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Summarizing slant perception with words and hands; an empirical alternative to correlations in Shaffer, McManama, Swank, Williams & Durgin (2014)

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ABSTRACT

The paper by Shaffer, McManama, Swank, Williams & Durgin (2014) uses correlations between palm-board and verbal estimates of geographical slant to argue against dissociation of the two measures. This paper reports the correlations between the verbal, visual and palm-board measures of geographical slant used by Proffitt and co-workers as a counterpoint to the analyses presented by Shaffer and colleagues. The data are for slant perception of staircases in a station ($N = 269$), a shopping mall ($N = 229$) and a civic square ($N = 109$). In all three studies, modest correlations between the palm-board matches and the verbal reports were obtained. Multiple-regression analyses of potential contributors to verbal reports, however, indicated no unique association between verbal and palm-board measures. Data from three further studies (combined $N = 528$) also show no evidence of any relationship. Shared method variance between visual and palm-board matches could account for the modest association between palm-boards and verbal reports.

1. Introduction

A recent methodological paper by Shaffer, McManama, Swank, Williams, and Durgin (2014) tested the effects of anchoring on hand based measures of the slope of a hill, termed geographical slant perception (see earlier discussions of the topic at Feresin, Agostini, & Saviolo-Negrin, 1998; Feresin & Agostini, 2007). Shaffer and colleagues reported that the starting orientation of the hand, i.e. horizontal or vertical, biased both palm-board and free hand measures of slant towards the start point. In particular, palm-board estimates of slant starting from the horizontal anchor were lower than those starting from the vertical anchor. In addition to this potentially interesting finding, the paper reports a series of bivariate correlations between palm-board or free hand measures and a subsequently obtained verbal estimate of the hill's slope. This second analysis attempts to address the issue of dissociation between different measures of geographical slant. Proffitt and co-workers have consistently reported exaggeration of a hill's apparent slope for verbal reports of the angle in degrees and visual matches to the cross-section of the hill by adjustments of a moveable, wedge-shaped segment of a disk (Bhalla & Proffitt, 1999; Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Schnall, Zadra, & Proffitt, 2010). In contrast, matches with the surface of a palm-board, anchored at horizontal, are more accurate than the verbal and visual measures, an 'accuracy' that Durgin, Hajnal, Li, Tonge, and Stigliani (2010) argued reflects constraints of wrist perception and flexion, though the relatively better accuracy remains when a reliance on wrist flexion is removed (Taylor-Covill & Eves, 2013a, 2013b).

Proffitt et al. (1995) linked verbal and visual estimates to explicit consciousness, suggesting they could be dissociated from the perceptual processes engaged by the palm-board measure. In Shaffer et al's paper, the correlation between the palm-board and the verbal measure is posed as a problem for a dissociated account in that the two measures of perception co-vary. They reason that correlations 'suggest that manual and verbal measures are based off a common perceptual representation' (page 1208, Shaffer et al., 2014). This paper reports the associations between all three measures of geographical slant pioneered by Proffitt and co-workers; the data have not been reported previously. In the introduction to their paper, Shaffer and colleagues proposed a more balanced position in that two alternative conclusions could be drawn from correlational data. They state that 'positive evidence of correlation suggests the possibility of contamination or of a shared perceptual representation' (page 1205, Shaffer et al., 2014). The 'missing' perceptual measure from Shaffer et al's data, visual matches with an adjustable disk that performs as an intermediate measure between verbal and palm-board estimates, strongly suggest contamination as an explanation of their correlations.

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2. Methods and results

The analyses below test the association between Proffitt's three measures of geographical slant. The data were collected for perception of staircases rather than hills. As with hills, verbal and visual measures of staircases greatly exaggerate slant whereas palm-boards, anchored at the horizontal, do not. Additionally, women and older participants make greater estimates with the verbal and visual measures but not with the palm-board. This pattern of differences for the perceptual measures, and effects for the demographics of sex and age confined to the verbal and visual measures, suggest a commonality of slant perception across natural and man-made slopes (Eves, 2014; Eves, Thorpe, Lewis, & Taylor-Covill, 2014).

Table 1 below reports the result of preliminary inspections of three data sets, none of which has been reported previously. The measures of slant perception matched closely those employed by Proffitt and colleagues and were identical across the three studies. The data from staircases in a station ($N = 269$; 39 steps, height = 6.45 m, overall staircase angle, including half landing = 23.4°, each stair section = 28.0°) and a shopping mall ($N = 229$; 24 steps, height = 4.08 m, overall staircase angle, including half landing = 25.2°, each stair section = 29°) have already been published (Eves et al., 2014) whereas the data for a staircase in a civic square are preliminary data collected in 2008 and unpublished ($N = 109$; 23 steps, height = 3.45 m, overall staircase angle, including half landing = 19.1°, each stair section = 23.2°). The station and square data are for judgments of real staircases while the shopping mall data were obtained for a life-size display of the staircase in a field laboratory in a vacant shop in the mall. Research has demonstrated equivalent judgments of real staircases and life-size displays of the same staircases in the laboratory (Taylor-Covill & Eves, 2013c), so the difference is not important, particularly for a test of association as is clear in the data.

Table 1 summarizes the bivariate correlations with 95% confidence intervals (95% CIs) between Proffitt and co-worker's measures of slant in the data sets. A consistent pattern is evident such that visual matches were more strongly correlated with the verbal estimates than the palm-board matches. There was also appreciable correlation between the visual and the palm-board matches whereas the weakest correlation was between the verbal and palm-board measures. The consistency of this pattern across three data sets, what could be termed 'triplication', makes it unlikely that it results from random variations in sampling, location or methodology. The directly comparable correlation for the palm board from the horizontal anchor across all of Shaffer and colleagues data with 49 participants, $r = 0.37$ (95% CI = 0.10, 0.59), appears compatible with the data presented in the table.

As is clear from the data above, there was some evidence of multicollinearity between the variables but also unshared variance that allowed exploration of potential effects on each measure of staircase perception. A complete absence of correlation between palm-board and verbal measures would have been surprising. These were real slopes, and any individual differences in overall perception should have resulted in some level of association between separate measures if they were related to perception.

To test the relative contribution of visual and palm-board matches to the verbal reports of slant, multiple regressions were computed, with visual and palm-board matches as potential predictors of the verbal estimate. Table 2 presents the regression coefficients, 95% CIs and the standardized β-weights from these analyses. Once again, a consistent pattern was evident across the data sets, echoing the 'triplication' in the correlations. Visual matches contributed to verbal estimates whereas palm-board matches did not account for any unique variance. It is possible that the modest bivariate correlations between palm-board and verbal estimates reflect shared variance between both measures and the visual matching data. When shared variances were accounted for in the analyses, no evidence of a unique association between palm-boards and verbal reports remained. Note that variance shared between the verbal and visual measures would not have to be the same variance that linked visual and palm-board matches for such an effect to occur.

3. Discussion

The summarized data reveal a common pattern across locations, populations and methodology; multiple regressions suggest that palm-board matches share no unique variance with verbal reports of angle when data from visual matching are included. Further, a commonality of slant perception across hills and staircases renders the differing stimuli an unlikely source of discrepancies (Eves et al., 2014). If the data across the three studies are combined, after mean-centering within each set, a visual regression coefficient of 0.548 (95% CI = 0.460, 0.637) contrasts with a palm-board coefficient of −0.021 (95% CI = −0.163, 0.122), with the model explaining 21.7% of the variance ($F_{2,604} = 85.05$, $p < .001$). Correlations can never demonstrate dissociation, only association, and null hypotheses cannot be proven. Nonetheless, the magnitude of the regression coefficient with a sample of 607 does not provide any encouragement for further search for a unique association between palm-board and verbal measures.

These data with the palm-board are probably the last that will be collected by this laboratory. An improved manual measure of geographical slant was required for the steeper slopes characteristic of staircases that are the primary interest, called a palm controlled inclinometer (PCI: Taylor-Covill & Eves, 2013a). Unpublished data from the PCI reveal a similar pattern to that seen with the palm-board. A visual regression coefficient of 0.514 (95% CI = 0.451, 0.709) contrasts with a palm-board coefficient of −0.057 (95% CI = −0.053, 0.168) with a sample of 362 for a 23.9° staircase on a university campus. While the slant estimates summarized so far were obtained for a restricted range of angles, 19.1°–25.2°, this range includes the 21.7° tested by Shaffer et al. (2014) with the larger sample on the Ohio campus. Earlier data obtained for shallower angles with the PCI reveal a similar pattern with student samples (Taylor-Covill & Eves, 2013c). Visual regression coefficients of 0.371 (95% CI = 0.069, 0.673) for an 18.4° staircase and 0.943 (95% CI = 0.748, 1.138) for a 15° staircase contrast with non-significant palm-board coefficients of 0.173 (95% CI = −0.198, 0.545) and 0.036 (95% CI = −0.186, 0.258) respectively for sample sizes of 80 and 86 comparable to Shaffer and colleagues' samples. These data suggest that it is unlikely that the actual angle of the slope is relevant to the

Table 1
Bivariate correlations (95% CIs) between verbal, visual and palm-board estimates of staircase slant in three different locations.

	Station		Shopping mall		Civic square	
	Verbal	Visual	Verbal	Visual	Verbal	Visual
Visual match	.47*** (.37,.56)		.40*** (.29,.50)		.60*** (.47,.71)	
Palm-board match	.16* (.04,.27)	.35*** (.24,.45)	.15** (.02,.27)	.38*** (.26,.49)	.20 (−.05,.42)	.39*** (.16,.58)
	$N = 269$		$N = 229$		$N = 109$	

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 2
Summary of multiple regression analyses with visual and palm-board matches as potential independent predictors of verbal reports of the slope of staircases in three different locations.

	Station		Shopping mall		Civic square	
	Coeff. (95% CI)	β-weight	Coeff. (95% CI)	β-weight	Coeff. (95% CI)	β-weight
Visual match	.57*** (.43,.70)	.472	.46*** (.31, .61)	.401	.68*** (.49,.87)	.608
Palm-board match	−.01 (−.25,.22)	−.007*	−.00 (−.22,.22)	−.001	−.06 (−.40,.28)	−.030**
Adj. R^2 =	0.215***		0.161***		0.344***	

Note; Coeff. = regression coefficient, 95% CI = 95% confidence interval, Adj. = adjusted.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

pattern of association. Further, these more recent 'triplicated' data with the PCI suggest that alternative measures to palm-boards are unlikely to be more fruitful in the quest for unique associations between 'haptic' and verbal estimates of slant.

Any correlation between two variables a and b, Observed $r_{a\text{-}b,}$ is composed of two elements (see Conway & Lance, 2010). The first element is the true association between the variables modified by their respective reliabilities of measurement to reflect the inevitable imprecision in measurement. Any imprecision will attenuate the observed correlation. The second element is the product of the effects of measurement method variance on each variable. The simplified equation below, adapted from Conway and Lance (2010), summarizes this relationship.

$$\text{Observed } r_{a\text{-}b} = (\text{reliability}_{a.b} \text{ x } r_{a\text{-}b}) + (\text{methods}_{a.b} \text{ x } r_{\text{methods a-b}})$$

When two variables are measured with the same method, i.e. perfectly correlated, the second, method related element can inflate the observed association when it is added to the first element. If, however, the variables are measured with different methods, then the effects of the second element are modified by the correlation between the two methods. If this correlation is positive, then the second element will inflate the observed correlation by a factor of that correlation. In contrast, any uncorrelated variance will attenuate the observed correlation between a and b (Lance & Conway, 2010).

3.1. Reliability

Unpublished data from two laboratory studies provide information on the reliability of verbal, visual and palm-board or PCI measures of slant. In both studies, participants estimated the slants using the same methods outlined earlier when positioned 3.6 m from life-size displays of two staircases in a laboratory. Order of staircase presentation was counterbalanced across participants; there were no effects for order. For the first pair of staircases, palm-board matches were used whereas the second pair employed the more recently developed PCI. The larger sample using a palm-board was composed of members of the general public whereas the student data for the second pair of staircases used a PCI. Table 3 below presents the test-retest reliability data for the two studies. Reliabilities appear similar for the three slant measures, suggesting similar levels of attenuation of the first element of the observed correlation by imprecision of measurement.

Table 3
Test-retest correlations (95 % CIs) for verbal, visual and 'haptic' slant estimates of two different staircases.

	Verbal reports	Visual matches	Palm-board/PCI matches
25° and 24°: $N = 316$	.74***,* (.69, .79)	.68*** (.62, .74)	.61*** (.54, .67)
29° and 18°: $N = 117$	.63***,** (.51, .73)	.67*** (.56, .76)	.68*** (.57, .77)

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 1, presented earlier, summarized the correlations between the three slant measures. The retest data suggest that any differences between the correlations in the earlier table are unlikely to reflect differential reliabilities of the measures. This leaves differences in the true correlation and effects of methodology as the only alternative explanations of any discrepancies. Where there is common methodology between measures, then inflation of the observed correlation is a plausible outcome.

3.2. Methods

A step back here to consider sources of method variance may be helpful. Participants, positioned in front of a hill or staircase, look straight ahead and estimate the slant pre-eminent in their visual world (Taylor-Covill & Eves, 2013b). All measures will have a measurement component that reflects the explicit nature of the procedure; aware participants summarize what they 'see' for the researcher. The original paper by Proffitt et al. (1995) employed three different estimates of geographical slant perception, verbal, visual and palm-board measures. Typically, to match with a disk, participants position the disk below their face at shoulder level and use central vision when adjusting it. Switching from near to far space to adjust the disk, a process not required for verbal reports, will attenuate any correlation between the verbal and disk-based estimates. Nonetheless, switching between near and far space is an active process. Similarly, the mental rotation required to translate the perceived slant into its cross-sectional representation must be primarily an explicit process. Verbal reports of angles cannot be anything other than explicit. They translate the slope into an angular token that is uniquely human. Typically, learning about these angular tokens will also be from cross-sectional, two-dimensional images. As a result, verbal reports and visual matches share substantial method variance, consistent with the magnitude of the correlations between the two in Table 1. It is perhaps unsurprising that Proffitt (2006) links both measures to explicit consciousness, given the active, cognitive processing that is required for both measures. Clearly, the data summarized here repeatedly demonstrate association between verbal reports and visual matches that would be consistent with any explicit commonality between them.

While Proffitt likened the processes involved for palm-board measures to visually guided actions, it is clear that the hand does not interact with the slope (Bridgeman & Hoover, 2008; Durgin, 2013; Taylor-Covill & Eves, 2013c). Instead, palm-boards match a far slope with movements of the perceiver's hands, inevitably in personal space. Free-hand gestures favored by Durgin and colleagues and the newly developed PCI also use hands in peripersonal space. For all of these measures, the hand attempts to parallel the slope, and no translation to a cross-sectional representation is required. In addition, the hand is unseen when performing the matching. As a result one might expect correlation associated with the shared method variance. Data for the PCI and palm-board reveal an average Pearson's correlation, following appropriate transformations involving Fisher's r', of $r = .74$ (range .54-.88) over the range of angles 4.5°-31° reported in Taylor-Covill and Eves (2013a). Correlation of either with the free-hand measure is unknown but is likely to be lower.

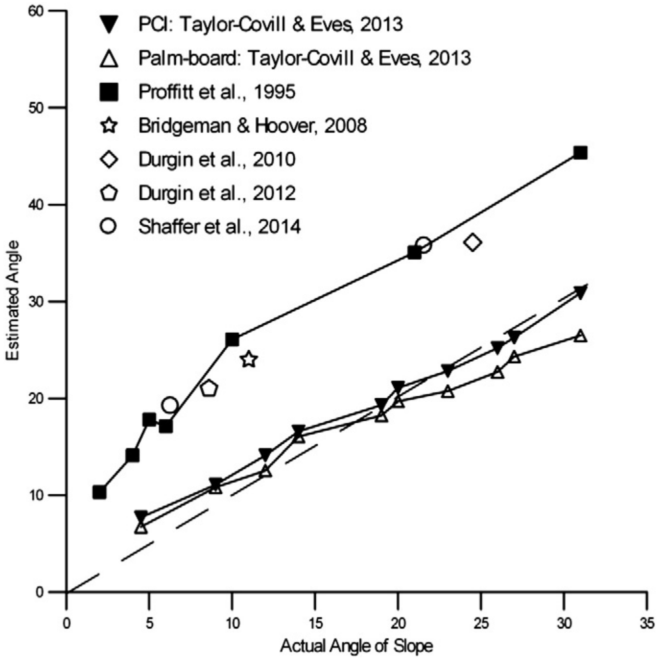

Fig. 1. An updated figure comparing free-hand matches with the original disk matches from Proffitt et al. (1995), and the subsequently obtained PCI and palm-board matches from Taylor-Covill and Eves (2013a). The broken line represents the actual angle of the slope.

3.3. Overestimation of angle with free hand matching

The free-hand matching that Durgin and colleagues have promoted as an alternative to palm-board matches behaves like the disk-based measure when estimating slant. They consistently overestimate the slope of far space stimuli such as hills whereas palm-board matches do not within the range of angles reported here (Taylor-Covill & Eves, 2013a). Fig. 1 below, an update of Fig. 6 in Taylor-Covill and Eves (2013a), depicts free-hand matches and the overestimation of visual matches to hills using a disk in the original data of Proffitt et al. (1995). This update includes Shaffer and colleagues' new data with a horizontal anchor for 6.3° and 21.7° slopes. Once again, these new data are comparable to visual matches with the disk; free-hands consistently overestimate for slants in far space in four separate studies.

3.4. Positioning of the hand in personal space

At first sight, this overestimation with the free-hand is puzzling given that both it and the palm-board attempt to parallel the surface. Note that the processes that produced exaggerated disk-based matches do not have to be the same processes that produce exaggeration with a freely wielded hand. It is possible, however, that the positioning of the hand in personal space is relevant. Typically, participants look straight ahead. Matches for the palm-board and PCI are performed with the hand at waist height whereas the free-hand gestures at mid-chest to shoulder level. Consequently, measurement with the palm-board and PCI positions the hand in the periphery of the visual field whereas the free-hand is positioned closer to the face. In addition, free-hand matches may position the hand further forward in the frontal-dorsal plane, explicitly so for Bridgeman's group as the elbow touches the torso and probably so for Durgin and colleagues (see Fig. 2, Shaffer et al., 2014). Taylor-Covill and Eves (2013c) were puzzled by the appreciable exaggeration of the slant with palm-board matches reported in a book chapter by Durgin, Ruff, and Russell (2012). For these unusual data, Durgin, Klein, Spiegel, Strawser, and Williams (2012) positioned the palm-board at chest height, i.e. closer to the face. He, Hong, and Ooi (2007) have also reported greater magnitude slant estimates for palm-boards positioned at shoulder height than waist level. These data would make sense if the proximity of the hand to the face was related to explicit processes that influenced estimates of slant. If the gradient of explicit estimates is preferentially distributed where the eyes and face are oriented towards a location in any scene, then hands positioned closer to the center of any explicit axis might overestimate angles, even without the translation required to match in cross section with the disk.

3.5. Effects of distance from the slope for real-world and virtual slopes

While Durgin et al. (2010) suggested that the exaggerations with free-hand matching reflect distance from the slope, the cited study by Bridgeman and Hoover (2008) did not actually measure distance from the slope. Instead, participants stood on the slope and looked at parts of that slope that were progressively further away, from 1 m to 16 m in front of them. As a result the study confounds effects due to direction of eye gaze and possible effects of distance from the surface; straight ahead would be at a distance of about 8 m from the participant. Gazing straight ahead increases verbal and free hand overestimations relative to gazing at the start of the hill but has no effect on palm board measures (Durgin et al., 2010; see also Proffitt & Zadra, 2011). Although the paper by Bridgeman and Hoover (2008) reported impressive fits of the relationship between overestimation and 'distance' with either logarithmic ($r = .98$) or power functions ($r = .98$), these fits are illusory. The within subject design inextricably confounds within and between subject variance in the analyses. When a design imposes an ordered relationship on a perceiver, an ordered relationship in each individual's output seems a likely outcome. Had different groups viewed at different distances, however, the nature of the relationship might have been interpretable (c.f. Proffitt et al., 1995). For the free-hand data, Bridgeman & Hoover reported only the overall mean estimate, 24° and stated that 'Mean error was smaller than the verbal error and varied less with distance' (page 857). A follow-up study, reported as a conference paper, provides missing data on the effects of distance. Looking 15 m-16 m up the slope was associated with an increase of +5.8° relative to looking at the slope 1 m in front of the participant ($N = 48$; Chiu, Hoover, Quan, & Bridgeman, 2011). As noted earlier, the estimate for the effects of 'distance' is inevitably confounded with direction of gaze.

Subsequently, Li and Durgin (2010) modeled the potential effects of distance in virtual reality. Using a within subject design, seated participants looked straight ahead ($N = 23$). Based on equation 6 of this modeling (page 5, Li & Durgin, 2010), increasing the distance from a slant from 1 m to 15 m should increase verbal reports by +18.6°, and a change from 5 m to 34 m should increase the exaggeration by +13.4°. Real world data for slant, with community samples of adequate size, do not support this virtual model. In formal tests of distance, the increase from 1 m to 15 m increased verbal reports of a staircase by +4.3° (95% CI = +0.9°, +7.6°; $N = 269$; Eves et al., 2014), whereas a change from 5 m to 34 m was associated with an increase of +2.5° (95% CI = +0.4°, +4.6°; $N = 671$; Taylor-Covill & Eves, unpublished). Comparable changes to estimates with disk-based matching were +3.5° (95% CI = +0.6°, +6.4°; Eves et al., 2014) and +3.3° (95% CI = +1.3°, +5.1°; Taylor-Covill & Eves, unpublished), with smaller magnitude but significant effects for 'haptic' measures. Distance has effects with real world slopes, but their magnitude could not explain the consistent free-hand overestimations summarized in Fig. 1. Disappointingly, free-hand data were not collected in the study by Li and Durgin (2010).

3.6. Replication

Recently, empirical approaches to psychology have seen a call for direct rather than conceptual replication (Makel, Plucker, & Hegarty, 2012; Pashler & Harris, 2012). To date, no study has formally compared free-hand matching with Proffitt's disk-based visual measure. Substantial association between the two and, based on the updated figure, similar levels of exaggeration of the actual slant seem likely. The free-hand match that Shaffer et al. (2014) treat equivalently to palm-board matches when correlating with verbal estimates may share substantial variance with the disk-based match; its sensitivity to manipulations underlines this point (Proffitt & Zadra, 2011; Durgin et al., 2012; Shaffer, McManama, Swank, & Durgin, 2013). It is possible that free-hand matches may be a better alternative explicit measure to verbal reports of slant than disk-based matches; there would be no commonality of translation into cross-section to increase the shared variance. Any clarification of potential dissociation between different measures of slant perception would benefit from direct replication of the measures employed originally. So far, the challenge to palm-board measures is characterized by repeated failures of replication of either the original research (Taylor-Covill & Eves, 2013a, 2013b) or of measures across studies that would be informative (Proffitt & Zadra, 2011). Replication can serve two functions. It can convince other researchers about any effect and alert them to inconsistency when it fails. For both outcomes, sampling from different underlying populations is informative. In addition, replication of methods across any series of studies helps calibrate the research for those conducting it.

3.7. Conclusion

This paper could not address the potentially interesting effects of anchoring reported by Shaffer and colleagues; it had no relevant data. Instead, it focused on the correlations between verbal and hand based measures of slant. Two 'triplicated' data sets revealed no unique association between verbal reports and matches to the slant by adjusting a board with the hand. It appears that palm-boards correlate with verbal reports because both measures share variance with visual matches made with Proffitt's original disk-based measure. Active, cognitive processing could account for the substantial correlations between verbal and disk-based measures. For palm-boards, shared method variance of the task, i.e. using hands to provide a match to a visual world, would be a plausible origin of the substantial association between disk-based and palm-board matches. Verbal reporting of slant with an angle in degrees is a uniquely human description of the world. The only things this verbal token definitely shares with the other measures of slant are the explicit nature of the procedure, the slope in front of the participant and potential effects of both the demographics and the state of the perceiver.

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