



# Perception of objects oriented downward from a vertical position

Dennis M. Shaffer<sup>1</sup> · Erica Bishop<sup>1</sup> · Mara Hernandez<sup>1</sup> · Cage Cramer<sup>1</sup> · Echoe Smith<sup>1</sup>

Published online: 23 July 2018  
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## Abstract

In the present work we investigated people's perceptions of orientation for surfaces that are conceived of as being sloped downward from vertical against a vertical reference frame. In the three conditions of Experiment 1, participants either (1) placed a ladder against a wall at what they thought was the most stable position, and then estimated its orientation; (2) gave a verbal (conceptual) estimate of what the most stable position of a ladder leaned against a wall would be; or (3) drew a line representing the most stable position of a ladder to be placed against a wall, and then gave a verbal estimate of the ladder's orientation. Ladder placement was *shallower* than the most stable position, as were the verbal estimations of both the positioned and drawn orientations and the verbal (conceptual) estimates of the most stable position for a ladder to be leaned against a wall, relative to the actual orientations. In Experiment 2, participants verbally estimated various ladder orientations. The estimates were again shallower than the actual orientations. For orientations between 60° and 90°, the estimates showed a scale compression effect from horizontal. This perceived exaggeration of the orientation of an object typically oriented down from vertical is similar to the perceived exaggeration of the orientation of hills and ramps, typically thought of as oriented up from horizontal. This may point to a generic perceived exaggeration of slant whose direction depends on the conceptual or actual reference frame being used.

**Keywords** Spatial cognition · Spatial vision · Visual perception

People verbally overestimate the slant of visually perceived geographical, virtual, and manmade surfaces, viewed from either the base or the top, by between 5° and 25° (Bhalla & Proffitt, 1999; Durgin & Li, 2011; Hajnal, Abdul-Malak, & Durgin, 2011; Li & Durgin, 2009, 2010; Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Shaffer & Flint, 2011). People's verbal overestimates of these slanted surfaces are explained nicely by a scale expansion theory, whereby people expand the scale by which slanted surfaces are overestimated by a factor of ~1.5 (Durgin & Li, 2011; Li & Durgin, 2010). Less work has looked at slanted surfaces that are commonly thought of as being sloped downward starting from a vertical position. This is partly because much of the aforementioned work grew out of work focusing on geographical slant (e.g., Proffitt et al., 1995). However, as common as it is to encounter slopes (and thus, as important as it is to focus work on these slopes), which we view as tilted upward from horizontal, we commonly think of many objects conceptually as leaning

down (or over) from a vertical position rather than upward from a horizontal position. This is the case with people leaning themselves, chairs, pictures and paintings, drywall, ladders, broom and mop handles, bulletin boards, bicycles, mirrors, or window screens against walls, as well as people orienting computer monitors away from a straight up-and-down position. Here people seem to be very good at finding fairly stable angular orientations at which to place these objects against a vertical reference frame. This begs the questions—how do we assess the slopes of objects typically tilted away from vertical, as compared with those slanted from horizontal; likewise, since such objects need to be leaned against something in order not to fall over, can this tell us something about assessing the angles of objects that have a vertical reference frame; and finally, does this process differ from making assessments of surfaces without a vertical reference frame?

Previous work has investigated whether sloped surfaces would be estimated differently from a vertical than from a horizontal reference. For instance, Durgin, Li, and Hajnal (2010) had participants estimate one of 18 irregularly shaped wooden surfaces at oriented at 16 different angles from 0° to 90° within a hemispheric enclosure of black felt that served as the background for the surface. Durgin, Li, and Hajnal told some of the participants to make their estimates relative to horizontal

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✉ Dennis M. Shaffer  
shaffer.247@osu.edu

<sup>1</sup> Department of Psychology, Ohio State University–Mansfield, 1760 University Drive, Mansfield, OH 44906, USA

(0° to 90°), and other participants to make their estimates relative to vertical (90° to 0°). In both groups, the participants made overestimates relative to horizontal, exhibiting what the authors called a “vertical tendency.” That is, the participants gave estimates that were farther away from the horizontal than from the vertical.

In the present work, we examined the perception of sloped surfaces that are typically thought of as being slanted downward from vertical, not upward from horizontal. Although the results from Durgin, Li, and Hajnal (2010) demonstrated a vertical tendency, their participants may have conceptually used a horizontal reference frame to make their judgments even when they were told to make their estimates relative to vertical, perhaps because it is easier to imagine a horizontal than to imagine a vertical frontal surface. As we sought to investigate the perception of sloped surfaces typically thought of as being slanted downward from vertical, we incorporated a vertical reference frame away from which we slanted our apparatus. This procedure differed from those employed in previous work examining slant perception, in that the previous work had used backgrounds that purposely did not allow participants to use a vertical reference frame. To examine this issue, we wanted to investigate whether people are able to understand at what angle an object is most stable when it leans against a vertical reference frame, by having participants (1) actually position a ladder in what they perceived to be its most stable position against a wall, (2) draw a line on a piece of paper at an angle that represented a ladder’s most stable position and then to verbally estimate at what angle the ladder/drawn line was oriented, or (3) verbally estimate the angle at which an object was most stable when leaning against a vertical reference frame. We chose to use a ladder because ladders best represent a stimulus that people have a lot of “hands-on” experience with leaning against a vertical reference frame. Doing this also ensured that we would invoke the representation and/or memory of something that was conceived of as being specifically tilted downward from above against a vertical reference frame, and not upward from a horizontal reference frame. Next, we systematically manipulated the orientation of a ladder placed against a wall, at angles from 50° to 86°, and had participants verbally estimate the ladder’s orientation.

## Experiment 1

In Condition 1 of Experiment 1, we first tested how accurate people are at performing an action-based task. To do this, we asked people to place a ladder at the most stable position against the wall and told them we would ask them to climb the ladder after doing so. We then asked people to estimate the orientation of the same ladder that they had placed against the wall. We did this to evaluate people’s intuitive beliefs about stability and compare their verbal estimates to their

positioning of the ladder. It is known that action-based tasks or verbal estimations of the orientations of objects within reach are fairly accurate for orientations less than 45° (Durgin, Hajnal, Li, Tonge, & Stigliani, 2010). We wanted to test whether the same was true for an action-based task with orientations closer to 90°. We expected that placing the ladder against the wall (the action-based task) would result in closer estimates than would verbal estimation, as had been shown in the past (Durgin, Hajnal, et al., 2010). In Condition 2, we asked another group of participants to verbally estimate the orientation of a ladder’s most stable position against a wall. In Condition 3, we asked a separate group of participants to draw a line representing a ladder and its most stable orientation. We expected that people would verbally overestimate and draw the orientation of the ladder away from vertical, as has been shown with a clear vertical reference frame (Dick & Hochstein, 1989), in much the same way that people overestimate slopes tilted upward from the ground away from the horizontal (reference frame).

## Method

### Condition 1

**Participants** Seventy undergraduates from the Ohio State University at Mansfield (37 female, 33 male), mean age = 18.73 years ( $SD = 3.11$ ), participated in fulfillment of an introductory psychology requirement.

**Procedure** Participants placed a free-standing ladder against a wall at what they thought was the most stable position to climb. The ladder used in all conditions of Experiment 1 and in Experiment 2 is shown in Fig. 1. Participants were told that they would be asked to climb the ladder a few steps, although later we never asked them to do this. They were then asked to estimate at what angle the ladder was oriented. They were told that 0° was horizontal—lying flat on the ground—and 90° was vertical, or straight up and down. We randomly assigned (1) the initial ladder placement prior to a participant’s picking it up and orienting it against the wall—either on the ground or straight up and down against an adjacent wall—and (2) the participant’s distance from the ladder when making verbal estimates—either standing at the base of the ladder or 1 m away.

### Condition 2

**Participants** Seventy-eight undergraduates from the Ohio State University at Mansfield independent of those participating in Condition 1 (45 female, 33 male), mean age = 18.88 years ( $SD = 1.55$ ), participated in fulfillment of an introductory psychology requirement.



**Fig. 1** Picture of the 6-foot aluminum sectional ladder used in Experiments 1 and 2.

**Procedure** We asked participants to give a verbal (conceptual) estimate of the most stable orientation of a ladder against a wall to support a climber. Prior to giving any estimates, all participants were given a brief review of standard geometry, to clarify that they understood different angular positions. They were told that  $0^\circ$  was horizontal—lying flat on the ground—and  $90^\circ$  was vertical, or straight up and down. We did not proceed until all participants had clearly understood the instructions.

### Condition 3

**Participants** Forty-six undergraduates (independent of those participating in Condition 1 or 2) from the Ohio State University at Mansfield (26 female, 20 male), mean age = 18.8 ( $SD = 1.94$ ) participated in fulfillment of an introductory psychology requirement.

**Procedure** Participants made an estimate of the most stable position at which to place a ladder against a wall in order to support a climber, by drawing a single line on a piece of paper to indicate the most stable orientation. We had a vertical line drawn on each piece of paper to indicate a vertical wall,

against which they would draw the ladder. We then asked participants to verbally estimate the orientation of the drawn line. Prior to producing any estimates, all participants were given a brief review of standard geometry in order to clarify that they understood the different angular positions. They were told that  $0^\circ$  was horizontal—lying flat on the ground—and  $90^\circ$  was vertical, or straight up and down. We did not proceed until all participants had clearly understood the instructions.

## Results

### Condition 1

**Positioning of the ladder at the most stable position** We compared where the participants oriented the ladder against the wall to  $75.5^\circ$ —or an  $\sim 4:1$  ratio of pitch, which is the most stable position at which one can place a free-standing ladder (American National Standards Institute, 2007a, b; Occupational Safety & Health Administration, US Department of Labor, 2017; Young & Wogalter, 2000). An independent-samples  $t$  test showed no difference in positioning due to ladder starting position (horizontal or vertical),  $t(68) = 0.3$ ,  $p = .765$ . Therefore, we collapsed the data for the next analysis. A one-sample  $t$  test indicated that people tipped the ladder away from vertical statistically more than the ideal stable position of  $75.5^\circ$  ( $90^\circ - 75.5^\circ$ ),  $t(69) = 6.02$ ,  $p < .001$ ,  $M = 71.91^\circ$ ,  $SD = 4.99^\circ$ . This statistical difference resulted from only a small difference between means ( $M_{Diff} = 3.59^\circ$ ).

**Verbal estimates of ladder orientation** Neither ladder starting position nor distance from the ladder affected the verbal estimates of ladder position,  $t(68) = 0.38$ ,  $p = .705$ , and  $t(68) = 0.79$ ,  $p = .432$ , respectively. Therefore, we collapsed the data for the remaining analyses. A paired samples  $t$  test showed that participants underestimated the slant of the ladder position relative to its actual position at which they oriented it against the wall,  $t(69) = 6.26$ ,  $p < .001$ ,  $M_{Diff} = 11.37^\circ$ ,  $SD_{Diff} = 15.2^\circ$ . The mean setting of the ladder was  $71.91^\circ$ , and the mean verbal estimate of where the ladder was placed was  $60.64^\circ$ .

### Condition 2

**Verbal (conceptual) estimates of ladder orientation** The mean verbal (conceptual) estimate of the most stable orientation of a ladder to be placed against a wall was significantly shallower than  $75.5^\circ$ ,  $t(77) = -14.17$ ,  $p < .001$ ,  $M = 50.31^\circ$ ,  $SD = 15.7^\circ$ . This was a large effect, Cohen's  $d = 1.6$ .

### Condition 3

**Drawing of the ladder at the most stable orientation** A one-sample  $t$  test indicated that people drew the orientation of the

ladder at a statistically shallower orientation than the ideal stable position of  $75.5^\circ$ ,  $t(45) = -7.68$ ,  $p < .001$ ,  $M = 58.04^\circ$ ,  $SD = 15.41^\circ$ . This was also a large effect, Cohen's  $d = 1.13$ .

**Verbal estimates of drawn ladder orientation** A paired-samples  $t$  test showed that participants estimated the slant of the ladder position similarly to the orientation at which they drew it,  $t(45) = 1.27$ ,  $p = .21$ ,  $M_{Diff} = 4.24^\circ$ ,  $SD_{Diff} = 22.67^\circ$ . The mean drawn orientation of the ladder was  $58.04^\circ$ , and the mean verbal estimate of the drawn orientation of the ladder was  $53.8^\circ$ .<sup>1</sup>

The perceived most stable ladder placement positions and estimated ladder orientations, along with drawn lines representing the most stable orientations and the estimated drawn orientations, are shown in Fig. 2.

Although the difference between the drawn and estimated drawn orientations (right panel) was not statistically different, both panels show a pattern of the mean verbal estimates being shallower than either the positioned ladder or the drawn ladder orientation.

**Comparison of estimates across conditions** To compare estimates made across the different conditions, we performed a one-way analysis of variance (ANOVA) on the orientations in the three conditions: the ladder placed physically against the wall, verbal estimates of the most stable position at which a ladder should be placed against a wall, and a drawn line representing the most stable position at which a ladder should be placed against a wall. The one-way ANOVA indicated a significant difference among the conditions,  $F(2, 191) = 53.03$ ,  $p < .001$ . This was a large effect,  $\eta^2 = .36$ . Tukey post-hoc tests indicated that all three sets of estimates were significantly different from one another ( $ps < .05$ ) and formed the pattern shown in Fig. 3.

## Discussion

The findings from Experiment 1 showed that people are pretty accurate at placing a ladder at the most stable position, erring on the side of placing the ladder slightly too shallow, as had been found in previous work (Häkkinen, Pesonen, &

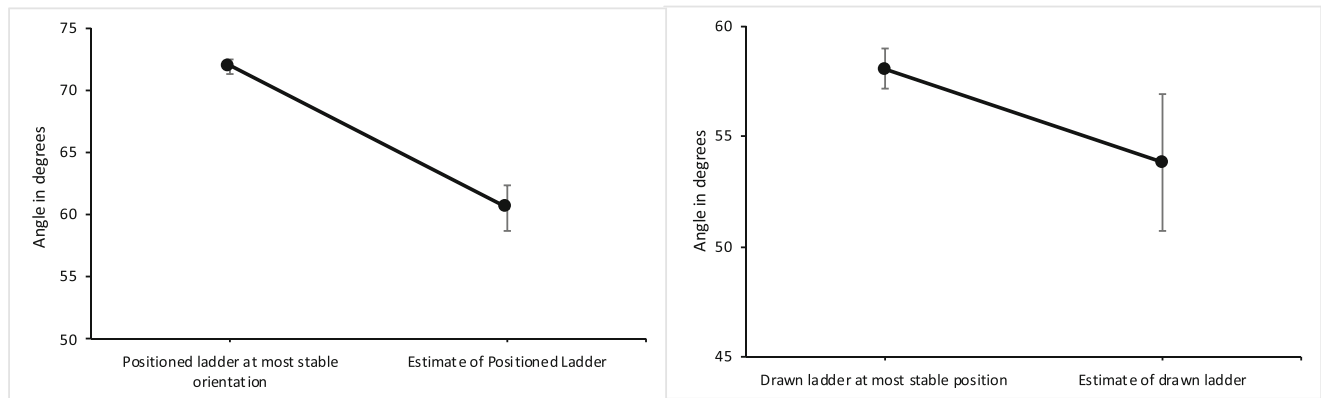
Rajamäki, 1988; Irvine & Vejvoda, 1977). This also fits the results of palm board and forearm tasks for near surfaces (Durgin, Hajnal, et al., 2010), in which gains are  $\sim 1$ , and also with manmade and geographical slants when there is no anchoring (e.g., Shaffer, McManama, & Durgin, 2015; Shaffer, McManama, Swank, Williams, & Durgin, 2014; Shaffer & Taylor, 2017). However, whereas the gains of free-hand or forearm measures are typically 1 for near surfaces and greater than 1 but less than the gains of verbal (over)estimates for geographical and ramp surfaces (i.e., *steeper* than the surface itself), the ladder placement was close to but *shallower* than the most stable position. Additionally, across the conditions of Experiment 1, verbal estimations of positioned and drawn orientations of the most stable position for a ladder to be leaned against a wall and verbal (conceptual) estimates of the most stable position at which to position a ladder were all *shallower* than the actual orientation of positioned or drawn ladders (i.e., lines representing ladder orientation). This is counter to most previous work showing that there is a perceptual scale *expansion* of geographic and manmade hills, roads, ramps, and people's own orientation, leading to *steeper* verbal estimates (Durgin & Li, 2011; Li & Durgin, 2010; Proffitt et al., 1995; Shaffer & McManama, 2015; Shaffer & Taylor, 2017; Shaffer, Taylor, McManama, et al., 2016; Shaffer, Taylor, Thomas, et al., 2016).

This finding is also contrary to what Durgin, Li, and Hajnal (2010) found. They told some participants that vertical was  $0^\circ$ , and others that horizontal was  $0^\circ$ . In both groups, their participants made overestimates relative to horizontal, exhibiting what the authors called a "vertical tendency." There are two differences between the present work and theirs. The first is a methodological difference. In the Durgin, Li, and Hajnal study, no vertical reference frame (planar wall) was visible. However, in our Experiment 1, a clear reference frame was evident to all of the participants. This vertical wall gave participants a clear angular deviation from vertical information that was unavailable to the participants in Durgin, Li, and Hajnal's work. The second difference was that even though some of the Durgin, Li, and Hajnal participants were told to make their estimations from vertical, the surface that they used, like the surfaces that had most been used in previous studies, was one that was probably conceived of as being tilted up from horizontal. Therefore, participants may have used the intrinsic horizontal reference frame to perform the task, even though they were asked to judge orientation from the vertical, because it is easier to imagine a horizontal than a vertical reference frame. In the present work, there was a clear vertical reference frame to which to compare the ladder orientation, and ladders are generally conceived of as being tilted away from straight up-and-down, and not upward from horizontal.

Interestingly, people's verbal estimates (conceptual idea, if you will) of the most stable orientation at which to place a ladder against a wall were significantly shallower than the

<sup>1</sup> In a previous study, we had asked 75 participants, independent of any of the participants in the present article, to make an estimate of the most stable position at which to place a ladder against a wall to support a climber, by drawing a single line on a piece of paper to indicate the ladder's most stable orientation, as we did in Condition 3 of the present work. However, in that study we did not ask participants to also verbally estimate the orientation of the drawn line as we asked them to do in Condition 3. An independent-samples  $t$  test showed no statistical difference between the orientation of the drawn line between the participants who drew the line without making a verbal estimate and the participants who drew the line and then made a verbal estimate,  $t(119) = 0.82$ ,  $p = .416$ ,  $M = 60.12^\circ$ ,  $SD = 12.32^\circ$ , and  $M = 58.04^\circ$ ,  $SD = 15.41^\circ$ , respectively.





**Fig. 2** (Left) Mean orientation of the ladder that participants positioned against the wall at what they thought was the most stable position, and the mean estimated angle at which they believed the ladder to be oriented (with standard errors). (Right) Mean slope of drawn lines that a different

group of participants drew representing the orientation of a ladder at the most stable position, and the mean estimated orientation of the line that they drew (with standard errors).

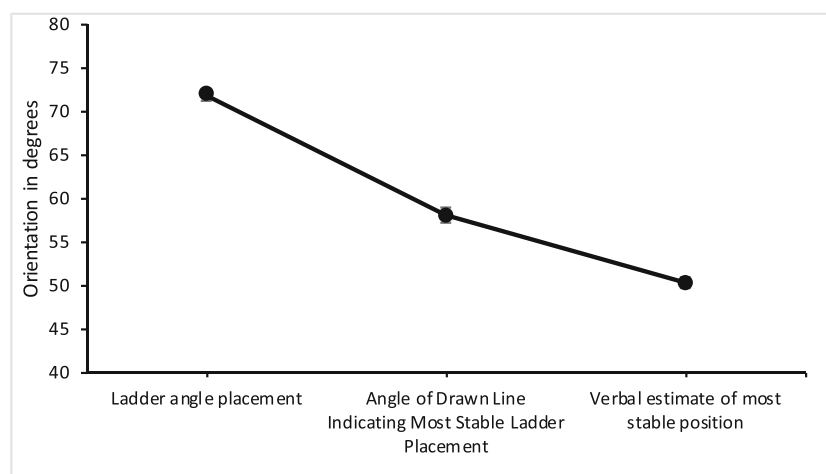
actual orientation, but also were very close to an estimate of  $45^\circ$ , or halfway between vertical and horizontal. In fact, 52.6% of the 78 participants verbally estimated the most stable position to be  $45^\circ$ . This may be because the ladder is about as far away from its tipping point backward at this position (although it is at a position where the possibility of it slipping out is greater). It may be that people rely on this approximate angle as a conceptual anchor for making estimates of orientations close to  $45^\circ$ . Although  $45^\circ$  is not the most stable position for a ladder in terms of supporting a climber, it is an orientation that, with the ladder by itself, is highly unlikely to tip over backward. Support for the idea that people may use  $45^\circ$  as an anchor came from the results of Experiment 1, Condition 1. When estimating at what angle the ladder was oriented after they had positioned it against the wall, 14.3% of the participants estimated it to be at  $45^\circ$ . This was in spite of the fact that the median ladder orientation for the participants who estimated the ladder to be positioned at  $45^\circ$  was  $71.25^\circ$ . Using  $45^\circ$  as a perceptual anchor has been found in other work, as well. For

instance, it has been shown that when making verbal and manual estimates of different angles close to  $45^\circ$ , people's estimates tend to converge on  $45^\circ$ , or people first use  $45^\circ$  as an anchor from which to make their estimates (Feresin, Agostini, & Negrin-Saviolo, 1998; Haun, Allen, & Wedell, 2005).

In Experiment 2, we sought to systematically investigate people's perception of different ladder orientations.

## Experiment 2

In Experiment 1 we found initial evidence of verbally overestimating the amount that a ladder is tilted *downward* from a vertical position, similar to the findings from previous work showing that people verbally overestimate the amount that manmade and geographical surfaces are slanted *upward*. However, in Experiment 1 we only used one angle of the ladder, and the ladder was put in that orientation by the participant. To investigate whether there is a systematic pattern of



**Fig. 3** Mean placed, drawn, and verbal estimates of the most stable position for a ladder, with standard errors.

verbal estimates of objects typically thought of as tilted downward from the vertical with a salient vertical reference frame present, we randomly placed the ladder against the wall at seven different angles, all in the range  $45^\circ < \alpha < 90^\circ$ , and then had participants estimate the ladder's orientation.

## Method

**Participants** The seventy-eight undergraduates used in Condition 2 of Experiment 1 also participated in Experiment 2. All of the participants took part in the present experiment after they had participated in Condition 2 of Experiment 1.

**Procedure** We placed a 1.83-m ladder at one of the following seven angles against a vertical wall:  $50^\circ$ ,  $56^\circ$ ,  $62^\circ$ ,  $68^\circ$ ,  $74^\circ$ ,  $80^\circ$ , and  $86^\circ$ . These angles correspond to angles measured from the ground up. Each participant stood directly in front of the ladder 1 m from its base and made one verbal estimate for only the one orientation of the ladder. Prior to giving any estimates, all participants were given a brief review of standard geometry, to clarify that they understood different angular positions. They were told that  $0^\circ$  was horizontal—lying flat on the ground—and  $90^\circ$  was vertical, or straight up and down. We did not proceed until all participants had clearly understood the instructions.

## Results

**Verbal estimates of ladder orientation** Means and standard errors are shown for each ladder orientation in Fig. 4, and means and standard deviations are shown in Table 1.

The use of  $45^\circ$  as a perceptual anchor was found in Experiment 1 and was supported by previous work (Feresin et al., 1998; Haun et al., 2005). Therefore, we tested whether participants were using  $45^\circ$  as an anchor for the angles closest to  $45^\circ$ . We first compared the angle estimations of  $50^\circ$ ,  $56^\circ$ , and

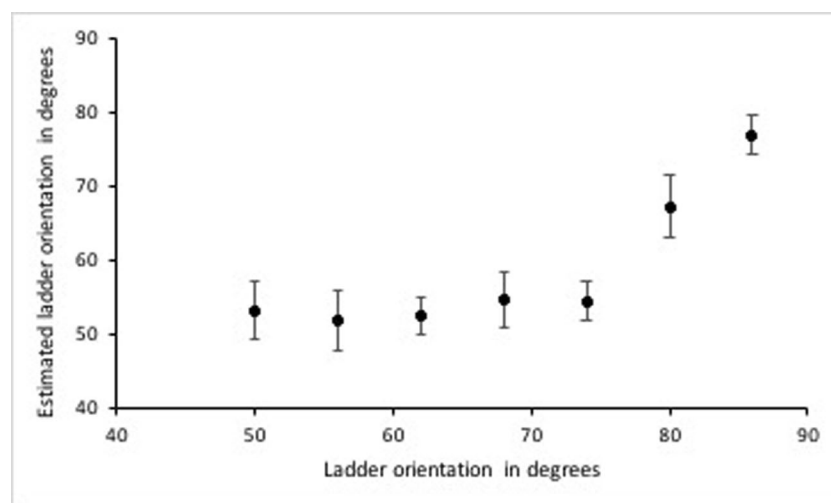
$62^\circ$  ladder placements to  $45^\circ$  as it seems like those three values are close enough to  $45^\circ$  so that participants might use that as an anchor to make their estimates. As is shown in Fig. 4, the mean estimates for those ladder placements are all about equal, as well. We used a Bonferroni correction alpha level of .017 (.05/3) to correct for the multiple one-sample  $t$  tests. Three one-sample  $t$  tests verified that the mean estimates for  $50^\circ$  and  $56^\circ$  were not statistically different from  $45^\circ$ , whereas the mean estimate for  $62^\circ$  was just barely statistically different from  $45^\circ$ :  $50^\circ$ ,  $t(12) = 1.7$ ,  $p = .113$ ;  $56^\circ$ ,  $t(12) = 2.14$ ,  $p = .052$ ;  $62^\circ$ ,  $t(11) = 3.1$ ,  $p = .01$ .

We then compared verbal estimates of the remaining ladder placements to the actual ladder placements, to test whether the verbal estimates were significantly shallower than the actual ladder orientations. We did not use a Bonferroni correction for multiple one-sample  $t$  tests here, as participants were independent of one another and the values we were using to compare the verbal estimates were different between groups. The verbal estimates for every ladder placement were statistically shallower than the actual ladder placement:  $62^\circ$ ,  $t(11) = -3.92$ ,  $p = .002$ ;  $68^\circ$ ,  $t(13) = -2.57$ ,  $p = .023$ ;  $74^\circ$ ,  $t(8) = -7.26$ ,  $p < .001$ ;  $80^\circ$ ,  $t(8) = -3$ ,  $p = .017$ ;  $86^\circ$ ,  $t(6) = -3.16$ ,  $p = .020$ .

Another pattern that is evident from Fig. 4 is that, starting at  $\sim 68^\circ$ , the difference between the verbal estimates of ladder orientations and the actual ladder orientation increases, from an average difference between the verbal estimates and actual placements of  $3.49^\circ$ , for ladder placements of  $50^\circ$ ,  $56^\circ$ , and  $62^\circ$ , to  $13.36^\circ$ ,  $19.48^\circ$ ,  $14.43^\circ$ , and  $6.73^\circ$  for ladder placements of  $68^\circ$ – $86^\circ$ .

## Discussion

In Experiment 2 we first found that participants verbally estimated ladder orientations of  $50^\circ$ ,  $56^\circ$ , and  $62^\circ$  statistically no differently from or very close to  $45^\circ$ . In fact, overall, 14.1% of the participants gave estimates of exactly  $45^\circ$ . This was in spite of the fact that the overall mean ladder orientation was



**Fig. 4** Mean estimated orientations of the ladder, plotted against the actual orientations of the ladder, with standard errors.

**Table 1** Means and standard deviations are shown for actual and estimated orientations of the ladder

Actual Orientation	50°	56°	62°	68°	74°	80°	86°
Mean	53.21°	51.92°	52.5°	54.64°	54.44°	67.22°	76.88°
SD	14.36°	14.65°	8.39°	17.04°	8.08°	12.78°	7.53°

62°. Using 45° as a perceptual anchor had been found in Experiment 1 and was supported by previous work, as well (Feresin et al., 1998; Haun et al., 2005). Next, we found that participants gave verbal estimates that were significantly *shallower* than the actual ladder placements for orientations from 68° to 86°. This is contrary to the results of Durgin, Li, and Hajnal (2010, Experiment 1), who found verbal estimates that were *steeper* than the sloped surface oriented in 6° increments from 60° to 90°. This may have been because the surface Durgin, Li, and Hajnal used is typically thought of as being sloped upward from horizontal, and even though they had 15 out of their 27 participants make estimates from vertical, these participants may have used an intrinsic horizontal reference frame to make their estimates. This may also have occurred because, in the present work, the participants had a very clear vertical reference frame to use when making their judgments. However, in spite of the shallower estimates for steeper orientations found in the present work, we did find a similar scale compression pattern in verbal responses to the five ladder orientations above 60°, similar to what Durgin, Li, and Hajnal found for angles from 60° to 90°.

Previous work supported the idea that a clear reference frame affects judgments from vertical in a similar way to that found in the present work, and it also supported the idea that differently oriented stimuli without a clear reference frame affect judgments in a way similar to that found in Durgin, Li, and Hajnal (2010; Dick & Hochstein, 1989). In Dick and Hochstein's work, the authors found that participants made systematic errors in their estimates of tilted bar stimuli, showing that the estimates were closer to the vertical axis than were the stimuli (Experiment 1). They also found that participants made systematic errors when estimating stimuli in what the authors called "an experimental set appropriate to the minute hand of a clock" (p. 231). One minute on a clock is equivalent to a separation of 6°. They found that the estimates of times between 1 and 6 min before or after the hour were estimated as being farther from the hour. Their data (see the bottom panel of their Fig. 4) also show a scale compression for angles greater than 45°, similar to angles from 60° to 90° shown in Experiment 2 and in the Durgin, Li, and Hajnal data.

## General discussion

When asked to perform an action-based task by placing the ladder against the wall in the most stable position to support a

climber, people positioned a ladder against a wall at a shallower than ideal orientation. However, people do pretty well, only slightly exaggerating the proper orientation by a little under 4°. This is consistent with previous work showing that free-hand measures of slant are well calibrated to near surfaces (Durgin, Hajnal, et al., 2010). Our previous work showed that placing the ladder at this orientation probably feels to participants like it is at a steeper orientation, consistent with the proprioception calibration hypothesis, which proposes that similar biases exist in both verbal estimates of visually perceived slant and proprioceptively perceived haptic orientation (Shaffer, Taylor, McManama, et al., 2016).

Additionally, our participants also verbally estimated a self-positioned, systematically positioned, and drawn line representing a ladder as shallower than actual. This finding is contrary to Durgin, Li, and Hajnal (2010), who found steeper verbal estimates than the actual slope of a surface when it was oriented at angles greater than 45°. However, although this difference may have been due to Durgin, Li, and Hajnal's participants who were told to estimate different orientations from vertical instead using an intrinsic horizontal reference frame to make their estimates, the difference also seems to be reflective of the clear vertical reference frame (Dick & Hochstein, 1989).

The present work shows that using a vertical reference frame and a device (a ladder) typically seen and thought of as being tipped away from the vertical, the ladder is perceived to be oriented at shallower than the actual angle from horizontal, as compared to surfaces shown in previous work that do not have a clear reference frame but are sloped at orientations between 45° and 90°, similar to those in the present work. One of the translations of the findings of this work is to people leaning objects against walls. When people do this, they will perceive the leaned object as leaning more away from them than it actually is. This perceived exaggeration of the orientation of an object typically viewed as upright or starting from vertical, then, is similar to the perceived exaggeration of the orientation of hills and ramps, which are typically viewed as slanting upward from a horizontal reference frame. This may point to a generic perceived exaggeration of slant whose direction depends on the conceptual or actual reference frame being used.

**Author note** We thank Meghan Burkhardt, Ky Mattingly, Brandon Short, Allyson Thomas, Ally Taylor, and Eric McManama for their help in collecting and coding data.

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