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Brief article

Near space and its relation to claustrophobic fear

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ABSTRACT

It is well established that the near space immediately surrounding the body (also known as peripersonal space) is represented differently than the space farther away. When bisecting horizontal lines, for example, neurologically-healthy adults show a slight leftward bias (known as pseudoneglect) in near space; this attentional bias, however, transitions rightward in far space. Recent research has used the rate at which this shift occurs to quantify the extent (i.e., size) of near space, showing consistent individual differences that relate to arm length. Here we examined whether the size of near space relates to individual differences in claustrophobic fear, as measured by reported anxiety of enclosed spaces and physically restrictive situations. Trait feelings of claustrophobic fear predicted the size of near space, even after accounting for the relation to arm length. Specifically, people with larger near spaces reported higher rates of claustrophobic fear than people with smaller near spaces. These results are consistent with a defensive function of near space representation and suggest that an over-projection of near space may play an important role in the etiology of claustrophobia.

1. Introduction

Fear has long been supposed to disrupt cognitive and perceptual processing (Baddeley, 1972; Beck, Emery, & Greenberg, 1985). Only recently, however, have such effects been formally investigated in both clinical and non-clinical settings. There are numerous cases of perceptual distortions accompanying phobias; for example, one man with intense fear of losing control of his car reported that bridges sloped dangerously and extended almost indefinitely (Rachman & Cuk, 1992). Such associations have also been reported in non-phobic individuals; fear, even when depicted in others, modulates even the lowest levels of visual processing (Anderson & Phelps, 2001; Phelps, Ling, & Carrasco, 2006; Vuilleumier & Schwartz, 2001). Other recent studies report systematic links between fear of slopes and perceived inclination of hills (Stefanucci, Proffitt, Clore, & Parekh, 2008), as well as between fear of heights and perceived vertical distance (Jackson, 2009; Stefanucci & Proffitt, 2009; Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008), with more intense fear predicting greater overestimation of steepness and height. Here we investigate the association between claustrophobic fear in a non-clinical sample and spatial perception as it relates to the near space immediately surrounding the body.

Claustrophobia is a situational phobia featuring intense anxiety in relation to enclosed spaces and physically restrictive situations (American Psychiatric Association, 2000). Claustrophobic individuals typically fear restriction in several spaces, including small rooms, tunnels, elevators, trains, and crowded areas. They may also fear suffocation, typically worrying that there would be insufficient air to support normal breathing if they were somehow confined to the space (Kirkpatrick, 1984). Although only a minority seek medical treatment, as many as 4% of people may experience severe claustrophobia (Curtis, Magee, Eatin, Wittchen, & Kessler, 1998), with many more experiencing at least slight symptoms (Radomsky, Rachman,

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Thordarson, McIsaac, & Teachman, 2001). Given recent findings showing an association between acrophobic symptoms (i.e., fear of heights) and perceived vertical height (e.g., Teachman et al., 2008), we investigated whether claustrophobic fear similarly relates to the representation of near space.

It is well established that near (or *peripersonal*) space is represented differently than more distant (or *extrapersonal*) space. Neurophysiological studies in monkeys have identified neurons in frontal and parietal cortical regions specifically responsive to vision of objects close to or approaching the body (Graziano, Yap, & Gross, 1994; Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981). Studies of neurological patients following brain injury to parieto–frontal regions have demonstrated double dissociations of attentional deficits such as hemi-spatial neglect for near and far space (Cowey, Small, & Ellis, 1994; Halligan & Marshall, 1991; see also di Pellegrino, Làdavas, & Farnè, 1997). In healthy adults, lateral attentional biases also vary as a function of distance. When bisecting horizontally-oriented lines (i.e., indicating the perceived midpoint) presented visually, participants generally show a small left bias in near space, known as pseudoneglect (for review, see Jewell & McCourt, 2000). At farther distances, however, bias shifts rightward (Longo & Lourenco, 2006; Lourenco & Longo, 2009; Varnava, McCarthy, & Beaumont, 2002). This shift in bias is generally continuous, and the rate at which it occurs can be taken as an index of the extent, or "size", of near space. Indeed, there are consistent individual differences and high test–retest reliability ($r > .8$) in the rate of this rightward shift (Longo & Lourenco, 2007). This spatial gradient of lateral attentional bias is also systematically related to arm length; shorter-armed participants show relatively abrupt shifts from left to right bias, indicating smaller near spaces, whereas those with longer arms show more gradual rightward shifts, indicating larger near spaces (Longo & Lourenco, 2007).

1.1. Current study

Following our previous studies, adult participants bisected horizontal lines with a laser pointer at multiple distances. For each participant, the size of near space was quantified by calculating the slope of the best-fitting line regressing rightward bias on distance. As noted above, these slopes are inversely related to the size of near space, with steeper slopes (i.e., more abrupt shifts in bias) corresponding to smaller near spaces and more gradual slopes to larger near spaces. We also assessed trait-level claustrophobic fear using the *claustrophobia questionnaire* (CLQ; Rachman & Taylor, 1993; Radomsky et al., 2001), a self-report measure which has been used for both clinical and research purposes (McIsaac, Thorardson, Shafran, Rachman, & Poole, 1998; Powers, Smits, & Telch, 2004).

Although the function of near space is most commonly regarded as controlling visuomotor action (e.g., Farnè, Iriki, & Làdavas, 2005; Làdavas & Serino, 2008; Maravita & Iriki, 2004), some investigators have suggested that near space may also function as a protective buffer, maintaining a margin of safety around the body surface and coordinating defensive behaviors against potentially noxious or threatening stimuli (Graziano & Cooke, 2006; see also Hall, 1966; Sommer, 1959). On this latter interpretation, the presence of objects in near space might produce anxiety and perhaps even lead to subsequent fear of encroaching features in the environment. Individuals with relatively large near spaces might thus be more prone to experience symptoms of claustrophobia than individuals with smaller near spaces. If claustrophobic fear is related to the representation of near space, then CLQ scores should be systematically related to regression slopes of bias from the line bisection task, with greater claustrophobic fear predicting larger near spaces (indicated by more gradual rightward shifts in bias over increasing distance).

2. Method

2.1. Participants

Thirty-five students (21 females) between 18 and 33 years of age ($M = 21.2$) participated for course credit or payment. Most participants (30) were right-handed ($M = 67$, *range*: −54.6 to 100; Oldfield, 1971). All had normal or corrected-to-normal vision. Procedures were approved by the local ethics committee.

2.2. Materials and procedure

Participants were tested in a large square room (wall length: 3.8 m; height: 2.9 m) where they bisected lines of 10, 20, and 30 cm (height: 1 mm) using a laser pointer at nine distances (30–270 cm, at 30 cm intervals). Lines were centered on legal-sized paper (21.6 × 35.6 cm) and attached horizontally to a wall (145.3 cm from the floor). A different sheet of paper was attached to the wall by an experimenter on each trial. Distances were marked on the floor with tape. A laser pointer was continuously activated and attached to the head of a tripod, the height of which was adjusted for each participant's comfort. The tripod was positioned to the right of the participant at the same distance from the wall as his/her feet. Participants used their right hand to move the tripod, bisecting lines with the laser beam. When satisfied with their response, participants moved away from the tripod; an experimenter (who had been out of view of the participant and who was blind to experimental hypotheses) marked the response. Across trials, participants stood at different distances, carrying the tripod with them as they moved from one distance to another. Each block consisted of one fully crossed set of trials (3 line lengths × 9 distances = 27 trials), with each participant receiving four blocks (108 total trials).

Following the bisection task, participants completed the CLQ (Radomsky et al., 2001), a self-report measure with 26 items (2 subscales: suffocation and restriction). Each item corresponds to a specific situation (suffocation: e.g., "using an oxygen mask"; restriction: e.g., "in a crowded train stopped between stations"). Participants rated each item in terms of how anxious they would feel in that situation. Items were rated on a scale of 0–4, with 0 indicating "not at all anxious" and 4 indicating "extremely anxious". The

CLQ has high internal consistency (Cronbach's α = .95) and excellent test–retest reliability (r = .89) (Radomsky et al., 2001). The length of the right arm (acromion to tip of middle finger) for each participant was also measured.

3. Results

Bisection responses were measured off-line by two coders who never disagreed by more than 0.25 mm. We estimated the size of near space using least-squares linear regression to determine the rate at which bias shifted rightward with increasing distance, as in previous studies. For each participant, we regressed rightward bias (% of line length) on distance to compute the slope of the best-fitting line. Fig. 1 shows a clear rightward shift in bias over distance, mean β = 0.55% line length/m, $t(34) = 6.29$, $p <$ .0001, consistent with previous findings (e.g., Gamberini, Seraglia, & Priftis, 2008; Longo & Lourenco, 2006; Lourenco & Longo, 2009; Varnava et al., 2002). Furthermore, these slopes were negatively correlated with arm length across participants, $r(34) = -.387$, $p < .02$, replicating our previous finding that the size of near space is scaled to body size (Longo & Lourenco, 2007).

Scores on the CLQ were comparable to existing normative data (Radomsky et al., 2001). The mean total score was 32.65 (SD = 17.2), with mean scores of 11.75 (SD = 7.63) for the suffocation subscale (SS) and 20.9 (SD = 10.5) for the restriction subscale (RS), which were strongly correlated, $r(34) = .776$, $p < .0001$. To investigate the relation between the size of near space and claustrophobic fear, as well as to further explore the influence of arm length, we used multiple least-squares regression, including scores on the CLQ and arm length as simultaneous predictors of the regression slopes of bias on distance. Both CLQ scores, mean $\beta = -.015$% line length/m/CLQ unit, $t(32) = -3.46$, $p < .002$, and arm length, mean $\beta = -.039$% line length/m/cm, $t(32) = -2.62$, $p < .02$, total $R^2 = .382$, were significant independent predictors of the size of near space (see Fig. 2). Though CLQ scores were not correlated with arm length, $r(34) = .048$, *n.s.*, the inclusion of both variables as simultaneous regressors provides strong evidence that any significant effect of either variable cannot be due to a lurking effect of the other. Similar results were obtained when SS (SS: mean $\beta = -.034$% line length/m/SS unit, $t(32) = -3.19$, $p < .005$; arm length: mean $\beta = -.040$% line length/m/cm, $t(32) = -2.59$, $p < .02$, total $R^2 = .356$), and RS (RS: mean $\beta = -.022$% line length/m/RS unit, $t(32) = -3.22$, $p < .005$; arm length: mean $\beta = -.039$% line length/m/cm, $t(32) = -2.58$, $p < .02$, total $R^2 = .358$) subscales were analyzed separately, suggesting reliable associations to near space for both components of claustrophobic fear.

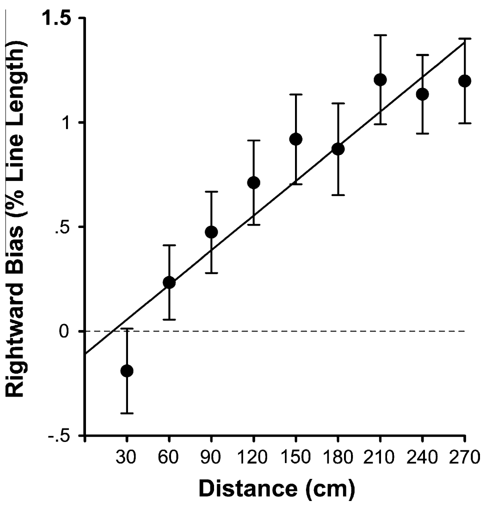

Fig. 1. Bias as a function of distance. Error bars are ±SEM.

Could differences in variability of bisection responses account for the effects of claustrophobic fear and arm length? For example, if people with higher CLQ scores responded more variably (perhaps because of greater anxiety in the testing environment), slopes could have been less steep purely because of greater response variability. To examine this possibility, we ran an additional regression analysis with CLQ scores, arm length, and trial-to-trial response variability (i.e., mean standard deviation calculated for bisection responses at each distance separately) for each participant as simultaneous predictors of slope. Whereas CLQ and arm length remained significant independent predictors (ps < .05), response variability had no predictive value (p > .8), suggesting that associations of near space with claustrophobic fear and arm length are not due to response variability.

4. Discussion

Individual differences in the size of near space, measured using a visual line bisection task, were systematically related to individual differences in trait claustrophobic fear in a non-clinical sample. Independent of arm length, participants with greater claustrophobic fear showed more gradual rightward shifts in attentional bias over distance (i.e., larger near spaces) than those with less claustrophobic fear. This suggests that people with greater anxiety of enclosed spaces and physically restrictive situations represent near space as larger than those with less of such anxiety. To our knowledge, these results provide the first empirical demonstration of an association between claustrophobic fear and a basic aspect of spatial experience (i.e., the representation of near space).

In the case of acrophobia, Proffitt and colleagues (Stefanucci & Proffitt, 2009; Teachman et al., 2008) recently observed that individuals with greater fear of heights showed more overestimation of vertical distance than individuals with less of such fear. The same distance viewed vertically (from above) was reported as farther than when viewed horizontally, providing evidence for overestimation of heights. Acrophobia involves a fear of being *too far* from something (i.e., the ground), which, at least in the vertical dimension, makes much adaptive sense, since there is great cost to falling. Claustrophobic fear, in contrast, involves increased anxiety when being *too close* to something (e.g., the limits of a surrounding space). It certainly makes sense to be fearful of objects or other features of the environment that approach the body,

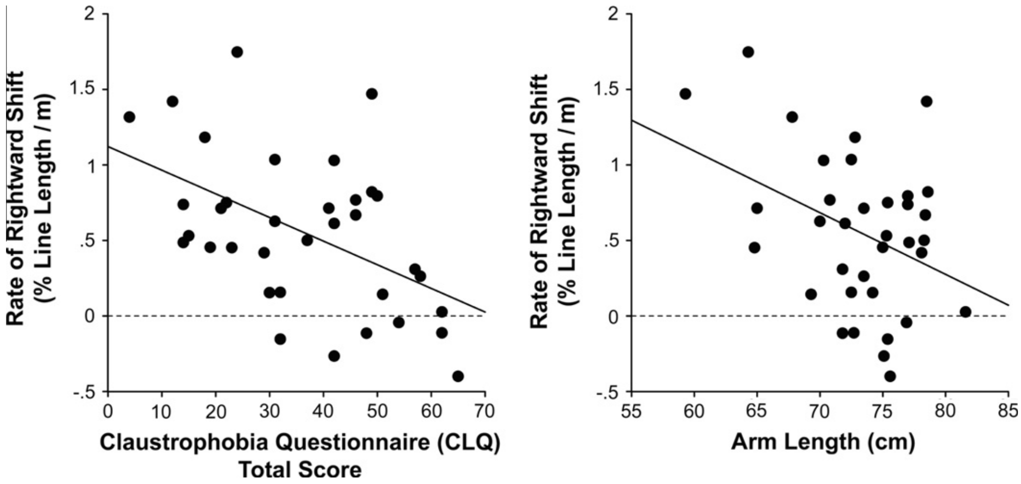

Fig. 2. Scatterplots relating regression slopes of bias to claustrophobic fear (left) and arm length (right).

especially if these are likely to cause injury or even death. While the exact perceptual relation between acrophobia and claustrophobia is unknown, it is an intriguing possibility that they represent opposite ends of a single continuum of space perception, namely, overestimation and underestimation, respectively.

4.1. Functions of near space

Given that near space representation related both to arm length and claustrophobic fear, it is reasonable to ask why there was no evidence of an association between arm length and claustrophobic fear. That is, if longer-armed people have larger near spaces, one might predict that they would experience greater claustrophobic fear than people with shorter arms. That we found no such association suggests independent functional connections of arm length and claustrophobic fear to the representation of near space. Above we described two proposed functions of near space: guidance of visuomotor action (e.g., Farnè et al., 2005) and protection of the body surface (e.g., Graziano & Cooke, 2006). Here we suggest that the effects of arm length and claustrophobic fear on lateral attentional bias may be rooted in these distinct functions, respectively.

Brain (1941) distinguished the *grasping distance* within arm's reach from the *walking distance* beyond. Following Brain, others have emphasized the role of near space in visually-guided action (e.g., Berti & Frassinetti, 2000; Farnè et al., 2005; Làdavas & Serino, 2008; Maravita & Iriki, 2004; Witt, Proffitt, & Epstein, 2005). Evidence for a link between arm length and the visuomotor function of near space comes from studies showing that changes in the range of effective action result in corresponding changes to the size of near space. For example, near space expands to include the tip of a wielded tool (Berti & Frassinetti, 2000; Holmes, Calvert, & Spence, 2004; Iriki, Tanaka, & Iwamura, 1996; Longo & Lourenco, 2006; Witt et al., 2005). Conversely, near space contracts when participants wear wrist weights, encumbering the arm and increasing the amount of effort required for action (Lourenco & Longo, 2009).

While the connection between arm length and near space may reflect a predominately visuomotor function, the connection between claustrophobic fear and near space may reflect the defensive function. Hediger (1955) argued that the sight of a predator might not be enough to cause an animal to flee; only when a threatening object enters the *flight zone* will the animal attempt escape. It has been suggested that the human fear of enclosed spaces is a vestigial fear of entrapment and that fear reactions experienced by clinically-diagnosed claustrophobic individuals resemble those displayed by threatened animals when their flight is prevented (Rachman, 1997). The representation of near space might serve to maintain psychological and physical distance between the body and potentially threatening or noxious stimuli. While we provide no evidence for a connection between arm length and the defensive function of near space, it is possible, indeed likely, that arm length (and body size more generally) is implicated in constructing a margin of safety around the body, though perhaps indirectly. Larger people may appear more threatening, such that others may refrain from approaching them. Larger people may also be less easily threatened by stimuli encroaching on their near space, even though this space would be larger than that of smaller people. These factors may potentially offset each other, perhaps accounting for the lack of any apparent relation in the current study between arm length and claustrophobic fear.

Our findings are correlational and thus do not allow for strong conclusions regarding the direction of causality between claustrophobic fear and the size of near space. Nevertheless, they are consistent with the possibility that claustrophobic fear may result, at least in part, from an underlying distortion in the representation of near space. Given the proposed link between near space and defense of the body (Graziano & Cooke, 2006), we consider it more probable that an over-projection of near space leads to greater claustrophobic fear rather than the reverse. It follows straightforwardly that individuals with relatively large near spaces may suffer from heightened anxiety in enclosed spaces in which objects strongly impinge on their near space. These individuals may thus be predisposed to experience claustrophobic fear and perhaps be more likely to develop claustrophobia following some relevant traumatic event or highly unpleasant experience (e.g., being stuck in an elevator) than individuals with smaller near spaces. Of course, the alternative possibility of some pre-existing anxiety for enclosed spaces (or more general situational factors) affecting the size of near space cannot be ruled out by our findings and should be tested directly in future research.

4.2. Implications for clinically-diagnosed claustrophobia

Just as the flight zones of grazing animals, which are generally quite large (e.g., 10 or more meters), can be modified, expanding or contracting depending on the circumstance (Hediger, 1955), recent studies with human adults are consistent with flexibly expanding and contracting representations of near space. Expansion has been documented under various conditions (Berti & Frassinetti, 2000; Gamberini et al., 2008; Longo & Lourenco, 2006), with evidence of long-term expansion in cases of expertise with specific tools (Serino, Bassolino, Farnè, & Làdavas, 2007).

That near space can also be made smaller in humans (Lourenco & Longo, 2009) suggests a possible treatment strategy for individuals with claustrophobia. Shrinking near space, especially if possible over the long term, could help to alleviate some of the symptoms accompanying claustrophobia. Such a treatment strategy, though, presumes that the causal direction runs from an over-projection of near space to claustrophobic fear rather than vice versa, which, as noted above, will need to be tested empirically in future research. It also depends on representations of near space that are sufficiently flexible. In Western societies, enclosed spaces and crowded areas are not uncommon, such that optimal functioning might require some degree of contraction in these circumstances (cf. Hall, 1966; see also Felipe & Sommer, 1966). An important area for future research will be to examine whether the representation of near space in claustrophobic individuals shows less plasticity, remaining larger than average across context.

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