Horizontal–vertical anisotropy with respect to bias and sensitivity

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Previous research suggests that participants are biased to assess horizontal distances as smaller than vertical distances. We explored the effect of horizontal versus vertical orientation on the sensitivity, as well as the bias, of distance judgments. In contrast to participants of most past studies, our participants never directly compared horizontal and vertical distances. On each trial, participants judged the horizontal or vertical distance between a pair of horizontally or vertically oriented dots as being greater than or less than the average distance between previously presented pairs of dots of the same orientation. When the same participants judged horizontal and vertical distance, the distance judged greater than average 50% of the time (P50) was larger for horizontal than for vertical judgments—a pattern consistent with the horizontal–vertical bias of past work. When different participants judged horizontal and vertical distance, the horizontal and vertical P50s did not differ. When participants did not know whether they would judge horizontal or vertical distance on the coming trial, sensitivity was lower for horizontal than vertical judgments. When participants knew what kind of judgment they would make on the coming trial, sensitivity did not differ for horizontal and vertical judgments. We consider the implications of these findings for accounts that attribute the horizontal–vertical bias (1) to real-world-retinal mapping, (2) to the elliptical shape of the visual field, or (3) to the asymmetry of the receptive fields used to assess frontal distance. We suggest that distance field asymmetry must be invoked to explain the present sensitivity effect.

Introduction

Humans use visual information to understand the layout of objects in the world. The human visual system accordingly registers many of the spatial relationships among input stimuli. This is easily seen for stimuli lying in a frontal plane. Length, distance, and separation judgments assess the system’s capacity for registering spatial relationships among such stimuli. The visual system is capable of high levels of performance in such judgments (Klein & Levi, 1985; Stevens, 1975; Wilson, 1986).

At the same time, however, the visual system is capable of making systematic errors regarding the spatial relationships among stimuli (Gillam, 2017). The horizontal–vertical illusion is such an error. The illusion can be shown in a frontal plane (Avery, 1970; Chapanis & Mankin, 1967; Landwehr, 2017; Schiffman & Thompson, 1974; Schiffman & Thompson, 1975; Thompson & Schiffman, 1974a; Thompson & Schiffman, 1974b) or in three-dimensional space (Higashiyama, 1996; Klein, Li, & Durgin, 2016; Li & Durgin, 2017). We focus on the case of the frontal plane. Here, the illusion is often shown with two line segments, configured as an upside-down T (Cormack & Cormack, 1974). Although the segments are of equivalent length, the horizontal segment is perceived as shorter than the vertical segment (Künnapas, 1955). A key component of the illusion is an orientational anisotropy whereby a horizontal extent is perceived as smaller than an equivalent vertical extent (Künnapas, 1955). The anisotropy has been demonstrated for length and distance judgments (Craven, 1993; Higashiyama, 1996; Higashiyama & Ueyama, 1988; McGraw & Whitaker, 1999; Pollock & Chapanis, 1952; Shipley, Nann, & Penfield, 1949; Verrillo & Irvin, 1979). Because we examine distance judgments, we speak in those terms.

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As for all systematic cases of non-veridical perception, an important question is whether the horizontal–vertical anisotropy manifests in terms of bias and/or sensitivity (Morgan, Hole, & Glennerster, 1990). Past research has focused on the former, showing that participants are biased to assess horizontal extents as smaller than vertical extents (Cai, Wang, & Song, 2017; Charras & Lupiáñez, 2009; Charras & Lupiáñez, 2010; Hamburger & Hansen, 2010; Harris, Hayes, & Gleason, 1974; Künnapas, 1955; Künnapas, 1958; Mikellidou & Thompson, 2013; Schiffman & Thompson, 1975; Thompson & Schiffman, 1974a; Thompson & Schiffman, 1974b; Williams & Enns, 1996).

Several ideas have been advanced regarding the origin of the horizontal–vertical bias. One idea attributes the bias to real-world retinal mapping. An early mapping account attributed the bias to size constancy scaling (Cormack & Cormack, 1974; Girus & Coren, 1975; Renier, Bruyer, & De Volder, 2006; Schiffman & Thompson, 1975; Thompson & Schiffman, 1974b; Ward, Porac, Coren, & Girus, 1977). Later real-world mapping accounts have treated the horizontal–vertical bias as a special case of a more general phenomenon whereby the perceived size of a frontal extent varies with its orientation (Howe & Purves, 2002; Pollock & Chapanis, 1952; Shipley, Nann, & Penfield, 1949; Zhu & Ma, 2017; see also Craven, 1993).

Another influential idea attributes the horizontal–vertical bias to the elliptical shape of the human visual field: Because the endpoints of a horizontal extent are farther than the endpoints of a vertical extent from the boundary of the visual field, the horizontal extent is seen as smaller than the vertical extent (Avery & Day, 1969; Chouinard, Peel, & Landry, 2017; Künnapas, 1957a; Künnapas, 1957b; Künnapas, 1957c; Prinzmetal & Gettleman, 1993; Rock, 1975; Verrillo & Irvin, 1979).

A third idea attributes the horizontal–vertical bias to asymmetries in the distribution of receptors or the shape of receptive fields (Harris et al., 1974; Ritter, 1917; Thompson & Schiffman, 1974a). We state the idea in terms of receptive field shape. Following previous accounts, we assume that the distance between two frontal points is assessed from the number of receptive fields between the fields in which the points register, where this number may be inferred through a spreading-activation-like process. Because of uncertainty as to the level of the visual system at which distance is assessed, we leave many details about the receptive fields (e.g., size, orientation, structure) unspecified. Because the receptive fields are specialized for distance perception, we term them distance fields (McGraw & Whitaker, 1999; Tsal, 1999; Tsal & Shalev, 1996). We suggest that horizontal extents are perceived as shorter than vertical extents because the distance fields have greater extension on the horizontal than on the vertical axis and yet are represented higher up as circular; this account is transposed from an account of anisotropies in the perception of distance along the mediolateral and proximodistal axes of the hand (Fiori & Longo, 2018; Longo & Haggard, 2011).

Little is known about the effect of horizontal versus vertical orientation on the sensitivity of distance judgments. This lack of knowledge reflects the methods that have been used in past studies. These studies have generally used tasks in which participants have indicated on each trial whether a horizontal or a vertical distance was greater (Charras & Lupiáñez, 2009; Mikellidou & Thompson, 2013; Williams & Enns, 1996; Wolfe, Maloney, & Tam, 2005). Because the studies have required the comparison of horizontal and vertical distances, they have been unable to independently assess the sensitivity of horizontal and vertical distance judgments.

In the present study, we assessed the effect of horizontal versus vertical orientation on the sensitivity as well as the bias of distance judgments. To do this we used a different method than has been used in past studies. In contrast to past studies, we did not require participants to directly compare horizontal and vertical distances. On each trial, participants made a judgment regarding horizontal or vertical distance only. Specifically, participants saw two test dots, aligned with the horizontal or vertical axis of the computer screen, and indicated whether the distance between the test dots exceeded the average distance between all pairs of dots heretofore presented with the same orientation as the test dots. This is the method of single stimuli (MSS), which has been shown to produce results comparable to the more common method of constant stimuli (Morgan, Watamaniuk, McKee, 2000; Westheimer & McKee, 1977). Using this method we attempted (1) to demonstrate an effect of horizontal–vertical bias paralleling the effect seen with more traditional methods, and (2) to assess the sensitivity of horizontal and vertical distance judgments.

We anticipated being able to demonstrate an effect of horizontal–vertical bias with the MSS in light of biases effects previously observed with this method. When participants have made MSS judgments concerning two subsets of distances in the same context, positive and negative biases have been observed for the smaller and larger distance subsets, respectively (Morgan, 1992). Specifically, psychometric functions have been plotted on the basis of individual participant responses to the items in the subsets, and the distance associated with 50% positive response (P50) has been computed for each function. The average P50s for the smaller and larger distance subsets have been observed to be, respectively, larger and smaller than the actual means of the subsets.
In light of these results, we predicted that a similar bias would be observed when judgments of horizontal and vertical distance were made by the same participants. Given that horizontal distances are perceived as smaller than vertical distances consequent to the horizontal–vertical bias and given the previous MSS bias effect, we predicted that the horizontal P50s would be larger than the vertical P50s in participant psychometric functions. At the same time, we predicted that, when horizontal and vertical judgments were made by different participants, the horizontal and vertical P50s would not differ. Taking the just noticeable different (jnd) of the participant psychometric function as our index of sensitivity, we were interested in whether the horizontal and vertical jnd would differ in either case.

With the forgoing rationale, we ran two experiments, differing in the manner in which horizontal and vertical judgments were juxtaposed and isolated for participants. In Experiment 1, a between-participants design contrasted a condition in which horizontal and vertical judgments were juxtaposed in the experience and expectation of participants to a condition in which the two sorts of judgment were isolated in the experience and expectation of participants. In the Same condition, the same participants made both horizontal and vertical distance judgments with the two types of judgments being randomly intermixed. In the Different condition, different groups of participants made horizontal and vertical distance judgments. On the basis of the forgoing rationale, we predicted that the average horizontal and vertical P50 would differ in the Same condition but not in the Different condition. Our goal was to find out whether the horizontal and vertical jnd differed in either condition.

In Experiment 2, a within-participants design contrasted a condition in which the two sorts of distance judgments were juxtaposed in the expectation of participants to a condition in which the two sorts of judgment were isolated in participant expectation, with the two sorts of judgment in both cases being juxtaposed in participant experience. In the Unprepared condition, a given participant made a horizontal or vertical judgment following a message that gave no indication which sort of judgment was subsequently going to be required. In the Prepared condition, the participant made a horizontal or a vertical judgment following a message that indicated which sort of judgment was subsequently going to be required. On the basis of the forgoing rationale, we predicted that the horizontal and vertical P50s would differ in both conditions. Our goal was to find out whether the horizontal and vertical jnd differed in either condition.

### Method

#### Design

In Experiment 1, the independent variables were Context (Same/Different), Axis (Horizontal/Vertical), and Distance. Axis was manipulated within and between participants, respectively, for the Same and Different levels of the Context variable, with the Axis level tested on a given trial being randomly selected in the Same condition. For Experiment 2, the independent variables were Preparation (Unprepared/Prepared), Axis (Horizontal/Vertical), and Distance. All variables were manipulated within participants. The same eight levels of Distance were tested in both experiments, with the Distance level tested on a given trial being randomly selected. Each participant responded to 850 trials.

#### Participants

The participants were drawn from an undergraduate psychology class. All participants had normal or corrected-to-normal vision. They participated in fulfillment of a course requirement. Informed consent was obtained from all participants prior to their participation. Participants were assigned as follows to the two experiments. For Experiment 1, 75 participants each were randomly assigned to the Same condition and to the Horizontal level and Vertical level of the Different condition; 57, 61, and 60 of the participants in each of these groups, respectively, were female. The participants ranged in age from 18 to 22 years, with the mean ages in the three groups being, respectively, 19.3, 18.9, and 19.0 years. Experiment 2 had 75 participants, 63 of whom were female. The participants ranged in age from 18 to 25 years, with a mean age of 19.0 years.

#### Stimuli

Each test dot was 0.337 cm in diameter. The levels of distance tested ranged in equal increments from 0.562 to 4.496 cm. The participant sat approximately 60 cm from the computer screen. Thus, each test dot subtended a visual angle of approximately 0.322°, and the levels of distance tested corresponded to visual angles ranging from approximately 0.537° to approximately 4.296°. The two test dots were shifted on each trial by the amounts \( h \) and \( v \) on the horizontal and vertical axes, respectively, where \( h \) and \( v \) were drawn from a uniform distribution ranging from \(-1.6°\) to \(1.6°\).
Procedure

In Experiment 1, participants viewed the stimuli binocularly, under standard fluorescent lighting. At the beginning of each trial, the message “Next Trial” appeared on the screen. When the participant pushed the space bar, the message disappeared, and two small dots appeared in the middle of the screen. Participants were instructed to indicate whether or not the distance between the test dots was greater than the average across all pairs of dots that had heretofore been presented in the same orientation. Participants were instructed to push the “N” key to indicate a positive response and the “B” key to indicate a negative response. Participants were encouraged to respond accurately and received feedback after making errors. Although past MSS results for experienced participants and single standards have found the accuracy and sensitivity of separation judgments to be unaffected by feedback (Morgan et al., 2000), feedback was provided in the present experiments because the participants were naïve and because two standards were tested concurrently in the Same condition. Figure 1 shows the trial sequence.

In Experiment 2, the procedure was the same as for Experiment 1 except that a set of blue dots was presented at the periphery of the screen, after the “Next Trial” message, to indicate the nature of the judgment that would be required. These preparatory dots remained on the screen until the participant pressed the space bar. On Unprepared trials, four dots were presented at the ends of the central horizontal and vertical axes. On Prepared trials, two dots were presented at the ends of either the central horizontal or vertical axis for horizontal and vertical judgments, respectively.

Results

Experiment 1

Figures 2 and 3 present the probability of the “greater than average” response as a function of Context, Axis, and Distance for sample participants and across all participants. A four-parameter logistic function was fit to the data for each participant (Wichman & Hill, 2001).

Same condition

The fit of the participant logistic functions was good, accounting, on average, for 98% of the variance in the data. Table 1 shows the means and standard deviations of the P50 and jnd statistics, measured in visual angle, across the participant functions. The horizontal P50 was larger than the vertical P50, \( t(74) = 4.48, p < 0.0001 \) (paired sample \( t \)-test). To guard against Type 1 errors, we set the family-wise error rate for tests of the P50 statistic in a given experiment at 0.0125 (McDonald, 2009). In addition, the horizontal P50 was larger than the objective mean (2.42), \( t(74) = 4.10, p = 0.000104 \), and the vertical P50 showed a trend toward being smaller than that mean, \( t(74) = -2.51, p = 0.014 \) (single-sample \( t \)-test). The horizontal jnd was larger than the vertical jnd, \( t(74) = 2.85, p = 0.0056 \) (paired sample \( t \)-test). To guard against Type 1 errors, we set the family-wise error rate for tests of the jnd statistic in a given experiment at 0.025.

Different condition

The fit of the participant functions was good, accounting, on average, for 98% of the variance in the data. Across the participant functions, neither the P50, \( t(148) = 0.08, p = 0.93 \), nor the jnd, \( t(148) = 1.57, p = 0.117 \), differed as a function of Axis (two-sample \( t \)-test assuming equivalent variance) (Table 1). Figures 4 and 5 present the distribution of P50 and jnd values across participants for Horizontal and Vertical

| Condition       | P50     | jnd      |
|-----------------|---------|----------|
| Same condition  |         |          |
| Horizontal      | 2.539 (0.252) | 0.126 (0.059) |
| Vertical        | 2.321 (0.344) | 0.110 (0.052) |
| Different condition |      |          |
| Horizontal      | 2.392 (0.137) | 0.104 (0.042) |
| Vertical        | 2.394 (0.130) | 0.094 (0.034) |

Table 1. Experiment 1: mean (SD) of P50 and jnd statistics across participant fits of the logistic function (in degrees of visual angle).
judgments in the Same and Different conditions. Raw data are available at the OSF site.

**Experiment 2**

Figures 6 and 7 present the probability of the “greater than average” response as a function of Preparation, Axis, and Distance for a sample participant and across all participants.

**Unprepared condition**

The fit of the individual participant logistic functions was good, accounting, on average, for 98% of the variance in the data. Table 2 shows the means and standard deviations of the P50 and jnd values across the participant functions. The horizontal P50 was larger than the vertical P50, \( t(74) = 10.26, p < 0.0001 \) (paired-sample t-test). In addition, the horizontal P50 was larger than the objective mean (2.42), \( t(74) = 3.27, p = 0.0016 \), and the vertical P50 was smaller than that mean, \(-t(74) = 10.71, p < 0.0001 \) (single-sample t-test).

### Table 2. Experiment 2: mean (SD) of P50 and jnd statistics across participant fits of the logistic function (in degrees of visual angle)

| Condition       | P50   | jnd   |
|-----------------|-------|-------|
| Unprepared      |       |       |
| Horizontal      | 2.506 (0.228) | 0.104 (0.043) |
| Vertical        | 2.221 (.0167) | 0.093 (0.047) |
| Prepared        |       |       |
| Horizontal      | 2.525 (0.225) | 0.106 (0.080) |
| Vertical        | 2.237 (0.153) | 0.096 (0.055) |
Finally, the horizontal jnd was larger than the vertical jnd, $t(74) = 2.34, p = 0.021$ (paired-sample $t$-test).

**Prepared condition**

The fit of the participant logistic functions was good, accounting, on average, for 99% of the variance in the data. Across participants, the horizontal P50 was larger than the vertical P50, $t(74) = 10.80, p < 0.0001$ (paired-sample $t$-test). In addition, the horizontal P50 was larger than the objective mean (2.42), $t(74) = 4.05, p = 0.00013$, and the vertical P50 was smaller than that mean, $-t(74) = 10.35, p < 0.0001$ (single-sample $t$-test). Finally, the horizontal and vertical jnds did
Figure 7. Experiment 2: Probability of “greater than average” response as function of Preparation (Unprepared, left; Prepared, right), Axis, and Distance. All participants.

Figure 8. Experiment 2, Unprepared condition: Distribution of P50 and jnd values for horizontal and vertical judgments (in degrees of visual angle).

Figure 9. Experiment 2, Prepared condition: Distribution of P50 and jnd values for horizontal and vertical judgments (in degrees of visual angle).

not differ, $t(74) = 1.38, p = 0.17$ (paired-sample $t$-test). Figures 8 and 9 present the distribution of P50 and jnd values across participants for Horizontal and Vertical judgments in the Unprepared and Prepared conditions.

**Discussion**

In the Same condition of Experiment 1 and the Prepared and Unprepared conditions of Experiment 2,
judgments of horizontal and vertical distance were juxtaposed in the experience of participants. The mean horizontal P50 was larger than the mean vertical P50 in these conditions. In the Different condition of Experiment 1, judgments of horizontal and vertical distance were isolated in participant experience. The mean horizontal P50 was not larger than the mean vertical P50 in this condition. In the Same condition of Experiment 1 and the Unprepared condition of Experiment 2, judgments of horizontal and vertical distance were juxtaposed in the expectation of participants. The mean horizontal jnd was larger than the mean vertical jnd in these conditions. In the Different condition of Experiment 1 and the Prepared condition of Experiment 2, judgments of horizontal or vertical distance were isolated in the expectation of participants. The mean horizontal jnd was not larger than the mean vertical jnd in either of these conditions.

Because the jnd results are more novel we discuss them first. A sensitivity difference covaried with the juxtaposition of horizontal and vertical judgments in the expectation of participants. Of the three ideas that have been suggested regarding the horizontal–vertical anisotropy, the real-world retinal mapping idea is probably least capable of explaining the sensitivity difference. It is unclear how preconceptions about the sizes of real-world objects could affect the sensitivity of distance assessment. The visual-field shape idea might possibly explain the sensitivity difference, although it is unclear how it could explain why this difference occurred only when horizontal and vertical judgments were juxtaposed in the expectation of participants. The distance field idea may be most capable of explaining the sensitivity difference. Consider the following, somewhat speculative, account.

We suggest that the horizontal–vertical sensitivity difference reflected distance fields having greater extension along the horizontal than the vertical axis (Longo & Haggard, 2011; McGraw & Whitaker, 1999). Thus, the sensitivity difference reflected distance fields having the same shape as the visual field. The sensitivity difference was statistically confirmed only when horizontal and vertical judgments were juxtaposed in participant expectation. We suggest, therefore, that distance fields were reshaped under such circumstances to match the visual field. (In fact, the hint of a horizontal–vertical sensitivity difference when horizontal and vertical judgments were isolated in participant expectation, in the Different condition of Experiment 1 and the Prepared condition of Experiment 2, suggests that the fields may have had somewhat greater horizontal extension at baseline, so that a large amount of reshaping was not needed.) Why were distance fields reshaped only when horizontal and vertical judgments were juxtaposed in participant expectation? One possibility, speculative but currently under test, is that juxtaposition of the judgments, by drawing attention to orthogonal orientations across trials, made visual-field shape more salient to participants. Future work will be needed to understand the functional significance of the proposed reshaping. We note that some evidence supports the plausibility of a rapid wholesale reshaping of distance fields such as we are proposing. Simultaneous stimulation of a participant’s adjacent fingers suppresses somatosensory evoked potentials for those fingers. If the participant views the fingers concurrently with the stimulation the suppression is enhanced and spatial acuity increases in a manner correlated with the enhancement of suppression (Cardini, Longo, & Haggard, 2011). These results have been interpreted as implying that lateral inhibition under top–down control can rapidly reduce the size of receptive fields serving a given skin area so as to support greater acuity.

The P50 difference covaried with the juxtaposition of horizontal and vertical judgments in the experience of participants. In previous work, when participants have made judgments regarding subsets of smaller and larger stimuli, the P50s for the smaller and larger magnitude subsets have been, respectively, larger and smaller than the actual means of the subsets (Morgan, 1992). The P50 difference is consistent with this previous work under the assumption that the horizontal distances were perceived as being smaller than the vertical distances. We suggest the following more detailed account of the P50 difference. Participants responded on each trial by matching the comparison stimulus against an internal reference. When horizontal and vertical judgments were juxtaposed in participant experience, a single reference was used that recorded the perceived overall mean across horizontal and vertical distances. Although instructed to judge horizontal and vertical distances independently, participants ignored the distinction. Underperception of horizontal distances caused the perceived horizontal mean to be smaller than the objective horizontal/vertical (H/V) mean, and overperception of vertical distances caused the perceived vertical mean to be larger than the objective H/V mean. The internal reference was the perceived H/V mean—the average of the perceived horizontal and vertical means. Underperception of horizontal distances required the horizontal P50 to be larger than the perceived H/V mean (objective horizontal distances had to be relatively large to match the perceived H/V mean), and overperception of vertical distances allowed the vertical P50 to be smaller than the perceived H/V mean (objective vertical distances needed to be relatively small to match the perceived H/V mean).

When horizontal and vertical judgments were isolated in participant experience, the internal reference for a given horizontal or vertical judgment recorded the perceived mean for that sort of judgment only. Underperception of horizontal distances caused the perceived horizontal mean to be smaller than the
objective horizontal mean and required the horizontal P50 to be the same amount larger than the perceived horizontal mean. Overperception of vertical distances caused the perceived vertical mean to be larger than the objective vertical mean and allowed the vertical P50 to be the same amount smaller than the perceived vertical mean. As a result, the horizontal and vertical P50s did not differ.

In short, underperception of horizontal distance and overperception of vertical distance were each expressed twice: (1) in physical–psychological mappings to the perceived horizontal and vertical means, and (2) in psychological–physical mappings from the internal reference(s) to the horizontal and vertical P50s. When the internal references were equivalent to the perceived horizontal and vertical means (when horizontal and vertical judgments were isolated in participant experience), the two mappings canceled out and went unobserved. When the internal reference aggregated the perceived horizontal and vertical means (when horizontal and vertical judgments were juxtaposed in participant experience), the effects of the mappings were observed. Our account is diagrammed in Figure 10.

Given that, under our account, our results reflect horizontal distances being perceived as smaller than vertical distances, the results also suggest a horizontal–vertical bias. Thus, the present study demonstrates a horizontal–vertical bias with a new method. In contrast to past methods, the present method does not require that horizontal and vertical distances be directly compared. The P50 difference was within range of the horizontal–vertical bias observed with traditional methods. In the two experiments, the horizontal P50 was, on average, 4.2% larger than the objective mean, and the vertical P50 was 5.7% smaller than the objective mean, making for an average vertical advantage of 9.9%. Previous assays of the horizontal–vertical bias have found a vertical advantage of from 2.6% to 12% (Avery & Day, 1969; Craven, 1993; Künnapas, 1957a; Künnapas, 1957c; Mamassian & de Montalembert, 2010; Mikellidou & Thompson, 2013; Pollack & Chapanis, 1952; Zhu & Ma, 2017).

The present horizontal–vertical bias effect is consistent with the general idea that the horizontal–vertical anisotropy can be explained in terms of asymmetrical distance fields. The internal referents might, for example, be stated in terms of numbers of distance fields. However, the dissociation observed in Experiment 2 between bias effects (present in the Unprepared and Prepared conditions) and sensitivity effects (present in the Unprepared condition) suggests that the distance field idea, although providing an explanation of the sensitivity effect, may not provide the best explanation of the bias effect. The ideas of real-world retinal mapping and visual fields may provide better explanations. Thus, our results suggest that multiple factors are probably reflected in the horizontal–vertical anisotropy, a conclusion consistent with previous work (Girgus & Coren, 1975; Thompson & Schiffman, 1974a; Williams & Enns, 1996).

Finally, our results were observed in a different sort of task than is customarily used to study the horizontal–vertical anisotropy. Whereas the anisotropy can be observed in a single judgment response in traditional tasks, multiple judgment responses were required to observe the anisotropy in our task. Thus, although our results certainly have implications for
the horizontal–vertical anisotropy, different processes may have been at work here than are at work in more traditional tasks. In sum, we have demonstrated a horizontal–vertical bias with a new method. Using this method, we found horizontal judgments to be less sensitive than vertical judgments when horizontal and vertical distance judgments were juxtaposed in participant expectation.

**Keywords:** distance perception, horizontal, vertical, receptive fields, visual field

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