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# Applying the Helmholtz illusion to fashion: horizontal stripes won't make you look fatter

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**Abstract.** A square composed of horizontal lines appears taller and narrower than an identical square made up of vertical lines. Reporting this illusion, Hermann von Helmholtz noted that such illusions, in which filled space seems to be larger than unfilled space, were common in everyday life, adding the observation that ladies' frocks with horizontal stripes make the figure look taller. As this assertion runs counter to modern popular belief, we have investigated whether vertical or horizontal stripes on clothing should make the wearer appear taller or fatter. We find that a rectangle of vertical stripes needs to be extended by 7.1% vertically to match the height of a square of horizontal stripes and that a rectangle of horizontal stripes must be made 4.5% wider than a square of vertical stripes to match its perceived width. This illusion holds when the horizontal or vertical lines are on the dress of a line drawing of a woman. We have examined the claim that these effects apply only for 2-dimensional figures in an experiment with 3-D cylinders and find no support for the notion that horizontal lines would be 'fattening' on clothes. Significantly, the illusion persists when the horizontal or vertical lines are on pictures of a real half-body mannequin viewed stereoscopically. All the evidence supports Helmholtz's original assertion.

**Keywords:** size perception, Helmholtz illusion, fashion.

## 1 Introduction

Helmholtz (1867) reported that a square composed of horizontal lines appears to be too tall, and one composed of vertical lines appears too wide (figure 1-left). Helmholtz notes: "There are numerous illustrations of the same effect in everyday life. An empty room looks smaller than one that is furnished; and a wall covered with a paper pattern looks larger than one painted uniformly in one colour. Ladies' frocks with cross stripes on them make the figure look taller" (page 193). This last observation is particularly interesting, as it is commonly assumed by people concerned with fashion that horizontal stripes on clothing makes the wearer look fatter rather than taller.

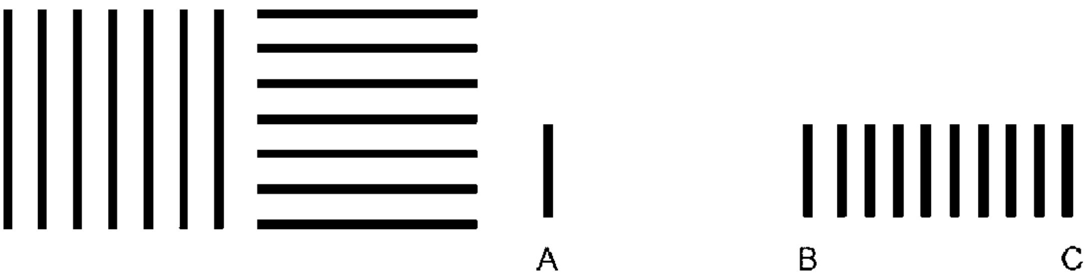


**Figure 1.** Left: The Helmholtz Illusion. The square of horizontal lines appears to be taller and narrower than the identical square of vertical lines. Right: The Oppel–Kundt Illusion. The line B lies equidistant between A and C but appears displaced towards A, indicating that the filled extent B–C appears larger than the unfilled extent A–B.

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The Helmholtz square illusion is one of a family of illusions of filled extent, of which the Oppel–Kundt illusion is the best known (Robinson 1972; figure 1-right). A spatial extent broken by a regular series of 'tick' marks appears longer than an unbroken line of the same length. There has been some research on the Oppel–Kundt illusion, but our understanding of the effect is still very limited. No convincing explanation of the illusion has emerged, and most suggestions from differential eye-movements to constancy mechanisms can be dismissed. What we have learned is that the illusion is greatest when the tick marks are more numerous and positioned in a regular fashion (Robinson 1972) and when the stimuli are smaller rather than larger (Obonai 1954; Long and Murtagh 1984).

The Helmholtz illusion has benefited from even less research, and it too is poorly understood. That the square of horizontal lines in figure 1 should look too tall might be explained by the vertical–horizontal illusion (Künnapas 1955), but this illusion should be equally applicable to the two squares. The fact that they look different is clearly a result of a different effect, the expansion of filled extent as seen in the Oppel–Kundt illusion. The general idea, that filled extent increases perceived size, is widespread; Coren and Girgus (1978) report this is common in the clothing industry "when a tailor or salesman suggests some particular striped pattern to make you look taller, shorter, fatter, or thinner in direct application of the Oppel–Kundt effect" (pages 45–46). However, they give no evidence that tailors or salesmen advise the wearing of horizontal stripes to make one slimmer and taller or the wearing of vertical stripes to make one look wider. Indeed, modern fashion advice seems almost universal in the opposite direction (eg, Feldon 2000, page 33).

It has been claimed (Taya and Miura 2007) that the 2-D Helmholtz illusion does not hold for 3-D forms, such as the human figure. They propose that vertical lines on clothing produce two competing effects, a widening by virtue of the Helmholtz illusion and a narrowing as a result of the 3-D cues given by the vertical lines. It is the latter effect that proves stronger, and hence vertically striped clothes have a slimming effect.

In the experiments described here we compare the Helmholtz illusion both in its usual format with squares of vertical and horizontal lines (experiment 1) and in the context of clothing on a human form (experiment 2). Further we examine the effects of vertical and horizontal stripes on real 3-D cylinders to test Taya and Miura's supposition (experiment 3). Finally, we examine the effects of vertical and horizontal stripes on pictures of half-body mannequins viewed stereoscopically (experiment 4).

## 2 Experiment 1

In our first experiment we measured the size of the Helmholtz illusion by the method of constant stimuli, with observers comparing the apparent width and height of near-square patterns of horizontal and vertical stripes. We also investigated the effect of 'duty cycle'—that is, the fraction of each cycle that is white (thus a duty cycle of 0.9 will have a narrow dark bar that occupies 10% of each cycle of the pattern).

### 2.1 Methods and results

Two conditions were interleaved; in one a standard square set of vertical stripes (5 deg. of visual angle on each side) was compared with one of five comparator stimuli composing a near-square of horizontal stripes of various widths, from slightly narrower to slightly wider than the vertical standard. The deviations from the standard width were $-24.3, -8.1, 8.1, 24.3$, and 40.6 minutes of arc. At the start of each trial a fixation stimulus of 300 ms (either a short vertical or horizontal line) indicated to the observer whether a judgement of the height or the width of the stimuli was required on that trial. The first of the stimuli to be compared (randomly the standard or one of the comparator stimuli) was then presented for 750 ms, followed by a 450 ms chequered pattern mask. The second stimulus followed for

750 ms followed by the mask as before. The observer then responded as to which of the two stimuli appeared wider or taller. Each of eight naïve observers (five female) undertook 1000 trials; twenty pairs of stimuli each presented ten times for five duty cycles from 0.1 to 0.9. Psychometric functions gave the point of subjective equality (PSE) where the vertical and horizontal patterns appeared of equal width. The second condition presented a square of horizontal stripes with a range of near-square vertical comparitors. All other details were identical to the first condition except that observers reported which of the two patterns appeared taller. This yielded the point of subjective equality where vertical and horizontal patterns appeared of equal height.

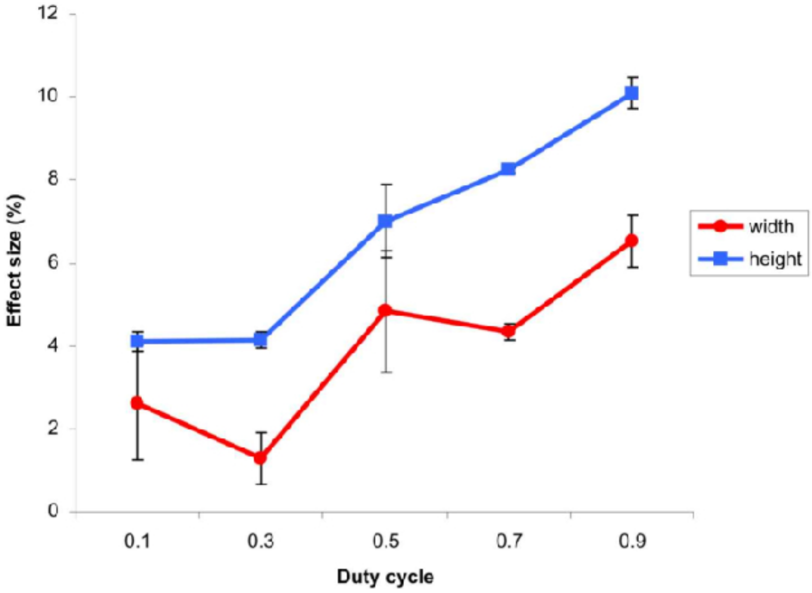


**Figure 2.** Results of Experiment 1. The blue squares indicate how much taller vertical stripes must be to match the height of horizontal stripes. The red circles indicate how much wider horizontal stripes must be to match the width of vertical stripes. Error bars indicate 95% confidence intervals.

The results (figure 2) show that a pattern of vertical stripes is perceived to be of equal height with a pattern of horizontal stripes when it is between 4.1 and 10.1% taller, depending on duty cycle. That is, when both patterns are the same height, the horizontals are perceived as being taller.

A pattern of horizontal stripes is perceived to be of equal width as a pattern of vertical stripes when it is between 1.3 and 6.5% wider, depending on the duty cycle. That is, when both patterns are the same width, the verticals are perceived as being wider. Note that the effect is consistently greater when the height of the horizontal lines is being judged rather than when the width of the vertical lines is being judged. These results confirm and quantify the Helmholtz square illusion and show that the duty cycle of the patterns used is important; narrow black lines on a white background produce a larger effect than broad black lines.

## 3 Experiment 2

Experiment 1's confirmation that vertical stripes make a pattern look wider than a pattern of horizontal stripes is at odds with the popular belief that the wearing of horizontal stripes makes the human figure look wider and that vertical stripes are slimming. Experiment 2 examined this aspect of the Helmholtz illusion, investigating the relative slimming effect of horizontal lines on clothes worn by a human figure (figure 3). This is an equivalent task to investigating the effect on height of horizontal stripes (which was Helmholtz's original claim), but the principle is the same, and in terms of fashion there appears to be more interest in one's perceived width than one's perceived height.

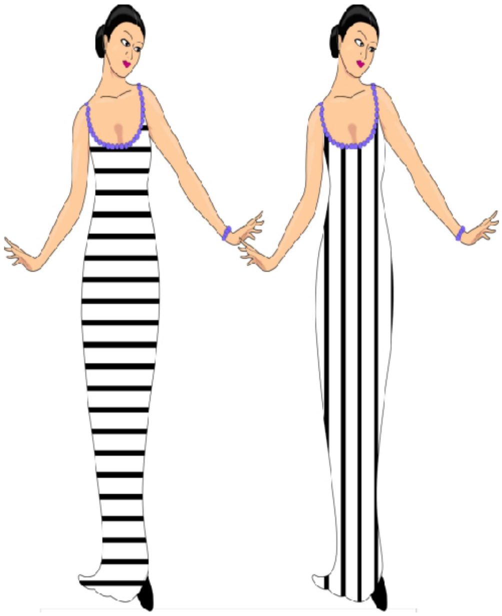

**Figure 3.** Examples of the human figures used in experiment 2. Here the outlines of the two women are identical, but the vertically striped pattern makes the hips appear broader.

### 3.1 Methods and results

Twelve naïve observers judged which of two figures—one clad in horizontal stripes, the other in vertical stripes—appeared wider in the hips (figure 3). The manipulation of the figure width affected only the width around the hips; there was no change in the upper body, head, arms, or lower leg regions. The grating pattern on the dress was now 15.5 cycles/deg., with a duty cycle of 0.75. For each trial a standard figure clad in vertical stripes was compared with one of nine horizontally clad figures: four narrower in the hips, four broader in the hips, and one identical to the vertically clad standard. The standard width was 25.8 mins arc with four narrower and four wider stimuli in steps of 0.5 mins arc. Only estimates of hip width were made; there were no measures of perceived height.

Again, as in experiment 1, psychometric functions were fitted to the data and the PSE calculated. In agreement with experiment 1 it was found that the horizontal stripes-clad woman needed to be 5.8% broader in the hips to be perceived as identical to the woman in vertical stripes. A paired sample t-test revealed a significant difference between the mean PSEs ($T = 4.59, df = 8, p < 0.05$). This suggests a relative slimming effect of horizontal compared with vertical stripes.

## 4 Experiment 3

Clearly the line drawings used in experiment 2 do not fully represent the 3-dimensional form of a human figure. Furthermore, it has been shown by Taya and Miura (2007) that in 2-D pictures of vertical cylinders the addition of shading and vertical stripes designed to increase the perceived 3-dimensionality of the cylinders serves to make the cylinders appear narrower. If vertical stripes were to convey more effectively depth information about a vertically oriented cylinder, then this effect might lead to the human body (essentially a vertical cylinder in most cases) appearing narrower when clad in vertical stripes despite the competing broadening effect of the Helmholtz illusion.

However, this proposal is at odds with findings by Li and Zaidi (2000) that the perception of 3-D shape from 2-D texture cues is most accurate when the orientation of the pattern lies parallel to the maximum curvature of the surface. That is, for a vertically oriented cylinder it is horizontal, not vertical, stripes that would give us the most depth information. In the human form the maximum curvature is along the horizontal axis (in most parts of the body, for most people), and thus horizontal lines, and not vertical ones, should give the most information about 3-D shape and hence give rise to perceived narrowing. Thus Li and Zaidi's results cast doubt on Taya and Miura's reconciliation of the Helmholtz illusion with prevailing fashion advice.

To resolve this issue, we examined the effects of horizontal and vertical stripes on the perceived width of real 3-D vertically oriented cylinders.

## 4.1 Methods and results

Ten participants matched (by adjusting the separation of two 1-degree long vertical lines on a computer screen) the perceived width of 20-cm-high cylinders covered with uniform grey (luminance 10 cd/m$^2$) and vertical or horizontal gratings (high contrast rectangular wave grating, duty cycle 0.75.). The viewing distance was 57 cm. Cylinders of 2.5, 4.0, 6.5, 8.0, and 11.5 degrees in diameter were investigated. Each cylinder was presented five times (in randomised order) and the mean perceived diameter calculated. The spatial frequency of the vertical stripes on each cylinder was such as to ensure that there were sixteen cycles per circumference; thus approximately eight cycles were visible on each cylinder. Horizontal and vertical stripes had the same spatial frequency.

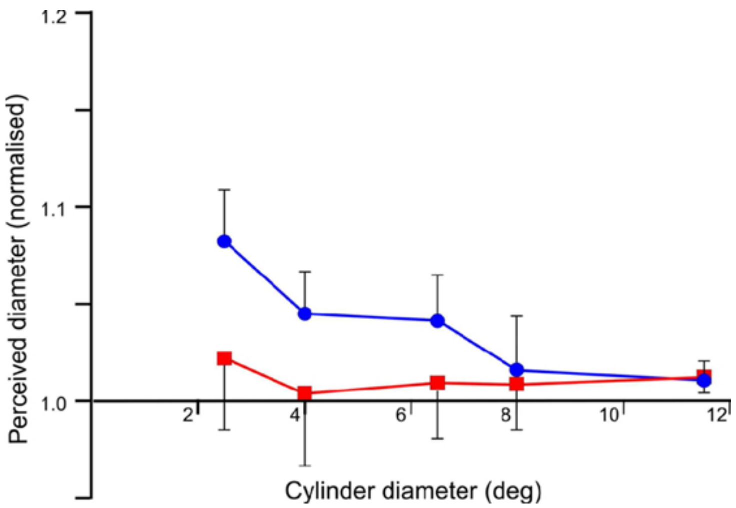


**Figure 4.** Results of Experiment 3. Perceived diameters of horizontally striped cylinders (red squares) and vertically striped cylinders (blue circles) expressed relative to perceived width of uniform grey cylinders. Error bars indicate 95% confidence intervals.

The results (figure 4) show that the perceived width of cylinders with horizontal stripes is close to veridical but that observers systematically overestimated the diameter of vertically striped cylinders in most conditions. There is no evidence of a slimming effect of the vertical lines. Again, this result is in agreement with Helmholtz's observations—that a filled extent looks bigger than an unfilled extent. We also find that the effect disappears with the largest cylinders; this result is in accord with the findings of Obonai (1954) and Long and Murtagh (1984), who found that the Oppel–Kundt illusion diminished with larger stimuli.

## 5 Experiment 4

Finally, we decided to address directly the debate on the Helmholtz's illusion regarding striped garments. The aim of this experiment was to observe what happens to the illusion when 3-D figures of real mannequins dressed in strapless t-shirts with either black horizontal or vertical stripes were used as stimuli.

We decided that a half-body model mannequin was suitably realistic to use as a stimulus because, according to Cornelissen et al (2009), people judge body size by focusing their gaze on the stomach, with the 'scanning' area consisting of only the upper part of the body (shoulders to pelvis). Therefore participants were asked to compare the width of two 3-D figures (ie, four 'fused' 2-D images) and indicate the wider one. An example stimulus is illustrated in figure 5 below.

**Figure 5.** Examples of the Figures Used in Experiment 4. Here the outlines of the two mannequins are identical, but the vertically striped pattern makes the figure appear broader.

### 5.1 Methods and results

On each trial a standard figure clad in vertical stripes was compared with one of a set of nine horizontally clad figures: four narrower, four broader, and one identical to the vertically clad standard. An example is shown is figure 6. The standard width was 40.5 mins arc and the height was 98.2 mins arc, with four narrower and four wider stimuli in steps of 0.5 mins arc. Only estimates of width were made; there were no measures of perceived height. Again, as in experiment 1 and experiment 3, psychometric functions were fitted to the data and the PSE calculated.

Pictures of the mannequin in two different positions 40.0 cm away from each other were taken so that participants would be able to view the two pairs of pictures simultaneously as if there were two model mannequins one next to the other. The digital camera was 115 cm away from the model mannequin and the left image was taken at a distance of 6.30 cm [representing the average pupillary distance (Dodgson 2004)] away from the right image. A mirror stereoscope was set up 56.0 cm away from a computer screen, and participants were asked to view the images from a specific eye position determined by a pair of goggles. The four mirrors were calibrated to allow fusion of the four 2-D images into two 3-D images. When the four 2-D images were combined, the illusion of depth was created. The four 2-D figures appeared simultaneously for 3000 ms followed by a white screen awaiting response. Eight observers able to fuse a sample stimulus took part in the experiment. The duty cycle of the striped t-shirts was 0.50, and the figures' width was manipulated using Corel Draw Graphics Suite (Version 13). The experiment was set up using SUPERLAB, and forced-choice responses were recorded. The screen's resolution was 1280 x 1024 pixels, and the frame rate was 76 Hz.

In agreement with experiment 1 and experiment 3, it was found that the mannequin in horizontal stripes needed to be 10.7% broader to be perceived as identical to the one in vertical stripes. A paired sample t-test revealed a significant difference between the mean PSEs ($T = 2.87, df = 8, p<0.05$), thus supporting the Helmholtz's illusion. This suggests a relative slimming effect of horizontal compared with vertical stripes.

## 6 Discussion

We have conducted 4 experiments to investigate the generality of the Helmholtz square illusion to pictures of the human form and real 3-D cylinders. The results show that in all cases space covered with vertical stripes appears wider than a similar space covered with horizontal stripes. In experiment 3, where we included a neutral grey condition, it appears that horizontal stripes do not significantly affect the perceived width of a pattern, and we would suggest that neither do vertical patterns affect perceived height.

In experiment 3 we can see that the illusion persists on real cylinders, contradicting the suggestion of Taya and Miura (2007) that perhaps vertical stripes increase the 3-dimensionality of figures and hence make them appear narrower. However, this effect seems to disappear for larger cylinders. This finding agrees with Long and Murtagh (1984), who reported that the Oppel–Kundt illusion was much more prominent with small stimuli.

Experiment 4 was our most direct attempt to resolve the debate on the application of Helmholtz's illusion to fashion. By using 3-D images of a mannequin, we have dealt with the limitations of experiments 2 and 3, where the stimuli were not as realistic. Findings from experiment 4 have shown that vertical stripes made the mannequin look 10.7% wider than the mannequin in horizontal stripes, and this effect was found to be significant. We did not make use of real women as models because doing so would bring with it many methodological problems, one of them being the inability to manipulate the stimuli.

One final observation, made in a personal communication by Wolfgang Metzler to Zanforlin (1967), may convince the reader: when asked to make a vertical pile of coins so that its height is equal to the coins' diameter, a subject will typically make the pile about 30% too low. This illusion is a compound of two effects—the Helmholtz illusion and the vertical–horizontal illusion. The horizontal orientation of the coins will make the pile appear taller than it really is because of the Helmholtz illusion, and the vertical–horizontal illusion, in which a vertical line appears to look longer than an identical horizontal one will reinforce this overestimation of the vertical. Hence, in judging the height of the coins equal to its width, observers make the pile too short. However, if this task is repeated with the coins turned 90 deg., the Helmholtz illusion and the vertical–horizontal illusion are placed in opposition to each other, and the size of the effect is markedly reduced, though not abolished, suggesting that the Helmholtz illusion is larger than the vertical–horizontal illusion.

## 7 Conclusions

The Helmholtz Square and Oppel–Kundt illusions show a consistent and large overestimation of filled space such that horizontal lines serve to make a space appear taller, and vertical lines serve to make a space look wider. This effect persists when used on pictures of clothing, on cylinders of diameter less than about 6 deg., and on pictures of half-body mannequins viewed stereoscopically. These results indicate that more research is needed to identify the underlying mechanisms of this effect and that there is no evidence to support the widely held beliefs that horizontal stripes make the human form appear wider and that vertical strips have a slimming effect. All the evidence here points in the opposite direction.

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