Perceived Contrast in Variegated Checkerboards

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September 2020

A thesis submitted for the degree of Master of Science

MSc Cognitive Science – Embodied Cognition

Faculty of Human Sciences

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Abstract

In contrast perception, induction and assimilation are two phenomena thought to have opposite effects on the perceived contrast of a target region. The thesis examined the question of whether, in variegated checkerboards, which are partially covered by transparent media, the perceived contrast of the covered region depends only on the physical contrast within this region, or it is also influenced by its adjacent surround as in contrast induction or assimilation. I used a matching task to test observers' perceived contrast in checkerboards covered by twelve different transparent media, with four different transmittance values, and three different reflectance values. In the experiment, the observers' task was to adjust the isolated cutout until it looked identical in perceived contrast to the target region in the checkerboard. All observers perceived the isolated cutout to be lower in contrast, for all combinations of transparency's reflectance and transmittance values. In addition, I compared the difference between the current checkerboard stimuli, which induce an effect of contrast assimilation, and the texture stimuli in the classic contrast contrast illusion for which we observe the opposite, induction effect. The comparison suggests that a stronger presence of perceived transparency might lead to a contrast effect in variegated checkerboards.

Keywords: perceived contrast, contrast contrast illusion, lightness perception

Zusammenfassung

Induktion und Assimilation sind zwei Phänomene, von denen man in Kontrastwahrnehmung annimmt, dass sie unterschiedliche Effekte auf den wahrgenommenen Kontrast einer Zielregion haben.

In dieser Arbeit untersuche ich, inwiefern auf variierten Schachbrettern, die teilweise durch transparente Medien abgedeckt sind, der wahrgenommene Kontrast der verdeckten Ebene nur von dem physischen Kontrast in dieser Ebene abhängt, oder ob dieser auch von der Kontrastinduktion und Assimilation der umgebenden Ebene beeinflusst wird. Zu diesem Zwecke habe ich in einem Experiment, den wahrgenommen Kontrast in Schachbrettern, die aus Kombinationen von zwölf verschiedenen Transparenten Medien, vier verschiedene Durchlässigkeitswerte und drei verschiedene Spiegelungswerte bedeckt sind, gemessen. Die Aufgabe der Probanden war es dabei die ausgeschnittene Region solange zu verändern, bis ihr Kontrast mit dem Kontrast der Zielregion übereinstimmte. Bei diesem Experiment wurde dabei stets der Kontrast der ausgeschnittenen Region aus niedriger wahrgenommen. Darüber hinaus verglich ich den Unterschied zwischen den aktuellen Schachbrettstimuli, welche einen Effekt der Kontrastassimilation induzieren, und den Texturstimuli in der klassischen Kontrasttäuschung, bei der wir den gegenteiligen Induktionseffekt beobachten. Dieser Vergleich legt nahe, dass eine stärkere Präsenz der wahrgenommenen Transparenz zu einem Kontrasteffekt bei variierten Schachbrettern führen könnte.

Schlagworte: Kontrast, contrast contrast Illusion, Helligkeitswahrnehmung

Selbstständigkeitserklärung

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Ort, Datum Unterschrift

Introduction

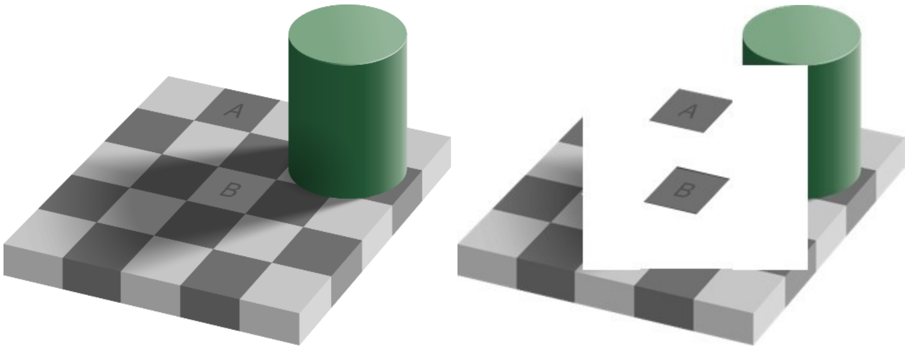
Most of us take vision for granted and we would not consider it a difficult task. But explaining how the visual system works is not as simple. In lightness perception, to tell whether a surface is black, grey, or white, the visual system is performing the following task. First, we need some light source. The surfaces we see reflect the light to our eyes. When light reaches the retina, it stimulates the retinal photoreceptors, which transmit information about the visual world to our brain as visual input. Finally, we perceive the lightness of the surface. To better understand the process, I will use the following terminology which is common in the field lightness perception: *Illuminance* is defined as the amount of light incident on a surface. *Reflectance* is defined as the fraction of incoming light that a surface reflects. *Luminance* is defined as the amount of light that comes to the eye from a surface and that stimulates the photoreceptors. *Lightness* is defined as perceived reflectance, the achromatic color of a surface.

Illuminance, reflectance, and luminance are physical quantities, whereas lightness is a perceptual quantity. My usage of the terminology follows Adelson (2000).

Lightness Constancy and Lightness Illusions

Lightness Constancy

Our photoreceptors receive luminance information from surfaces, which can be considered as the product of the illuminance and reflectance. The visual system attempts to extract the reflectance from the luminance signal in the retina. The luminance of a grey surface in bright illumination and a white surface in dim illumination might be equal, but we seldom perceive them as the same color. A white surface in a dim illumination is still perceived as a white surface, even though it reflects less light compared to a white surface placed in bright illumination. This phenomenon is called lightness constancy (see Figure 1 Adelson's checker-shadow illusion for an example).



(a) (b)

Figure 1: Adelson's checker-shadow illusion (a). The visual system perceives the dark square A and the light square B as different in lightness although they have the same luminance value. (b): If cues of the illuminance context of light and shadow are reduced, square A and square B would appear to be less different in lightness.

In the past decades, lightness constancy has been studied through surfaces viewed under different illumination conditions (Gilchrist, 1979; Gilchrist & Soranzo, 2019), as well as surfaces viewed through partially-transmissive layers (Gerbino, Stultiens, Troost, & de Weert, 1990; Singh, 2004). Under realistic viewing conditions, i.e. with a number of cues to depth and illumination, the visual system seems to have the ability to decompose the surface luminance into the illumination context (or the partially-transmissive layer in the latter case) and surface reflectance.

However, most of the stimuli used in the laboratory have been rather simple stimuli, i.e. flat images without cues to depth or illumination. Under such circumstances, our visual system's ability to 'discount' the context luminance sometimes leads to illusory effects. In some special cases, so-called lightness illusions, the same gray value is perceived differently, when it is viewed in different contexts. Simultaneous contrast effect (Figure 2) is an example of such an illusion, and also the Adelson's checkerboard from above (Figure 1).

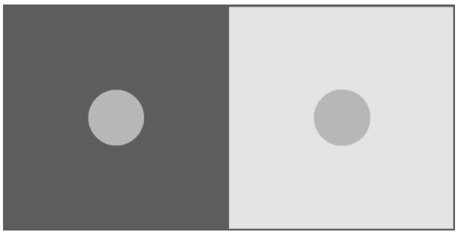


Figure 2: Illustration of simultaneous contrast illusion. Observers perceive the circular patches as different in lightness although they have the same luminance value. The light and dark grey backgrounds are comparable with the Adelson's checker-shadow illusion (Fig. 1).

Lightness Illusions

Traditionally, illusory perception is believed to be cases where our perception does not correspond with physical reality. For example, the simultaneous contrast effect is sometimes considered as an illusion, because we perceive patches with the same luminance as different in lightness. However, when considering the Adelson's checkerboard, it becomes clear that the concept of an illusion is much more difficult than we initially think (Rogers, 2014). In the Adelson stimulus, the observer correctly perceives the checks as different in lightness, although they have the same luminance value. Rogers argued that visual illusions are consequences of our visual perception which reveal how the visual system works in particular situations. In this thesis, I aim at exploring the visual mechanism of contrast perception. One possible way is to look at some specific contrast illusions.

Contrast Contrast Illusion and Variegated Checkerboard Illusion

The contrast contrast illusion is believed to be an analogous lightness phenomenon to the simultaneous contrast illusion. Chubb, Sperling, and Solomon (1989) found that the apparent contrast of a textured patch varies inversely with the contrast of its surrounding texture (Figure 3). They showed that a medium-contrast patch embedded in a high contrast background appears lower in contrast than the same patch surrounded by a homogeneous grey background. The contrast contrast illusion is considered as a contrast induction effect, where we observe a contrast shift away from the contrast of the surrounding texture. In other words, the high-contrast surrounding texture (Figure 3 right) reduces the perceived contrast of the central region via a (putative) induction mechanism. The center-surround contrast induction effect can be found in a series of

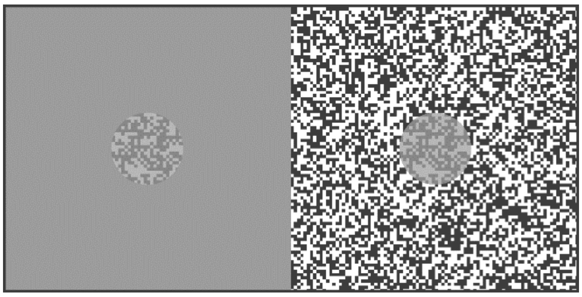


Figure 3: Illustration of the contrast-contrast illusion. Observers perceive the circular patches as different in contrast, although they are identical and have the same physical contrast.

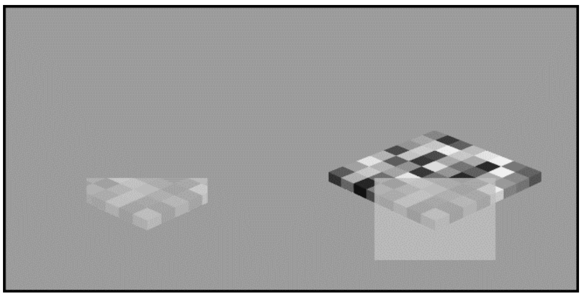


Figure 4: Illustration of the variegated checkerboard illusion. Observers perceive the polygon regions as different in contrast, although the left is a cut-out of the region under transparency from the right, identical in luminance and physical contrast.

stimuli (Olzak & Laurinen, 1999, 2005; Xing & Heeger, 2001), and has been considered as a conflicting effect towards assimilation effects.

However, Maertens and Aguilar (2019), when exploring the perceptual scales of perceived transmittance in variegated checkerboards, noticed the opposite effect. They tested several sets of checkerboards covered by transparent media with different reflectance and transmittance values, and accidentally observed that for checkerboards that were partially covered by transparent media with some specific transmittance values, the cutout of the transparency region appeared to be lower in contrast compared to the same region viewed against the checkerboard (Figure 4). Interestingly, the stimuli in contrast contrast illusion and variegated checkerboards are both images with center-surround contrast differences, where the central patch or polygon region are (partially) surrounded by peripheries with higher contrast. But in variegated checkerboards, the effect is assimilation-like. We observe a contrast shift in the polygon toward the contrast of its surrounding checkerboard. It is unclear why for variegated checkerboards the effect seems to be opposite than in the contrast contrast illusion.

Contrast Definition in Variegated Checkerboards

The variegated checkerboards are a series of stimuli that covered by different transparent media varying in reflectance τ and transmittance α. The usage of τ and α follows the idea of Metelli's episcotister model of transparency (Metelli, 1974). An episcotister is a wheel with a sector cut out. When rotating at a high speed it produces the perception of a transparent layer (see Figure 5). The physical properties of the transparent layer can thus be measured by two dimensions: τ, which is the reflectance of the episcotister, and α, which is the angle of the open sector. The transmittance of the transparent layer is indicated by α because a larger angle results in a more transparent layer when rotated.

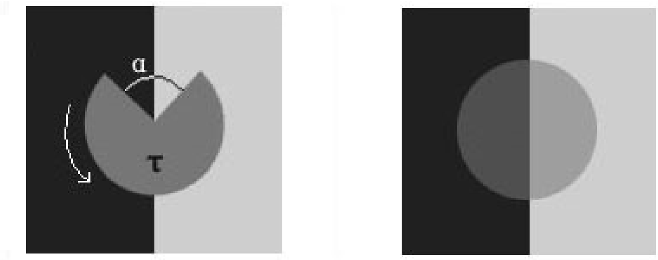


Figure 5: Illustration of the episcotister model of transparency. When the rotation of an episcotister with a reflectance τ and open area α is fast enough (left), the episcotister introduce an impression of transparency (right).

The checkerboards were created to induce the perception of transparency, but the images can also be measured by contrast. One possible quantification of image contrast is the root mean square (rms) contrast, which is defined as:

$$RMS = \sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(I_{ij} - \bar{I}\right)^2},$$

where I_{ij} is the luminance of the i-th j-th element of an image of size M by N, and $\bar{I}$ is the mean luminance. When covered by a transparent medium with a reflectance value τ and transmittance value α, the reflectance value τ modules the mean luminance of the covered region, whereas the transmittance value α modulates the rms contrast of the covered region. As the value of reflectance value τ increases, the mean luminance of the covered region increases. As the value of transmittance value α increases, the rms contrast increases (see Figure 6). When the transmittance value α reaches its upper limit 1, the transparent medium becomes fully transparent, the rms contrast of the covered region reaches its maximum. When the transmittance value α of the transparent medium reaches its lower limit 0, the transparent medium becomes opaque, and the rms contrast of the covered region also decreases to 0.

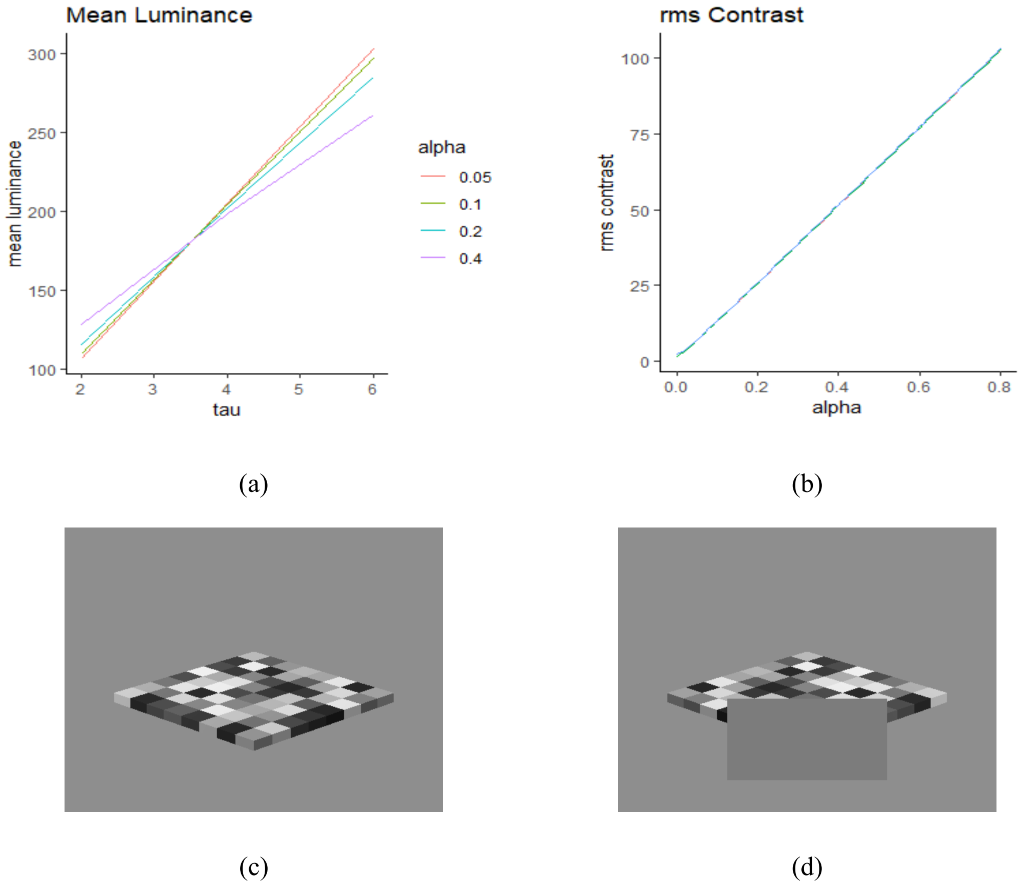


Figure 6: Mean luminance of checkerboard cutouts (a). The mean luminance of the target region increases with the reflectance τ. Tau values are in arbitrary *povray* units, from black to white. (b): Rms contrast of checkerboard cutouts. When covered by a transparent medium with a reflectance τ and transmittance α, the rms contrast of the target area increases with the transmittance α. (c): The transparent medium becomes fully transparent, when the transmittance value α reaches its upper limit 1. (d): The transparent medium becomes opaque when the transmittance value α of the transparent medium reaches 0, and the rms contrast of the covered region also decreases to 0.

Both the checkerboard illusion and the contrast contrast illusion can be considered as contrast illusions, where the perceived contrast of an image area is shown to depend not only on its physical contrast, but also on the contrast of its surround. Their different appearances lead to opposite perceptual effects. To better understand the underlying mechanism of contrast perception, it is meaningful to compare the differences between the two stimuli. This is why in a first step I would like to design an experiment to quantify the perceived contrast effect in variegated checkerboards to be able to compare the informal observation of Aguilar and Maertens (2019) to the results reported by Chubb et al, 1989.

My hypothesis is: if in variegated checkerboards the perceived contrast of the target region depends only on the physical contrast within this region, then the perceived contrast of the target region should be identical in the variegated checkerboards and in the isolated cutout. Alternatively, if the checkerboard illusion shares the same visual mechanism with the contrast contrast illusion, then the perceived contrast of the target region should be lower in the variegated checkerboards than in the isolated cutout.

To test this hypothesis, I designed and conducted a psychophysical experiment that aimed to specifically measure the perceived contrast effect observed by Aguilar and Maertens in variegated checkerboards. In this thesis I quantified the effect size across several different reflectance and transmittance values of the transparent media, and discussed the potential mechanism that might lead to the perceptual difference in these contrast effects.

Method

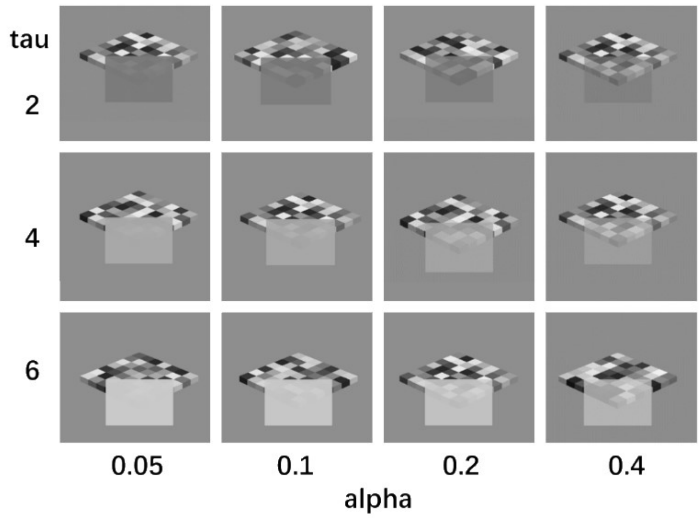
Observers

Five observers, with normal or corrected to normal visual ability, participated in the experiment. Two of them were naïve observers and were reimbursed for participation. The rest were experienced observers (GA, MM), including the author (YX). Informed consent was given before the experiment.

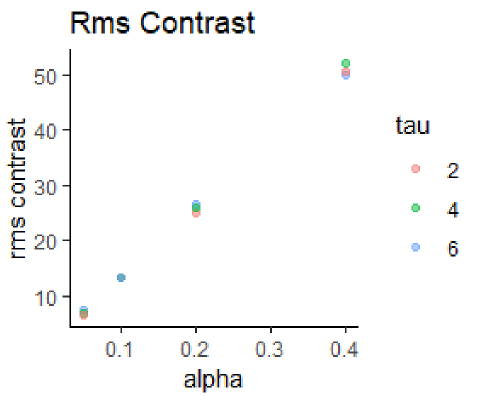
Stimuli and Apparatus

Stimuli were images of variegated checkerboards composed of 8 x 8 checks of varying reflectance. The luminances of the checks ranged from 15 to 415 cd/m^2. Part of the checkerboards was covered by transparent media that varied in reflectance (τ) and transmittance (α). Twelve standard stimuli were rendered using *povray* (three τ values, 2, 4, and 6 in arbitrary *povray* units, from black to white, by four α values, 0.05, 0.1, 0.2, and 0.4, see figure 7a). Figure 7b shows the pixelwise rms contrast of cutouts from the 12 standard stimuli. For each standard stimulus, 80 test images were rendered for the matching procedure (see 'Design and Procedure'), with transmittance α values ranging between 0 and 0.8 in steps of 0.01. The matching stimuli were identical checkerboards as the standard, except for its varying transmittance α. In total, I rendered 960 images (12 standard checkerboard layouts x 80 transmittances) for the matching procedure.

Stimuli were presented on a linearized 21-inch Siemens SMM2106LS monitor (400 x 300mm, 1024 x 768px, 130Hz). During the experiment, observers sat in a dark cabin, 130 cm away from the monitor. Control of stimuli presentation was realized using a DataPixx graphics toolbox (Vpixx Technologies, Inc., Saint-Bruno, QC, Canada)



(a)



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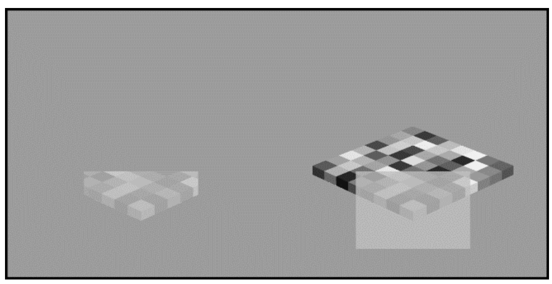

(c)

Figure 7: Experimental stimuli and task (a). Stimuli were checkerboards partially covered by transparent media with three τ values, 2, 4, and 6 in *povray* units, from black to white, by four α values, 0.05, 0.1, 0.2, and 0.4. (b): Rms contrast of the cutouts of 12 sets of stimuli from above. (c): A single trial in the matching experiment. The observers' task was to adjust the cutout until it looked identical in perceived contrast to the target region in the checkerboard.

and custom presentation software (http://github.com/computational-psychology/hrl). Observers' responses were recorded by a RESPONSEPixx 4-button fiber-optic response box (Vpixx Technologies, Inc., Saint-Bruno, QC, Canada).

Design and Procedure

We assessed perceived contrast of the target region using a matching task following Fechner's method of adjustment (Fechner, 1860) . In each trial, a variegated checkerboard was randomly presented on the left or the right half of the screen, covered by a transparent medium with one of the twelve stimuli rendered with a particular α and τ (Figure 7c). Images of the cutout of the same checkerboard covered by a transparent medium of the same τ and all possible α were loaded, and one of the 80 possible images was randomly presented on the other half of the screen as a starting point for further adjustments.

Observers were asked to adjust the image of the isolated cutout until it looked identical in perceived contrast to the target region in the checkerboard. The adjustment was realized by displaying cutouts of pre-rendered checkerboards covered by a transparent medium with a higher or lower alpha, which effectively increased or decreased the physical contrast of the displayed cutout. Observers could use two buttons for coarse adjustments and two buttons for fine adjustments on the response box. No time limit was imposed on the adjustment procedure. The presentation of the next trial was triggered by a fifth button which confirmed a match. Each judgment was repeated ten times, resulting in a total of 120 matching trials.

Results

Figure 8 shows the result of the matching experiment by each trial. The diagonal lines indicate matches where the observers' adjusted rms contrast fits the standard rms contrast. If observers perceive the isolated cutout to be of the same contrast as it is in the variegated checkerboard, they would approximately adjust for the same rms contrast, and the matches should lie around the diagonal line. In figure 8, it is clear that for all observers, almost all matches are above the diagonal line. These results show that observers adjust a higher rms contrast for the cutout than the actual (standard) rms contrast of the same region in the checkerboard, indicating that they perceived a higher contrast in the variegated checkerboards than in the isolated cutout. The increment in perceived contrast is different from what we observe in contrast contrast illusion.

Figure 9 shows the mean difference in matched and standard rms contrast in different conditions. For all observers, the mean differences are greater than zero in all

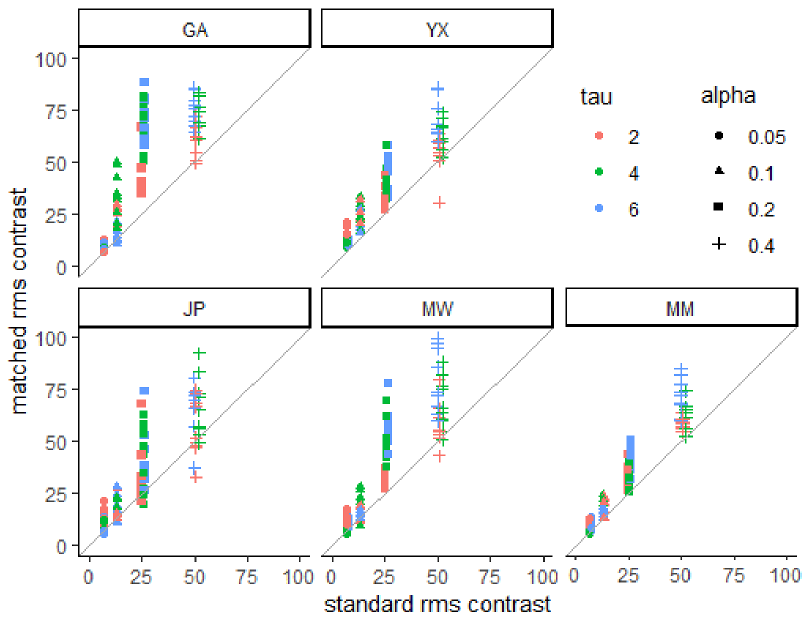

Figure 8: Results of the matched and standard rms contrast on each trial. Observer's matched rms contrast is higher than standard rms contrast in most trials.

conditions. Observers always adjusted a cutout with a higher rms contrast as a match.

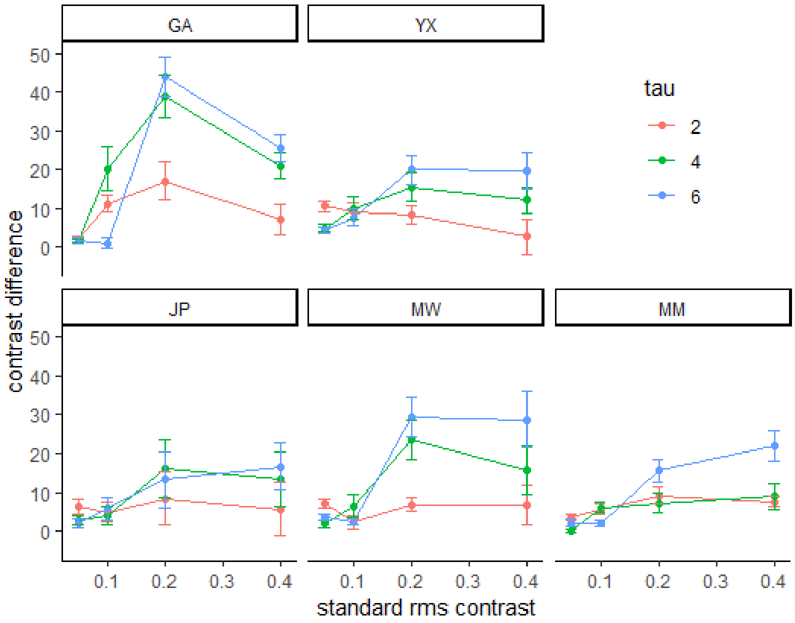

Figure 9: Results of mean matched and standard rms contrast by conditions.

An independent sample t-test reveals that the mean differences between matched rms contrast and standard rms contrast (M=10.71, SD=7.86) are significantly great than 0, $t(11)=4.72$, $p<0.001$.

As is mentioned before, the root mean square contrast indicates the variance of the intensity of all pixel values. In variegated checkerboards, it is only moderated by the transmittance of the transparent media, but not by the reflectance. Since we included three different reflectance conditions, it is also meaningful to see whether observers' performances are consistent across all reflectance conditions. Root mean square contrast is not capable of distinguishing the difference between reflectances. Another way to quantify the contrast intensity is the normalized root mean square (nrms) contrast, which is rms contrast normalized by mean luminance. The nrms contrast of the test region depends not only on transmittance but also on reflectance (see Figure

10).

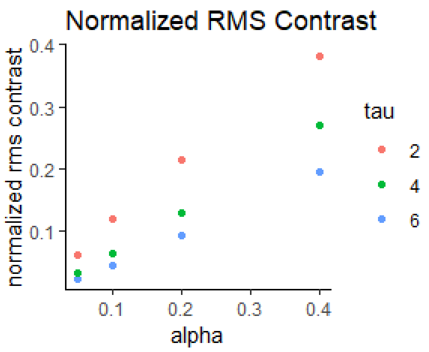

Figure 10: Normalized rms contrast of the cutouts of 12 sets of stimuli.

Figure 11 shows the same results as in Figure 9 but using nrms contrast as a metric. For all observers, when the standard nrms contrast is low, the contrast difference is less strong as when the standard nrms contrast is high. For some observers, for example, observer GA, JP, and YX, there might be a trend that the perceptual differences are strongest when the nrms contrast of the test region has a mid-range value (e.g., alpha = 0.2, tau =2; alpha = 0.2, tau = 4; alpha=0.4, tau = 6).

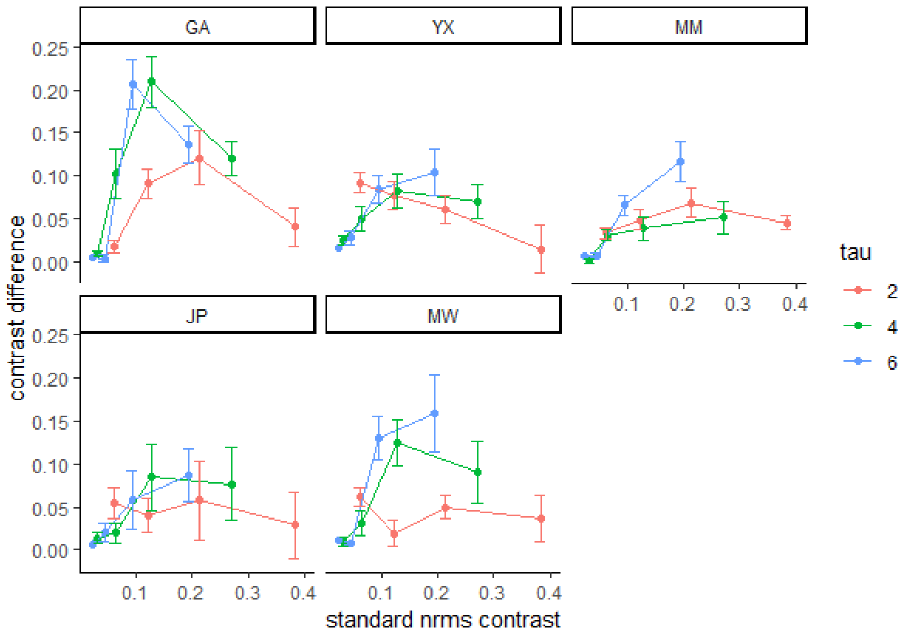

Figure 11: Same results as in Fig. 9 plotted as a function of the standard normalized rms contrast.

Discussion

The experiment aimed to measure the perceived contrast effect in variegated checkerboards across different reflectance and transmittance values of the transparent media. In all conditions, observers tended to adjust a cutout with a higher contrast as a match.

The result indicates that observers perceive the isolated cutout to be lower in contrast, than compared to the same region viewed in the checkerboard. This means that the checkerboard illusion seems not to share the same visual mechanism with the contrast contrast illusion. Instead, the effect of the checkerboard illusion is analogous to a contrast phenomenon called assimilation, which by definition will "induce the opposite transformation of that produced by contrast enhancement mechanism (Anderson, 1997, p.10)". To understand what causes such an effect in the checkerboard illusion, it might be helpful to compare the differences between our stimuli and the texture stimuli of the contrast contrast illusion.

The features of the checkerboard stimuli are prominently different from the texture stimuli in the following way:

a. The cutout of the checkerboard stimulus is a polygon instead of a circle.

b. The cutout is not necessarily in the center of its background.

c. The checkerboard stimulus depicts a 3D object instead of a texture.

Levels of visual processing

These three differences can be anchored to different levels of visual processing. In terms of the complexity of the underlying perceptual activity, visual processing is generally categorized into three different stages (see Adelson, 2000; Gilbert & Li, 2013).

Low-level processing involves the simplest analysis such as contrast and orientation, while high-level processing involves object recognition and acts in a 'top-down' direction. In between, there is the mid-level processing, which involves contour integration and surface segmentation. From such perspective, the checkerboard stimuli involve much more complex processing than the texture stimuli. For example, differences a. and b. both contribute to a stronger perception of transparency, which can be located at a mid-level processing stage. Difference c. suggests the involvement of high-level processing in the checkerboard stimuli that we recognize the image as a depiction of a variegated checkerboard.

From Checkerboards to Textures

To further compare the differences, my attempt here is to decompose the variegated checkerboard into a texture-like stimuli, and inspect at each step if the contrast effect recedes. If the effect changes with the reduction of a certain cue, that cue might play an important role in the contrast assimilation of variegated checkerboards.

Reduction in Spatial and Orientational Cues

Figure 12 shows a checkerboard surface with its edges removed, to include fewer cues of spatial information which are generally considered as mid or high level processing cues. Here the isolated cutout of the checkerboard surface still appears to be lower in contrast than the same region viewed in the checkerboard. But although the edges are removed, the checkerboard surface still introduces a sense of space, because the surface layer has a certain angle with our perspective.

The next attempt is to further reduce the spatial cues of the checkerboard. In Figure

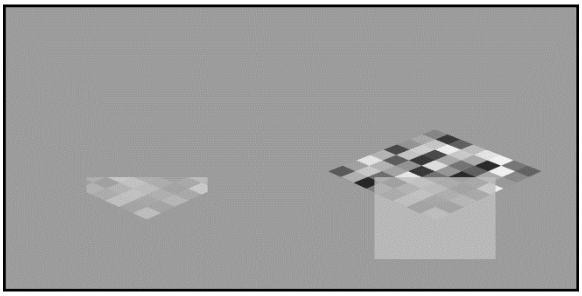

Figure 12: The checkerboard surface. Perceived contrast: left < right.

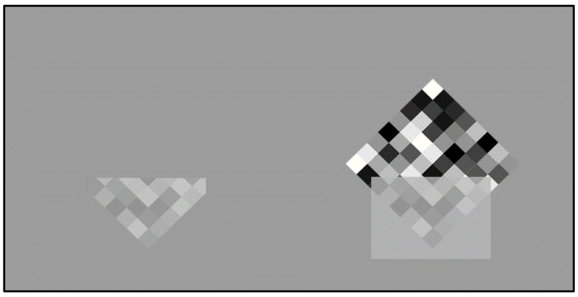

Figure 13: The vertical checkerboard surface. Perceived contrast: left < right.

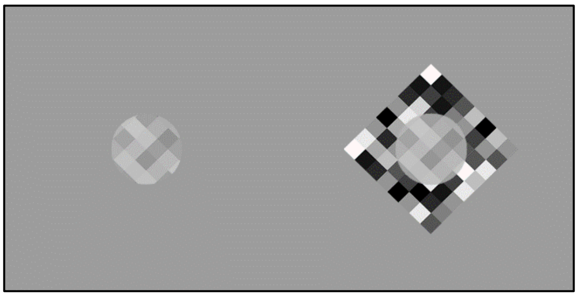

Figure 14: The center-surround vertical checkerboard surface. Perceived contrast: left ≤ right.

13 the checkerboard surface is reoriented vertically to be parallel to the screen. The isolated cutout in the vertical checkerboard surface still appears to be of lower contrast, compared to the same region in the complete checkerboard. Until now the reduction of contextual cues related to higher-level processing does not change the effect of the checkerboard illusion. A further reduction of high-level processing cues could be to fill the checkerboard into the entire screen so that it would be closer to a texture instead of an object, but this adaption would also change the layout of the stimuli.

Before any further adaptations, an interesting question would be whether the

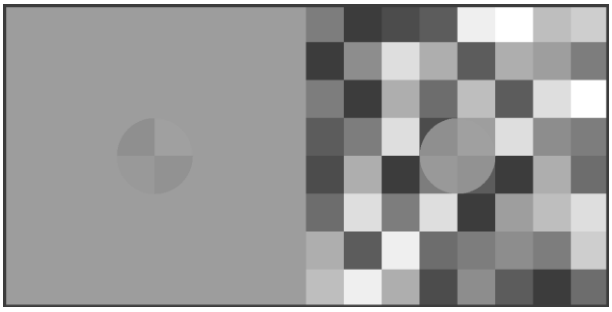

Figure 15: An 8x8 variegated checkerboard. Perceived contrast: left > right.

center-surround construction (differences a and b) plays an important role in the reduction of perceived contrast in the vertical checkerboard surface. In Figure 14, the rectangular transparent medium is substituted by a circular patch which is the same size as it is in the textured stimuli from the contrast-contrast illusion. Compared to the rectangular transparent medium, the circular transparent medium can be considered as involving fewer cues of transparency, because it involves fewer contour junctions, which induce illusory transparency and lightness percepts (Anderson, 1997). Here the isolated cutout of the covered circular region still seems to be slightly lower in contrast, but the effect is much weaker than in the original checkerboard illusion. It might be possible that the difference between the contrast-contrast illusion and the checkerboard illusion is mediated by the perception of transparency.

As we further reduce spatial cues, the checkerboard is no longer an object but closer to a texture. In figure 15, the isolated cutout on a homogenous background appears to be of higher contrast. This effect is parallel to what is perceived in the contrast-contrast illusion, instead of the original checkerboard illusion. But it is also worth noting that the spatial frequency of the checkerboard grids changes drastically, as the checkerboard surface spreads into the entire screen.

Assimilation and Spatial Frequency Cues

It is suggested by some vision researchers that contrast assimilation and contrast reduction are continuum effects moderated by spatial frequency (Barkan, Spitzer, & Einav, 2008; White, 2010). To understand whether the change of the effect is also influenced by spatial frequency, I further generated a 16x16 variegated checkerboard (Figure 16) and a 32x32 variegated checkerboard (figure 17). In these variegated checkerboards stimuli, a contrast contrast illusion-like effect is perceived.

I also tried some other manipulations with the classic checkerboards rather than the variegated ones. The classic checkerboards can be viewed as the most simplified version of the checkerboard illusion, which eliminates the difference a, b and c, yet still keep some feature of a checkerboard. A contrast contrast illusion like effect can be observed in Figure 18, 19, and 20. The isolated cutouts on the homogenous background appear to be of higher contrast.

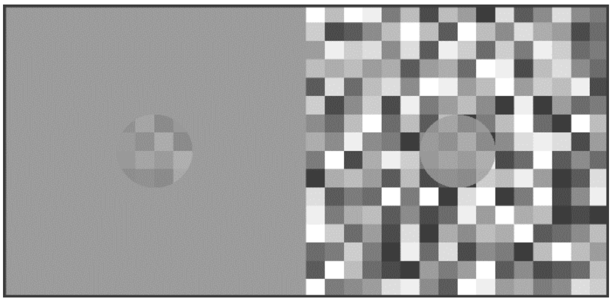

Figure 16: A 16x16 variegated checkerboard. Perceived contrast: left > right.

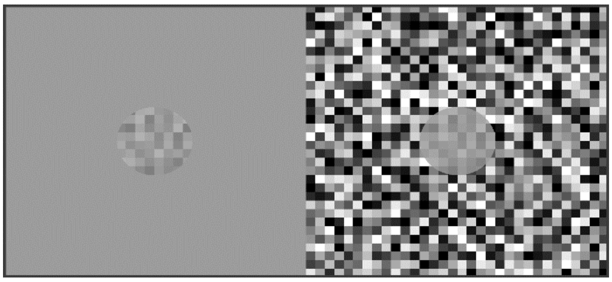

Figure 17: A 32x32 variegated checkerboard. Perceived contrast: left > right.

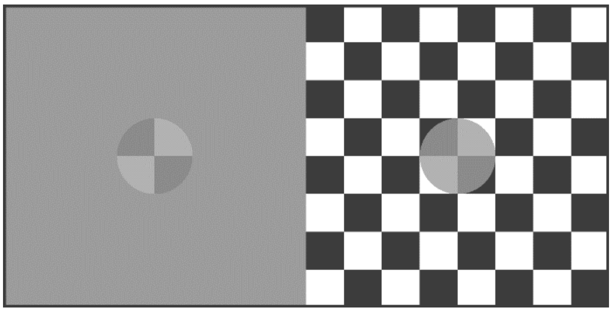

Figure 18: An 8x8 classic checkerboard. Perceived contrast: left ≥ right.

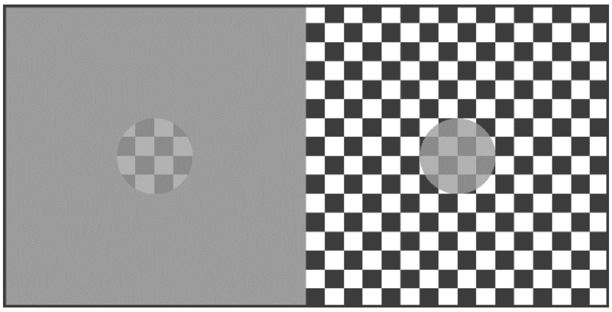

Figure 19: A 16x16 classic checkerboard. Perceived contrast: left > right.

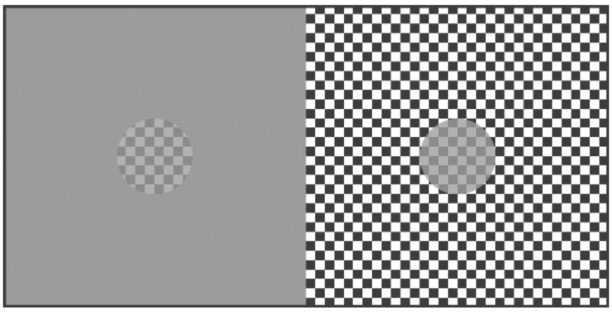

Figure 20: A 32x32 classic checkerboard. Perceived contrast: left > right.

Contrast Assimilation and Transparency

Koning, De Weert and Van Lier (2008) found when stimuli presentation times are restrained, an assimilation effect is enhanced by the presence of transparency. It is unclear whether in variegated checkerboards, the assimilation effect is also moderated by perceived transparency. Compared with the checkerboard stimuli, the texture stimuli involve less perception of transparency. If we fill the checkerboard with the same textured noise from the contrast contrast illusion (Figure 21), the assimilation effect can still be observed. The textured checkerboard still induces a strong perception of transparency.

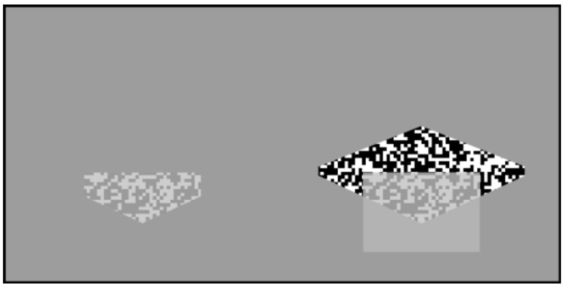

Figure 21: A textured checkerboard. Perceived contrast: left < right.

From the above attempts, it is clear that the contrast assimilation effect recedes as the checkerboard stimuli are decomposed into checkerboard-like textures. But when filled with the textured noise, the assimilation effect can still be observed. It might be possible that the checkerboard illusion is related to some high-level mechanisms, as well as transparency related mid-level processing. In future research, it would be meaningful to examine how the contrast induction and assimilation effects are influenced by perceived transparency.

Conclusions

In variegated checkerboards, observers perceived the isolated cutout to be lower in contrast. A contrast assimilation effect can be observed in the checkerboard illusion. Such an effect is different from the induction effect in contrast contrast illusion. The difference might be derived from the interpretation of transparency.

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