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Titchener's ⊥ with its lines tilted—A partial replication and extension of Cormack and Cormack (1974)

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Abstract Following Cormack and Cormack (*Perception & Psychophysics*, *16*, 208–212, 1974), modified versions of Titchener's (*Experimental Psychology,* Vol. 1, Pt. 1, 1901) ⊥, in which the ⊥'s lines were tilted (Experiment 1), or tilted and dissected into two separate lines (Experiment 2), were used as stimuli. In Experiment 1, the overestimation of the length of the ⊥'s vertical, undivided line tended to decrease with its tilt relative to the horizontal, divided line. For ⊥s rotated 90° or 270°, the divided line was tilted, and the overestimation of the length of the now horizontal, undivided line vanished except for ⊥s with orthogonal lines. Separation of the ⊥'s lines in Experiment 2 led to an attenuation of the overestimation of the length of the undivided line for the default ⊥, and an underestimation of the length of this line for rotated ⊥s. Results only partly confirm Cormack and Cormack, probably because of the different psychophysical methods used. Findings support the notion of a T-schema as a coherent unit in midlevel visual processing, but also suggest medium- and long-range interactions between orientation-sensitive neural mechanisms.

Keywords Visual illusion · Symmetry · Neural mechanisms · Stimulus range effects

In 1974, Elizabeth and Robert Cormack published an article on "Stimulus Configuration and Line Orientation in the Horizontal-Vertical Illusion" in the precursor of this journal. The authors built on earlier work by Shipley, Nann, and Penfield (1949), Pollock and Chapanis (1952), and others who had found that slightly tilted verticals gave rise to a greater overestimation of these lines' lengths than perfect uprights. Furthermore, the effect seemed to be larger for tilts to the left as compared to tilts to the right. In Cormack and Cormack's (1974) experiment, L, ⊥, and + figures were shown to observers who adjusted the horizontal lines of the figures to appear as long as a constant vertical standard. Here, I shall be concerned with the ⊥ figure only, which in the original experiment was shown at three orientations (default or rotated 90° or 270°). Vertical lines were either upright or tilted to the right or to the left (see Fig. 1a for an example).[1] For the default ⊥, the overestimation of the length of the vertical, undivided line diminished symmetrically with tilt. The one, statistically uncorroborated observation that Cormack and Cormack dwell upon most in their discussion is the fact that "in no case did the true vertical standard (90°) give the largest illusion" (1974, p. 210). Although this appears plausible for the rotated ⊥s, where amounts of illusion were 2 to 4 times larger at small tilts of the vertical, it is less so for the default ⊥, where amounts of illusion at these tilts differed from the one at 90° by a factor of 1.1 only (values read off from the plots).

Before Cormack and Cormack (1974), Finger and Spelt (1947) and Künnapas (1955) already had shown that the ⊥ figure, as introduced by Titchener (1901), cannot be regarded as a pure case of a horizontal-vertical illusion, because the bisectioning of one line by another one enters as an additional, illusion-inducing factor. For rotated ⊥s, Finger and Spelt (1947), like Cormack and Cormack (1974), still found a horizontal-vertical illusion (i.e., an overestimation of the lengths of the verticals), whereas Künnapas (1955) and Tedford and Tudor (1969) found a reversal of the illusion

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[1] Note that for the default ⊥, its undivided line was vertical or tilted, whereas for the rotated ⊥s, the divided line was vertical or tilted.

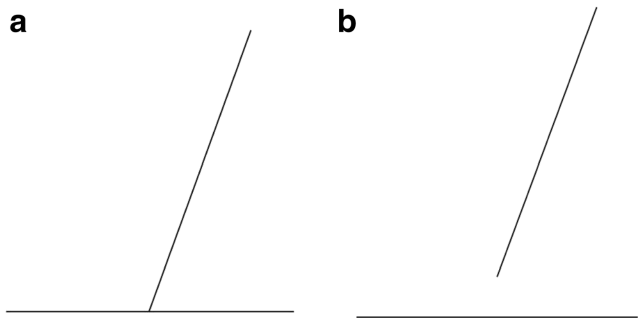

Fig. 1 A ⊥ (**a**) with its undivided line tilted and (**b**) with its undivided line tilted and dissected from the divided line.

(i.e., an underestimation of the lengths of the verticals, which Finger & Spelt, 1947, called a bisection illusion). As suggested by Cormack and Cormack (1974, p. 211), the different results were probably due to the different methods used: While the first group of authors had used the method of adjustment, the second group had used the method of constant stimuli. By repeating Cormack and Cormack's experiment with this method, a bisection illusion is to be expected for rotated ⊥s (cf. Avery, 1970; Begelman & Steinfeld, 1967; Gardner & Long, 1960; Gescheider, 1997).

In view of Cormack and Cormack's (1974) finding that the ⊥ illusion varied as a function of the relative tilt of the figure's lines, I suggested that the notion of bisection does not yet appear to be sufficiently precise, and proposed that it might be more appropriate to characterize the original illusion figure in terms of its dihedral symmetry group *d1* (Landwehr, 2015, p. 2151; Landwehr, 2016, pp. 289–290). On the assumption that observers carry an internally distorted T-schema (the origin of which might either be acquired or innate), they will provide biased estimates of the lengths of the figure's two lines as long as it does not deviate too much from a prototype T (cf. Neisser, 1976, for a more elaborate discussion of schema theories; Changizi, Zhang, Ye, & Shimojo, 2006, for a possible origin of letter forms; Shevelev et al., 2001, for potentially relevant neurophysiological evidence in the cat; and Chang et al., 2015, for similar evidence in humans). On this account, contrary to Cormack and Cormack's (1974) reading of their data, the ⊥ illusion should always be largest at a 90° tilt between the figure's two lines. Experiment 1 tested this hypothesis along with the one mentioned in the preceding paragraph.

As we shall see, both hypotheses received but partial support. For the default ⊥, the overestimation of the length of the undivided line was at its maximum at the 90° tilt between the figure's two lines, but the effect of the angle of tilt failed to reach statistical significance. With rotated ⊥s, an overestimation of the length of the undivided line was obtained, but only for ⊥s with orthogonal lines; for those ⊥s, the divided lines of which were tilted relative to the horizontal, undivided lines, all misestimation vanished.

General method

Participants

A total of 50 psychology undergraduates of the University at Mainz participated, either in partial fulfilment of a class requirement or for an hourly return of EUR 8 (Experiment 1, Sample 1: $N = 13$, Sample 2: $N = 12$; Experiment 2, Sample 3: $N = 12$, Sample 4: $N = 13$; four independent samples—see the Design sections of the experiments, how samples were administered to experimental conditions). All participants were right-handed and all had normal or corrected-to-normal vision. One participant of Sample 3 was slightly disabled (malformed fingers), but data from this person were similar to those from the others. Written, informed consent was obtained from all participants, and they were treated in accordance with the Declaration of Helsinki (World Medical Association, 1964/2013).

Apparatus

The apparatus was the same as in most of my previous experiments on Titchener's ⊥ (Landwehr, 2014). Its essential part was a touch-sensitive computer screen (size: 50.9 × 28.6 cm; resolution: 1920 × 1080 pixels; response time: 5 ms) that was used for both stimulus presentation and response registration. The screen was oriented frontoparallel at a distance of 44 cm from the observer. Stimuli were presented within a circular, light gray window (diameter: 28.5 cm; plane visual angle: 35.9°; luminance: 228 cd m^{-2}; dominant wavelength: $\lambda = 478$ nm; CIE-coordinates: $x = 0.306$; $y = 0.308$; Weber contrast between stimulus and background: $C_W = -0.998$); the rest of the screen was dark (0.355 cd m^{-2}), and there was only faint, indirect illumination of the room.

Stimuli and responses

The stimuli—variants of Titchener's ⊥—will be described in detail for each experiment separately. Stimulus presentation time was 2 s. Then, target lines were indicated by "blinking"—that is, a 200-ms color change from black to red and another 200-ms change back to black. The response format was two alternative forced choice (2AFC), answering the question whether the target line appeared to be shorter or longer than the nontarget line. Participants were requested to deliver responses immediately after stimulus wipeout. Responses were registered via response buttons on the computer screen. Successful presses were signaled by the buttons shining light blue. Responses started the next trial after a delay of 200 ms.

Experiment 1

As already mentioned in the introduction, Experiment 1 was a partial replication of Cormack and Cormack (1974), with a different methodology. The method of constant stimuli was used, and there was no fixed standard. Instead, observers had to verbally judge the relative lengths of the ⊥'s two lines by comparing the undivided one to the divided one and vice versa. Because of better control of stimulus presentation conditions, I took advantage of modern computer equipment instead of attempting to rebuild Cormack and Cormack's (1974) mechanical apparatus (cf. General Method, Apparatus sections). As a consequence of this move, interstimulus intervals were much shorter in my experiment as compared to their's (1–3 s vs. 10 s). Other minor differences between the two studies will be described in the next section.

Stimuli

The stimulus for Experiment 1 was Titchener's ⊥, which, like in Cormack and Cormack's (1974) original experiment was presented at three different orientations. At the default orientation of 0°, the undivided line of the ⊥ was inclined at seven different angles, and at the rotational orientations of 90° and 270°, the divided line of the ⊥ was inclined at the same set of angles. To keep increments of tilt at about the same size as in the original, but to avoid the prototypical diagonal orientations of 45° and 135°, which are known to invite specific "oblique effects" (Westheimer, 2003), tilt angles of 20°, 40°, 60°, 90°, 120°, 140°, and 160° were used. My stimuli were also much larger (8.45°–9.74°) than Cormack and Cormack's (1.8°–5.4°), but this was not considered problematic because in previous experiments, in which I had used smaller stimuli (3.91°–4.56°), no important differences were seen (Landwehr, 2016, p. 286, Footnote 6). In terms of centimeters, three different lengths of the ⊥'s lines (6.5, 7.0, and 7.5 cm) were used and factorially crossed, yielding nine different ⊥s.

Design

To keep the number of trials reasonable and also to guard against possible interference effects that might come with the different orientations of the ⊥ figure as a whole, the experiment was split into two parts. One sample of observers only saw the default ⊥, and a second sample of observers only saw rotated ones. For Sample 1, there were 7 tilts × 9 size calibrations of the ⊥ × 2 directions of comparing the ⊥'s two lines, making for 126 trials. For Sample 2, there were 2 orientations of the ⊥ × 7 tilts × 9 size calibrations of the ⊥ × 2 directions of comparing the ⊥'s two lines, making for 252 trials. All trials were run in a single session per participant, lasting 30 to 60 minutes.

Results

Data were analyzed by fitting psychometric functions. The binary logistic regression routine of SPSS was used to estimate model parameters. Regressions were computed separately for the two orientations of the ⊥ (default vs. rotated), the seven angles of tilt, and the two lines of the ⊥. Points of subjective equality (PSEs) were found at the cross-points of the functions for *longer* and *shorter* judgments, plotted against an abscissa defined by the difference between the lengths of the divided and the undivided lines of the ⊥ (Urban, 1908; cross-points were found numerically by plotting functions in Mathematica).

Although the data for the default ⊥ (Fig. 2) immediately showed a close correspondence with Cormack and Cormack's (1974, p. 210) plots, the data for the rotated ⊥s (see Fig. 3) at first appeared mirror-inverted—but in fact they are not. While Cormack and Cormack found a horizontal-vertical illusion for the rotated ⊥s in which the vertically oriented, divided lines of the ⊥s always appeared to be longer than the horizontally oriented, undivided lines, I found a bisection illusion for the 90° tilts between the lines and almost no illusion for the other tilt angles. For Figure 3, Cormack and Cormack's data were sign inverted; positive percentages of illusion magnitude represent an overestimation of the length of the ⊥'s undivided line, and negative percentages an overestimation of the length of the ⊥'s divided line. For a first quantitative comparison of Cormack and Cormack's and my results, amounts of illusion were converted into visual angles and correlated. For the default ⊥, $r = .823$, $p < .023$, and for the rotated ⊥s, $r = .833$, $p < .020$, were obtained.

To evaluate Cormack and Cormack's (1974) claim, that "in general, slight inclinations . . . of the upright lead to an increase in illusory effect" (p. 211), two measures were computed. For the default ⊥, chi-square tests did not indicate reliable differences in the distributions of *shorter* or *longer* responses

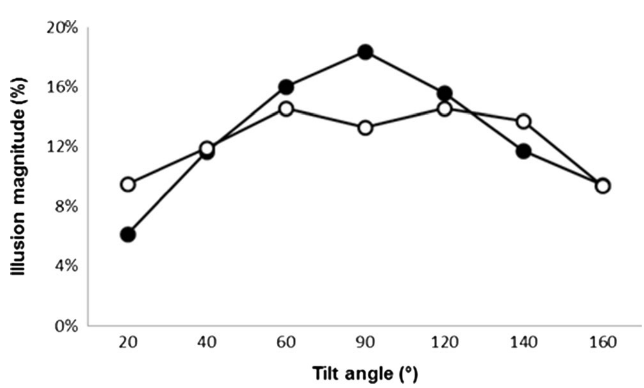

Fig. 2 Plot of the data from Experiment 1 for the default ⊥ (black dots), compared to the data of Cormack and Cormack (1974, p. 210: Fig. 1, top left). Tilt angle refers to the tilt of the ⊥'s vertical, undivided line relative to its horizontal, divided line. Larger illusion magnitudes signify greater overestimations of the length of the ⊥'s undivided line.

across tilts 60°, 90°, and 120°. As the PSEs plotted in Figure 2 are means of two estimates each, the minimum requirements to perform an *F* test are met, $F(6, 14) = 2.867$, $p < .097$, $\eta_p^2 = .711$. For the rotated ⊥s (Fig. 3), $F(6, 14) = 11.220$, $p < .003$, $\eta_p^2 = .906$, resulted, and post hoc Scheffé tests yielded two groups, 90° versus the rest. Here, chi-square tests did not indicate reliable differences in the distributions of *shorter* or *longer* responses, when the 90° condition had been deselected. Either way, the low power of these tests calls for caution, but the huge effect sizes suggest that the factor *tilt* did have an effect also for the default ⊥; detailed claims about effects of individual tilt angles, however, do not yet seem warranted.

Discussion

My hypothesis that the overestimation of the length of a ⊥'s undivided line would always be greatest at a right angle relative tilt between the ⊥'s two lines received qualitative support for the default ⊥ and statistically reliable, quantitative support for ⊥s rotated 90° or 270°. The observations from Shipley et al. (1949) and Pollock and Chapanis (1952) on individual lines do not seem to generalize to multiple line arrangements or figures, at least not to Titchener's ⊥. My second hypothesis, that the use of the method of constant stimuli would yield a bisection illusion for rotated ⊥s, was supported for orthogonal ⊥s; for ⊥s, the divided lines of which were tilted relative to the constantly horizontal, undivided line, all illusion vanished. While the first set of findings is consistent with the idea of a T-schema, the last mentioned finding is more difficult to understand. It may have to do with an *underestimation* of the length of the undivided line in rotated ⊥s or decreased

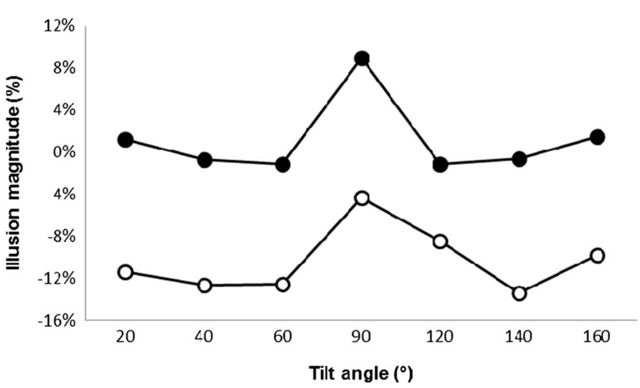

Fig. 3 Plot of the data from Experiment 1 for the rotated ⊥s (orientations 90° and 270° combined; black dots), compared to the data of Cormack and Cormack (1974, p. 210: Fig. 1, bottom left; data have been averaged and sign inverted). Tilt angle refers to the tilt of the ⊥s' vertical, divided lines relative to their horizontal, undivided lines. Positive illusion magnitudes signify an increasing overestimation of the length of the ⊥s' undivided lines, and negative magnitudes signify an underestimation of the length of these lines.

sensitivity for angular deviations of a vertical line that is attached to a horizontal one—but sophisticated control experiments are needed to test these speculations.

Methodological considerations suggest a different interpretation. Orthogonal ⊥s may have appeared unique because of the relatively coarse sampling of tilt angles. In fact, in a prestudy (Doerfel, 2015), in which we had used only five angles of tilt of the undivided line of a default ⊥ (30°, 60°, 90°, 120°, 150°), we found the same amounts of illusion for the middle trio as I found now, but an inverted illusion at the extremes. Hence, the present results may have been influenced by such a stimulus range effect. Eventually, Cormack and Cormack's (1974) experiment, as well as my replication of it, contained a confound: The variably tilted line was always the vertical one—which entails that it was a different type of line for the default ⊥ versus rotated ones. We still have to test the default ⊥ with a variably tilted, divided line, and rotated ⊥s with a variably tilted, undivided line. Although I do not expect grossly different results, we cannot be certain yet.

Experiment 2

In Landwehr (2015, Experiment 3), I described another modification of the ⊥ that proved successful in attenuating the illusion that is commonly observed with this figure: dissecting the ⊥ into two separate lines. For Experiment 2, this modification was added to the one introduced by Cormack and Cormack (1974) so as to yield ⊥s, the lines of which were both tilted relative to one another and separated from each other (see Fig. 1b). Because effect sizes are known from my earlier experiment and this Experiment 1, we can now make quantitative predictions about amounts of illusion for different gap sizes and tilt angles. Across all my previous experiments on Titchener's ⊥ (Landwehr, 2009), the average overestimation of the length of the ⊥'s undivided line had been 11.8 %, which will be used as critical margin for all the calculations that follow. Dissection of the ⊥ lead to a mean absolute decrease of this overestimation of 6.1 % at a gap of 3 cm, and 9.6 % at a gap of 10 cm—that is, remaining overestimations of 5.7 % and 2.2 %, respectively (Landwehr, 2015, p. 2150). Similarly, tilting the undivided line of the default ⊥ in the present Experiment 1, relative to 11.8 %, yielded absolute *increases* of the overestimation of the length of the ⊥'s undivided line of up to 4.2 % and, at the most extreme angles of tilt, absolute reductions of up to 5.7 %. Tilting the divided lines of rotated ⊥s yielded reductions between 10.3 % and 13 % (cf. Figs. 2 and 3). If effects are additive, for Experiment 2, chances are good that a stimulus configuration that affords an error-free comparison of the lengths of two lines will be found. However, for a large gap and extreme angles of tilt, and for rotated dissected ⊥s in general, we would have to expect an overestimation of the length of the ⊥'s divided line, which numerically would be indicated by negative percentages. Such shifts in illusion magnitude and direction will tell an interesting story about medium- and long-range interactions between neural, orientation-sensitive mechanisms, which I suggested might be responsible for the illusion's survival in dissected ⊥s (Landwehr, 2015), and also for context effects within patterns of several ⊥s (Landwehr, 2016)—effects for which the concept of a T-schema is not applicable.

The hypotheses for Experiment 2 were clearly supported: Despite the absence of an effect of the size of the gap between the two lines of the ⊥, for the default, dissected ⊥, the overestimation of the length of the ⊥'s undivided line dropped to values close to zero at tilt angles of 20° and 160°, and for the rotated ⊥s, the illusion reversed, and at all tilts, the length of the divided line was overestimated.

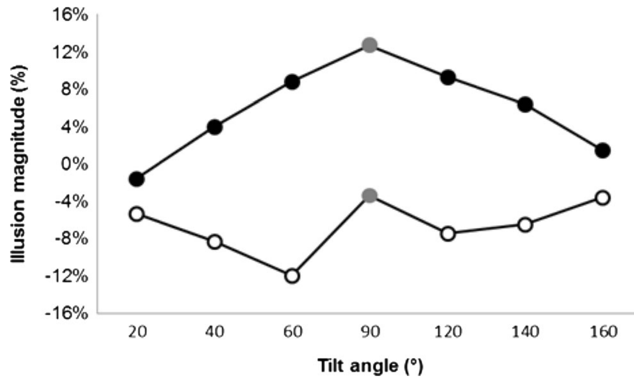

Fig. 4 Plot of the data from Experiment 2 for the default dissected ⊥ (black dots) and for the rotated dissected ⊥s (orientations 90° and 270° combined; white dots). The gray dots at the 90° tilt angles are from Landwehr (2015). For the black dots, tilt angle refers to the tilt of the ⊥'s vertical, undivided line relative to its horizontal, divided line. For the white dots, tilt angle refers to the tilt of the ⊥s' vertical, divided lines relative to their horizontal, undivided lines. Positive illusion magnitudes signify an increasing overestimation of the length of the ⊥'s undivided line, negative magnitudes signify an underestimation of the length of this line

Stimuli

The stimuli of Experiment 2 were the same as in Experiment 1, except for the introduction of a gap between the ⊥'s two lines. The gap was constructed in such a way that one end of the originally undivided line of the ⊥ hovered above the midpoint of the originally divided line. Gap sizes—3 cm and 10 cm (≡3.9° and 13° visual angle, respectively)—were selected from my earlier experiment (Landwehr, 2015, p. 2149).

Design

To reduce the number of trials, the 90° tilt between the ⊥s' two lines was deselected because it had already been incorporated in my earlier experiment (Landwehr, 2015, pp. 2146, 2149). This left 3 lengths of the ⊥'s originally undivided line × 3 lengths of its originally divided line × 6 tilts × 2 gap sizes × 2 targets = 216 trials for the default ⊥. By only partially crossing tilt angles and the orientations of the ⊥ (90° and 270°), trials could be limited to the same number for the rotated ⊥s as well. This was deemed admissible because of the symmetries involved and also because it kept the workload comparable.

Results and discussion

Data were analyzed as in Experiment 1. There was no effect of the size of the gap between the ⊥s' lines; therefore, data were aggregated across gap sizes. These data are plotted in Figure 4. Evidently, for the default ⊥, there is a strong, almost symmetric effect of the originally undivided line's tilt, $F(5, 11) = 37.423$, $p < .001$, $\eta_p^2 = .969$. Scheffé tests allocated those angles that differed most (i.e., 20° vs. 60° and 120° vs. 160°) to clearly distinct groups; angles 40° and 140° occupied intermediate positions.[2] For the rotated ⊥s, something entirely different happened: The effect of the originally divided line's tilt angle did not reach significance, $F(5, 12) = 1.666$, $p < .275$, $\eta_p^2 = .581$, but the illusion—as predicted—was inverted. Compared to Experiment 1, all data points from Experiment 2 were reliably shifted downwards, but at the same time, they remained highly correlated with the corresponding sets from Experiment 1; for the default ⊥, $t(5) = 16.357$, $p < .001$, $r = .976$, $p < .001$, $d = 6.69$, for the rotated ⊥s, $t(5) = 8.496$, $p < .001$, $r = .801$, $p < .055$, $d = 3.47$. Because there was no effect of gap size, the best predictor for the shift of illusion magnitudes is the mean effect of gap sizes 3 and 10 cm as observed in my earlier experiment (Landwehr, 2015), which predicts a shift of –7.85 %. In terms of absolute amounts, observed shifts deviated from the expected ones by 0.12–2.54 % for the default ⊥, and by 0.18–3.06 % for the rotated ⊥s. Hence, it seems fair to say that the effects of tilting the two lines of the ⊥ and of dissecting the whole figure into two separate lines combined almost additively. Although the effects of tilt and dissection as such can both be understood in terms of deviations from a T-schema, the attenuation of the overestimation of the length of the undivided line of a dissected default ⊥ and the eventual switch to an overestimation of the length of the divided line with rotated ⊥s are better accounted for in terms of continuously modulated interactions between orientation-sensitive mechanisms that feed into those mechanisms that generate comparative judgments of length.

[2] Inclusion of the 90° data point, taken from my earlier experiment (Landwehr, 2015, p. 2150), did not substantially change results. The same, mutatis mutandis, is true for the analyses that follow.

General discussion

My replication of that part of Cormack and Cormack's (1974) experiment that used Titchener's ⊥ worked remarkably well. Data sets were highly correlated, and they exhibited similar effects of the relative tilt of the ⊥'s two lines: For the default ⊥, the overestimation of the length of its undivided line decreased with increasing tilt of this line, and for ⊥s rotated 90° or 270°, tilting their divided lines did not have an effect except for ⊥s with orthogonal lines (see Figs. 2 and 3). Dissecting the ⊥ into two separate lines did not change this pattern, but merely shifted the amount and direction of the illusion that is typically seen with the ⊥ from an overestimation of the length of its undivided line towards an underestimation of the length of this line (see Fig. 4). Two puzzles remain: (1) Why did the use of a different psychophysical method—adjustment versus constant stimuli—matter for ⊥s rotated 90° or 270°, but not for the default ⊥? (2) Why did tilting the default ⊥'s undivided line lead to a continuous decrease of the overestimation of the length of this line, whereas tilting the rotated ⊥s' divided lines yielded a singularity for ⊥s with orthogonal lines? To make sure that these marked differences in the results concerning the different orientations of the ⊥ are not another instance of a stimulus range effect, an additional, more comprehensive experiment is required in which the ⊥ is rotated full circle around (cf. Landwehr, 2009, 2014).

Results support both ideas that I put forward for an explanation of the ⊥ illusion at the level of neural mechanisms. The diminishing of the overestimation of the length of the ⊥'s undivided line with increasing tilt of this line, and the special status of ⊥s with orthogonal lines as compared to ⊥s the divided lines of which were tilted, support the notion of a T-schema as a coherent unit in midlevel visual processing. However, as the differences between specific angles of tilt were not always statistically reliable, the tolerance of such a schema against minor deviations still needs to be determined. The attenuation of the overestimation of the length of the ⊥'s undivided line, and the ultimate reversal of the illusion for ⊥s rotated 90° or 270° when the ⊥'s lines were dissected into two lines, support the idea of medium- and long-range interactions between orientation-sensitive neural mechanisms. As the effects of tilt and dissection combined almost additively, the two hypothesized processes—the registering of a figural schema and the (internally interacting) registering of the orientation of singular lines—seem to operate independently. On the other hand, because for ⊥s rotated 90° or 270° the effect of dissecting the ⊥ into two separate lines was roughly equivalent to using the method of adjustment instead of the method of constant stimuli, orientation-sensitive mechanisms may be activated in a similar manner when confronted with dissected ⊥s or when confronted with the task to manually or verbally adjust the lengths of the lines of nondissected ⊥s.

These experiments aimed at the identification of the proximate causes of the ⊥ illusion. If observers' response bias in judgments of the relative lengths of the ⊥ figure's two lines is mediated by a distorted T-schema, then the question remains why the schema is distorted in the first place. One possibility is ontogenetic adaptation to a letter schema (cf. Chang et al., 2015). A test of this conjecture will have to comprise two steps at least: (1) a statistical survey of written Ts to establish that their upstrokes are typically longer than their cross-strokes, (2) a test of observers who are not (yet) thoroughly acquainted with this letter—for example, persons not using the Latin alphabet. Another implication of the conjecture, which is easier to test, is this: The ⊥ illusion should be unaffected by changes in writing style or printing font. Titchener's ⊥, like most other geometrical illusions, has escaped a definite explanation for more than 100 years, but we are gradually getting closer to it.

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References

Avery, G. C. (1970). Errors of the standard in the horizontal-vertical illusion. *Perception & Psychophysics, 8,* 26–28.

Begelman, D. A., & Steinfeld, G. (1967). An investigation of several parameters of the horizontal-vertical illusion. *Perception & Psychophysics, 2,* 539–543.

Chang, C. H. C., Pallier, C., Wu, D. H., Nakamura, K., Jobert, A., Kuo, W.-J., & Dehaene, S. (2015). Adaptation of the human visual system to the statistics of letters and line configurations. *NeuroImage, 120,* 428–440.

Changizi, M. A., Zhang, Q., Ye, H., & Shimojo, S. (2006). The structures of letters and symbols throughout human history are selected to match those found in objects in natural scenes. *The American Naturalist, 167,* E117–E139.

Cormack, E. O., & Cormack, R. H. (1974). Stimulus configuration and line orientation in the horizontal-vertical illusion. *Perception & Psychophysics, 16,* 208–212.

Doerfel, H. K. (2015). *Die ⊥-Täuschung in Abhängigkeit vom Neigungswinkel der ungeteilten Linie* [The ⊥-illusion as a function of the inclination of the undivided line] (Unpublished Bachelor's thesis, Universität Mainz, Germany).

Finger, F. W., & Spelt, D. K. (1947). The illustration of the horizontal-vertical illusion. *Journal of Experimental Psychology, 37,* 243–250.

Gardner, R. W., & Long, R. I. (1960). Errors of the standard and illusion effects with the inverted-*T. Perceptual & Motor Skills, 10,* 47–54.

Gescheider, G. A. (1997). *Psychophysics: The fundamentals* (3rd ed.). Mahwah, NJ: Erlbaum.

Künnapas, T. M. (1955). An analysis of the "vertical-horizontal illusion.". *Journal of Experimental Psychology, 49,* 134–140.

Landwehr, K. (2009). Opposite haptic and visual induction effects observed with Titchener's ⊥. *Attention, Perception, & Psychophysics, 71,* 1197–1202.

Landwehr, K. (2014). Visual and visually mediated haptic illusions with Titchener's ⊥. *Attention, Perception, & Psychophysics, 76,* 1151–1159.

Landwehr, K. (2015). Titchener's ⊥ dissected. *Attention, Perception, & Psychophysics, 77,* 2145–2152.

Landwehr, K. (2016). Titchener's ⊥ in context 1—delimited, discrete monomotif patterns, line arrangements, and branching patterns. *Attention, Perception, & Psychophysics, 78,* 278–292.

Neisser, U. (1976). *Cognition and reality.* San Francisco, CA: Freeman.

Pollock, W. T., & Chapanis, A. (1952). The apparent length of a line as a function of its inclination. *The Quarterly Journal of Experimental Psychology, 4,* 170–178.

Shevelev, I. A., Lazareva, N. A., Novikova, R. V., Tikhomirov, A. S., Sharaev, G. A., & Cuckiridze, D. Y. (2001). Tuning to Y-like figures in the cat striate neurons. *Brain Research Bulletin, 54,* 543–551.

Shipley, W. C., Nann, B. M., & Penfield, M. J. (1949). The apparent length of tilted lines. *Journal of Experimental Psychology, 39,* 548–551.

Tedford, W. H., & Tudor, L. T. (1969). Tactual and visual illusions in the T-shaped figure. *Journal of Experimental Psychology, 81,* 199–201.

Titchener, E. B. (1901). *Experimental psychology (Vol. 1, Pt. 1).* New York: Macmillan.

Urban, F. M. (1908). *The application of statistical methods to the problems of psychophysics*. Philadelphia, PA: The Psychological Clinic Press.

Westheimer, G. (2003). Meridional anisotropy in visual processing: Implications for the neural site of the oblique effect. *Vision Research*, *43*, 2281–2289.

World Medical Association. (1964/2013). *WMA Declaration of Helsinki—Ethical Principles for Medical Research Involving Human Subjects*. Retrieved from http://www.wma.net/en/30publications/10policies/b3/index.html