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Review

The use of virtual reality in acrophobia research and treatment

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ABSTRACT

Acrophobia, or fear of heights, is a widespread and debilitating anxiety disorder affecting perhaps 1 in 20 adults. Virtual reality (VR) technology has been used in the psychological treatment of acrophobia since 1995, and has come to dominate the treatment of numerous anxiety disorders. It is now known that virtual reality exposure therapy (VRET) regimens are highly effective for acrophobia treatment. This paper reviews current theoretical understanding of acrophobia as well as the evolution of its common treatments from the traditional exposure therapies to the most recent virtually guided ones. In particular, the review focuses on recent innovations in the use of VR technology and discusses the benefits it may offer for examining the underlying causes of the disorder, allowing for the systematic assessment of interrelated factors such as the visual, vestibular and postural control systems.

Contents

1. Introduction and overview of acrophobia

According to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) (APA, 1994), acrophobia, which is an extreme fear of heights, is considered a specific phobia of naturalistic type. Although long since recognized as a disorder, there is still some doubt about its typology due to its similarities to both panic disorder (Antony, Brown, & Barlow, 1997) and agoraphobia (Davey, Menzies, & Gallardo, 1997). Acrophobia appears closely related to the fear of elevators and fear of flying, both of which belong to the specific phobia, situational type, as defined in the DSM-IV (Muris, Schmidt, & Merckelbach, 1999). Acrophobic behavior typically involves the avoidance of a variety of height-related situations, including stairs, terraces, apartments

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and offices located in high buildings, bridges, elevators and plane trips. Considering the striking breadth of aversive situations and stimuli, it is not surprising that individuals with acrophobia feel impaired and restricted in their movements, even in comparison to sufferers of other specific phobias (Menzies, 1997).

Specific phobias have a high prevalence rate in epidemiological data, both in adolescents (Essau, Conradt, & Petermann, 2000) and in adults (Boyd et al., 1990). In the ECA Study, which was comprised of 20,000 participants, 4.7% of the participants fulfilled the criteria for a diagnosis of acrophobia (Chapman, 1997). A study by Fredrikson, Annas, Fischer, and Wik (1996) presented similar results with 6.3% of men and 8.6% of women presenting with acrophobia. Moreover, this disorder tends to evolve to chronicity (Burns, 1980) largely due to the pervasive avoidance of a wide-range of height-related situations that form part of everyday living.

It is clear then, that due to its high prevalence, chronicity, and cumulative social impact, research into the underlying causes and treatment of acrophobia is particularly important. Additionally, by studying underlying acrophobic fear mechanisms, uncertainties can be addressed relating to its typology as well as etiology and treatment. This review makes particular reference to the use of virtual reality (VR) technology as a superior methodology in achieving improvements in both the treatment and our understanding of the causes of this disorder.

2. Contributing factors to the development and maintenance of acrophobia

This section reviews the available evidence on contributing factors to the development and maintenance of acrophobia. To date, this literature has tended to focus either on factors gleaned from the broader literature on specific phobias or on the role of specific factors in isolation, rather than on the development of a comprehensive model of acrophobia fear acquisition *per se*.

2.1. Non-associative accounts

Because some individuals who fear heights have often been unable to report a clear height-related aversive experience as a primary etiological factor, some authors have proposed hereditary or non-associative accounts in the disorder's development (Menzies & Clarke, 1993, 1995c). In one study, Menzies and Clarke (1993) compared fearful and non-fearful participants' responses to heights in an attempt to assess their acquisition of height-related fear. Results showed that 21 participants were categorized as developing their fears through non-associative pathways. Additionally, the non-fearful group also had participants who had experienced direct conditioning relevant events but did not develop a fear of heights. These data were seen as consistent with a non-associative account for the acquisition of the fear of heights, in which ontogenetic learning is not required, at least for the fear of heights.

A few years later, Menzies and Clarke (1995b) were able to extend these findings using a much larger clinically defined group of acrophobics ($n = 148$) who were age and sex-matched to a non-phobic control group. The phobic group met the DSM-III-R criteria for simple phobia (APA, 1987) and had a mean age of 40.3 years. The results of this study questioned once again the significance of associative-learning events in the acquisition of fear of heights, since the categories consistent with the ethological theory accounted for 83 participants. Moreover, the authors did not find significant differences between groups with respect to the proportion of participants who exhibited other height-related fears, or who experienced relevant associative-learning events. The ages at which these events had occurred were also not significantly different. All this evidence led the authors to rule out a latent inhibition hypothesis (e.g. Bond & Siddle, 1996; Lubow, 1973).

Of course, failure to remember any particular experience related to the emergence of the disturbance might equally be attributed to problems inherent in self-report and memory rather than a non-associative etiology (see Muris, Merckelbach, de Jong, & Ollendick, 2002). To overcome these methodological problems, Poulton, Davies, Menzies, Langley, and Silva (1998) conducted a longitudinal study of a large cohort of approximately 1000 participants from birth. Corroborating the previous findings, the authors noticed that serious falls that resulted in fracture, dislocation, laceration or intracranial injury had no positive correlation with fear of heights in later ages. Contrary to what was expected, falls resulting in serious injuries between the ages of five and nine occurred more frequently in participants who later exhibited no discernable fear of heights at the age of 18. Also, no participant with fear of heights at 18 possessed a history of serious falls before nine years of age. In summary, 'participants with less fear of heights seem to be those who sustained more injuries due to falling and the conditioning experiences do not seem to have produced fear. . .' (Poulton & Menzies, 2002, p. 135). Similar results were reported by Menzies and Parker (2001), namely that participants without fear of heights reported a higher incidence of fearful and painful experiences than those with fear, suggesting that those without fear are likely to pay for their innate lack of caution.

Longitudinal studies of this type do offer some insight into the processes involved in fear of height acquisition but one might still arguer that failures in recall may lead to underreporting of significant events. Several studies suggest that memory reliability decays in the space of weeks or months (Loftus, 2004; Mineka & Öhman, 2002; Taylor, Deane, & Podd, 1999). Perhaps more significant, is the possibility that phobia emerges through accumulation of subtle, non-traumatic experiences which are not in themselves very memorable (e.g. Field, Argyris, & Knowles, 2001; Graham & Gaffan, 1997; Withers & Deane, 1995) but that can nonetheless influence long-term behaviors (Forsyth & Chorpita, 1997; Usher & Neisser, 1993) and give rise to fear (Emmelkamp, 1982) that is difficult to associate with conditioning.

In general, all of these arguments undermine non-associative theories of phobias but accord with acrophobia phenomenology. In particular, a fear of heights is acquired before verbal acquisition, at a time when children are learning to crawl and falls occur, educating children about the nature of surfaces (Joh & Adolph, 2006), locomotion, balance and posture (Adolph, 2008). Whilst Adolph noted that learning strategies do not transfer from crawling to walking, the avoidance of heights does seem to be maintained across developmental postures (Witherington, Campos, Anderson, Lejeune, & Seah, 2005). It is therefore plausible that some of these skills act as latent inhibition, thus preventing more skilful children from developing a fear of heights.

2.2. Role of cognitive processes

Combining cognitive and biological factors, Davey et al. (1997) argued that fear of heights may develop in ways similar to panic disorder. That is, cognitive biases may develop leading individuals to increasingly interpret bodily sensations that are tied to movement in height-related situations as threatening. These researchers assessed 100 students for bodily sensations, acrophobia, spider phobia, cognitive bias, trait anxiety, and depression using a suite of questionnaires. Analysis revealed a correlation between measures of acrophobia and a bias to interpret and report internal bodily sensations of anxiety as threatening. There was no such bias evident for external stimuli or social stimuli and the bias was not found with measures of spider phobia. The authors concluded that 'in the case of the development of acrophobia, individuals may come to interpret some bodily sensations as indicative of dizziness and nausea, and these may occur in situational circumstances which might lead the individual to associate these signs with the possibility of an imminent catastrophic fall (e.g. if they are looking down a circular stairway, or standing on a chair)' (Davey et al., 1997, p. 1000). Thus, Davey and colleagues' (1997) conclusion highlights the possibility that cognitive and biological vulnerabilities can underlie the development of height fear in humans and that a catastrophic, conditioning event may not be necessary.

2.3. Contemporary learning models

Davey et al.'s integrated approach is echoed in the work of Mineka and Zinbarg (2006) who emphasized the need to recognize the concept of preparedness, that is that certain stimuli are evolutionally predisposed to evoke fear responses (Seligman, 1971). This, they argued, could help answer some of the questions that classical conditioning accounts could not. In particular, they argued that it was necessary to provide an explanation for the fact that not all fearful participants have a history of failed learning experiences, while at the same time some participants without fear have been through traumatic experiences (Seligman, 1971). From their perspective, and in contrast to non-associative accounts (see Kendler, Myers, & Prescott, 2002), a diathetic-stress model offers the most attractive framework for describing acrophobia, since it considers learning histories (such as vicarious and modeling learning) within the context of inherited 'prepared' liabilities, such as the personality trait of neuroticism, for example. Together, these vulnerabilities make certain individuals more or less susceptible to developing anxiety disorders (Mineka & Zinbarg, 2006; Mineka & Oehlberg, 2008).

What has yet to emerge from this more holistic, multifaceted approach is a description of how the various factors interact. Combining learning and biological factors appears to suggest that the development of acrophobic depends on a combination of specific and general factors including, for example, cognitive biases, the extent of prior experience with heights, and possibly, the development of a sense of control over the height environment. Control might therefore be achieved in a learning process similar to the one used by Doogan and Thomas (1992) in the treatment of the fear of dogs. They argued that participants who had previous experience with dogs have more knowledge of how dogs behave, and that they may view a dog's behavior as predictable and controllable, and hence less threatening (Doogan & Thomas, 1992). As it will be argued later, participants with acrophobia might tend to interpret the visuo-vestibular[1] discrepancies present in elevated environments as sign of a possible fall. Through extended experience of visuo-vestibular interactions in elevated locations, the link between this sign and an imminent fall becomes diminished, and with it, the associated fear.

Both the non-associative and the diathesis-stress models accord with Rachman's (2002) account that experience and habituation with the environment can work towards eliminating biologically relevant fears. In the particular case of heights, habituation is observed in individuals who go through repeated exposure to heights such as 'steeplejacks, roof-workers, and tightrope artists, who achieve a remarkable degree of postural balance with seeming insensitivity to height' (Brandt, Arnold, Bles, & Kapteyn, 1980, p. 513). The absence of fear of heights in certain individuals can be taken as evidence for both learning processes such as habituation, latent inhibition and immunization (e.g. Bond & Siddle, 1996; Craske & Waters, 2005; Mineka & Cook, 1986; Rachman, 2002) as well as inherited factors, such as preparedness (e.g. Poulton & Menzies, 2002). If the majority of humans have an inherited disposition to avoid heights and this avoidance can later develop into a phobia, it is equally possible that people with low levels of fear develop an absence of fear through habituation that develops from frequent exposure opportunities. Conversely, those born with a particular fear can fail to overcome it due to lack of safe exposure in early life (see Poulton, Waldie, Menzies, Craske, & Silva, 2001).

The importance of each vulnerability and learning factor remains a matter of ongoing debate. What is clear from studies in children (e.g. Scarr & Salapatek, 1970; Schwartz, Campos, & Baisel, 1973) is that a fear of heights accompanies the emergence of self locomotion (crawling) and that habituation processes can aid in overcoming a fear of heights.

2.4. Self-locomotion and the role of the visual and vestibular systems

One of the earliest laboratory-based investigations of fear of heights was based on studies of the 'visual cliff'—a transparent walkway spanning a drop. These studies were conducted with a variety of animals (e.g. Hein, 1972; Held & Hein, 1963) and human infants (Campos, Bertenthal, & Kermoian, 1992; Campos, Hiatt, Ramsay, Henderson, & Svejda, 1978; Gibson & Walk, 1960; Scarr & Salapatek, 1970; Schwartz et al., 1973). The animals and humans showed various reactions to the cliff, each of which was characteristic of the particular species studied. For example, in human infants, the studies suggested a developmental shift corresponding to a marked increase in a fear of heights after the onset of crawling (Campos et al., 2000). Although some initial degree of fear of heights is a normative experience of development, most individuals overcome this fear through processes inherent to development itself – practice, exposure, development of mastery, etc. – to eventually retain a degree of healthy wariness about heights that is functional and adaptive to survival. At present, it is unclear if acrophobia is in someway related to a failure to achieve this developmental milestone.

Coelho, Santos et al. (2008) recently tested eight participants diagnosed with acrophobia in a virtual reality environment and found that participants experienced elevated anxiety not only to increases in height, but also when required to move laterally at a fixed height. These anxiety levels were significantly higher than those elicited by viewing the fear-evoking scene without movement. Coelho et al.'s results suggested a potential link between movement and acrophobia in line with earlier developmental studies of infant crawling, such as the ones of Campos and colleagues (2000). As children learn to detect threats to balance and find compensatory strategies to regain posture when in disequilibrium (Adolph, 2002), acrophobic participants might similarly learn to use the visual, vestibular and somatosensory systems to learn how to move in height-related situations. Moreover, similar to motion sickness, fear of heights might be due to a conflict between vision, somatosensory and vestibular senses (Brandt et al., 1980). This mismatch can occur because of the image flow associated with head movement i.e. motion parallax. Motion parallax is the perspective transformations of the retinal image, produced by either the movement of an observer or the movement of objects in the visual world (Rogers & Graham, 1979). These transformations are greatly reduced for objects viewed at large distances (Brandt et al., 1980). This issue is addressed later in the review.

The evidence of the abovementioned research studies suggests that it is too soon to defend a behavioral, diathesis-stress or non-associative model for the etiology of fear of heights. It seems that some models are in fact quite complementary. Some of the liability for fear of heights might be inherited, however it is also likely that

[1] The conflict exists when the prevailing inputs from the visual and vestibular systems are at variance with stored patterns derived from previous interactions with the spatial environment (see Reason, 1978).

such a fear might only manifest if other factors: vicarious, informational or behavioral, are part of the individual story.

3. Fear of heights treatment models—an historical perspective

Mowrer (1939) proposed one of the first theoretical accounts of acrophobia to be used as a basis for treatment. The two-factor theory of phobia treatment is still in use today and has remained practically unchanged. Fundamentally, this theory states that phobic anxiety is a conditioned response, triggered by a conditioned stimulus (the phobic situation). However, it also adds that situational avoidance develops and remains due to the reinforcement of reduced anxiety (negative reinforcement). This successful avoidance of the phobic situation assures the perpetuation of the anxiety. Currently, it is widely accepted that because avoidance decreases anxiety in the short-term, it is a major contributor to fear maintenance (Agras & Jacob, 1981; Arntz, Rauner, & van den Hout, 1995; Tolin, Lohr, Lee, & Sawchuk, 1999). However, by avoiding and/or escaping their fears quickly, phobic individuals do not experience their distress diminishing in anxiety-provoking situations (Marks, 1987).

Following on from Mower's early work, Wolpe (1958) developed a technique called 'systematic desensitization' that was a milestone in the development of effective phobia treatment. Wolpe had participants "avoid" avoidance, that is, remain steadfast in the presence of the feared stimulus. Wolpe (1958) explains that this procedure consists of imaginarily linking feared situations with muscle relaxation, which works as an anxiety inhibiting response. Central to the development of this procedure was the notion that deep muscular relaxation and the imagination of relaxing scenes was an anxiety antagonist. Wolpe suggested that relaxation could be capable of suppressing the anxiogenic properties of the stimulus, breaking the link between them. A series of later studies supported the fact that systematic desensitization was effective in eliminating fears and after Wolpe, numerous studies have tried to uncover the active therapeutic agents.

Later, self-efficacy theory (Bandura, 1977) identified the participants' judgment about their ability to perform specific actions as a major cognitive determinant of human behavior. Although self-efficacy judgments and anticipated outcomes jointly determine behavior, Bandura claimed that phobic behavior is influenced more by self-efficacy judgments than by outcome expectations. When people have confidence that they can successfully execute various courses of action, then their expectations regarding consequences should tend to be the major determinants of performance variation. However, when people have strong incentives to perform a given action their perceptions of self-efficacy will tend to exercise the greater influence over whether they attempt it and how well they succeed (Williams & Watson, 1985).

Several treatment models emerged from this early work, in particular, "reinforced practice" and "self-efficacy" treatments. Reinforced practice is a combination of "therapeutic ingredients" combined in a therapeutic model (Leitenberg, 1976) and assumes that improvements in cognitive and physiological components of anxiety will occur after modeling approach responses and continuous practice of these responses (Agras & Jacob, 1981; Leitenberg, Agras, Edwards, Thomson, & Wincze, 1970; Leitenberg, Agras, Allen, Bitz, & Edwards, 1975). The therapeutic ingredients included exposure to stimuli that trigger fear, therapeutic instructions, client progress control, feedback on performance, and conditional performance reinforcement (Leitenberg, 1976; O'brien, 1981). In contrast, self-efficacy treatment places more emphasis on the phobic individuals' self-efficacy regarding how well they can execute the requisite behavior rather than on the exposure itself. This model gives emphasis to the quality and quantity of information as the main factors to increase the self-efficacy that participants acquire and the manner in which they incorporate that information when assessing their own capacities (Bandura, 1977).

4. Acrophobia therapy efficacy: early theory-based approaches

The earliest research on acrophobia treatment followed these early theoretical approaches. For example, Ritter (1969a) examined a "contact desensitization" treatment (CD) involving the use of contact with the therapist's hand and arm while engaging in approach responses to the desired behavior. The physical assistance was then gradually eliminated with eventual independent response rehearsal by the participant. Ritter considered the therapeutically effective components of CD to be: (a) information regarding the avoided object or situation; (b) observation of model(s) performing target behaviors with no adverse consequences; (c) contact with the phobic object; (d) contact with the therapist; (e) skill obtained in performing the desired behavior through rehearsal; (f) hierarchical exposure to the avoided object or situation and to the desired responses. For testing these components, the therapist worked with 12 participants (10 women and two men) who were extremely fearful of heights. Participants were exposed to one of the following three conditions: (1) treatment with CD; (2) treatment which involved all elements of CD except for physical contact, or (3) no treatment. The treatment consisted of successive approaches (in groups) to progressively higher landings of a staircase with nine landings, 15.8 m high in total, until two minutes exposure was achieved at the highest landing. The contact between the therapist and the participant involved placing the therapist's (woman's) arm around the waist of each participant and leading him/her to the testing site. Gradually the therapist removed the arm while the participant was still at the lowest landing, and gradually the therapist extended the period of time the participant stayed at the testing site without contact. The exposure was performed in groups and part of the treatment involved the participants linking arms and walking to the edge of the stairway. Results showed significantly better results in the group with physical contact. In another study, Ritter (1969b) compared CD with the same treatment without contact (demonstration-plus-participation – DP) and modeling. The study involved 13 women and two men with severe height phobia. Results revealed that CD treatment was similar to DP and modeling, producing clinically reliable benefits. In a related study, Morris and Magrath (1979) did not observe differences in acrophobia treatment with CD as a function of "warm" versus "cold" types of therapist behavior. The warm therapist maintained eye contact, used voice inflection and facial expression of friendliness and support. The cold therapist avoided eye contact and spoke "nonchalantly" while maintaining a blank facial expression.

Baker, Cohen, and Saunders (1973) compared two types of treatments for acrophobia: systematic desensitization applied by the therapist versus the same intervention applied by the participant with the help of a tape recorder replaying desensitization instructions. The study, which involved 30 acrophobic participants (nine men and 21 women), revealed that the two interventions were equally effective. Interestingly, the only difference emerged in a later follow-up test after eight months, which revealed a greater improvement for participants who used the tape recorder. The results suggest that desensitization is an effective treatment even with reduced therapeutic contact. The authors concluded that some participants functioned better in a therapeutic situation that offered greater autonomy and control over the procedures used. Additionally, the "tape recorder" participants might have taken on a longer-term responsibility of self-help after the official end of treatment since this version required a higher personal responsibility from the participants.

In contrast to Baker et al.'s (1973) study, Williams, Dooseman, and Kleinfield (1984) found the therapist's role in treating acrophobia to be important. The authors compared the exposure model with the self-efficacy model in 32 participants with severe fear of heights or driving. The self-efficacy model was significantly more effective than the exposure model regarding actual behavior, sense of self-efficacy, anticipatory anxiety and anxiety during performance. However, unlike the reinforced practice model of Leitenberg (1976), the emphasis of the self-efficacy model is not upon simple exposure to the feared stimuli. The latter model emphasizes the quality and quantity of information as the main factors in the efficacy of the treatment in addition to the use of such information when assessing their own capacities. This and other minor treatment differences lead to further studies in which acrophobia represented the major symptom.

Pendleton and Higgins (1983) also tested the effectiveness of systematic desensitization, in a study with negative practice and relaxation. Negative practice helps clients learn to control their anxiety symptoms by voluntarily practicing the symptoms associated with anxiety, and then by attempting to make the outcomes of this practice as close as possible to the involuntary anxiety response. Participants ($n = 58$) participated in six weekly treatment sessions and it was found that both negative practice and desensitization produced a substantial reduction in the participants' acrophobia.

Williams, Turner, and Peer (1985) also compared the systematic desensitization and self-efficacy models in participants with severe acrophobia. The authors again concluded that the self-efficacy model was more effective than desensitization when treating acrophobic participants in respect to anxious behaviors associated with heights, with improved perceptions of self-efficacy and reduced anticipatory anxiety, and danger-related thoughts. Once again, this treatment relied on the mastery of subtasks including reaching intermediate goals, physical support (holding the client's arm), modeling (demonstration), elimination of defensive maneuvers (e.g. rigidity or standing still), and various other performances.

In a similar vein, Marshall (1985) performed two studies of participants with acrophobia. In the first study, the total duration of the exposure was ignored and the participants were exposed to stimuli only until their anxiety came down to a baseline. The study also assessed the effect of the use of self-statements as a coping strategy. In the second study, the total exposure time remained constant, varying only the exposure frequency, sometimes intermittently for brief periods, sometimes continuously until the baseline was reached. The brief exposures resulted in little or no change, while the other procedures reduced fear. The inefficacy of brief exposures is consistent with other theories, such as the incubation theory of Eysenck (1968), which suggested that brief exposures may even cause an increase of fear. In this respect, excessive brief exposure can have similar effects to those of avoidance, thereby perpetuating the fear.

All of these studies were important steps in the process of validating different treatment programs for acrophobia. Nevertheless, the studies were essentially designed to explore and compare acrophobia treatment models, and were not specifically designed to understand the trigger features associated with fear of heights, as the visual-cliff studies had done with human infants and animals.

5. Acrophobia therapy efficacy: the role of cognitive processes

Other early treatment studies of acrophobia focused on the cognitive processes that occur during exposure to heights (Emmelkamp & Felten, 1985; Marshall, Bristol, & Barbaree, 1992; Sutton-Simon & Goldfried, 1979; Williams & Watson, 1985). Sutton-Simon and Goldfried (1979) found acrophobic thoughts in a clinical acrophobic group ($N = 58$) to be related to faulty thinking statements about themselves, but only when accompanied by reports of discomfort or stress. Moreover, in comparing social anxiety with acrophobia, the authors found that negative self-statements played a greater role in situation-specific (e.g. acrophobia) compared with more pervasive anxiety (e.g. social phobia).

Marshall et al. (1992) also found perceived danger to be an important feature in fear of heights. Marshall and colleagues found that in a sample of 50 participants (29 fearless and 21 fearful of heights), many of those with acrophobia had irrational beliefs about catastrophic consequences that might occur when they entered a high location. They reported that height fearful participants were more likely to believe, and repeat to themselves, that the structure will collapse, a strong wind will suddenly blow them off the building, or that they will accidentally fall from the balcony of a theatre.

Conversely, in a study with a smaller number of participants ($N = 15$), Williams and Watson (1985) found self-efficacy (measured as the participants' self-assessed ability to ascend, stand and look down, in each of the balconies of a 10-story building) to be more accurate in predicting acrophobic behavior than perceived danger and anxiety arousal. In fact, four of the 15 participants gave very low or zero perceived danger ratings for all height tasks at pre-test. These are nevertheless unusual findings since more recent studies (Menzies & Clarke, 1993, 1995c) confirm danger expectancies related to heights as good prediction factors.

Menzies and Clarke (1995a) examined differences between participants with acrophobia ($n = 59$) and without acrophobia ($n = 59$) regarding their danger expectancies before and during exposure to heights. Before exposure, participants with acrophobia estimated a higher probability of falling, worse consequences from the fall, and also considered their anxiety levels as more appropriate to the situation than the control group's anxiety levels. The estimates of falling increased when the participants started to climb a ladder, whereas the control group's estimates did not. The authors argued that insight in acrophobia was diminished in the clinical group, contrary to the usual finding that individuals with phobias have considerable insight into the inappropriateness and excessiveness of their distress (e.g. Marks, 1969).

Later studies by Marshall and colleagues (1992) and Menzies and Clarke (1995a, 1995b, 1995c) appeared to contradict the findings of Williams and Watson (1985) in so far as they concluded that perceived danger and anxious arousal did not significantly predict acrophobic behavior. In fact, until its fourth edition in 1994, the DSM included in the diagnostic criteria the requirement that the phobic individual understood fear as irrational and disproportionate to the danger imposed by the object or situation. But in 1998, Menzies, Harris, and Jones (1998) proposed a sub-category of poor insight similar to the one used to specify obsessive compulsive disorders. This suggestion was made after their data indicated that some people actually have poor insight as to the real danger of the feared situations, even when distant from them. In their study, 64 participants (34 women and 30 men) with acrophobia were placed on the same ladder of 27 steps used in an earlier study (Menzies & Clarke, 1993). Participants were then asked to predict their probability of falling. On the basis of this, two groups were created: a poor insight group composed of those predicting more than a 50% chance of falling, and a good insight group composed of those predicting less than 50% chance of falling. Interestingly, each group's average estimate for the probability of falling was very different. On the last step, the good insight acrophobic group estimated a 9.84% chance of falling and the poor insight group estimated a probability of 88.6%.

These findings suggest that it is possible to develop a fear of heights via a number of distinct pathways. Some participants have fear despite being sure that they will not fall, and others feel a real danger from this situation. This would also explain why some researchers find danger expectations to be important as predictors of fear (Marshall et al., 1992) and others do not (Williams & Watson, 1985). One feature universal to all studies is the presence of irrationality about the specific height situation. This might be a signal that a trigger, exclusively related to height environments, is causing some people to 'overreact'. Overall, these studies suggest the absence of an underlying "general anxiousness" in participants with acrophobia. Instead, there appears to be a specific catastrophic cognitively based association with height situations, in particular during exposure to height stimuli.

Emmelkamp and Felten (1985) approached the same question by combining self-report with a physiological measure (heart rate). Their study group was comprised of 19 participants (nine men and 10 women) for whom acrophobia imposed marked and distressing impairment on their everyday life. Since the study was designed to assess the influence of cognitive processes, half of the participants were instructed in adaptive thinking during an exposure in vivo task and the other half underwent exposure alone. In contrast to the studies described above, the authors concluded that cognition was unimportant in the process of habituation to heights, since changes in participant anxiety during treatment did not precede changes in heart rate (HR). The authors also found that although only the group instructed in adaptive thinking changed in the cognitive measures, participants improved significantly on HR and the behavioral measure in both conditions.

The role of cognitive factors in contributing to the etiology and maintenance of acrophobia remains unresolved. Many of the more recent attempts to understand their role have made use of virtual reality (VR) technology. Exposed to modern, high-fidelity systems, participants can become thoroughly immersed in the task, in objects, entities and event perception (Lombard & Ditton, 1997). This so-called 'presence' in the virtual environment (see Coelho, Tichon, Hine, Wallis, & Riva, 2006) then becomes a tool for exploring insight in people with acrophobia. Knowing that an augmented sense of presence is related to an increased amount of anxiety in individuals with a specific phobia (Price & Anderson, 2007), it is possible to evaluate thoughts of acrophobics with poor insight, in a realistic VR environment. Here participants would have a similar visuo-vestibular input to a real situation, but without any physical danger. Conversely, acrophobics with good insight might be susceptible to less cognitive bias and hence more prone to a visuo-vestibular susceptibility. Given its potential to provide these answers, this review will now evaluate what has been done in the area of VR and acrophobia research.

6. The potential utility of VR in treating acrophobia

Since 1995, there has been a significant lack of studies on the treatment of acrophobia outside the field of virtual environments. This seems primarily due to the advent of virtual reality exposure therapy (VRET) in 1996, to which this review now turns. Although VR is only a recent field of technological application in research and clinical practice, many of its core concepts have been explored and developed over the past 50 years. Its roots go back to the development of the flight simulator in the American aerospace and defense industries during the Second World War (Littman, 1996). From the Army's first digital computer (the ENIAC) in the 1940s, to the Air Force's research into visualization helmets (VCASS) in the 1980s, the American armed forces have always been the main source of funding for the most important innovations in computer technology. Besides the military, advances in computer graphics technology in general have also been driven by the film and entertainment industries (for review see Grau, 2004; Ijsselsteijn, 2003; Pimentel & Teixeira, 1993). When applied to the health sciences, the military origins of VR mean it is perhaps most apposite for the treatment of the fear of flying (aerophobia) and the fear of heights (acrophobia). In fact, during testing of a VR device in 1992, North, North, and Coble (1996) found that it produced emotional and physical symptoms in the participant that seemed to be phobic behaviors, similar to those of a person reacting to a feared situation. The device was a "flying carpet" that flew in a particular direction depending on which area was stepped upon. The observers then realized that the symptoms were not due to motion sickness but to real fear (see North et al., 1996). The first clinical VR application for acrophobia was described by Rothbaum et al. (1995b) while North and colleagues (1996) and Rothbaum, Hodges, Watson, Kessler, and Opdyke (1996) used VR for aerophobia.

Currently, VRET is seen as a viable alternative to exposure in vivo since it can elicit fear and anxiety (Foa & Kozak, 1986) thereby functioning as an alternative mode of inducing exposure (Krijn, Emmelkamp, Biemond et al., 2004). Additionally, when using a VR system, the therapist and patient do not need to leave the consulting room. This implies a saving of time and money (e.g. Botella et al., 1998; Cavanagh & Shapiro, 2004; Emmelkamp et al., 2002; Krijn, Emmelkamp, Biemond et al., 2004) but also brings the benefit of not risking possible public embarrassment for the patient as well as preserving their confidentiality (Choi, Jang, Ku, Shin, & Kim, 2001; Rothbaum et al., 1995a). VR can, in this way, be an intermediate step towards live exposure, i.e. a step between a completely protected consulting room and the 'threatening real world'. However, VR may also represent an end in itself since it offers the ability to render height-related situations that are not easily accessible to the therapist and patient, e.g. an airplane, a high-rise building, etc. (Botella et al., 1998).

VRET may also be useful as a form of therapy for clients who have difficulty with imaginal exposure (Hodges et al., 1995a). The VR-based treatment can also be more precisely tailored to each client, offering greater control over stimuli and even the possibility of creating stimuli of greater magnitude than one could experience in the real world (Choi et al., 2001). Equally, by creating stimuli of lesser magnitude than is experienced in the real world, participants may start treatment even if they are too anxious and fearful to be treated via real exposure (Emmelkamp, Bruynzeel, Drost, & van der Mast, 2001).

The flexibility and confidentiality offered by VR brings with it another important advantage in that it can encourage more people to seek treatment. Indeed, one assessment of students with a fear of spiders showed that almost 90% would prefer VR exposure over in vivo exposure therapy (Garcia, Hoffman, See, Tsai, & Botella, 2001). This is particularly important for participants with phobias since they do not seek help readily (Burns, 1980). According to Boyd et al. (1990), help-seeking is higher among individuals with agoraphobia (fear of open spaces) and social phobia, than for other specific phobias.

The combined benefits of VR approaches suggest that it holds great promise as a therapeutic tool for enhancing acrophobia treatment outcomes. Since the technology in this area is developing rapidly, there is good reason to believe that this same technology will soon be economically accessible to private therapists. Currently, there is ongoing VR work on posttraumatic stress disorder, eating disorders, sexual dysfunction, schizophrenic hallucinations, and addictions (for review see Glantz, Durlach, Barnet, & Aviles, 1996).

7. Specific acrophobia treatments in virtual environments

According to Botella and colleagues (1998) and Schneider (1982) can be credited with the first use of VR in the treatment of the acrophobia, although one might better describe it as an altered, rather than virtual, reality. In that work, Schneider used binoculars with inverted lenses to alter the perception of depth, so as to magnify the sensation of height during a process of exposure in a real context. This procedure was published as a case study. The participant, a 40-year-old man who lived in a city filled with skyscrapers, looked out from an eighth floor with the binoculars. The effect of the binoculars was to give the impression of standing on the 56th floor, and the removal of the binoculars at the end of each viewing trial produced an immediate and dramatic decrease in apparent height, thus helping to overcome the participant's acrophobia (Schneider, 1982).

By the early to mid-1990s, computer-based VR systems became widely available and clinicians began to consider their use in treatments. In the first reported study, Lamson (1994) exposed 30 acrophobic participants to simulated height situations. After one week of treatment, 90% of the participants were capable of coping with real situations. A follow-up at 30 months revealed that 27 of the participants were quite capable of using a glass elevator whilst looking outside. This study seemed to indicate that the treatment was beneficial in both the short and long term. Unfortunately, this study lacked any kind of rigorous analysis and it is possibly the reason why a study by Rothbaum and collaborator's (1995b) is more often cited as the first clinical application of a VR system to acrophobic disorders. In their paper they presented a single case study involving the assessment and treatment of a 19-year-old acrophobic.

The success of this study motivated the authors to continue their research, and in the same year they published a more elaborate study in which they assessed 478 university students and selected 20 that had presented with a substantial fear and avoidance of heights (Rothbaum et al., 1995a). Of these 20, 12 were selected to participate in VR therapy, while the remaining eight acted as an untreated control group. The treatment consisted of seven weekly sessions of 35–45 min. Anxiety, avoidance and stress were significantly diminished among the 12 students involved in VR therapy but not in the control group. Although a clear advance in the assessment of VR therapy, the study was still open to criticism as it lacked a control group treated with real exposure (i.e. in vivo), provided no follow-up tests, and included no formal assessment of phobic avoidance.

A year later, North and North (1996) reported a case study in which they employed eight VR sessions lasting between 15 and 28 min each. The treatment was conducted using standard protocols, beginning with the least threatening situation, as in the classic treatment of systematic desensitization (Wolpe, 1958) and reinforced practice (Leitenberg, 1976). The Subjective Units of Discomfort (SUDS) questionnaire (Wolpe, 1969), was administered every 2–5 min. One month after treatment, the results indicated significant improvement, with a decrease in both anxiety symptoms and the avoidance of anxiety-producing situations.

A few years later, Emmelkamp et al. (2001) directly compared the effectiveness of VR with a real-world exposure control. In comparison to the previous studies by Rothbaum and collaborators (1995a, 1995b), the hardware used was less sophisticated, offering just 10 frames per second to define movement through the visual environment. All the participants received VR treatment in the first two sessions and then kept receiving treatment in a real-world environment. They discovered that the subsequent real exposure did not lead to a significant improvement in the measurements of avoidance in the Acrophobia Questionnaire (Cohen, 1977) and of Attitudes Towards Heights (Abelson & Curtis, 1989). Unfortunately, all participants were exposed to the VR environment first and this proved to be so effective that little or no room was left for the later real-world treatment to produce measurable improvements.

A subsequent study by Emmelkamp et al. (2002) took a more structured approach than any previous studies. The authors began by reproducing the real-world exposure site in VR. The authors then applied three 1-h sessions to 33 acrophobic participants (16 exposures in vivo and 17 with VR) and noted that the VR treatment was as effective as exposure in vivo in combating anxiety and avoidance. The measures used were the Acrophobia Questionnaire (AQ) (Cohen, 1977), the Attitude Towards Heights Questionnaire (ATHQ) (Abelson & Curtis, 1989) and a Behavioral Avoidance Test (BAT). This method, in contrast to the previous studies, showed improvements not only in the self-report but also in the BAT. The results remained the same in a six month follow-up with 29 of the participants. The authors claimed that: "Given the chronic nature of the acrophobia (mean duration of 31.5 years) in our patients, it is highly unlikely that the results are due to spontaneous recovery" (Emmelkamp et al., 2002, p. 515).

Taken as a whole, there is now a considerable body of evidence that VR exposure is an effective means of treating acrophobia (Choi et al., 2001; Coelho, Santos, Silverio, & Silva, 2006; Coelho, Silva, Santos, Tichon, & Wallis, 2008; Emmelkamp et al., 2001; Hodges et al., 1995b; Rothbaum et al., 1995a, 1995b). Building on this encouraging fact, more recent studies have moved on to use VR to help explore acrophobic triggers and features of treatment. For example, Krijn, Emmelkamp, Ólafsson, Shuemie, and van der Mast (2007) tested 26 participants with acrophobia in VRET sessions and coping cognitive self-statements. Results showed improvements regardless of the addition of coping self-statements. Despite this, the importance of cognitive factors surfaced in a study by Ressler et al. (2004) who found that D-Cycloserine (DCS) (a cognitive enhancer) combined with exposure therapy in a VR environment resulted in significantly larger reductions in acrophobia symptoms compared with placebo and exposure therapy. The treatment was conducted in VR and 27 participants (11 men and 16 women) with acrophobia were assigned a placebo plus VRET ($n = 10$); 50 mg of DCS plus VRET ($n = 8$), or 500 mg of DCS and VRET ($n = 9$). The difference between the 50 mg and 500 mg was not found to be statistically significant. DCS and VRET showed maintained improvements at three months follow up reevaluation in 21 of the 27 participants.

8. Examining the triggers of acrophobic behavior using VR

8.1. Visuo-vestibular triggers

Some of the earliest attempts to understand fear of heights independently of cognitive factors were made by Brandt et al. (1980) and Bles, Kapteyn, Brandt, and Arnold (1980). The authors postulated a physiological mechanism for heights vertigo, separate from psychological factors. Similar to motion sickness, heights vertigo was, in their opinion, due to a conflict between vision and the somatosensory and vestibular systems. They postulated that such a discrepancy occurs when the vestibular and somatosensory receptors sense a body shift (the natural lateral head sway – 2 cm) which is not detected by the visual system, due to the large distance to the nearest viewed objects. "This conflict might be resolved by increasing the postural sway and thereby reactivating visual control" (Brandt et al., 1980, p. 515). In other words, they proposed that one reason for the increase in sway might be that participants are attempting exploratory behavior aimed at increasing visual balance feedback (Gatev, Thomas, Kepple, & Hallett, 1999). This make intuitive sense because the further a viewer is from a visual target (e.g. height above a ground plane) the smaller the motion parallax cue (provided by movement of the head) becomes. This can be compensated by exaggerating head movements and body sway. As Whitney et al. (2005) point out; an alternative explanation for increased body sway is that it is simply an indicator of poor control in the absence of strong visual cues, rather than an attempt to drive the visual system more strongly.

A growing body of literature shows that this conflict between vestibular and visual information can lead not only to motion sickness, but to anxiety as well (Jacob, Redfern, & Furman, 1995; Jacob et al., 1993; Redfern, Yardley, & Bronstein, 2001; Whitney et al., 2005). A recent study from Alpers and Adolph (2008) showed that fear of heights was probably not due to any vestibular malfunctioning, but rather possible cognitive bias in interpreting bodily sensations, thereby partially supporting Davey and colleagues' (1997) conclusions. Thus, it is possible that individuals with acrophobia tend to interpret visuo-vestibular conflict as an alerting sign of a possible fall.

Recently, Boffino et al. (2008) corroborated the non-associative mode of fear acquisition in acrophobia by reporting evidence for the existence of a physiological mechanism responsible of triggering the phobic behavior. Using a dual-task paradigm, they found lower scores in balance stability (on a mobile platform) in participants with fear of heights. The authors also noted that the addition of a manual tracking task significantly impaired postural stability in acrophobics. The task consisted involved moving a joystick to keep a computer displayed circle inside a square. It was also found that individuals with acrophobia had lower scores than controls in the manual tracking task even when the platform remained stationary, suggesting abnormalities in the visual perception of movement (Boffino et al., 2008).

In their review of VR technology as a research tool, Loomis, Blascovich, and Beall (1999) describe how VR might be used to investigate the role of vision in acrophobia. In particular the asked: "does pure visual information elicit acrophobia, or must appropriate head orientation, signaled by neck proprioception and vestibular cues (e.g. looking down from a high bridge) accompany the visual information? To answer this, one can decouple the participant's visual stimulation from his or her head and eye movements, so that exactly the same visual information is presented with the head facing downward (normal coupling) or facing upward (decoupled)" (Loomis et al., 1999, p. 561). These postural behaviors and visuo-vestibular cues can best be manipulated and measured in VR environments since they are extremely difficult to control in the real world (Simeonov, Hsiao, Dotson, & Ammons, 2005).

Research along these lines will also allow the exploration of the nature of fear of flying and its similarities and differences with fear of heights. The two specific phobias are clustered together suggesting that the situational and the natural environment phobia type could share a common underlying theme (Fredrikson et al., 1996). Nonetheless it is also conceivable that fear of flying is composed of one or more other fears, being an expression of several subtypes of fear and phobias such as fear of accidents, need of control, claustrophobia, acrophobia, social phobia, and symptoms of panic attacks (Howard, Murphy, & Clarke, 1983; VanGerwen, Spinhoven, Diekstra, & VanDyck, 1997). In the future, VR will assist in answering questions regarding the influence of the vestibular system in postural stability control and acrophobia.

8.2. Postural triggers

Nakahara, Takemory, and Tsuruoka (2000) found similar results to Brandt et al. (1980) in which normal individuals exposed to heights exhibited increased body sway. In a study with 30 participants in which eight had acrophobia, Nakahara and colleagues (2000) noticed that the frequency and amplitude of sway increased significantly (measured with a stabilometer) at 10.2 m (on a roof) but showed no change at 1 or 2 m. In participants with acrophobia ($n = 6$, since two were unable to stand on the roof) the postural pattern was of: "small and frequent vibrations with a small sway area, despite a large sway locus length. Acrophobic participants' legs were observed to be shivering" (Nakahara et al., 2000, p. 502). In a second group ($n = 12$) with two acrophobics, participants were blindfolded and guided to a roof without being told where they were going. In this condition, nonacrophobic participants lessened their body sway when the blindfold was removed. In contrast, acrophobic participants' sway increased. These results seem to contradict those of Carpenter, Frank, & Silcher (1999) who found that fear of falling instigates a stiffened posture in participants.

There is a growing literature studying the link between anxiety about falling and postural control (e.g. Adkin, Frank, Carpenter, & Peysar, 2000; Adkin, Frank, Carpenter, & Peysar, 2002; Brown & Frank, 1997; Brown, Polych, & Doan, 2006; Carpenter et al., 1999; Carpenter, Frank, Silcher, & Peysar, 2001). These studies originally focused on the idea that a fear of falling in older adults was negatively impacting on their posture. To investigate this, the researchers studied individuals' standing posture at different surface heights above the ground. It was hypothesized that the threat or risk of injury associated with a loss of balance would increase when standing at a high surface height. This situation was supposed to be similar to the one experienced by an individual who has a fear of falling. Even though they were not specifically interested in acrophobia, the fact that these researchers systematically varied height in their studies makes their findings of relevance to the study of acrophobia as well.

What these authors generally reported was that the central nervous system imposes modifications to postural control when fall anxiety increases (Adkin et al., 2000; Brown et al., 2006), altering posture by reducing the amplitude and increasing the frequency of postural sway (Adkin et al., 2000; Carpenter et al., 1999). This is achieved by co-contraction of ankle joint agonist/antagonist muscle pairs, resulting in a tighter regulation of centre of mass (COM) (Carpenter et al., 2001). This accommodation may serve to reduce the permitted range of COM displacement and minimize the probability of a loss of balance (Brown et al., 2006). The increased frequency and decreased amplitude in elevated environments are usually accompanied by an adoption of more posterior COM and centre of pressure position (COP) compared to the non-elevated environments (Carpenter et al., 1999).

These results are important because they show the possibility that individuals with acrophobia have an extremely stiffened posture that impoverishes performance in a similar mechanism to that of Parkinson's Disease (Koller, Glatt, Vetereoverfield, & Hassanein, 1989). In patients with Parkinson's disease, falls were found to be correlated with rigidity and not with tremor. In the acrophobia case, a similar phenomenon might occur, but due to a postural strategy problem. It is plausible that height fearful individuals' strategies to control balance become critically impaired and stiffened in the absence of visual cues or in the presence of unexpected visual environments. These studies on postural control reveal the need to further explore the influence of postural threat on the control of upright stance.

8.3. Visual dependence and motion

It is well known that motor action and depth vision are linked (Wexler & van Boxtel, 2005) and that some participants rely more on visual cues to control balance than others (Kitamura & Matsunaga, 1990). Participants with an increased dependence on visual field information (FD) are characterized as less physically stable and more reliant on visual cues (particularly motion visual cues) for controlling body stabilization. By contrast, the participants not dependent on this information (FI) are more physically stable and rely less on vestibular and somatosensory cues (Isableu, Ohlmann, Cremieux, & Amblard, 2003). Moreover, FD participants have a greater sensitivity to motion cues due to self-movements than FI participants (Isableu, Ohlmann, Cremieux, & Amblard, 1998). This increased reliance on visual cues may be a vulnerability factor that promotes disequilibrium during certain situations of daily living that include complex environments, moving visual fields and heights (Redfern et al., 2001) and thus may predispose participants to the development of agoraphobia or acrophobia (Jacob et al., 1995).

It is possible that self-motion has an important role in triggering fear of heights. As previously noted (i.e., Coelho, Santos et al., 2008; Coelho, Silva et al., 2008), acrophobic participants experience high levels of anxiety when required to move laterally at a fixed height. Isableu et al. (1998) further suggested that oscillation phases of locomotion, involving monopedal stance (on one leg), could increase balance instability especially in field-dependent participants. Visual dependence seems to increase with height, and participants can be especially visually dependent when walking on a narrow support (Isableu et al., 1998). Although speculative at this stage, it is possible that perceptual estimates of heights relate to cognitive and other fear-relevant biases when they are activated by concerns about acting in the environment, as recently noticed by Teachman, Stefanucci, Clerkin, Cody, and Proffitt (2008). These researchers found that high fear of height participants ($n = 35$) estimated the vertical extent of a two-story balcony ledge to be higher compared to 36 participants with low acrophobic symptoms. Additionally, given that perception informs us about the opportunities for action and the costs associated with these actions (Proffitt, 2006), Teachman et al. (2008) proposed that geographical height perception is influenced by the risks of the inherent dangers of behaving near the edge of a high drop-off. This suggests a possible interactive model in which cognitive factors (e.g. fear of falling; catastrophic interpretations), perceptual factors (e.g. visual dependence), learning factors (e.g. prior exposure to heights), and biological factors (e.g. heredity) can interact, provoking either habituation or extreme fear in height-related environments.

9. Summary and conclusion

It emerges from the present review that numerous studies with acrophobic participants aimed to investigate the efficacies of different treatment models and not necessarily to study acrophobia itself. Between 1973 and 1992, research on participants with acrophobia was essentially focused on comparisons between the exposure model and the self-efficacy model. Treatment within the self-efficacy model was usually more structured and had more therapeutic components, such as the mastery of subtasks, physical support, modeling and elimination of defensive maneuvers and this in turn lead to it producing the most effective clinical approach for the treatment of acrophobia. Although perhaps not the main focus of their work, the self-efficacy approach also provided important insights into the root causes and triggers of acrophobia. For example, Bandura (1977) noticed that a person's judgment about his or her ability and confidence to perform various specific actions (self-efficacy) is a major determinant of human behavior. In a similar vein, we and other researchers have begun to recognize the crucial role of movement in generating acrophobic responses in sufferers, making it a key feature to address in treatment (Coelho, Santos et al., 2008; Coelho, Silva et al., 2008; Whitney et al., 2005). Movement has also emerged as an important fear trigger. As we have argued in this review, it seems likely that motion parallax and visuo-vestibular conflict play an important role in the development of acrophobia in some sufferers (Brandt et al., 1980).

From its outset in 1995 as a treatment of acrophobia, VR has come to dominate the treatment of numerous anxiety disorders (Rothbaum et al., 1995b). Much of the subsequent research has been focused on exploring the viability of this technology in treatment. It is now known that both the real-world and VRET regimens are highly effective for treating acrophobia. A recent meta-analysis (Powers & Emmelkamp, 2008) presented estimates of effect size for VR treatments across a range of phobias and anxiety disorder in comparison to in vivo exposure and control conditions and found VRET was "slightly, but significantly, more effective than exposure in vivo, the gold standard in the field" (Powers & Emmelkamp, 2008, p. 568). Because VR hardware is becoming more reasonably priced (Wiederhold & Wiederhold, 2005) and VR systems can create a greater variety of stimuli and situations applicable to treatment, practitioners and researchers are still actively exploring the potential of this technology (for review see Krijn, Emmelkamp, Olafsson, & Biemond, 2004). Overall, VR offers some practical advantages over real-world exposure such as (1) better control of the situation by the therapist; (2) avoidance of public embarrassment; (3) preservation of confidentiality; (4) maintenance of the protective environment of the therapist's office (see also Rothbaum et al., 1999; Roy, 2003).

Besides the utility of VR as a tool for treatment, it also offers a route into further investigating and understanding acrophobia. Our own studies based on VR treatment suggest to us that motion combined with simulated height, rather than height *per se*, can trigger phobic responses (Coelho, Santos et al., 2008; Coelho, Silva et al., 2008). In fact, between 1993 and 2001, the majority of studies were related to the etiology of acrophobia and suggested a non-associative account. Nonetheless, both the non-associative and the behaviorist account accept the important role of learning to overcome the fear, whether it is learned or innate. The relative magnitude of each vulnerability and learning factor in the diathesis remains a topic of current debate. At the moment, we would tend to agree with Mineka and Oehlberg's (2008) suggestion to explore the possible mechanisms of diathesis-stress interactions in the development of anxiety and fear. In our particular case, this review suggests that the exploration of visuo-vestibular and motion mechanisms that might be present in acrophobia is also important. It is clear from seminal studies in children (e.g. Campos, 1978; Scarr & Salapatek, 1970; Schwartz et al., 1973) that a fear of heights accompanies the emergence of self-locomotion (crawling) and that habituation processes can aid in overcoming a fear of heights, supporting the idea that the etiology of acrophobia is intimately linked to body movement (Campos et al., 1992).

It seems plausible that an increased dependence on dynamic visual cues for controlling body stabilization might be a key factor in the predispositions to the development of acrophobia (Isableu et al., 1998; Isableu et al., 2003; Jacob et al., 1995). This relation between motion and fear still requires systematic examination. In the coming years research investigating the links between acrophobia, motion triggers, and implications for acrophobia treatment, will draw heavily on VR technology, which is proving to be an invaluable tool for measuring physiological and behavioral indices in response to controlled visual and motion triggers. VR is probably the most useful tool to decouple visual information, head orientation, proprioception and vestibular cues, and independently evaluate their role in acrophobia. As such, we look forward to VR ushering in a period of discovery that will greatly enhance our understanding of this debilitating and widespread phobia.

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