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# ANTI-GRAVITY HILLS ARE VISUAL ILLUSIONS

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**Abstract**— *“Anti-Gravity Hills”, also known as “Spook Hills” or “Magnetic Hills”, are natural places where cars put into neutral are seen to move uphill on a slightly sloping road, apparently defying the law of gravity. We show that these effects, popularly attributed to gravitational anomalies, are in fact visual illusions. We recreated all the known types of anti-gravity spots in our laboratory using tabletop models; the number of visible stretches of road, their slant, and the height of the visible horizon were systematically varied in four experiments. We conclude that these effects follow from a misperception of the eye level relative to gravity, caused by the presence of contextual inclines or of a false horizon line.*

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Psychological Science, 14, 441-449 (2003)

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“Anti-Gravity Hills” (also known as “Gravity Hills”, “Spook Hills”, or “Magnetic Hills”) are natural places where cars put into neutral are seen to move uphill on a slightly sloping road, apparently defying the law of gravity. Typically, the “spooky” stretch of road is rather short (50-90 m), only a few meters wide, and surrounded by a natural hill landscape, without nearby buildings.

Such places are found in several countries all around the world [Footnote 1], and have been tourist attractions for decades. They should not be confused with the “Mystery Spots” found in amusement parks. These are generally tilted cabins, purposely built as such; a person walking inside feels disoriented, getting a very strong impression of standing at an angle in a perfectly normal room (Gregory, 1998; Shimamura & Prinzmetal, 1999).

The effects experienced on Spook Hills are so impressive that they have been accounted for by physical (magnetic, or gravitational) anomalies; these are indeed the only explanations offered to the tourists on site. Magnetic causes can be ruled out easily, since the effects are visible even on non-magnetic materials, such as plastic balls, or water poured on the ground. The other favorite explanation is that in these locations the force of gravity is not directed toward the earth’s center, but slightly tilted, for some unknown reason. However, the inclination of several such roads has been measured using spirit levels, and the actual slope has always been found to be opposite to the apparent one. To prevent the objection that gravitational anomalies would influence the level as well, in at least one case (Montagnaga, Italy) measurements were also made from a distance (i.e., away from the “spooky” stretch of road) by using a professional

surveyor's instrument, a theodolite (Polidoro & Garlaschelli, 2001). The parallelism between a plumb line hanging within the critical area and another outside it was first checked; then, height quotes were taken on graduated yardsticks, thus calculating that the real slope was about 1% and opposite in direction to the apparent.

The most economical explanation for Anti-Gravity Hills is that they are visual illusions in the natural environment. In this paper, we report four experiments showing that these phenomena can be reproduced in the laboratory, and suggest that they are due to the visual anchoring of the “spooky” surface to a gravity-relative eye level whose perceived direction is biased by the sloping surrounds.

## EXPERIMENT 1

In Experiment 1, we used a tabletop model with three hinged moveable boards, to investigate the case in which the critical spot is a sloping stretch of road between two other stretches, and these run both either uphill or downhill (as one moves forward from the observation point). Since our model was 2.40-m long, devoid of visible texture, and viewed monocularly through a reduction screen, most depth cues (aerial perspective, texture gradients, and binocular cues such as disparity and convergence) were absent.

### Method

The tabletop model is schematically shown in Fig. 1, and described in detail in the Appendix. We used five different inclinations for the boards, relative to the observer's viewpoint: Horizontal (H), 1.5% Uphill (U1.5, a rise of 3 cm over 2 m), 3% Uphill (U3, a rise of 6 cm over 2 m), 1.5% Downhill (D1.5, a negative rise of 3 cm over 2 m), and 3% Downhill (D3, a negative rise of 6 cm over 2 m). In every trial, board B (the middle one) was given one of these five rises (H, U1.5, U3, D1.5, or D3), and boards A (the closest to the observer) and C (the farthest away) were both given the same rise. Thus, the possible combinations were  $5 \times 5 = 25$ .

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FIGURE 1 ABOUT HERE

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**Fig. 1.** Schematic illustration of the tabletop model used in Experiment 1.

Sixty undergraduate students (30 females and 30 males) participated as subjects. They were divided into three groups of 20 subjects each; each group saw two or three of the eight conditions. For completeness, the remaining 17 conditions were shown to a different sample of six observers. All subjects were unaware of the actual setup and of the purpose of the experiment.

Observers sat, one at a time, in front of screen I. They were asked to look into the hole L, describe what they saw, and then assess the slope of the three stretches A, B and C on a five-point scale, where -2=strongly downhill, -1=slightly downhill, 0=horizontal,

1=slightly uphill, and 2=strongly uphill. Each trial was followed by a break of about one minute, during which the hole was occluded and the model modified.

## Results

*Slants are underestimated.* Three stretches with the same slant were seen as horizontal by all subjects, whether they were truly horizontal, 1.5% downhill, or 1.5% uphill. On the other hand, three 3%-downhill or 3%-uphill stretches were always perceived, respectively, as (slightly) downhill and (slightly) uphill.

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### FIGURE 2 ABOUT HERE

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**Fig. 2.** Experiment 1. Perceived slant (mean rating on the five-point scale) of middle stretch (board B) as a function of physical slant of nearer and farther stretches (boards A and C respectively), for four different physical slants of B. Top panel: B horizontal and 1.5% uphill. Bottom panel: B 1.5% uphill and 3% downhill. Bars indicate the standard error of the mean.

*Perceived slant depends on contextual inclines.* Fig. 2 shows how the apparent slope of a middle stretch is affected by the inclines that precede and follow it. A slightly downhill stretch between two strongly downhill inclines was seen as illusorily uphill by 16 subjects out of 20, and as illusorily horizontal by the other four (top panel, leftmost closed symbol); this condition reproduces the natural case of Gravity Hill, in Pennsylvania. However, a slightly uphill stretch between two strongly uphill inclines, i.e. the physically symmetrical condition, was seen by all subjects as level, not as downhill (bottom panel, rightmost open symbol). This implies that inducing an illusory downhill is not nearly as easy as inducing an illusory uphill (Experiment 2 will show that it requires steeper inducing slopes). A horizontal stretch between two downhill inclines was always seen as illusorily uphill (top panel, two leftmost open symbols), whereas uphill inclines failed to make it appear downhill (two rightmost open symbols). Also, although it never reversed in slope, a 3%-downhill middle stretch could be made to look horizontal when accompanied by any non-downhill stretch (13/20, 7/20, 7/20 «horizontal» responses for the horizontal, slightly-uphill and strongly-uphill contextual stretches respectively), but a 3%-uphill middle stretch appeared uphill to all subjects in all conditions.

This asymmetry between uphill and downhill is reiterated by the way the apparent slopes of the first and third stretches (which, it will be recalled, had always the same inclination) were modulated by the middle incline. Two horizontal stretches appeared uphill when separated by a downhill slope (72/80 «uphill» responses across two stretches and two conditions, 20 subjects), but failed to look downhill when separated by an uphill slope (24/24 «horizontal» responses across two stretches and two conditions, 6 subjects). Again, a slightly downhill farther stretch preceded by a steeper downhill could look uphill (8/20 «uphill» vs 11/20 «downhill» responses), but a slightly uphill farther stretch preceded by a steeper uphill appeared to all subjects level, and never downhill.

In summary, then, Experiment 1 showed that small slant angles are underestimated relative to the horizontal plane; and that horizontal stretches, or slight downhills, can appear uphill when accompanied by steeper downhills.

## EXPERIMENT 2

In Experiment 2, we studied the special case where the visible stretches of road are two rather than three. Most popular spots, such as Spook Hill (Florida), Magnetic Hill (Canada, shown in Fig. 3), and Ariccia (Italy) belong to this class. In these places, cars stopping on the apparent downhill stretch of road that precedes the uphill one, and put into neutral, roll backwards as though repelled by a mysterious force (described, at Spook Hill, as “the curse of the Indian Chief”).



**Fig. 3.** Magnetic Hill (Canada): the nearer stretch of road is (mis)perceived as running downhill.

### Method

The tabletop model was similar to the one used in Experiment 1, but the boards were two rather than three. The boards measured 100x120 cm each, and were hinged to each other so as to give a plane of 100x240 cm. They could be lifted or lowered independently by two lab jacks.

The experiment consisted in the presentation, in random order, of eight different conditions. In four conditions the first stretch always ran slightly Uphill (1.5%), and the second stretch could be Horizontal or Uphill (3%, 6%, or 9%). In the other four, the first stretch was always Downhill (3% or 6%), and the second stretch was either Horizontal or slightly Downhill (1.5%).

Eight undergraduate and graduate students, who had not participated in the previous experiment, served as subjects.

## Results

The apparent slope of a slightly-uphill first stretch was a function of the physical slope of the second (Friedman 2-way Anova, Chi-Square=16.9,  $p=0.0007$ ), as can be seen in Fig. 4. Although it was always actually uphill, the first stretch was seen as such only when the second stretch was horizontal. As the slope of the second stretch increased, the first stretch was viewed first as level (thus replicating the lack of slope reversal in the comparable condition of Experiment 1, where a 1.5%-uphill stretch between two 3%-uphill inclines was always seen as horizontal) and then as increasingly downhill. The most extreme condition (rightmost closed symbol in Fig. 4) reproduces very well the illusions seen at Spook Hill and Magnetic Hill, and the illusion seen at Ariccia when one watches the critical spot from the opposite side. The stretch of road in the background is veridically seen as strongly uphill, and the stretch of road in the foreground is erroneously seen as downhill (see Fig. 5a).

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FIGURE 4 ABOUT HERE

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**Fig. 4.** Experiment 2. Perceived slant (mean rating on the five-point scale) of nearer and farther stretches (boards A and B respectively) as a function of physical slant of farther stretch (board B). Board A was always 1.5% uphill. Bars indicate the standard error of the mean.

A horizontal stretch preceded by a downhill was perceived as uphill by all subjects; a 1.5% downhill preceded by a 3% downhill was also reported as uphill by all subjects. The latter condition reproduces exactly the illusion seen at Ariccia, when the “spooky” spot (whose physical slope is about 1%) is watched from the standard viewpoint. The stretch of road in the foreground is seen as sloping downhill very gently (but it is in fact steeply downhill), and the stretch of road in the background is erroneously seen as uphill (but it is actually downhill: see Fig. 5b).

Thus, Experiment 2 showed not only that illusory slope reversal also occurs in a two-stretch condition, but that slight uphills can turn into perceptual downhills, too – provided they are followed by much steeper uphills.



**Fig. 5.** Ariccia (Italy): (a) the nearer stretch of road is (mis)perceived as running downhill; (b) the farther stretch of road is (mis)perceived as running uphill.

### **EXPERIMENT 3**

In Experiment 3, we studied the case where two roads with different slopes depart from a crossing on a hillside. One such case (Montagnaga, Italy) is shown in Fig. 6.



**Fig. 6.** Montagnaga (Italy): the road on the right is (mis)perceived as running uphill.

## Method

A sloping landscape similar to a hillside was created on a large level table, by fitting a thin green cloth on a number of aligned supporting blocks of decreasing sizes (Fig. 7). Relative to the observer, the terrain was high on the left, and sloped down toward the right border of the model at an angle of about 15°.

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FIGURE 7 ABOUT HERE

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**Fig. 7.** Schematic illustration of the tabletop model used in Experiment 3.

The roads were constructed with two triangular boards, each 7x200 cm, covered with tan-colored textureless paper. These roads departed from nearby positions at the same height, as they were both resting on a single block placed just below the observation hole, and were seen as converging on the sloping horizon line of the “hillside”. The far ends of boards A and B could be lifted or lowered independently.

A rectangular piece (100x40 cm) of brown cardboard could be interposed between the “hill” and the “sky” to simulate a faraway horizon. Such cardboard could be lifted to different positions, so that subjects could see the horizon at five different heights: lower than both roads, higher than both roads, in an intermediate position, at the vanishing point of the right (lower) road, or at the vanishing point of the left (higher) road. The

reduction screen and the sky background were the same as in Experiment 1. The procedure was also identical.

Eleven different conditions were obtained by changing the slopes of the two roads; each condition was shown with five horizon heights, for a total of 55 trials, presented in random order. Eight members of the University of Padova community, none of which had participated in the previous experiments, served as observers.

## Results

Figure 8 shows the results for 24 (those deriving from the combination of eight slope pairings and three horizon conditions) of the 55 conditions.

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FIGURE 8 ABOUT HERE

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**Fig. 8.** Experiment 3. Perceived slant (mean rating on the five-point scale) of test road as a function of physical slant of flanking road, for three different physical slants of test road. Top panel: No horizon. Middle panel: Horizon on test road. Bottom panel: Horizon on nearby road. Bars indicate the standard error of the mean.

*No horizon.* A horizontal road was always seen as such when accompanied by an uphill; but when accompanied by a downhill, it was seen as uphill by six subjects out of eight. A downhill road flanked by a steeper downhill road was seen as uphill by seven subjects out of eight (top panel, leftmost point; for the eighth subject the illusion went in the same direction, but was smaller, so that he reported the 3% downhill as slightly downhill, rather than horizontal, and the 1.5% downhill as horizontal, rather than uphill.) This condition reproduces the illusion found at Montagnaga (Fig. 6). Actually, the slope of the trait of road that illusorily reverses at Montagnaga is about 1% (rather than 1.5% as in our experiments), and the accompanying road is 10% (much steeper than our 3%), which makes the illusion absolutely compelling.

*Horizon on same road.* When the vanishing point of a road is seen on the horizon line, the road itself tends to appear level (as shown by the clustering of data points around the dashed line, middle panel). In this case, the slant of the road nearby changes as though the two roads were solidly hinged. For example, a downhill road whose edges are seen to converge at the horizon becomes horizontal, while the flanking horizontal road is reported as uphill (seven subjects out of eight; the eighth saw no illusion). Especially interesting is the case in which both roads are uphill (rightmost point): the gentler incline is seen as horizontal by seven observers, and as downhill by one.

*Horizon on nearby road.* Comparison between the top and bottom panels of Fig. 8 shows that the presence of a horizon at the vanishing point of the flanking road has virtually no effect on the test road when the flanking road is a downhill (data points on the left half of each graph), whereas it makes an obvious difference when the flanking road is an uphill (data points on the right halves). The simplest interpretation is that the perceived slope of the test road depends on the relative position of the horizon. This is, of course, lower than the test road with flanking downhills, and higher with flanking

uphills. Horizons lower than the vanishing point of the test road would push it uphill: but the test road appears uphill already, by virtue of the flanking downhill. On the other hand, horizons higher than the vanishing point of the test road clearly push it downhill, something the flanking uphill cannot do on its own (as shown by the no-horizon condition).

When the vanishing point of a steep uphill road was seen on the horizon line, to seven subjects out of eight this road seemed level, and the gentler uphill stretch appeared clearly downhill (bottom panel, rightmost point; the eighth subject saw a weaker illusion in the same direction, reporting the 3% uphill as slightly uphill, and the 1.5% uphill as horizontal.) This reversal reproduces the illusion found at Martina Franca (Italy), where a moderately-uphill highway points towards a far hilly landscape, and a slightly-uphill short stretch departing from the highway is erroneously perceived as downhill.

## **EXPERIMENT 4**

In Experiment 4, we studied the case where the “spooky” road consists in a single uphill stretch, whose borders converge below a raised horizon line created by faraway hills. The road seems to be running downhill. The best-known site of this type, Electric Brae, is in Scotland. It has been suggested (Ross, 1974), but never experimentally tested, that the illusion is due to the height of the visible horizon.

### **Method**

The stimulus materials consisted of three 16x10-cm greyscale images (Fig. 9), computer-generated starting from a digitalized photograph and printed on separate paper sheets. The first was a photograph of the Electric Brae; the other two were generated by modifying this image with a computer-graphic program, so as to obtain different heights for the horizon line (see caption for details).

The three images were presented in the frontal plane, in random order, to a new sample of 24 observers. They were asked to assess the slope of the road in each image on the usual five-point scale.

### **Results**

The mean ratings for the three conditions were significantly different from each other (Friedman 2-way Anova, Chi-Square=14.15,  $p=0.0008$ ). The high-horizon road appeared downhill (mean rating  $-0.59$ ), the mid-horizon road appeared approximately level (mean  $0.08$ ), and the low-horizon road looked uphill (mean  $0.67$ ). The high-horizon condition portrays the truly uphill view of the Electric Brae, which runs into a mountain background. In the natural counterpart of the low-horizon condition (the Electric Brae viewed from the opposite side) there are no low faraway hills at all, and the road meets a sky background, making for an even stronger illusion.



**Fig. 9.** The stimuli used in Experiment 4. (a) the high-horizon road, i.e. the original Electric Brae (after Ross, 1974): the road seems to be running downhill, below a raised horizon line created by hills in the background; (b) the mid-horizon road, obtained by combining the Electric Brae road viewed from the opposite side (after Ross, 1974) with the horizon of photograph (a); (c) the low-horizon road, obtained by lowering the horizon line of photograph (a).

## GENERAL DISCUSSION

Three of our results have a clear bearing on the issue of Anti-Gravity Hills. First, slopes were underestimated, to the point that slight inclines were always perceived as horizontal (Experiment 1). Slope underestimation has also been reported by McDougall (1903). [Footnote 2.] Second, perceived slope was an inverse function of the height of the visible horizon (Experiments 3 and 4). Third, perceived slant was affected by other slants: when accompanied by downhills, horizontal stretches were perceived as uphill, and slightly downhill slopes could also be seen as uphill (Experiments 1, 2 and 3). Underestimation was weaker for uphill than for downhill slopes, in agreement with McDougall's (1903) data; however, slight uphills could be seen as horizontal when accompanied by much steeper uphills, and as increasingly downhill as the inclination of the accompanying slope increased (Experiment 2).

Assessment of slant is made relative to the eye level normal to the direction of gravity (GREL, or Gravity-Referenced-Eye-Level), which normally coincides with the geographical ("true") horizon plane. A plane is perceived as horizontal when it is parallel to such eye level, and as slanted otherwise. In uncluttered conditions (in front of the sea, for example, or of a flat land), the judged eye level coincides with the visible horizon line. When the vanishing point (the point where its borders seem to meet) of a road viewed frontally is at eye level, such road will be perceived as horizontal; when the vanishing point lays below or above the eye level, the road will be judged as running downhill or uphill respectively.

However, the vestibular and postural information on which the gravity-relative eye level is based can be contaminated by visual cues. It has been shown (see a brief review in Stoper & Cohen, 1989) that GREL is not always assessed veridically, but it becomes biased in the direction of the eye level parallel to the ground plane (SREL, or Surface-Referenced-Eye-Level) whenever the two do not coincide, as in front of a slope. This is a large effect: judged GREL is typically shifted approximately half of the way toward SREL, but much larger biases have been reported, up to 88% (Asch & Witking, 1948). We suggest that this compromise could account parsimoniously for all our findings.

First, the effect of a shift of judged GREL toward SREL will be that of decreasing the perceived angle of any incline relative to GREL, hence the incline's apparent slant (explaining why slopes are underestimated). For small physical slopes, a shift of the reported magnitude would be enough to bring perceived slant under threshold (explaining why our 1.5% inclines appeared horizontal). Second, SREL does not require proprioceptive information, but is specified by optical information alone; whenever possible, directly by the visible horizon, i.e. the line between the ground plane and the sky (Gibson, 1950; Sedgwick, 1980). This accounts for our finding that perceived slope depends on the height of the visible horizon. In the presence of a raised horizon line, such as that created by distant hills at Electric Brae and Martina Franca, SREL will pitch

up from the horizontal, shifting judged GREL in the same direction and making a slightly uphill road appear downhill.

Likewise, by pitching SREL up or down, the presence of a steeper slope will bias judged GREL in the same direction, flattening or reversing the accompanying gentler slope, and explaining the dependence of perceived slant on contextual inclines. Our data suggest a bias approximating 50% when SREL is pitched up from the horizontal (1.5% uphill accompanied by 3% uphill became horizontal), and larger than 50% when SREL is pitched down from the horizontal (1.5% downhill accompanied by 3% downhill became uphill).

## CONCLUSIONS

We found that perceived slope depends on the height of the visible horizon; that surface slant tends to be underestimated relative to the horizontal plane; that, when preceded, or followed, or flanked by a steep downhill slope, a slightly-downhill stretch is perceived as uphill. The visual (and psychological!) effects obtained in our experiments were in all respects analogous to those experienced on site. When, after each observer's task was concluded, we placed a small roll of tape on the misperceived slope, this was seen to move against the law of gravity – producing surprise and, on occasion, reverential fear.

The over 20 natural cases of Anti-Gravity Hills reported to date are all variations on a single theme. Our study shows that the phenomenon can be recreated artificially, with no intervention whatsoever of magnetical, anti-gravitational, or otherwise mysterious forces. The spooky effects experienced at these sites are the outcome of a visual illusion, due to the inclination of a surface being judged relative to an estimated eye level that is mistakenly regarded as normal to the direction of gravity. Using miniature, or even life-size reproductions of our tabletop models, it should now be easy to recreate the fascination of this challenge to gravity in Amusement Parks and, for twice the benefit, Science Museums anywhere.

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**Acknowledgments**— We are grateful to Bruce Bridgeman, Dennis Proffitt, Dave Rose, and an anonymous reviewer for their critical reading of the manuscript.

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## FOOTNOTES

1. U.S.A.: *Confusion Hill*, Idelwild Park, Ligonier, Pennsylvania; *Gravity Hill*, Northwest Baltimore County, Maryland; *Gravity Hill*, SR 42, Mooresville, Southwest Indianapolis, Indiana; *Gravity Road*, Ewing Road, Route 208, Franklin Lakes, Washington; *Gravity Hill*, State Route 96, south of New Paris, Bedford County, Pennsylvania; *Gravity Hill*, White's Hill, Rennick Road, La Fayette County, Wisconsin; *Mystery Spot*, Putney Road, Benzie County, Michigan; *Mystery Hill*, Blowing Rock, Hwy 321, North Carolina; *Spook Hill*, North Wales Drive, North Avenue, Lake Wales, Florida; *Spook Hill*, Gapland Road, Burkittsville, Frederick County, Maryland.

Canada: *Gravity Hill*, McKee Road, Ledgeview Golf Course, Abbotsford, British Columbia; *Magnetic Mountain*, Canada Highway, Moncton, New Brunswick; *Magnetic Hill*, Neepawa, Manitoba.

Europe: *Electric Brae*, A719, Croy Bay, Ayr, Ayrshire, Scotland; *Malveira da Serra*, road N247, Lisbon, Portugal; *Mount Penteli*, Mount Penteli, Athens, Greece; *Ariccia*, Roma, Italy; *Martina Franca*, Taranto, Italy; *Montagnaga*, Trento, Italy.

Other countries: *Mount Halla*, Cheju Do Island, South Korea; *Anti-Gravity Hill*, Straws Lane Road, Wood-End, Victoria, Australia; *Morgan Lewis Hill*, St Andrew, Barbados.

2. It has also been reported that the slant of inclines tends to be overestimated, rather than underestimated, relative to the horizontal plane – both in outdoors conditions, where hills look steeper than they are (Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Proffitt, Creem, & Zosh, 2001), and in the laboratory (see Perrone, 1982). In the first case slant angles were much larger than ours, and their up versus down orientation unambiguous. In the second case, stimuli were either geometrical figures on a homogeneous background, or textured surfaces seen through a hole. It has been suggested that, in these conditions, the observer's perceived straight-ahead direction would deviate towards the nearest part of the surface, altering the derived pitch angle

(Perrone, 1982). Incidentally, in these experiments surfaces are typically slanted  $0^\circ$  to  $90^\circ$ , and can never represent a “downhill” plane.

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## APPENDIX

Three plywood boards, A, B and C, each 100x80 cm, were hinged to each other, giving a plane of 100x240 cm. This was accurately set horizontal on a large table F by means of a spirit level. Middle-board B could be tilted by inserting small blocks (G, G') of the required thickness under the timbers E. Boards A and B could then be lifted or lowered independently by two lab jacks beneath them. By adjusting the height of blocks G and G', and that of the lab jacks, the rise of the single stretches could be set precisely, and was measured by a ruler placed vertically on the table surface, and touching the edge of the board.

The model was hidden by curtains, running along its sides, and illuminated by two fluorescent lamps producing a diffuse light, and no noticeable shadows. An opaque screen I, with a hole L (a tube, 4.5 cm in diameter), was placed in front of the model, 30 cm from the nearest edge. In each condition, the viewpoint was always 34 cm above the nearest point of the road, and only allowed monocular vision, with no parallax information; the model edges were invisible.

A light-blue screen H was hung behind the model to simulate the sky. At the far end of board C we arranged a few small model trees, to add to the realism of the scenery. The boards were covered with thick, smooth, textureless green padded felt; on top of it we laid a “road” M, cut out from tan-colored textureless paper. In real life, the edges of a level road, viewed frontally, are seen to converge at a vanishing point on the horizon, which is located by definition at the observer's eye level. Such convergence was simulated by cutting the paper in the shape of a long isosceles triangle (30x240 cm). These measures were decided after preliminary observations of a real road using a protractor, which enabled us to measure the angle by which the edges of a 3-m-wide road are seen to converge at the horizon.