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DOI:
10.1037/xhp0000137

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Taylor-covill, GAH & Eves, FF 2015, 'Carrying a Biological “Backpack”: Quasi-Experimental Effects of Weight Status and Body Fat Change on Perceived Steepness. Body weight, body fat and perception', Journal of Experimental Psychology: Human Perception and Performance. https://doi.org/10.1037/xhp0000137

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Checked November 2015

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Carrying a biological ‘backpack’; quasi-experimental effects of weight status and body fat change on perceived steepness

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Abstract

The apparent steepness of hills and stairs is overestimated in explicit perception. These overestimations are malleable in that when physiological resources are compromised, apparent steepness is further overestimated. An alternative explanation of these experimental findings attributes them to demand characteristics. This paper tests the relationship between estimated steepness and naturally occurring differences in body composition. A quasi-experimental field study revealed more exaggerated reports of staircase steepness in overweight than healthy weight participants in a situation where experimental demand would be an implausible explanation for any differences. A longitudinal follow-up study used Dual X-ray Absorptiometry (DXA) to objectively measure participants' body composition at the beginning and end of a weight-loss program (*N*=52). At baseline, higher levels of body fat were associated with steeper explicit estimates of staircase steepness. At follow-up, changes in body fat were associated with changes in estimated steepness such that a loss of fat mass co-occurred with shallower estimates. Discussion focuses on the malleability of perceived steepness at an individual level and the implication of these findings for the debate surrounding 'embodied' models of perception.

Keywords: Geographical slant perception, Embodied Cognition, Staircases, Weight, Body fat, DXA.

Introduction

During pedestrian locomotion, hills and stairs represent a significant challenge to energetic resources. The apparent visual steepness of these slopes, termed geographical slant perception, is overestimated in explicit awareness. In a seminal paper, a 21° hill viewed from its base was reported to be around 40° (Proffitt, Bhalla, Gossweiler & Midgett, 1995) whereas, more recently, a 23° staircase was estimated to be 45° (Eves, Thorpe, Lewis & Taylor-Covill, 2014). Explicit estimates of geographical slant are provided through verbal reports and visual matching, measures that consistently exaggerate the steepness. In contrast, ‘haptic’ judgements, that involve matching the slope by adjusting a flat surface, reveal more accurate estimates (Proffitt et al., 1995; Taylor-Covill & Eves, 2013a).

Proffitt’s (2006) ‘economy of action’ account suggests that explicit perception of steepness is influenced by the available resources of the perceiver to facilitate management of locomotor resources. Demographic groups with less available resources give more exaggerated estimates of steepness relative to their comparison groups; women estimate hills and stairs as steeper than men (Proffitt et al., 1995; Eves, et al., 2014; Taylor-Covill & Eves, 2013b), and the elderly more than young adults (Bhalla & Proffitt, 1999; Eves et al., 2014). Less stable resource-related factors such as physical fatigue (Bhalla & Proffitt, 1999; Proffitt et al, 1995; Taylor-Covill & Eves, 2013b) and blood glucose levels (Schnall, Zadra & Proffitt, 2010) have also been associated with increased explicit estimates of steepness.

One manipulation that has provoked much debate is an artificial increase in the perceiver’s weight. Bhalla & Proffitt (1999) showed that estimated hill steepness increased when participants were encumbered with a heavy backpack. Verbal and visual estimates of steepness became more exaggerated when the demands of climbing were increased by carrying the added weight of the backpack. An alternative explanation of these experimental findings attributes them to demand characteristics (Orne, 1962). In a partial replication, some participants were led to believe that the backpack contained equipment to monitor the leg muscles (Durgin, Baird, Greenburg, Russell, Shaughness & Waymouth, 2009). Participants, given a cover story to *explain* the presence of backpack did not differ in their perceptual estimates relative to participants who did not carry one. Durgin and colleagues contend that participants in Bhalla & Proffitt's study must have *deduced* the experimental hypothesis associated with the manipulation and provided elevated estimates of steepness in line with their expectations of the experiment. In reply, Proffitt & Zadra (2009) suggested that Durgin and colleagues' results cannot speak to the debate on geographical slant perception, because the stimulus used in their experiment did not afford a sufficient climb for the influences of resources to appear (see also Durgin, Klein, Spiegel, Strawser, & Williams, 2012; Firestone, 2013; Proffitt, 2013).

Concerning additional weight, few studies have tested how natural levels of encumbrance are related to perceptions of steepness. Individuals carry differing amounts of 'dead-weight' in the form of body fat. If the additional dead-weight of a backpack causes hills to appear steeper, differences in perception would be expected between overweight and leaner individuals. Furthermore, Proffitt's work suggests that a recalibration of perceived steepness should occur over time as the level of body fat increases or decreases. When body weight has been included, increased body weight was associated with increased reported steepness of stairs (Eves et al., 2014) and hills (Sugovic & Witt, 2013).

In the first study, body shape was used to recruit pedestrians in a train station into unequivocally healthy weight and overweight categories, as used in public health (Eves, 2014), and then we compared the perceptual estimates of the two groups for a staircase in this built environment location. It is unlikely that the recruitment strategy in this quasi-experimental design would be sufficiently transparent for any individual to deduce why they had been recruited and, hence, derive any hypothesis about the expected effects of their weight status on perception. A follow-up study assessed effects on perception of objectively measured body weight and body composition, both cross-sectionally and longitudinally.

Study 1

Methods

Setting. The study was conducted in a railway station in Birmingham (UK). A staircase (height = 6.45m, angle = 23.4°) that led off the platform acted as the stimulus for estimates of steepness.

Participants. To ensure separation by weight status, travellers who were clearly of healthy weight or clearly overweight (see below) were recruited for “an interview about the built environment” while waiting for their trains (N=187; M=41.6, age range 18-65 years).

Measures and procedure. Participants were asked to stand on a marked spot on the ground 3m back from the base of the staircase to standardise the distance from which they made perceptual judgements and comply with health and safety concerns of the station staff. Participants provided three measures of perceived geographical slant (verbal, visual, and haptic) in a counterbalanced order. For the verbal measure, participants reported the apparent angle of the staircase relative to the ground in degrees. For the visual measure, participants were handed a visual disk (Figure 1a) and asked to adjust the movable segment so that it matched their perceived angle of the staircase slant in cross-section. For haptic judgments, participants used a Palm-Controlled Inclinometer (PCI, Figure 1b) to match the slant of the flat surface within the box to that of the staircase (Taylor-Covill & Eves, 2013a).

Field testing requires further confirmation of the validity of participants' perceptual estimates. Following perceptual measures, participants were turned perpendicular to the staircase, handed back the visual disk (Figure 1a) and asked to produce a 30° angle, with a 10° range of error allowed in order to pass this test of angle knowledge. Those who verbally report the staircase angle as 45° were asked if they thought all staircases were 45°. Finally, participants were handed a form to sign consent to their data being used, on which they also indicated their gender and age, before being offered an information sheet on the study to take away and given the opportunity to ask the team any questions they had about the research. This order of events minimised the possibility of experimental demands having an influence on staircase judgements. No experimental manipulation was used and participants were asked about their weight until *after* estimates of perception had been collected

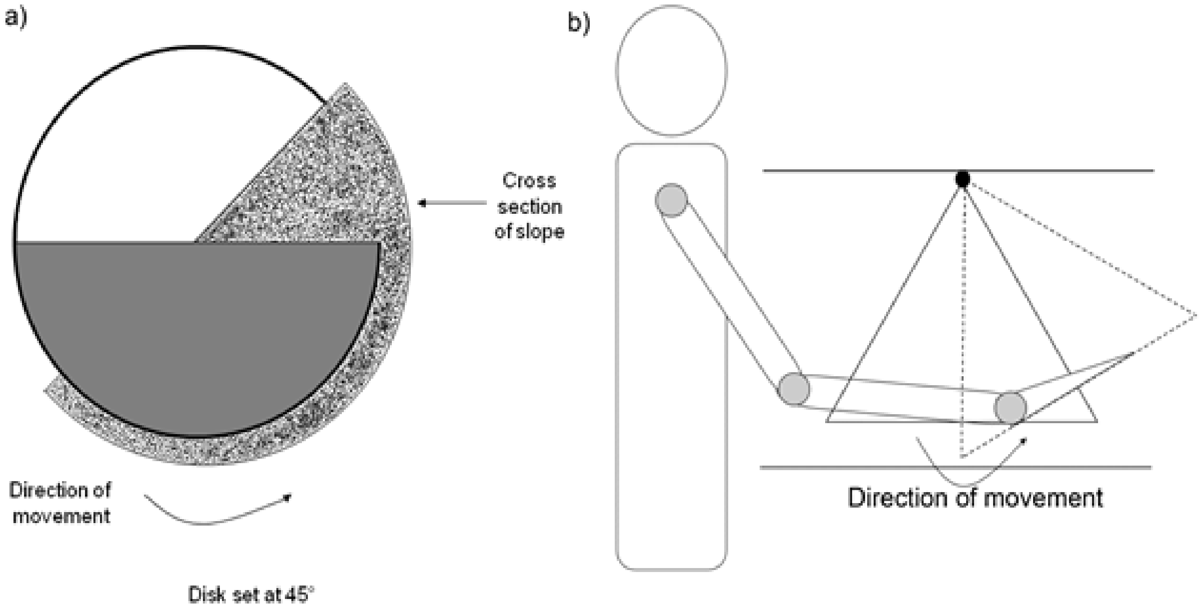

Figure 1. Schematics of apparatus used for visual matching (a) and haptic (b) measures.

Weight coding. During testing, a second experimenter who had been trained in weight coding with BMI silhouettes (Stunkard, Sorensen & Schulsinger, 1983), coded each participant's weight status as either clearly healthy weight and BMI less than 25, or clearly overweight and BMI more than 25.

Analysis. Participants were excluded if they expressed a belief that all staircases were 45° (*N*=7) or failed the angles knowledge test (*N*=9). The final sample for analysis (*M* age=41.8, *SD*=12.6) contained 171 participants made up of 41 females and 41 males coded as overweight, and 42 females and 47 males coded as healthy weight. Analyses took place in two stages; Repeated-measures Analysis of Variance included a within-subject factor of Measure (verbal, visual, haptic) and two between-subject factors of Sex and Weight Status. Follow-up Multivariate Analysis of Covariance tested for effects of Sex and Weight Status on the three perception measures individually while controlling for the covariate of Age.

Results

Repeated-measures analysis revealed main effects of Weight Status ($F(1, 167)=5.93$, $p<.05$, $\eta_p^2=.034$) and Sex ($F(1, 167)=12.42$, $p<.01$, $\eta_p^2=.069$), and a within-subject effect of Measure ($F(2, 166)=293.78$, $p<.001$, $\eta_p^2=.78$), which interacted significantly with Weight Status ($F(2, 166)=3.22$, $p<.05$, $\eta_p^2=.037$) but not Sex ($p=.19$). Overall, females ($M=40.64$ $SD=8.50$) provided steeper estimates than males ($M=36.49$ $SD=6.71$). There was no interaction between Sex and Weight Status ($p=.93$). Follow-up analyses showed that overweight participants gave more exaggerated verbal reports of staircase steepness ($F(1, 166)=8.03$, $p<.01$, $\eta_p^2=.046$), with a similar, though non-significant, difference in the same direction for the visual measure ($F(1, 166)=2.71$, $p=.10$, $\eta_p^2=.016$). There were no between-group differences for the haptic measure (*F*(1, 166)=0.00, *p*=.94). Figure 2 summarises these data.

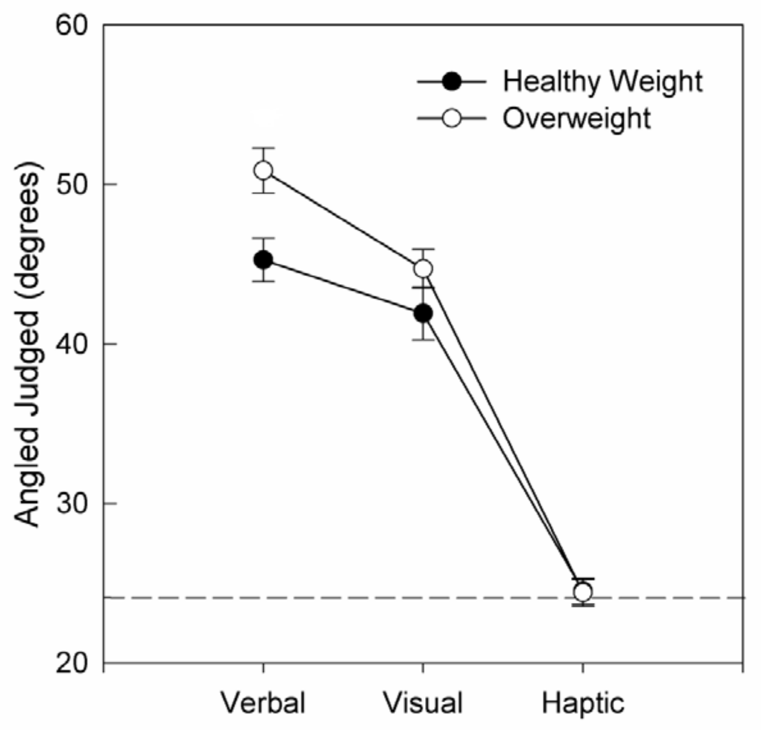

Figure 2. Mean and SE bars for perceptual responses by weight status. The dashed line represents the overall angle of the staircase.

Discussion

This quasi-experimental study confirms a link between weight status and explicit measures of steepness. Participants, clearly carrying excess fat, provided steeper perceptual estimates than those coded as healthy weight. In line with Proffitt (2006), differences in estimated steepness occurred for the explicit measures, but not the haptic one. Effects of experimental demand seem an implausible explanation of this quasi-experimental result, given the recruitment strategy.

Body weight is composed of fat and fat-free mass with potentially opposite effects on perceived steepness. The ‘dead-weight’ of fat mass must be carried up stairs by leg muscles that are part of fat-free mass; weight alone is a potentially confounded variable (Eves et al., 2014). The second study objectively measured body weight and composition to assess the relative contributions of fat and fat-free mass to perceptual estimates of life-size displays of staircases in a laboratory. Equivalent estimates of steepness to their real-world counterparts, and sensitivity to fatigue, have been found for laboratory displays (Taylor-Covill & Eves, 2013b). Participants attempting to lose weight were measured at the beginning and end of their weight loss programmes. It was predicted that a) baseline body weight would be related to verbal and visual estimates of staircase steepness, and b) changes in body weight would be associated with changes in verbal and visual estimates of staircase steepness.

Study 2

Method

Participants. Participants (*N*=52, 11 male) between 19 and 67 years of age (*M*=37.4, *SD*=12.7) were recruited from local weight loss groups and through online advertisements offering participation in research that would include free body composition scans. Prior to enrolment, participants were screened by telephone interview for any knowledge about perception, and confirmed absence of any health or vision problems that might influence their perceptual responses. Seventeen participants were lost to follow-up; health problems (*N*=4), pregnancy (*N*=2), relocation (*N*=2), loss of contact (*N*=9). There were no significant differences between the lost participants and the retest sample (*N*=35) on perceptual or demographic variables at baseline (all *p*>.20). Of the participants that returned for follow-up, the average time between visits to the laboratory was 407 days (SD=137.45).

Measures and Procedure.

Perception. Life-size displays of four staircases (20°-33°) that ascended above eye-height, were presented on a 4m x 4m customised projection screen in one of four counterbalanced orders using a Hitachi CP-SX1350 multimedia projector linked with a Dell Latitude laptop. The design of the projection screen allowed the base of each staircase image to occur at the junction between the floor and the screen. In line with a validation study (Taylor-Covill & Eves. 2013), participants stood 3.6m back from the screen to allow frontal projection of the staircase images and provided the same three perceptual estimates as in the first study (verbal, visual and haptic).

Body Composition. Height and weight were measured with a Seca 213 height stadiometer and Seca 877 electronic scales respectively. Body composition was estimated using a Hologic 'Discovery' Dual-energy X-ray Absorptiometry body scanner (DXA).

Procedure. Participants arrived at the laboratory at an allotted time, having only consumed water in the two hours prior to the appointment. On arrival, participants sat with the experimenter and completed a screening questionnaire to confirm they were in good health. A full briefing was given about the body composition scan and the potential radiation risks made explicit to participants so that informed consent for this aspect of the experiment could be obtained as specified by the ethical approval. Details of the study hypothesis, however, were withheld at this stage. Participants were escorted to the perception laboratory, where the experimenter explained to them the three measures of perception they would be making in response to 'images of the built environment' before agreeing to take part voluntarily, all participants agreed. Assessement of body weight and composition followed the perception test on both visits to the laboratory to minimise any potential effect that explicit knowledge of body composition might have on perceptual responses.

Data Reduction and Analysis. For the perception measures, estimates for each measure were averaged across the four staircases[1]. Analyses employed hierarchical linear regressions with Sex, Age, BMI, Fat mass and Fat-free mass as potential predictor variables. Sex, Age and BMI were entered first as they have previously been associated with differences in perception (Eves et al., 2014). On subsequent steps, BMI was decomposed into its Fat mass and Fat-free mass components which were entered separately. Fat mass and Fat-free mass (kg) were divided by the BMI divisor of height (m) squared. All weight related variables were mean-centred within each sex to avoid confounding with Sex in the analyses (see Eves et al., 2014).

Results and Discussion

Baseline. Table 1 contains the standardized coefficients and summarizes the results of multiple regression analyses. On the first step, age and BMI were related to the verbal (F (3,48) = 7.88, p<.001) and visual measures (F (3,48) = 5.19, p=.004) whereas only Age made a contribution in the non-significant model for the haptic measure (F (3,48) = 2.04, p=.12). On the second step, BMI was replaced by the Fat mass and Fat-free mass components in the models. Fat mass was associated with steeper perceptual estimates in the verbal (F (4,47) = 5.93, p=.001) and visual models (F (4,47) = 5.77, p=.001) , but did not contribute to the non-significant haptic model (F (4,47) = 1.64, p=.18). Fat-free mass did not contribute significantly to any perceptual measure.

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[1] Converting the estimates to a proportion of the actual angle of each staircase produced an identical pattern of results and the raw estimates were retained.

Table 1. β weights from baseline regression analyses.

Variable		**Step 1**	**Step 2**
Verbal:	Gender	.133	.133
	Age	.303*	.252‡
	BMI	.328**	
	Fat Mass (kg.m^{-2})		.336*
	Fat-free Mass (kg.m^{-2})		.114
	Adjusted R^2 =	.288***	.279***
Visual:	Gender	-.059	-.056
	Age	.279*	.188
	BMI	.326*	
	Fat Mass (kg.m^{-2})		.543**
	Fat-free Mass (kg.m^{-2})		-.215
	Adjusted R^2 =	.195**	.272***
Haptic:	Gender	.057	.056
	Age	.336*	.354*
	BMI	-.026	
	Fat Mass (kg.m^{-2})		-.095
	Fat-free Mass (kg.m^{-2})		-.014
	Adjusted R^2 =	.058	.048

‡ p=.10, * p<.05, ** p<.01, *** p<.001.

Longitudinal Analysis. Longitudinal analyses employed *change* scores for perceptual and weight related variables that were created by subtracting the scores of measures at follow up from baseline values. Once again, weight related variables were mean-centred within sex to avoid confounding. A four-step hierarchical regression was conducted, with Sex and Age entered on step one, BMI added on step two and then replaced with Fat mass on step three, and Fat-free mass added on step 4. One multivariate outlier with a studentized residual of 3.9, almost twice the acceptable magnitude (Tabachnick & Fidell, 2013), was identified during these analyses (see Figure 3). Table 2 summarises analyses of changes in angle for the full data set and when the outlier was removed (presented in parentheses throughout the table). In step one, the only unique contribution of demographics was for Age to the haptic measure; increasing age was associated with reduced changes in angle. Addition of changes in BMI on step two revealed significant unique contributions to verbal and visual models, both for the full data set and with the outlier removed. The same pattern of results was evident when BMI was replaced by changes in body fat. As with the baseline data, Fat-free mass did not contribute to any measure of angle The overall step three models were significant for the verbal measure (full data set, $F(3,31) = 3.59$, $p=.03$; outlier removed, $F(3,30) = 6.69$, $p=.001$) whereas for the visual measure only the model with the outlier removed was statistically significant with conventional two-tailed probability (full data set, $F(3,31) = 2.61$, $p=.07$; outlier removed, $F(3,30) = 3.74$, $p=.02$). Figure 3 depicts the relationship between changes in estimates of angle and body fat. A reduction in body fat was associated with shallower explicit estimates of perceived steepness whereas increasing body fat was associated with more exaggerated explicit estimates. No relationship was apparent for the haptic measure.

Table 2. β weights from longitudinal regression analyses.

Variable		Step 1	Step 2	Step 3	Step 4
Change in Verbal:	Gender	.013 (.066)	.015 (.071)	.015 (.074)	.015 (.074)
	Age	-.105 (.028)	-.039 (.114)	-.046 (.117)	-.038 (.116)
	BMI		.513** (.615***)		
	Fat Mass Change (kg.m^{-2})			.500** (.636***)	.463* (.640***)
	Fat-free Mass Change (kg.m^{-2})				.088 (-.008)
	Adjusted R^2 =	.000 (.000)	.200* (314**)	.186* (.341***)	.166* (.318**)
Change in Visual:	Gender	.137 (.165)	.138 (.168)	.138 (.171)	.138 (.172)
	Age	.204 (.274)	.248 (.324‡)	.250 (.332*)	.249 (.329*)
	BMI		.343* (.365*)		
	Fat Mass Change (kg.m^{-2})			.380* (.422*)	.385* (.453*)
	Fat-free Mass Change (kg.m^{-2})				-.011 (.070)
	Adjusted R^2 =	.001 (.040)	.095 (.152*)	.124‡ (.199*)	.095 (.176*)
Change in Haptic:	Gender	.096 (.083)	.096 (.083)	.096 (.084)	.095 (.085)
	Age	-384* (-.404*)	-.382* (-.403*)	-.379* (-.400*)	-.388* (-.403*)
	BMI		.013 (.006)		
	Fat Mass Change (kg.m^{-2})			.039 (.025)	.082 (.061)
	Fat-free Mass Change (kg.m^{-2})				-.101 (-.080)
	Adjusted R^2 =	.106‡ (.120‡)	.077 (.090)	.079 (.091)	.057 (.066)

‡ p<.10, * p<.05, ** p<.01. *** p<.001. Numbers in parentheses are for analyses with verbal outlier removed.

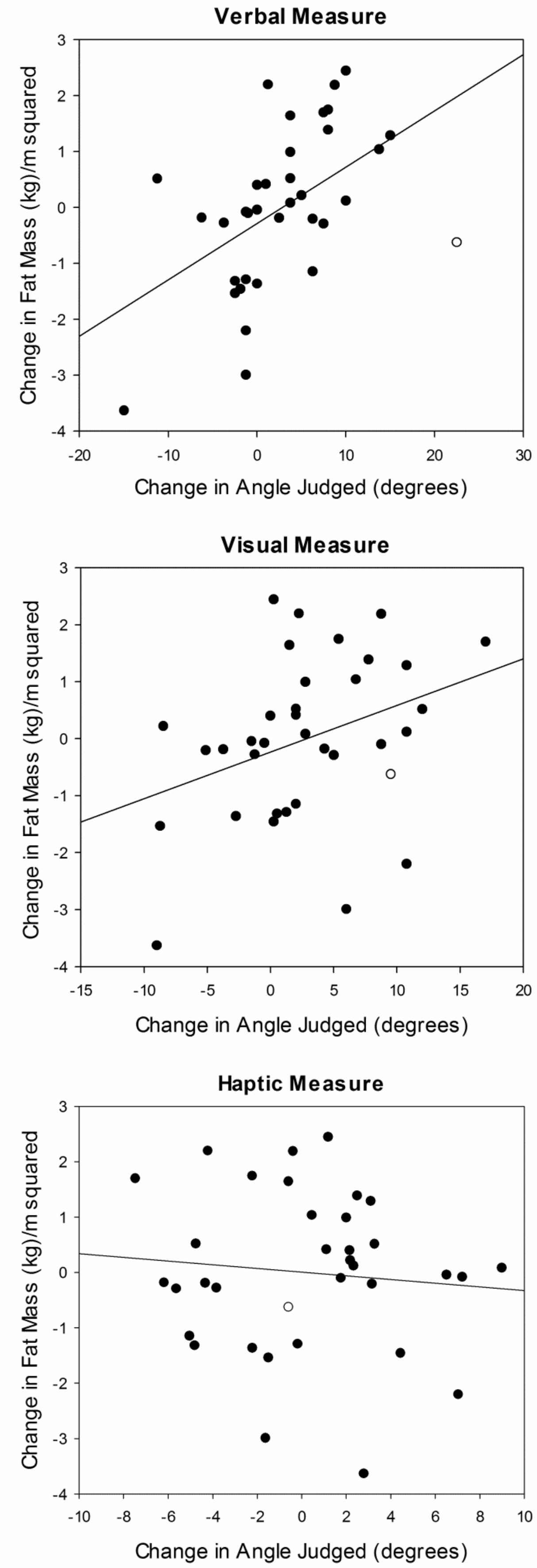

Figure 3. The relationship between changes in fat mass (kg.m^{-2}) and change in reported staircase angle for the three measures of perception including regression line. The outlier is identified by the white circle.

Discussion. Concerning weight, the baseline results confirmed those of the first study; greater body weight was associated with steeper explicit estimates. Further, the ‘dead-weight’ component of fat mass, rather than fat-free mass was important. Longitudinally, changes in BMI, and specifically the body fat component of BMI, were coupled with changes in verbal and visual estimates of steepness; no significant models emerged for the ‘haptic’ measure. There were no effects of sex of participant. The unbalanced nature of the sample for sex (79% female), and the small sample size compared to the preliminary study (c.f. Bhalla & Proffitt, 1999), may account for this discrepancy.

General Discussion

Consistent with an embodied account, explicit measures of steepness were greater in overweight participants in the first study, and scaled by objectively measured BMI and fat mass in the second study (Proffitt, 2006; Proffitt & Linkenauger, 2013). Furthermore, changes in fat mass over time were associated with changes only in the explicit measures. Perception of the locomotor challenge of climbing was related to the ‘dead-weight’ of body fat, and was malleable over time to fit with changes to body composition at an individual level.

Previous studies have demonstrated short-term recalibration of the visual system for body-scaled and energy-scaled action-specific perceptions relevant to pedestrians (Witt & Riley, 2014). ‘Climbability’ of stairs and ‘passability’ of apertures, such as doors, were rescaled to match changes in apparent body metrics such as eye-height (Mark, 1987; Warren & Whang, 1987; Wraga, 1999). In complementary research on resources, perceptions of distance and steepness were susceptible to change when the effort required for the task was increased (Bhalla & Proffitt, 1999; Witt, Proffitt & Epstein , 2004, 2010). In the longer term, the progressive increase in waist circumference that occurs during pregnancy produced a progressive recalibration of the ‘passability’ of a door aperture (Franchak & Adolph, 2014). As with ‘climbability’, experience was required to recalibrate the affordance (Mark, 1987; Franchak & Adolph, 2014). For effects of resources, rather than body metrics, there is no direct evidence for longer-term recalibration, though two cohort studies suggest it. For ageing, a reduction in locomotor resources occurs over time due to a loss of leg strength, cardiovascular fitness and general health. In a study which links body-scaled and energy-scaled perception, the ‘climbability’ of stairs changed in line with this reduction in climbing resources (Konczak, Meeuwsen & Cress, 1992). Consistent with this, older participants provided more exaggerated reports of hill and staircase steepness relative to younger participants (Bhalla & Proffitt, 1999; Eves et al., 2014), as they did in the second study here. These effects of age occurred for the relatively steep slopes characteristic of stairs (Bhalla & Proffitt, 1999) and leg strength relative to body weight may be the key (Konczak et al., 1992). To climb stairs, an individual requires sufficient leg strength to raise body weight over the support foot so that the trailing foot can be positioned on the next stair above. An older individual with reduced leg strength would require a greater proportion of their available resources to climb (Eves, 2014). Nonetheless, between subject cohort studies cannot estimate effects within an individual that would be consistent with malleable perception (Bhalla & Proffitt, 1999; Konczak et al., 1992). Longitudinal data on resources, similar to Franchak and Adolph’s (2014) study of body metrics, are required. For body weight, as for weight carried in a backpack, the individual must raise any additional weight against gravity. Participants wearing a backpack might deduce that the manipulation should increase their reports of steepness (Durgin et al., 2009; Firestone, 2013). Body weight is more complex. Participants in the current research might have known their weight, but would not know how much fat they carried, nor what was gained or lost until *after* they estimated steepness. They did not have explicit knowledge of the ‘dead weight’ they would have to carry. In this ‘natural’ experiment, it would be difficult for participants to conform to any *fat specific* expectation rather than one based on observed weight; weight loss is not synonymous with fat loss. Participants who lose weight through exercise may confound any reduction in body fat with potential gains in weight, and resources, resulting from the formation of new muscle tissue. These individuals may see no change in their weight when looking at the scales, and assume they were unsuccessful at fat loss. In reality, changes in their body composition could have increased their action capabilities. Alternatively, individuals using a diet-focussed approach might see a reduction in weight on the scales that would not be matched by positive changes to body composition that could increase their action capabilities. Calorie restrictive dieting *without* exercise can result in decreases of body fat and muscle tissue of similar levels (Chomentowski et al., 2009; Weiss et al., 2007). Expectations from self-weighing may not match the actual resources available for climbing. Consistent with this emphasis, actual weight, rather than beliefs about body weight, was associated with the perception of hill steepness in a recent conference paper (Sugovic & Witt, 2013).

In the first study, pedestrians carrying excess body weight estimated stairs as steeper than their healthy weight comparison group. This quasi-experimental approach has implications for testing embodied perception. The matchless evidence for causal effects provided by manipulations in experimental designs may be compromised if the expected outcomes are transparent to participants. Induced demand is a potential pitfall for tests of energy-scaled effects in embodied perception (Durgin et al., 2009; 2012). In a quasi-experimental sampling paradigm, however, explanations based on experimental demand are implausible. There was no explicit manipulation and participants were unlikely to have deduced why they were selected in the first study. This sampling approach complements quasi-experimental field studies in which the choice made by an individual allocates that individual to a perceptual group. Choices can precede the perceptual estimates (Eves et al., 2014; Taylor-Covill & Eves, 2014; Taylor-Covill, 2013) or follow them (Taylor-Covill & Eves, 2014). In neither case, is the link between behaviour and perception explicit, reducing the potential effects of experimental demand. Quasi-experimental sampling and choice paradigms, which circumvent many of the problems of demand characteristics, can be a fruitful alternative to experimental designs for research on embodied perception. Stratified sampling and subsequent multivariate analyses can allay some of the concerns about non-random allocation (Eves et al., 2014).

The second study confirmed effects of the first; *objectively* measured weight was related to explicit estimates of steepness. Replicated observations from different research designs revealed that body weight can be associated with estimated steepness, consistent with a previous report (c.f. Eves et al., 2014). Importantly, the second study speaks to the mechanisms underlying this effect. It was the biological ‘backpack’ of fat mass, rather than fat free mass, that was responsible for the association. Fat free mass is composed of bones, muscles and internal organs (Heymsfield, Lohman, Wang & Going, 2005). All three components supply climbing resources. Muscles that perform the climbing are attached to the skeleton and require oxygenated blood. It is only fat mass that can make no contribution to a typical stair climb; it is truly ‘dead-weight’ to be carried. Effects on explicit estimates of steepness for fat mass, and its change, independent of fat free mass, clearly implicate weight to be carried in this embodied perception. Demand is always possible in laboratory studies; a complex explanation in which demand influences fat mass differently from fat-free mass would be tortuous compared to the simplicity of a resource-based account. Daily experience of any changes in body composition would be expected to recalibrate the action-specific perception just as they do for body-scaled perceptions (Mark, 1987; Franchak & Adolph, 2014). Non-visual factors related to the learnt cost of climbing could result in changes to the ‘feel’ of stairs that are reflected in perceptual estimates (c.f. Woods, Philbeck & Danoff, 2009).

From a broader perspective, this particular embodied perception has implications for public health. Overweight pedestrians are more likely to avoid stair climbing when a motorised alternative is available (Eves, 2014). Estimates of steepness have been directly linked to the behavioural choices pedestrians make while navigating the built environment (Eves et al., 2014; Taylor-Covill, 2013). Pedestrians who chose the escalator to ascend, reported the stairs that they had just avoided as steeper than their comparison group (Eves et al., 2014). Pedestrians navigating the built environment are likely to base their choices on ‘feel’ rather than making careful perceptual estimates of the alternatives (Eves et al., 2014). Hence, the greater perceptual bias in the overweight for stair steepness might deter them from a type of physical activity that would be beneficial for their health. Increased stair climbing during everyday life is a public health target of many health bodies in the developed world (e.g., Centres for Disease Control, 2013). Health promoters may struggle to encourage the overweight to choose the stairs over the escalator against this greater perceptual bias.

In conclusion, two studies support Proffitt’s embodied model of perception in which the units used to scale explicit perception are derived from the body (Proffitt, 2006, 2013). The perceptual bias that deters stair climbing is malleable at an individual level in line with our natural level of biological encumbrance.

Acknowledgements

The research team thanks Dr. Dave McIntyre and Steve Allen for their assistance with the construction and maintenance of the apparatus used throughout studies reported here. We also thank Devon James, Hannah Brown, Shelby Sands and Helen Muschamp for their assistance in recruiting participants in the first study.

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