Perspectival Structure and Vestibular Processing

A Commentary on Bigna Lenggenhager & Christophe Lopez

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I begin by contrasting a taxonomic approach to the vestibular system with the structural approach I take in the bulk of this commentary. I provide an analysis of perspectival structure. Employing that analysis and following the structural approach, I propose three lines of empirical investigation to selectively manipulate and measure vestibular processing and perspectival structure. The hope is that this serves to indicate how interdisciplinary research on vestibular processing might advance our understanding of the structural features of conscious experience.

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Egocentric | Egomotion | First-person perspective | Galvanic vestibular stimulation (GVS) | GVS | Head-mounted display | Perspective | Phenomenal groove | Phenomenal grooves | Scalp EEG | Self-consciousness | Structural features of consciousness | Tendon vibration stimulation | The body-swap illusion | The full-body illusion | The senses | Vestibular | Vestibular evoked potentials

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1 Structural vs. taxonomic approaches to vestibular processes

Philosophical work on the senses has largely been concerned with taxonomic issues: What makes an event sensory? Under which sensory kind should that event be classified? Answering these questions requires criteria of individuation. These would enable us to determine whether an event is the same as (or different to) sensory events in general and whether it is the same as (or different to) sensory events of a specific kind. A criterion of the first sort would allow us to identify vestibular events as sensory events. This would justify the belief that vesti-

bular processes are sensory processes. A criterion of the second sort would allow us to identify vestibular sensory events as being of a specific kind, i.e., distinctively vestibular sensory events. This would justify the belief that there is such a thing as a vestibular sense. Failing to provide a criterion of the first sort would force one to classify vestibular events as non-sensory. But even if one were able to determine that vestibular events are sensory, one would still require a criterion of the second sort to classify vestibular events as sensory events of a kind that is distinct from, e.g., visual or haptic events.

To expand on this last point: as Lenggenhager and Lopez so masterfully describe, central vestibular processes are inherently multisensory, and as a consequence there is scarcely a part of our sensory and cognitive life that vestibular processes leave untouched (see especially §2.2 of the target article). But then, if vestibular processes are implicated in so many sensory and cognitive processes, it may be most accurate to see vestibular processing as simply a common part of many processes, rather than as an independent sensory system. That is, one may begin to seriously consider the possibility that vestibular processing does not constitute a form of sensory processing of its own kind, but rather constitutes a form of processing common to various other processes that are themselves sensory. This is, in effect, an issue that arises from applying a criterion for individuating the senses that includes the physiology (and neurophysiology) of the entire system. One might not be forced to this conclusion if one used an alternative criterion (Macpherson 2011a, 2011b). But it seems that each of the criteria commonly discussed would generate their own problems. For instance, employing a more restrictive criterion that delimited sensory systems according to their peripheral sensory organs would face the issue of whether the sensory organs of the vestibular system ought to include or exclude the so-called "truncal" or "somatic" graviceptors (Mittelstaedt 1992, 1996; Vaitl et al. 2002). Similar issues would be faced when attempting to individuate the senses in terms of a distinctive proximal stimulus. Alternatively, one might individuate the senses by means of certain distinctive experiences: vision distinctively represents the brightness, hue, and saturation of colours; audition represents the volume, pitch, and tone of sounds. The natural candidates for the vestibular system would be experiences that represent verticality, rotation, and translation. But whilst it is certain that the vestibular system typically contributes to experiences of verticality, rotation, and translation, these are all experiences of a kind that can be had through visual sensation alone, or through a combination of visual, somatic, and proprioceptive sensation. Moreover, although vertiginous experiences are the hallmark of vestibular dysfunction, these are either experiences of rotation, which brings us back to the aforementioned issue, or they are more vaguely classified as pseudo-vertiginous experiences of dizziness that may have any number of non-vestibular aetiologies. Suffice to say that it may be surprisingly difficult to find appropriate criteria to justify the claim that there is such a thing as a *distinctively* vestibular sensory process.

The foregoing characterises what would be the typical philosophical approach to the vestibular system, *qua* sensory system. This *taxonomic approach* captures certain philosophical interests, but it is completely inadequate for the task of bringing out the significance of the scope of the vestibular system's influence. An alternative, *structural approach* focuses on the role played by vestibular events in processes that exhibit a certain kind of structure, to determine the contribution of those events to that structure. Note that the structural and taxonomic approaches are independent, insofar as they have different epistemic goals. They aim to further our knowledge in different ways. The goal of the taxonomic approach is to determine whether, and if so why, there is a distinctive sensory system of a certain kind. The goal of the structural approach is to determine whether, and if so how, a certain kind of process contributes to a certain kind of structure. By assuming that one can identify processes as objects of study without first employing an exhaustive taxonomy, a structural approach can assume that there are such things as vestibular

processes without any commitment to these processes being wholly distinct from others. And by tracking the varied yet systematic effects of vestibular processes, one can determine whether vestibular processes contribute to a certain kind of structure, irrespective of, whether or not the vestibular system is a distinctive sensory system. As vestibular processes are implicated in so many and various sensory and cognitive processes, the structural approach seems to be the most fruitful in terms of the amount we might learn. It also seems more fruitful in terms of the kind of knowledge we might gain. For we may learn nothing about how vestibular processes affect our experiential life by learning that vestibular processes may not be, in the final analysis, of a distinctive sensory kind. But we will certainly learn something about how vestibular processes affect our experiential life by learning that vestibular processes contribute to a certain experiential structure. Accordingly, I leave aside taxonomic issues in the rest of this commentary and focus on structural issues. Specifically, I focus on issues concerning the role of the vestibular system in providing a particular kind of structure to our experience of the body and the world, namely a perspectival structure.

To begin with, we need a preliminary analysis of experiential phenomena that exhibit perspectival structure. I will call these *perspectival phenomena*. In the next section, I offer a rudimentary analysis of perspectival structure, the aim of which is to show that perspectival phenomena are more differentiated than commonly recognised. In the following three sections, I propose three lines of empirical investigation. Each would attempt to selectively study perspectival phenomena through measurement and manipulation of vestibular processes. If the experiments proposed yielded interesting results, they would further our knowledge of how vestibular processes affect the perspectival structure of our experiential life. Accordingly, the overall aim is to demonstrate how an analysis of perspectival structure might fruitfully interface with empirical research and facilitate understanding of structural features of conscious experience that would otherwise be obscured.

2 The differentiation of perspectival phenomena

The notion of a subjective perspective (sometimes described as a *first-person perspective*) is at the core of contemporary research on bodily self-consciousness (Blanke & Metzinger 2009; Metzinger 2003, 2009). However, its role has often been merely facilitative, serving as a means to study *other* components of bodily self-consciousness, such as the experience of bodily agency, ownership, and self-location (Ehrsson 2007; Lenggenhager et al. 2007; Petkova et al. 2011a, see Serino et al. 2013 for review). Consequently, the fact that the very notion of perspective covers a range of distinct phenomena has tended to be overlooked.[1] Referring to someone's perceptual experience as having a perspectival structure may mean any one of several distinct things. It may mean that there is an *origin* to her sensory field, relative to which certain things (or parts of things) are perceptible and perceived from a particular direction and relative to which certain other things (or parts of things) are not perceptible or noticeably occluded.[2] Alternatively, it may mean that her experience is organised according to an *egocentric* frame of reference centred upon her body, according to which she experiences locations as situated relative to a particular point at the intersection of three orthogonal axes. Or it may be that, thanks to *egomotion*, the flow of her sensory experience is such that she can see where she is headed as she moves. Taking *another individual's* perspective into account in social interactions can involve either of the first two forms of perspective (Moll & Meltzoff 2011).

1 My discussion is restricted to spatial perspectival phenomena; I omit discussion of the respects in which temporal experience may be perspectival. This is mostly for the sake of simplicity. However, there is good reason to think that we represent time in a manner that is asymmetrically dependent upon the ways in which we represent space (Boroditsky 2000; Casasanto & Boroditsky 2008). Addressing issues concerning the structure of spatial experience first may thus be prudent.

2 This notion is intended to capture the idea that there is a point of "origin" to the so-called line of sight (which is not so much a line as an angle). This corresponds to perhaps the earliest documented notion of perceptual perspective, associated with what Euclid and Ptolemy respectively called the "visual pyramid" and "visual cone", where the apex (origin) of the pyramid or cone is at the eye and the base at the object (Howard 2012).

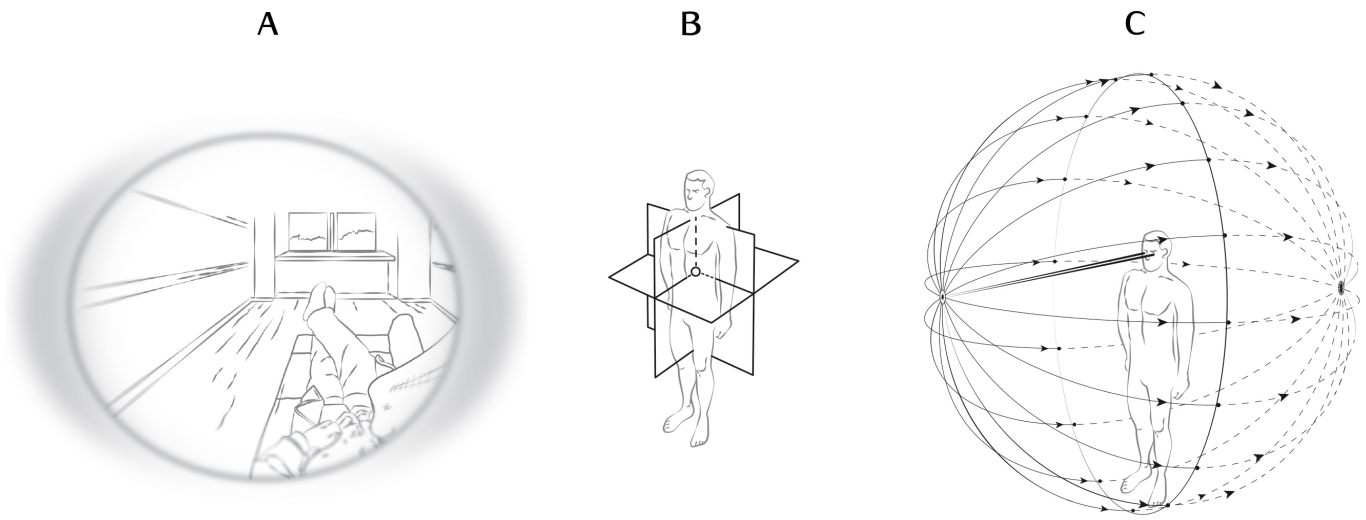

Figure 1: Three forms of perspectival structure. A. An artistic rendition of a human monocular visual field. After Mach 1959, p.18. **B**. An egocentric frame of reference centred upon a human torso. **C**. The directions of deformations in the visual field specifying egomotion. Cf. Gibson 1950, p. 123.

Moreover, the perspective of the subject need not figure explicitly in the experience for it to be perspectival; perspective can structure perceptual experience implicitly, by determining the way in which objects are experienced, without itself being part of the content of the *experience* (Campbell 1994; Merleau-Ponty 2002; Perry 1993; Zahavi 2005).

We can summarise these remarks by saying that perspectival phenomena in spatial experience vary along three dimensions.[3] First, perspectival structure can take at least three forms: [4]

- Origin of a sensory field (*origin*)
- Centre of an egocentric frame of reference (*egocentric*)
- Focal point of a sensory flow field in action (*egomotion*)

Perspectival phenomena that exhibit any of these forms of perspectival structure can vary along two further dimensions: the perspective of a given perspectival experience may be either *implicit* or *explicit*, and may be attributed to the subject or to another individual. A perspective is *explicit* in a perspectival experience if the subject is consciously aware of the location of the origin, centre, or focal point in question; it is *implicit* if the subject is not.[5] The perspective in question may belong to the subject, a *first-person perspective*, or it may belong to another individual, a *third-person perspective*.

This simple framework enables one to study perspectival phenomena selectively, rather than studying an undifferentiated cluster of perspectival phenomena simultaneously. In the sections that follow, I shall suggest a number of ways in which one might engage in such a selective study of perspectival phenomena by in-

3 I do not intend the following to be exhaustive. Moreover, although all of the perspectival phenomena that I discuss are visual, I do believe that each of the forms of perspectival structure that I describe also characterises perspectival experience in haptic perception.

4 The most I intend to claim here is that these forms of perspectival structure are non-identical. Perhaps the origin of a given sensory field, the centre of a given egocentric frame of reference, and the focal point of a given sensory flow field could occupy the same location under some description. However, this certainly need not always be the case. Moreover, each form of perspectival structure will present the objects of perceptual experience as related to the subject of experience in different ways, e.g., as only partially visible, as straight ahead, or as in one's way. Below I will suggest various ways in which these might be selectively manipulated, but I do not intend to make the case that forms of perspectival structure can be dissociated from one another.

5 When a perspective is explicit, the location of the origin, centre, or focal point is part of the content of the experience. Any beliefs that the subject has about the location in question do not go beyond the content of that experience (cf. Peacocke 1999, p. 265). The experience may represent the location in question in an imprecise or wholly incorrect manner; the subject's beliefs will be correspondingly imprecise or incorrect. Implicit perspectives structure experience without being part of the content of experience. I leave it open whether implicit perspectives are nevertheless experienced *qua* structural feature, or whether, for example, they are merely formal structures that determine the ways in which things are experienced, without themselves being experienced. Issues like this are difficult to evaluate, but for discussion see Alsmith (2012).

tervening upon and registering the activation of vestibular processes.

3 Perspectival variation in multisensory stimulation

One consequence of not distinguishing between perspectival phenomena is that the notion of a *first-person perspective* becomes ambiguous. One can clearly see this ambiguity in descriptions of the role of *first-person perspective* in the multisensory stimulation protocols developed in recent work on the neuroscience of bodily self-consciousness. These protocols all involve participants being touched on their torso whilst visually observing a body-shape (either the body of another person, a mannequin, or a virtual body) being touched on its torso. The protocols differ along two dimensions: the side of the torso stimulated and the location of the origin of the participants' line of sight with respect to the body being observed. In one protocol, the body-swap illusion, participants are stroked on their chest whilst they look at a body being stroked on its chest from a position located where its head would be (cf. Ehrsson 2007; see Petkova et al. 2011b; Petkova & Ehrsson 2008; Petkova et al. 2011a). In another protocol, the full-body illusion, participants are stroked on their back, whilst they observe a body from behind being stroked on its back from a position entirely removed from its location (Ionta et al. 2011; Lenggenhager et al. 2007; Pfeiffer et al. 2013). The body-swap illusion protocol is often distinguished from the full-body illusion protocol as involving first-person perspective as an independent variable (Petkova et al. 2011a). However, recent work on the full-body illusion has demonstrated effects that the authors describe as changes in first-person perspective (Pfeiffer et al. 2014): Participants lain prone whilst feeling and observing strokes on the back report experiences of either looking up or down at the body they observe (Ionta et al. 2011). These variations in report seem to depend upon the individual's relative weighting of vestibular and visual gravitational cues (Pfeiffer et al. 2013).

Admitting the differentiation of perspectival phenomena allows us to make sense of the differences in use of the term *first-person perspective*. In the terms introduced in the previous section, the *first-person perspective* in the body-swap illusion is an *origin* perspective. It presents the typical view of one's own body with a line of sight originating in the head. The *first-person perspective* in the full-body illusion is an *egocentric* perspective. It forms the centre of an egocentric frame of reference, according to which the observed body occupies a location in a particular egocentric direction (up or down). Distinguishing these forms of first-person perspectival experience reveals that each of these protocols facilitates manipulation of a distinct form of perspectival experience. It also sheds light on the fact that the differences in vestibular and somatosensory processing between these forms of perspectival experience have yet to be compared.

One way of conducting such a comparison would be to use virtual reality display techniques to present an individual with two avatars in series, whilst measuring time-locked vestibular evoked potentials via scalp EEG.

Experiment 1: Participants are stroked on *both* their chest *and* their back whilst supine, whilst wearing a head-mounted display. In the meantime, participants observe either the chest of Avatar 1 being stroked on its chest, presented from a position corresponding to the avatar's head, as in the body-swap illusion, or they observe Avatar 2 being stroked on its back, as in the full-body illusion. Ideally, the two avatars are presented in the same viewing, such that the participant views one avatar and then in a continuous movement shifts their gaze to view the other.[6]

I have claimed that each of the two protocols conjoined in this proposed experiment facilitates manipulation of different forms of perspectival experience. If this is correct, then finding significant differences in vestibularly-evoked potentials between observation of Avatar 1 and Avatar 2 would be a first step in determining differences in vestibular processing between these forms of perspectival experience.

6 This would be, I take it, as close as practically possible to viewing the two avatars at the same time, given limitations in the field of view.

As noted earlier, there do seem to be individual differences in the contents of *egocentric* perspectival experience in the full-body illusion. This would suggest that some individuals, those who are more heavily dependent upon vestibular gravitational cues to determine orientation, would experience themselves as looking upwards at Avatar 2. Whereas if the right *visual* gravitational cues were provided, some individuals may experience themselves as looking downwards at Avatar 2 (Ionta et al. 2011; Pfeiffer et al. 2013). This might allow the investigation of the relationship between *egocentric* perspectives and *egomotion* perspectives, by incorporating a second phase into a new experiment:

Experiment 2: Phase 1: experiment 1, described above. Phase 2: Participants continue to be stroked on their back and chest. Participants fixate upon Avatar 2 and observe it rotating about a horizontal axis, whilst being visibly stroked on its back and chest. Both reports of experienced orientation (upward vs. downward) and reports of experienced *egomotion* are gathered.

Participants may experiences themselves as rotating around a horizontal axis in just the way they observe Avatar 2 rotating. Alternatively, they might experience themselves as revolving around Avatar 2. In particular, what would be of interest would be the way in which any resultant illusory experiences of *egomotion* might correlate with experienced *egocentric* orientation (upward vs. downward). Moreover, individual differences in experienced *egocentric* orientation might even predict the contents of experienced *egomotion*. This would be a major step in determining both the relative influence of vestibular processing on these forms of perspectival experience and the relationship between these forms of perspectival experience.

4 Perspectival variation in misalignment

In much recent philosophical and neuroscientific research on self-consciousness, the experienced *first-person perspective* is treated as a simple phenomenon identified with the experienced origin of an *egocentric* frame of reference centred upon an individual's own body (Blanke & Metzinger 2009; Vogeley & Fink 2003). But *egocentric* perspective, despite being an *apparently* simple phenomenon, is in fact as potentially complex as the macroscopic structure of the body itself (Smith 2010). Human bodies are composed of a number of parts that are to some degree independently mobile, any of which may serve to centre a distinct *egocentric* frame of reference. As this observation is well known, we may presume that theorists who treat egocentric perspective as simple are assuming that locations in these various egocentric frames of reference are translated into a single, *ultimate* egocentric frame reference which itself determines egocentric perspectival phenomena.

However, neurophysiological and neuropsychological research on spatial representation suggests independent motivation for this ultimate frame being centred upon the head (e.g., Avillac et al. 2005) or the torso (e.g., Karnath et al. 1991). By rotating head and torso in opposite directions, an egocentric frame of reference centred upon the head can be misaligned with another frame centred upon the torso. In such a "misalignment" situation, a single object may be "to the right" with respect to the head and "to the left" with respect to the torso (Longo & Alsmith 2013). Following Christopher Peacocke's (1992) description of the phenomenology of experienced direction, one would hypothesise that differences in experienced posture would determine differences in *egocentric* perspectival experience.[7] One could thus use mis-

7 Peacocke writes: "The use of a particular set of labeled axes in giving part of the content of an experience is not a purely notational or conventional matter. The appropriate set of labeled axes captures distinctions in the phenomenology of experience itself. Looking straight ahead at Buckingham Palace is one experience. It is another to look at the palace with one's face still toward it but with one's body turned toward a point on the right. In this second case the palace is experienced as being off to one side from the direction of straight ahead, even if the view remains exactly the same as in the first case" (1992, p. 62). Assuming that Peacocke's prediction is correct, then in this example changes in the egocentric perspectival structure of visual experience follow changes in the orientation of the torso. By misaligning the torso from the direction of the gaze, one discerns that (in the case as described) the appropriate set of labelled axes centre upon the torso. In the paradigm described in experiment 3, both head and torso may be misaligned with the individual's gaze. This makes it possible to determine the contribution of both head- and torso-centred frames of reference to the individual's egocentric perspectival experience of a given location. It would then be possible to discern whether, for the egocentric perspectival experience of a given location: (i) the appropriate set of axes centre on the torso; (ii) the axes centre on the head; (iii) both sets of axes make relative contributions to the structure of the experience.

alignment situations to determine the respective contributions of the head and the torso to the organisation of *egocentric* perspectival experience at a given point in time in the following experiment:

Experiment 3: Standing with their head and torso aligned or misaligned ±15°, participants perform a task that involves either an *explicit* or only an *implicit egocentric* perspective (see below). The angular deviation of the stimulus in relation to the head and/or torso is recorded, such that one would be able assess the respective contributions of each body-part's orientation to the participants *egocentric* perspectival judgments. Participants would receive either galvanic vestibular stimulation (GVS) or tendon vibration stimulation to precisely assess the relative contribution of vestibular processes to *egocentric* perspective.

In more detail, the suggestions are these. For an explicit task, stimuli could be presented across the entire visual field in regular intervals, varying in distance and elevation, and participants would judge whether a stimulus presented looks "to their left or to their right". A potential limitation of the explicit task is that in using overt left/right judgements, participants' responses may reflect a stipulated meaning of these terms that is independent of the *egocentric* perspectival structure of their experience. However, a recent study using a covert attentional cuing paradigm found that rotation of the torso primes participants to respond more quickly to visual stimuli appearing on the side of a computer screen congruent to the direction of rotation (Grubb & Reed 2002).[8] One could adapt this paradigm to directly compare the respective influences of head and torso by rotating the head and/or the torso ±15° relative to the screen where stimuli would be presented. Target and cueing visual stimuli would appear on either congruent or incongruent sides of the screen and participants would make speed responses to indicate whether the target appears to the left or the right on each trial. Again, as the angular deviation of the stimulus in relation to the head and/or torso would be known, one would be able assess the respective contributions of each body-part's orientation to the participant's *egocentric* perspectival judgments.

Based on previous work, I would expect participants' judgements to implicate *both* their head *and* torso as determining their *egocentric* perspectival experience (Alsmith & Longo 2014). More specifically, I would expect that both head- and torso-centred reference frames would influence *explicit* and *implicit egocentric* perspectival phenomena (Longo & Alsmith 2013), though the exact weighting will be unequal at lateral extremes of each body part and will differ between individuals (Alsmith et al. in preparation). The further prediction would be that manipulating vestibular and proprioceptive processing will modulate felt postural misalignment and thereby systematically influence performance on *explicit* and *implicit egocentric* perspectival tasks.

5 Perspectival variation in sensorimotor control

Arguably, one of the core structural features of the experience of intentionally-directed bodily movement is the presentation of the agent as the "perspectival source" of the motion experienced (Horgan et al. 2003; Marcel 2006). However, a strikingly robust experimental finding is that individuals will correct for a deviation introduced into a movement they perform via a bias in visual input, thereby ensuring the action they intend achieves its goal, whilst nevertheless *not* reporting such corrections in their movement (Fourneret & Jeannerod 1998; Knoblich & Kircher 2004; Slachevsky et al. 2001). Recent developments of this paradigm have adapted it to test *explicit egomotion* perspectival experience in walking movements, by using a motion-tracked avatar, observed from the rear. Kannape and colleagues found that by introducing a slight bias into the subject's visual experience of the trajectory of the avatar, they could induce subjects to perform appropriate corrective movements in walking to a target, whilst not noting the discrepancy between their actual movements and the avatar (Kannape

8 It is perhaps worth noting that by "congruent" I intend the more general sense of the term, as often used in describing the design of behavioural studies, the meaning of which is equivalent to "in agreement". I do not intend the more specific geometrical sense of the term, which expresses identity of a certain kind, typically of form.

et al. 2010). Again, the corrections went largely unnoticed within a certain range of angular deviation between observed and actual movements.[9] Thus, a natural explanation of the pattern of data is that the mechanisms enabling the experience of agency present bodily movements in a manner that is far more coarse-grained than the level of detail required to make corrective changes in movement trajectory. In short, *egomotion* perspectives structure experiences of intentionally-directed bodily movement. They do so by specifying what we might call coarse-grained phenomenal grooves, within which a movement must unfold if it is to seem like the movement that the subject intended or is trying to perform.

Strangely, as yet the potential contributions of the vestibular system to the structuring of agentive experience by *egomotion perspective* have not been manipulated. Moreover, as noted, the work that has been done in this area has been restricted to *explicit egomotion* perspectival phenomena. A natural further step would be to investigate the nature of vestibular processing in implicit egomotion perspective, by controlling a participant's optic flow in a manner corresponding to the control of the avatar's motion in Kannape and colleagues' original study.

Experiment 4: Study 1: Participants view a textured environment via HMD in which optical flow fields are regulated by their motion-tracked movements. Study 2: Participants control a motion-tracked, real-time avatar seen from behind. In both studies, participants are tasked with walking directly towards a virtual target. All the while, they either receive GVS or sham stimulation and visual feedback (optic flow or avatar position) that is either faithful to motion-tracking or systematically deviated left/right of the participant's mid-line, as a function of distance from a point of displacement onset.

Participant trajectory could thus be compared to the dynamics of the flow field or avatar trajectory and participants could be asked to rate the degree to which their movements in the virtual environment or the movements of the avatar corresponded to their actual movements, as respective measures of *implicit* and explicit *egomotion* perspectival experience. The question would be whether, in trials in which GVS is applied, the range of angular deviation in which participants would judge that movements in the virtual environment correspond to their own would be equal to or larger than trials in which participants receive only biased visual feedback. If the latter occurs, then in the evocative terms used above, it would suggest that vestibular processes are one of the determinants of the coarseness of the phenomenal groove specified by an *egomotion* perspective.

6 Conclusion

I began by contrasting a taxonomic approach to the vestibular system with the structural approach I have taken in the bulk of this commentary. I then provided an analysis of perspectival structure. Employing that analysis and following the structural approach, I proposed three lines of empirical investigation that would selectively manipulate and measure vestibular processing and perspectival structure.

Day & Fitzpatrick (2005) quip that vestibular processes provide a "silent sense" (see also §2.2.1 of the target article). I suggested at the outset that (following the taxonomic approach) it might be surprisingly difficult to say with any precision why vestibular processing provides a sense of its very own. But even if it is true, that is, if the experiments described yield the expected results, they would show that vestibular processing is hardly silent. Indeed, each of the proposed lines of investigation would be a step towards a better understanding of how vestibular processes affect myriad forms of perspectival structure, all of which would further demonstrate the centrality of vestibular processing to our experiential life. In any case, my hope is that these remarks display the extent to which I have found Lenggenhager and Lopez's work to be not only inspirational, but also a rich and fruitful avenue for interdisciplinary research into the structural features of conscious experience.

9 The authors write that "deviations of 5°, 10°, and 15° lead to many erroneous self-attributions", found to be "decreasing in magnitude with increasing angular deviation" (Kannape et al. 2010, p. 1631). As broached above, one explanation of this pattern would be that deviations below 15° all fall (to a greater or lesser degree) within the phenomenal groove of the action specified by the task.

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