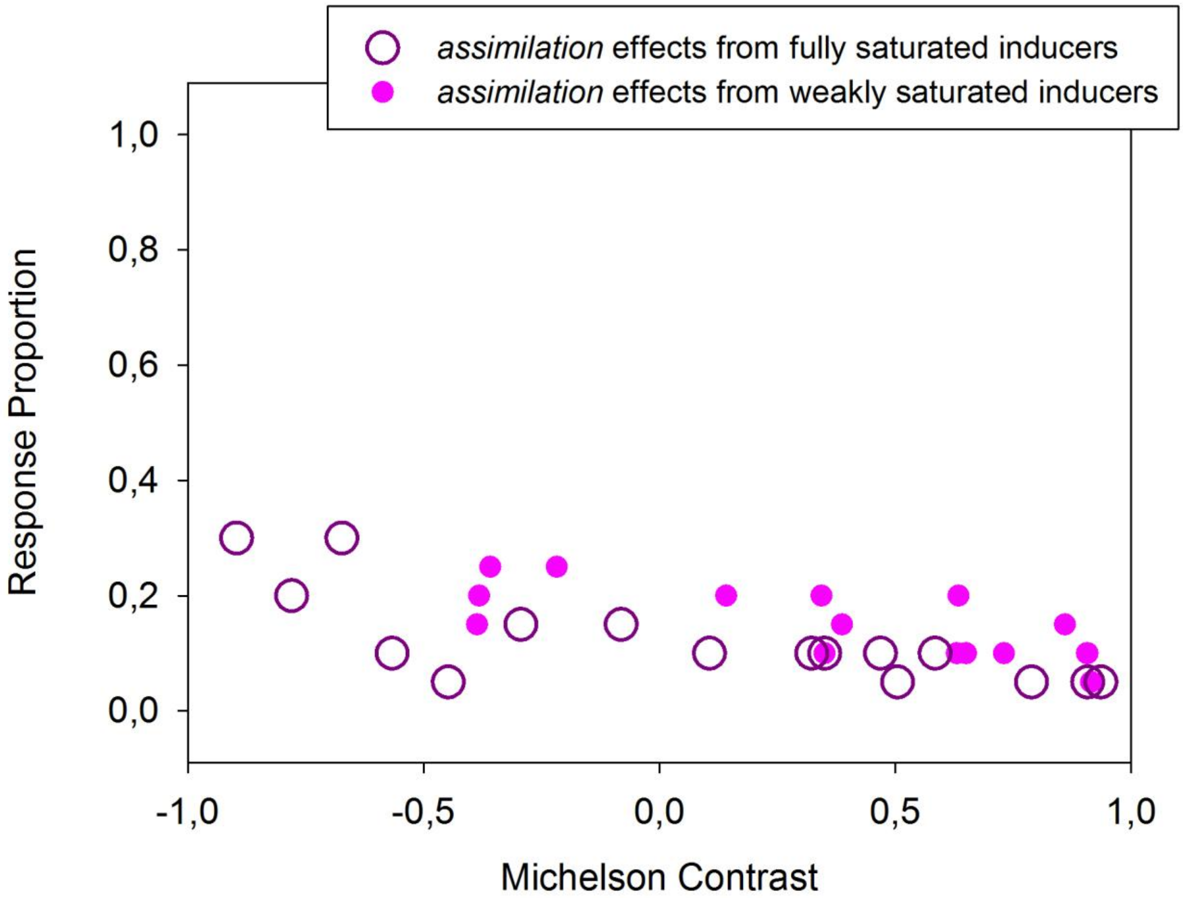
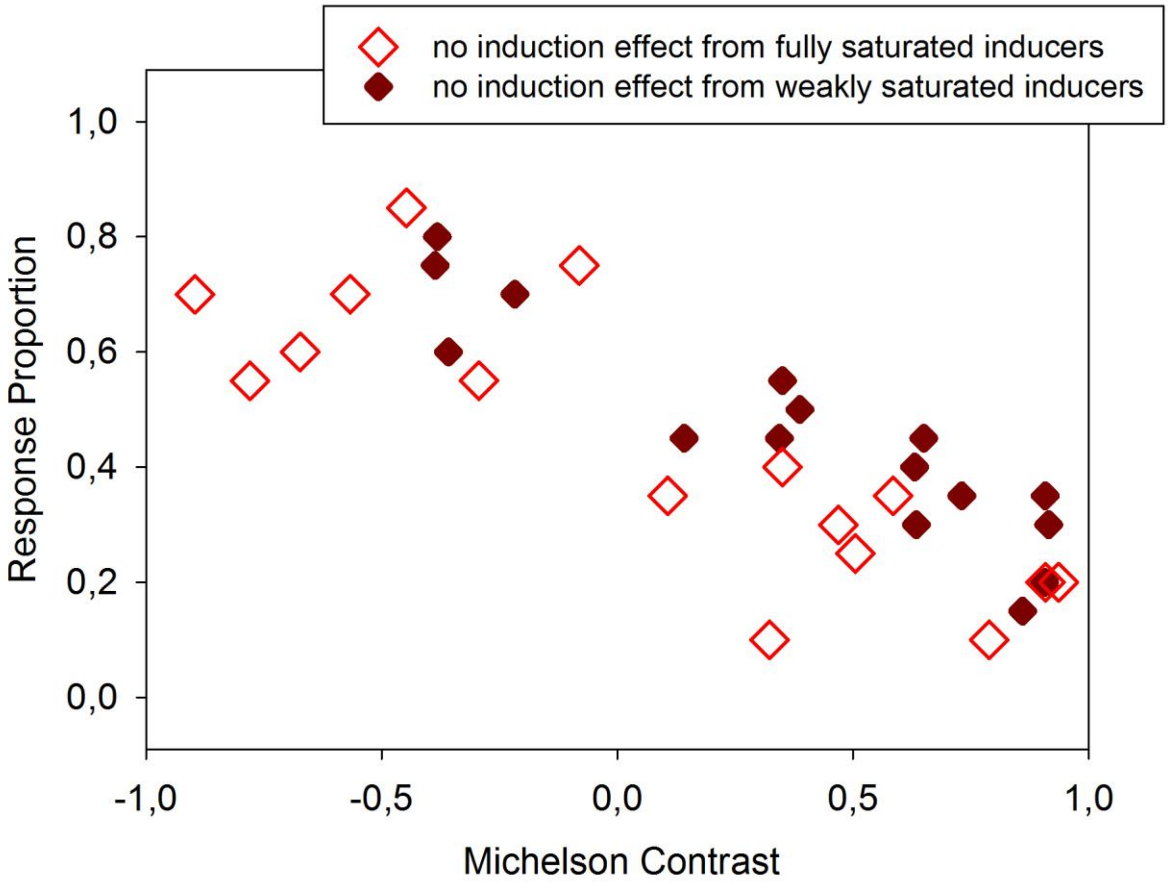


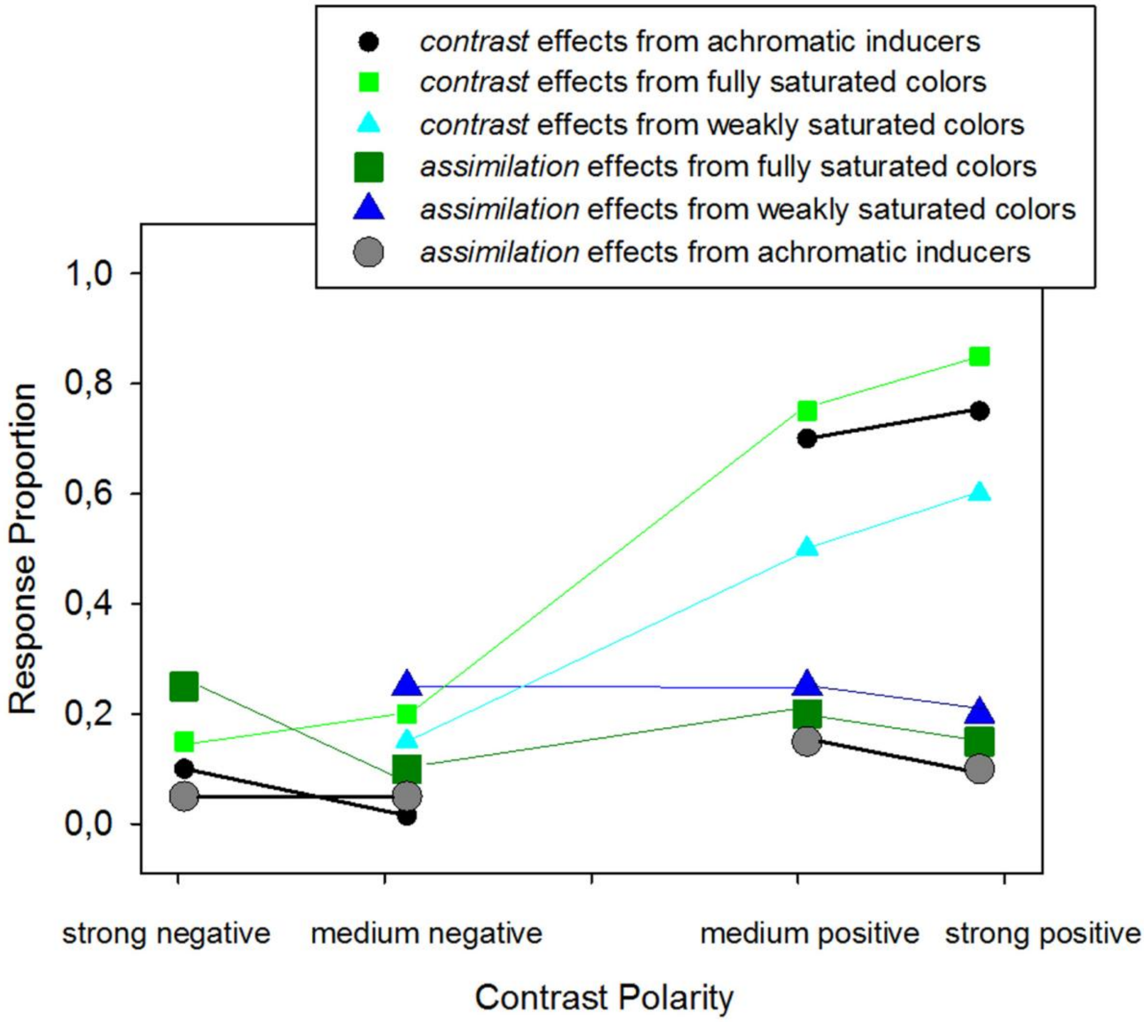
Figure 5

Response proportions for *assimilation* effects as a function of the Michelson contrast and saturation level of colored inducers.



<u>Figure 6</u>

Response proportions for *no effect* as a function of the Michelson contrast and saturation level of colored inducers.



<u>Figure 7</u>

Response proportions for *contrast* and *assimilation*, summarized here including effects of achromatic inducers for comparison, as a function of the saturation level and the contrast polarity range (each data point represents the mean of two or more observations here; there were no observations for weakly saturated inducers in the strong negative range).

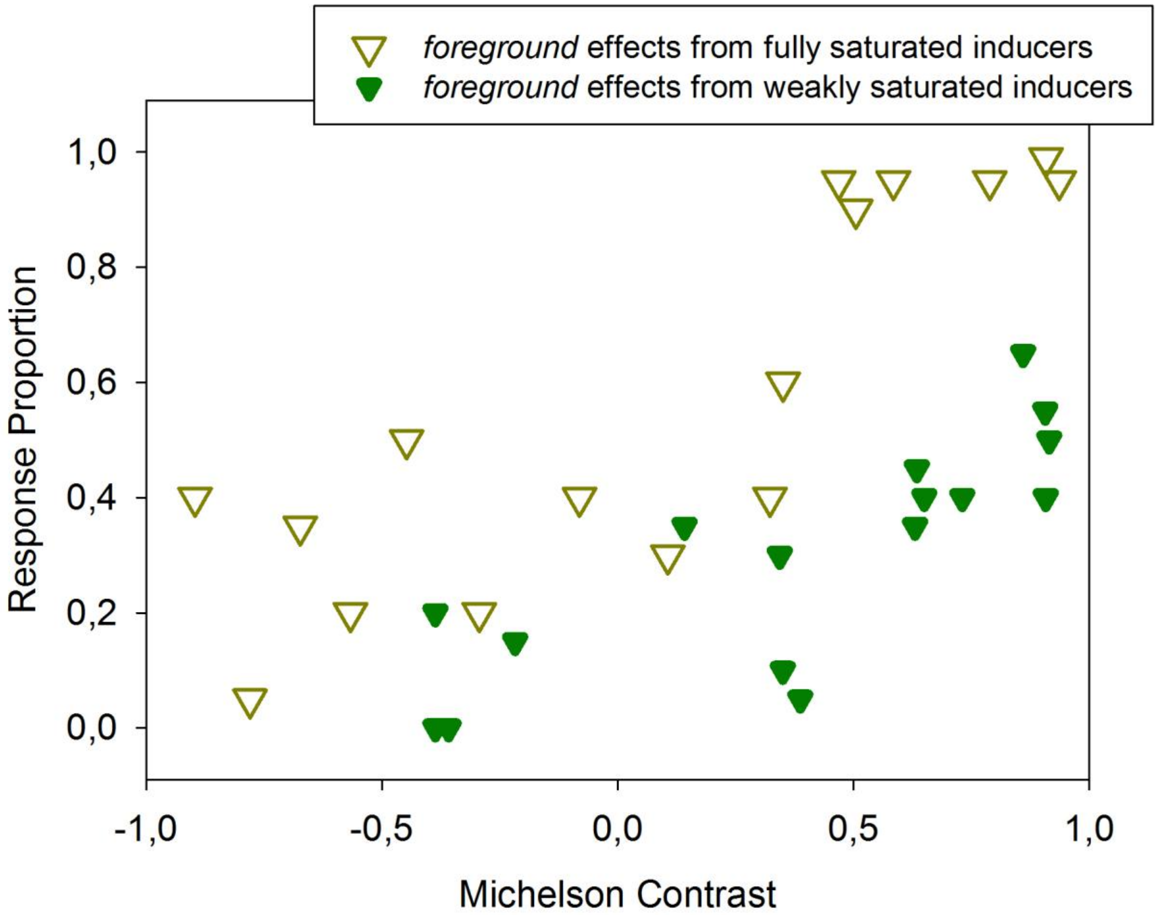


Figure 8

Response proportions of *foreground* effects, indicating that the colored inducers are seen as *figure*, as a function of their Michelson contrast and saturation level.

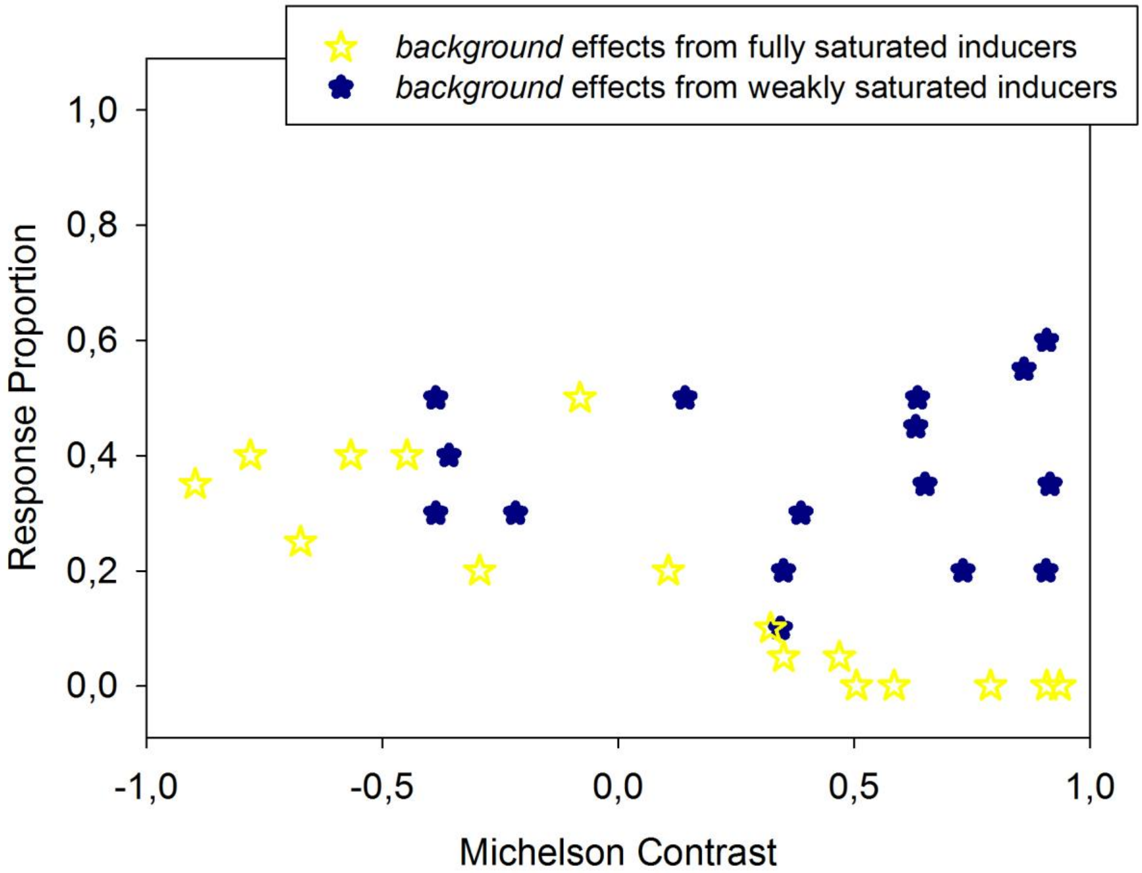


Figure 9

Response proportions of *background* effects, indicating that the colored inducers are seen as *ground*, as a function of their Michelson contrast and saturation level.

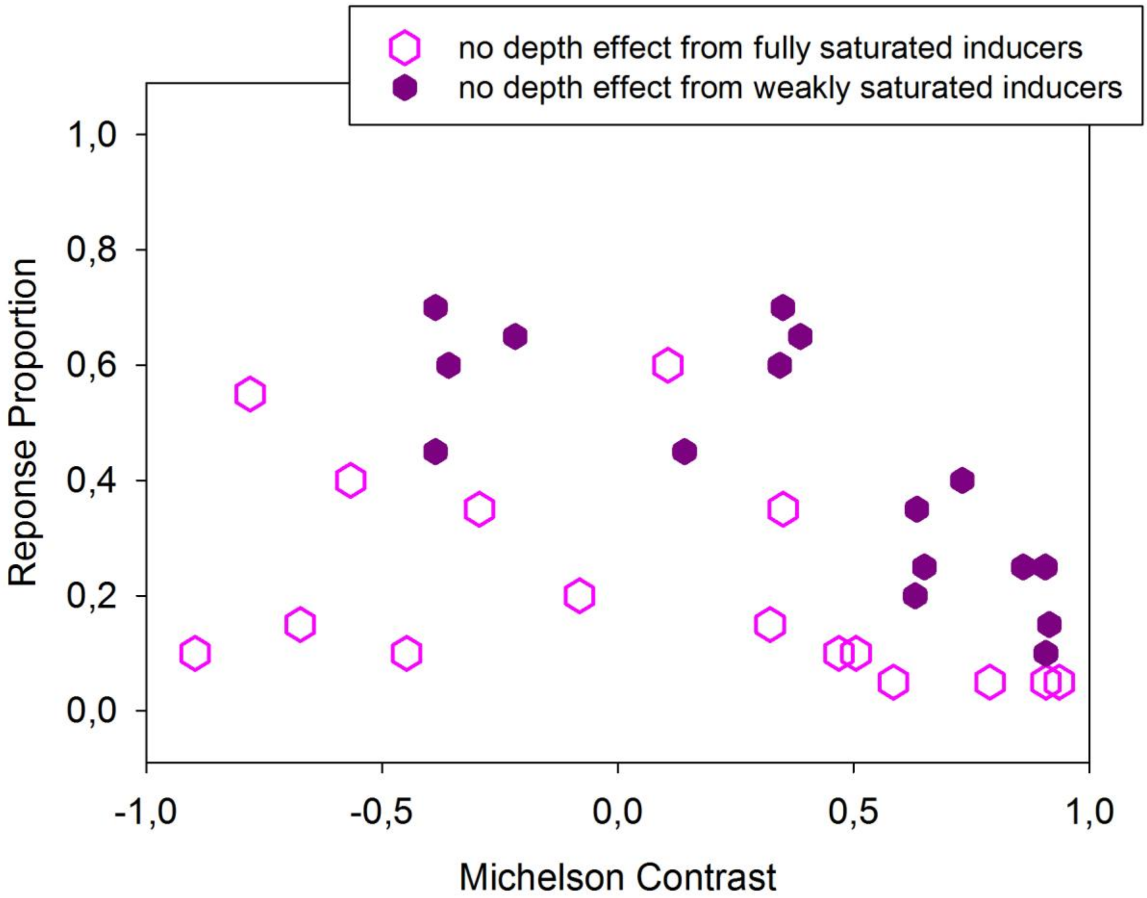


Figure 10

Response proportions relative to *no depth effect* produced by colored inducers as a function of their Michelson contrast and saturation level.

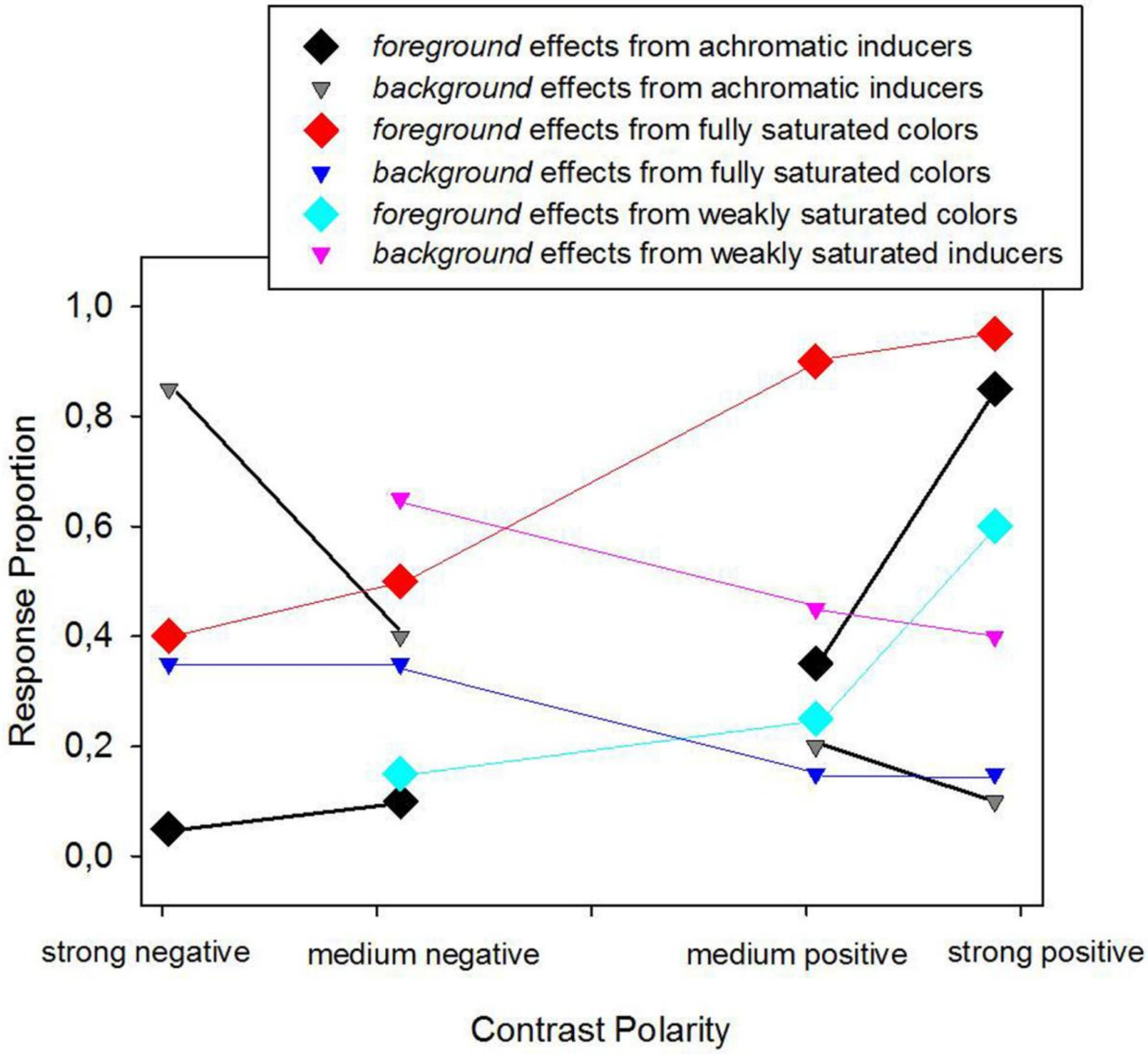


Figure 11

Response proportions summarizing figure-ground effects in terms of *foreground* or *background* effects. This graph includes observations with achromatic inducers, for comparison. Data are shown as a function of the saturation level and the contrast polarity range (each data point representing the mean of two or more observations here; there were no observations for weakly saturated inducers in the strong negative range).

	COLOR COORDINATES							
	"Weakly" saturated hues				"Fully" saturated hues			
	x	**y**	**z**	**R G B**	**x**	**y**	**z**	**R G B**
Color appearance								
« Light » RED	0.33	0.33	0.34	[235,197,197]	0.68	0.31	0.01	[250, 0, 0]
« Dark » RED	0.33	0.33	0.34	[127, 99, 99]	0.68	0.31	0.01	[100, 0, 0]
« Light » GREEN	0.31	0.35	0.34	[183,221,183]	0.20	0.70	0.10	[0 ,250, 0]
« Dark » GREEN	0.31	0.35	0.34	[91,110, 91]	0.20	0.70	0.10	[0 ,100, 0]
« Light » BLUE	0.29	0.30	0.41	[180,201,255]	0.15	0.05	0.80	[0 ,0 ,150]
« Dark » BLUE	0.29	0.30	0.41	[90,104,160]	0.15	0.05	0.80	[0 ,0 ,125]
« Light » YELLOW	0.32	0.36	0.32	[220,220,175]	0.42	0.51	0.07	[255,255, 0]
« Dark » YELLOW	0.32	0.36	0.32	[130,123, 85]	0.42	0.51	0.07	[100,100, 0]

Table 1

Color coordinates (X, Y, Z) and RGB (Adobe) triplets associated with the different hues (shown on their grey backgrounds here in Figure 3).

Hues	**"Fully" saturated**				**"Weakly" saturated**			
RED inducers:	-0.44	-0.08	0.58	0.79	-0.21	0.30	0.73	0.91
GREEN inducers:	-0.57	0.35	0.47	0.91	-0.38	0.35	0.63	0.91
BLUE inducers:	-0.90	-0.67	-0.29	0.32	-0.38	0.14	0.63	0.86
YELLOW inducers:	-0.78	0.11	0.51	0.94	-0.36	0.30	0.65	0.92
ACHROMATIC inducers:	-0.45	0.52	0.59	0.94				

Table 2

Michelson contrasts (four per hue and saturation level and four additional achromatic conditions) of the inducer-background configurations.