

Research Article

DECONSTRUCTING ACROPHOBIA: PHYSIOLOGICAL AND PSYCHOLOGICAL PRECURSORS TO DEVELOPING A FEAR OF HEIGHTS

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Background: *Acrophobia is one of the most prevalent phobias, affecting as many as 1 in 20 individuals. Of course, heights often evoke fear in the general population too, and this suggests that acrophobia might actually represent the hypersensitive manifestation of an everyday, rational fear. In this study, we assessed the role of sensory and cognitive variables in Acrophobia.* **Methods:** *Forty-five participants (Mean age 25.07 years, 71% female) were assessed using a booklet with self-reports as well as several behavioral measures. The data analysis consisted in multivariate linear regression using fear of heights as the outcome variable.* **Results:** *The regression analyses found that visual field dependence (measured with the rod and frame test), postural control (measured with the Sharpened Romberg Test), space and motion discomfort (measured with the Situational Characteristics Questionnaire), and bodily symptoms (measured with the Bodily Sensation Questionnaire) all serve as strong predictors for fear of heights (Adjusted $r^2 = .697$, $P < .0001$). Trait anxiety (measured with the State Trait Anxiety Inventory Form Y-2) was not related with fear of heights, suggesting that this higher order vulnerability factor is not necessary for explaining this particular specific phobia in a large number of individuals.* **Conclusion:** *The findings reveal that fear of heights is an expression of a largely sensory phenomena, which can produce strong feelings of discomfort and fear in the otherwise calm individuals. We propose a theory that embraces all these factors and provides new insight into the aetiology and treatment of this prevalent and debilitating fear. Depression and Anxiety 27:864–870, 2010.* © 2010 Wiley-Liss, Inc.

Key words: *acrophobia; visual field dependence; posture; space and motion discomfort; bodily symptoms; anxiety*

INTRODUCTION

Acrophobia is a specific phobia characterized by an extreme fear of heights, affecting as many as 1 in 20 adults.^[1] Acrophobic behavior involves the avoidance of various height-related circumstances, including stairs, terraces, apartments, and offices located in high buildings, and sometimes bridges and elevators. Given the striking breadth of aversive situations and stimuli avoided, it is not surprising that individuals with acrophobia feel extremely impaired and restricted in their movements.^[2] Moreover, due to the pervasive and chronic avoidance of a wide range of situations that form part of everyday living, this disorder carries an increasing social impact. Current taxonomic models postulate the existence of hierarchical dimensions falling under

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the umbrella of the anxiety disorders.^[3] Successive models have labeled these general traits differently, but as Zinbarg and Barlow^[4] point out, the conceptual and empirical overlap remains strong: all these models imply the overarching involvement of trait anxiety based largely on the comorbidity of fear subtypes.

Earlier research indicates that anxiety disorders associated with more vague and/or unpredictable triggers (e.g., panic, general anxiety disorder) correlate more with trait anxiety than do more circumscribed disorders, such as specific phobias,^[5] but that neuroticism represents a general vulnerability factor for all forms of anxiety.^[6] Despite commonalities between these disorders, the heterogeneity of specific phobias is formally recognized in the DSM-IV,^[7] which identifies four subtypes: animal, natural environment (e.g., heights and water), situational (e.g., airplanes and elevators), and blood-injection-injury.

In the last few years, studies have begun to reveal a link between postural control and anxiety disorders.^[8] Unfortunately, the tendency to regard these disorders as related has led to patients with differing specific disorders being lumped together, making it difficult to ascertain the selective effects of factors such as balance control. There are, in fact, several good reasons for thinking that acrophobics may struggle with postural control. One concerns the related phenomenon of heights vertigo: a warning signal created by loss of postural control when the distance between the observer and visible stationary objects becomes too large.^[9] The explanation for this everyday loss of postural control is that the increased distance between the observer and the nearest available visual targets reduces motion parallax cues.^[10] The lack of these important depth cues leads to a perceptual conflict, as the vestibular and somatosensory receptors sense a body shift not detected by the visual system.^[11] This, in turn, has an intense influence on postural responses.^[12] The resolution of this conflict is achieved by increasing postural sway, thereby reactivating visual control.^[13] Despite the parallels to acrophobia, authors in the heights vertigo literature are at pains to dissociate the two.^[9] Nonetheless, it seems possible that acrophobia could be regarded as an extreme response to this normal warning signal.

Expanding the notion of a role for postural control in acrophobia, one possibility is that some individuals are more reliant on visual cues to control posture than others. This would make them particularly vulnerable to heights vertigo.^[14] In fact, it has been known for some time that some individuals rely heavily on vision to regulate their posture and balance.^[15] Recent findings do suggest that individuals with acrophobia have poor postural control, especially in the absence of strong visual cues.^[16] What we also know is that persons with acrophobia have high levels of space and motion discomfort (SMD), a construct related to physical symptoms elicited by inadequate visual or kinesthetic information for normal spatial orientation.^[17] What is

more, there is evidence that acrophobics report a heightened sensitivity to physical symptoms, such as dizziness, feeling short of breath, or heart palpitations.^[18]

The unique contribution of this article is to explore the role of the abovementioned factors,^[19] which have been studied before in disconnected articles concerning heights and fear of heights. Our hypothesis is that visual field dependence, postural stability, space and motion discomfort, and bodily symptoms combine to elicit the fear and that they will, therefore, predict a person's level of acrophobia independently of any underlying trait anxiety.

MATERIALS/METHODS

PARTICIPANTS

Forty-five participants, recruited from the university population, took part in the study (Mean age 25.07 years, 71% female) and received a nominal fee for their participation. Participants with past or current history of psychiatric disorder were excluded, as were participants with a known history of vestibular and balance deficits or other reported neurological or orthopedic disorders that affect postural control. The 45 selected participants had normal or corrected to normal vision. All participants were informed of the testing protocol and provided full informed written consent for research participation. At the time of initial testing, subjects were naïve to the experimental hypothesis. The study was approved by the Committee of Ethics of the University of Queensland.

RATING SCALES

The four questionnaires used in the experiment were:

- (1) The *Acrophobia Questionnaire*^[20] describes 20 situations frequently mentioned by acrophobics as anxiety provoking (e.g., standing next to an open window on an elevated floor). This instrument shows good internal consistency and test-retest reliabilities,^[20] and served as a complement for fear of heights, also measured with a Behavioral Avoidance Test (BAT) explained after the rating scales section of this paper.
- (2) The *Bodily Sensation Questionnaire* (BSQ)^[21] contains 17 items which list body sensations that are usually reported as being associated with fear and that clients report to be disturbing. Example items include heart palpitations, dizziness, and feelings of short breath. Participants report how frequently they experienced these symptoms on a 5-point Likert scale. The BSQ has very good internal consistency, stability, and concurrent validity.^[22]
- (3) The *Situational Characteristics Questionnaire* (SitQ)^[17] was designed to measure SMD. The SitQ is recommended for quantifying SMD in patients with anxiety and/or balance disorders. The scores evaluate situations characterized by: (a) long visual distances (e.g., fields, wide streets, courtyards); (b) confusing or complex visual stimuli (e.g., fluorescent lighting or moving stripes); (c) combinations of unusual or complex visual, proprioceptive and vestibular cues (e.g., widescreen movies, walking down supermarket aisles); (d) excessive vestibular stimulation (e.g., dancing); and (e) movements involving neck extension and reorientation with respect to gravity (e.g., closing eyes in shower, looking up at tall buildings).^[23]
- (4) The *State Trait Anxiety Inventory Form Y-2*^[24] is a 40-item questionnaire (20 for state and 20 for trait anxiety). For the purpose of this study, we used the trait anxiety scale listing several

statements about the general state of being and levels of trait anxiety, including items such as “I am happy” (item 30) or “I feel inadequate” (item 35). Participants report how these sentences are appropriate in describing them on a four-point Likert scale (1 = not at all to 4 = very much). The total score varies from a minimum of 20 to a maximum of 80 points.

BEHAVIORAL MEASURES

(1) The BAT is frequently used as a measure of fear of heights.^[25] In our study, participants were requested to ascend a 15 m high external stairway which had 70 steps, divided into six landings (including the ground floor), each separated by 14 steps (Fig. 1). Participants were invited to climb seven steps at a time, spending about 15 sec on each landing during which they explored their surroundings. After this brief exploration period, they evaluated their level of anxiety (Units of Subjective Distress—USD)^[26] on a scale from 1 to 10. While ascending the first set of steps, participants were accompanied by the researcher in order to explain the exercise. Participants were explicitly instructed not to hold onto the railing during testing and were required to look down over the railing at each landing before filling out their SUDS score. The test finished on attaining the fifth floor or earlier if the participant reported being unable to ascend further.

(2) The *Rod and Frame Test*^[27] provides a measure of error in the perception of verticality in degrees. It measures a participant's ability to align a rod to vertical within a tilted frame.^[28] The Rod and Frame

visual scene was rendered by a Silicon Graphics Onyx 3200 (SGI Inc., Fremont, CA) equipped with an InfiniteReality III graphics. The scene was projected onto a wall using a BARCO 808S (Kortrijk, Belgium) analogue projector. The projected image was 2.7 m high and 3.2 m wide (300 mm above the floor), placed at approximately 2 m from the participant, subtended approximately $78 \times 68^\circ$ of arc. The image frame rate was 72 Hz and the update rate of the projection, 24 Hz. Image resolution was set at $1,280 \times 1,024$ pixels. To remove extraneous visual cues to verticality, the test was conducted in the dark. Participants performed 20 repetitions of the task. We followed the procedures outlined by Isableu and co-workers,^[15] tilting both rod and frame at 18° where the effect has been found to be maximal (Fig. 2). When the outer frame is tilted, errors in the alignment of the rod result and these errors can be measured as deviation from true vertical. The resulting error produces a figure indicative of a participant's visual field dependence.

(3) The *Sharpened Romberg Test*^[29] is a postural task that assesses balance. It is commonly used in Diving Medicine.^[30] This test adds sensitivity to the classical Romberg test^[31] in routine clinical settings. Participants are instructed to stand quietly with arms crossed in front of their chest for a single trial of 2 min, or up to six trials if none accomplished the summed time of 120 sec before making a visible step to the side. The final measurement is either 120 sec or the average of the six trials, if none reached 120 sec. Participants stood barefoot with eyes closed and arms crossed, with the tip of one foot close to the heel of the other (tandem position), such that both feet occupied a lateral area not greater than the width of one foot. The participant was required to use the same foot position for each consecutive condition. Although the Romberg test is now fairly standardized, there is some variability in examination technique and interpretation across expert neurologic examiners.^[32] In particular, there is variability in how much postural instability is required for a positive test (e.g., increased sway only, a step to the side, or a fall); whether sway is critical at the ankles or the hips; whether footwear should be worn or removed; whether hands should be held at the side or extended forward or laterally; etc.^[32] For the purpose of our study, we chose to use the most sensitive version of the test (barefoot with arms crossed) because participants reported no obvious dysfunction of the proprioceptive, cerebellar, or vestibular pathways.



Figure 1. The behavioral avoidance test (BAT) used in these studies to behaviorally assess fear of heights. The figures on the left-hand side indicate height in meters.

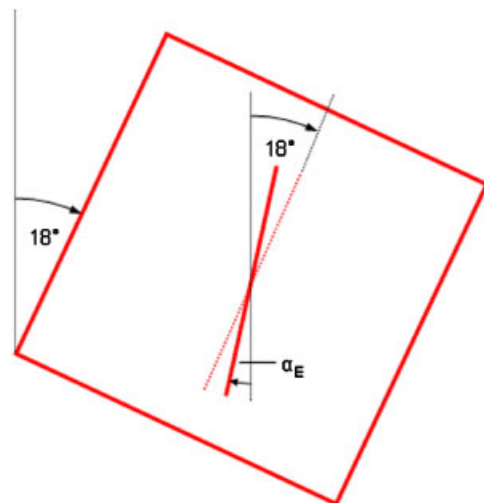


Figure 2. Participants were invited to adjust the orientation of the rod (inside the frame), such that the rod seemed to align with vertical. The visual field dependence offset error is depicted in the figure as α_E .

ANALYSIS

Statistical analyses were conducted through Student's *t*-test for comparison of two normally distributed independent samples and multivariable linear regression. Subjective discomfort for heights, as recorded by the participants, was established as the outcome variable, whereas predictor variables were visual field dependence, Romberg test (nonvisual postural control), and the questionnaires relating to situations evoking disorientation, body symptoms, and trait anxiety. Earlier to the multivariate model, correlations between the outcome

(USD) and predictive variables were observed using Pearson's. The accuracy of the model was assessed through outliers and residuals diagnoses and generalization, as well as the goodness of fit.

RESULTS

Table 1 summarizes the results of the comparison between participants low and high in discomfort for heights on the BAT. There were significant differences between groups on all variables. This analysis was repeated using trait anxiety to divide participants (STAI cut-off point <40). Participants with high trait anxiety also scored more highly in disorientation and body symptoms, but there were no significant differences between groups in balance ($\chi^2(1) = 1.5$, $P > .05$) and visual field dependence ($t(43) = -.09$, $P > .05$).

Correlations analysis, as displayed in Table 2, indicated that the designated outcome variable, USD, correlated moderately with SitQ ($r = .70$, $P < .0001$) and BSQ ($r = .62$, $P < .0001$), and low with STAI-Tr ($r = .33$, $P < .05$). USD was measured from 0 to 10 at the highest level of the staircase climbed, with a proportional adjustment for individuals unable to scale the entire staircase (two additional points for each set of stairs).

To assess the predictive power of the various factors, a linear regression analysis was performed in which three separate hierarchical models were generated. Visual field dependence and posture were entered in Model 1, disorientation and body symptoms in Model 2, and trait anxiety in Model 3. Visual field dependence, posture, disorientation, and body symptoms were all unique predictors of subjective discomfort. Trait anxiety not only failed to contribute significantly to the regression but actually decreased the predictive power of the model. Table 3 displays the standardized regression coefficients and adjusted r^2 for each model. Model 1 accounted for 43% of the variance in subjective discomfort in heights

TABLE 1. Discomfort in heights in participants who scored low and high ($N = 45$)

	Low ($n = 22$)	High ($n = 23$)	P
VFD (vision)	4.78 (2.85)	7.04 (2.90)	.012*
Romberg (balance)	23% ^a	65% ^a	.005** ^b
SitQ	23 (19)	54 (28)	.000**
BSQ	31 (11)	45 (10)	.000**
STAI-Tr	36 (12)	44 (11)	.029*

STAI-Tr, State Trait Anxiety Inventory; SitQ, Situational Characteristics Questionnaire; BSQ, Body Symptoms Questionnaire; VFD, Visual Field Dependence. Significance levels * $P < .05$, ** $P < .01$, two-tailed independent samples *t*-test.

^aPercentage of participants who were unstable.

^b χ^2 test; USD cut off point ≤ 5 .

TABLE 2. Pearson's correlations between subscales

	VFD	BSQ	SitQ	USD
STAI	.04	.26	.47**	.33*
VFD		.12	.25	.54***
BSQ			.53**	.70***
SitQ				.62***

STAI, State Trait Anxiety Inventory; SitQ, Situational Characteristics Questionnaire; BSQ, Body Symptoms Questionnaire; VFD, Visual Field Dependence. Significance levels * $P < .05$, ** $P < .01$, *** $P < .0001$, two-tailed correlations.

TABLE 3. Hierarchical regression analysis for subjective discomfort in heights ($N = 45$)

Variables	β	Sig	Adjusted R^2	R^2 change	F	df	P
Model 1			.432	.457	17.702	2, 42	<.0001
VFD	.338	.005					
Romberg	-.540	.000					
Model 2			.697	.267	26.272	4, 40	<.0001
VFD	.311	.001					
Romberg	-.339	.001					
SitQ	.299	.006					
BSQ	.329	.004					
Model 3			.689	.000	20.503	5, 39	<.0001
VFD	.312	.001					
Romberg	-.339	.001					
SitQ	.292	.019					
BSQ	.329	.005					
STAI TR	.013	.902					

STAI, State Trait Anxiety Inventory; SitQ, Disorientation Sensitivity Questionnaire; BSQ, Body Symptoms Questionnaire; VFD, Visual Field Dependence.

($P < .0001$), Model 2 accounted for 69.7% of the variance, and Model 3 explained 68.9%. Trait anxiety failed to attain statistical significance. The inspection of the plot for the regressed standardized residuals indicated the absence of outliers, which was also observed by the analysis of standardized residuals and Mahalanobis distances. Generalization assumptions of multicollinearity, homoscedasticity, normality of errors' distribution, and independence of errors were met and goodness of fit was ascertained ($F(5, 39) = 20.987$, $P < .0001$).

In summary, the regression analyses found visual field dependence, postural control, space and motion discomfort, and bodily symptoms all serve as strong predictors for fear of heights (Adjusted $r^2 = .697$, $P < .0001$). Trait anxiety was not related with fear of heights, suggesting that this higher order vulnerability factor is not necessary for explaining this particular specific phobia in a large number of individuals.

DISCUSSION

This study has tested a range of factors thought to be related to fear of heights. Our aim has been to generate a unified model of how these factors interrelate and contribute to the disorder. On the basis of our results and analyses, we propose that the likelihood of developing a fear of heights is greatest in visual field-dependent participants with poor nonvisual postural control and high sensitivity to body symptoms. Under a series of subsections, we discuss how each of these factors contributes to the ultimate response.

VISUAL FIELD DEPENDENCE

Participants with acrophobia showed higher visual field dependence errors. More specifically, they were given to occasionally producing large errors, significantly higher than the largest errors of non-fearful participants. This result points to an overreliance on visual information in acrophobics. This, in turn, offers the first compelling evidence that this reliance is independent of the phobia itself, because the rod and frame stimuli do not evoke any sense of depth or height, unlike the flow stimuli used in an earlier study.^[33] The natural lack of motion cues at heights causes the visual input to differ from that gained through natural postural sway at ground level. This, in turn, triggers postural vertigo.^[9,34]

POSTURAL INSTABILITY

At heights, reduced visual feedback creates postural destabilization. Individuals attempt to increase postural sway to reactivate visual balance feedback,^[13] but their poor postural control^[16] causes further instability. Recent studies^[14,35] showed that fear of heights is probably not due to a vestibular malfunctioning. Nonetheless, vestibular sensations or "symptoms" can arise with discordant or incongruent information

among the sensory channels. In these circumstances, vestibular sensations are experienced even by individuals with normal vestibular function.^[23]

Nonetheless, the relation between self-motion and fear of heights is still a matter for further study, for it is also possible that when acrophobics freeze at heights, they reduce their motion parallax cues to depth, leading to an overestimation of the distance, thereby increasing fear.^[36-38]

SPACE AND MOTION DISCOMFORT

Participants with acrophobia also have higher scores of SMD. This implies that people with acrophobia are sensitive to inadequate visual or kinesthetic information for normal spatial orientation.^[17] SMD seems to arise with discordant or incongruent information among visual, kinesthetic, and vestibular sensory channels.^[39] Our results also support the claim that patients with anxiety and SMD rely more heavily on visual cues for postural control.^[8] Jacob and co-workers^[14] also found that disorientation sensitivity was related to postural instability, and it is likely that postural instability precedes body symptoms, in a process similar to that seen in motion sickness.^[40]

BODY SYMPTOMS

Postural control relies on multisensory processing and motor responses that seem to be automatic and occur without conscious awareness.^[12] An individual's interpretation of their own body symptoms may serve to differentiate between a sensation of arousal or fear. Like Davey and co-workers,^[18] we found a high correlation between measures of acrophobia and a tendency to interpret internal body sensations of anxiety as threatening. These findings led Davey and co-workers^[18] to suggest that cognitive biases increasingly lead the individual to interpret bodily sensations as threatening, and that this may be a mechanism through which chronic acrophobia is acquired (Fig. 3).

SUMMARY

There are currently two major approaches to the conceptualization of phobias. The first, built around cognitive models, assumes that individuals with phobia learn to regard feelings of anxiety as evidence of actual danger.^[41] One criticism of such models is that they can seem somewhat circular: "I'm anxious because I fear, and I fear because I'm anxious." The alternative approach holds that phobias are not learnt, but are manifestations of general aversive responses to evolutionarily prepared threat stimuli. This approach has been shown to have some explanatory power, but likewise has been criticised for falling into a circular argument when explaining the relative prevalence of specific phobia subtypes: "The fear is common because it is prepared, and is prepared because it is common." The main problem with either approach is that it is

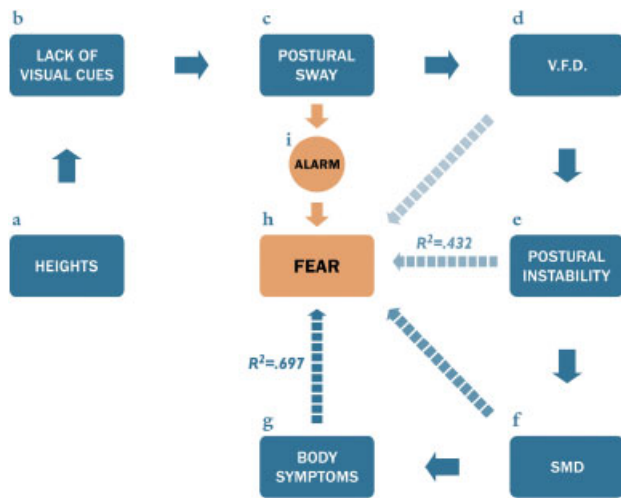


Figure 3. When exposed to heights (a) the lack of visual cues (b) creates a natural increase in postural sway (c) aimed at reactivating visual control. In visual field-dependent individuals (d) with poor nonvisual postural control, the lack of visual cues will result in postural instability (e) and a feeling of being off-balance resulting in a moderate level of fear. For those individuals who tend to feel disoriented and sick through such instability (f) more fear will result. However, some individuals may experience a thrill or excitement through disorientation rather than a debilitating fear. It is only those who experience discomfort in the presence of dizziness and disorientation (g) who will go on to experience a strong fear response.

largely hung up on the question of what is learnt and what inherited, leaving the precise causes of phobia unknown. As LeDoux points out, “Nature and nurture are partners in our emotional life. The trick is to figure out what their unique contributions are.”^[42] Our results provide an answer to this question by specifying the anatomy of the fear as a combination of factors tied to a specific situation, thereby clarifying the relative contributions of nature and nurture. What our model also does is help clarify where acrophobia fits into the larger scheme of specific phobias and emotions in general.^[19,43] Future research, using these parameters, could be improved by the assessment of sway and physiological measures during BAT,^[44] particularly through the use of virtual reality.

On the basis of the results described in this paper we have revealed the specific sensory and cognitive biases that contribute to the development of the fear of heights, and in so doing have helped identify a need to reassess its link to the other anxiety disorders. It is hoped that our model will form the starting point for new and effective clinical interventions. To that end, work in our lab is now focused on treatments using postural training and desensitization to bodily symptoms.

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