Motorists Vestibular Disorientation Syndrome Revisited

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Abstract

We present a framework within which to understand the causes of chronic susceptibility to disorientation and how it may be resolved. Motorists Disorientation Syndrome is given as an example disorientation syndrome which may occur without sensory or marked psychological disorder and resembles pilots' disorientation. The syndrome may begin with an episode of disorientation or a sensory impairment and thereafter can cause dysfunctional behaviour. A neglected feature of disorientation is that contextual stimuli such as differential movements of parts of the visual field may support alternative interpretations affecting orientation. These are not necessarily at a conscious level but are still able to induce apprehension or inappropriate behaviour: a susceptibility to subliminal percepts. Once sensitised to the intrinsic ambiguities of a complex environment it becomes difficult to adjust gains and asymmetries or re-establish rules of reference between somaesthetic and vestibular signals. A fundamental problem in establishing rules for interpreting sensory input is circularity of reference between somatic and visual signals and vestibular signals of motion in space. Somatic and visual signals which give relativistic information about motion are referenced to vestibular signals of absolute motion in space for interpretation. Conversely vestibular signals are calibrated by reference to these other sensory input. Should a problem of interpretation arise in this potentially vicious circle the only recourse is to make an exploratory appraisal of the environment in which the natural first choice for perceptual sampling of world events is vision because of it teleceptive and panoramic power. Unfortunately, this tactic creates 'visual dependency' which, in a complex environment, risks creating increased susceptibility to vection illusions and visual vertigo (correspondingly, clinical experience indicates that the longer symptoms remain untreated the more patients suffer visual vertigo). Resolution of this deterioration is by recourse to cognitive behavioural therapy and desensitisation, commencing with dealing with simple stable environments and progressing through levels of increasing instability and ambiguity.

Introduction

Some 16 years ago Page and Gresty described a group of patients whose main presenting symptoms were of episodes of disorientation experienced whilst driving [1]. The incidents were generally of illusory veering or tilting motion of the vehicle which could be so compelling that the driver made corrective adjustments to the cars heading; often with untoward consequences. Some drivers affected in this way initially attributed the apparently abnormal motion of their vehicle to mechanical fault or extreme road camber and it was not until they recognised that the symptoms could occur under stable road conditions and in different cars that they sought help. At that time the experiences of disorientation were attributed to abnormalities of vestibular

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function and an attempt was made to explain the types of disorientation in terms of asymmetries of canalicular and otolithic function heightened by exposure to the conditions of motion experienced in a moving vehicle. This diagnosis was supported by abnormalities found on vestibulometry comprising asymmetries in nystagmus responses to rotational testing and caloric irrigation but it should be emphasised that these were slight. Since this original description the syndrome has been recognised widely and it has become clear that patients suffering motorists' disorientation (MDS) in general have few demonstrable vestibular disorders of significance. Consequently the syndrome has been classified as an extension of agoraphobia [2] or an aspect of a functional disorder which has been termed phobic postural vertigo [3,4].

Frequently patients affected in this way admit to other experiences of disorientation such as susceptibility to visual vertigo, but typical features of distinct vestibular disease in the form of an attack of vertigo are not present. Motion sickness susceptibility may be unremarkable in MDS and neither marked trait anxiety nor phobia are necessarily obvious contextual features. Accordingly, we view the syndrome as a functional spatial disorientation caused by heightened awareness of potentially disorienting stimuli (although, for obvious reasons, one which may provoke anxiety and phobia!). In this respect MDS has many features in common with susceptibility to disorientation which can occur in pilots. Our intention is to review the features of MDS, speculating on the specific mechanisms of disorientation as a springboard to proposing a framework which helps us to understand susceptibility to disorientation and rationalise its rehabilitation.

The clinical syndrome

Each year in the neuro-otological clinic with which one of the authors (MG) is associated an average of 10 patients out of 200 seen as outpatients present with primary MDS. Amongst patients with definite vestibular syndromes almost all are found to have problems with motion environments; in particular travelling as a passenger in a car, using the metro or buses and seeing motion such as streaming crowds of people. Typically the patients with MDS report very similar disorienting experiences on the road. These are described below together with an interpretation of how they may be generated. One should be aware that it may be difficult to unravel whether the description a patient gives of disorientation is of illusory movement or of a reflex countermeasure.

i) *The car feels as if it veers on wide open roads such as motorways.* This is by far the most frequent 'symptom' to be reported being a feature of every patient the writer has encountered. In a sense it is not unexpected since motorway driving may be monotonous and similar to a sensory deprivation situation, for example a pilot on a long flight at high altitude. My own interpretation of this illusion is that visual estimates of distance orientation and heading are impaired because of the paucity of nearby visual cues. It is interesting that drivers suffering illusory veering on motorways do not get the symptoms when driving in town. Although we have referred to the veering as illusory much may be real. The reader is probably aware of the 'lane drifting' often encountered on motorways both on the part of other drivers and of oneself. Hence illusory veering may be a heightened perception of true veering.

ii) *The car feels that is turning into vehicles being overtaking.* Everyone who drives will admit to some trepidation when overtaking, particularly at speed and when passing large vehicles such as buses and trucks. One is perhaps even more disquieted at oneself being overtaken by a large truck. A visual flow analysis of the situation (Figure 1) reveals one likely reason which is that the asymmetrical pattern of optic flow from ahead to the right versus ahead to the left is consistent with rotation which would take ones car into the path of the parallel vehicle. The disoriented driver appears to 'switch in' to this alternative interpretation of orientation.

Figure 1

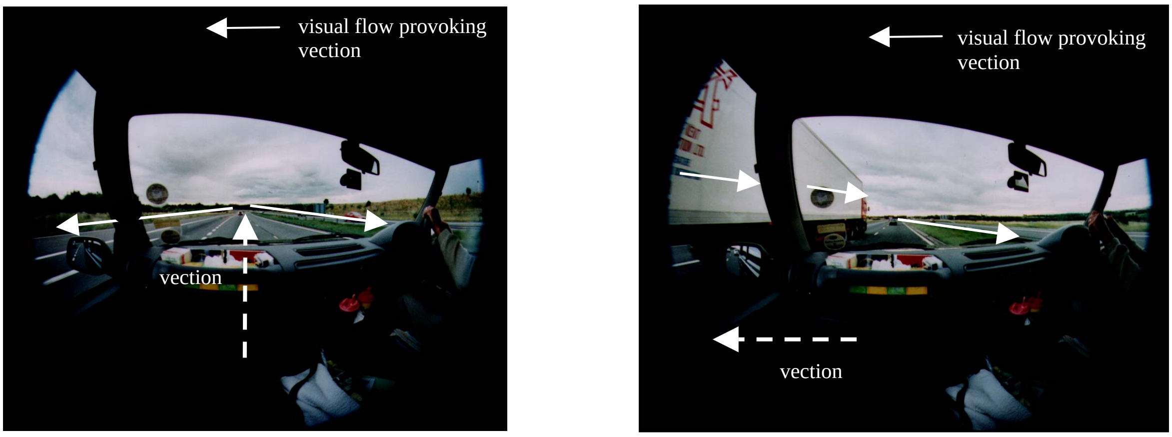

Figure 1 180° view taken with an equal-area fish-eye lens from the level of a drivers head in the cockpit of a car travelling on a motorway. The centrifugal visual flow when alone on the road is equivalent on the left and right sides confirming a straight ahead trajectory. A passing vehicle creates unequal flow which is consistent with a curved trajectory. The lens shows that the truck occupies almost one half of the are of moving visual field which is why the vection-illusion of turning can be so compelling.

iii) *The car feels that it is about to turn over when descending and rounding a bend* (Figure 2). Whilst descending the hill at constant velocity Ig is earth upright and the driver is tilted forwards of earth upright. Braking towards the bottom of the hill just before and into the bend will tilt Ig backwards with respect to g and the driver may perceive an enhanced forwards tilt (SOIg). When entering the bend on the flat the Ig vector rotates into the bend because of centripetal acceleration. The driver tilts from Ig upright out of the bend. In the disoriented driver the percept of tilt from inertial upright seems to dominate so that he perceives that he tilts from ‘upright’, firstly rotating forwards then backwards and sideways. At the same time the frame (ie, car seat) within which the body is ‘anchored’ by buttocks (the point of origin of the subject's Z vector) rotates in the opposite direction into the bend. In vestibular terms the tilt and rotation in different directions is a possible source of canal-otolith conflict [5]. This percept is similar to what one would experience if falling sideways and rotating at the same time, threatening a landing on ones back.

The key element in the situations we describe is that the force-motion environment is potentially ambiguous[6,7]. If the subject loses track of his cognitive appraisal of what is most likely to be happening or the most useful for behaviour then alternative interpretations of events spring to mind: the classic example being the railway train illusion wherein visual motion alone provokes the perception of self motion in the absence of contextual cues such as jolt and noise of ones own train moving. The cognitive context may also be inappropriate in that one may be far from the time of departure; particularly in the UK. Most readers will have experienced some instances of illusory motion or inappropriate apprehension provoked by motoring incidents. A common misperception is probably that one is drifting backwards after stopping in a line of slowly moving traffic which provokes a sudden stomp on the brake pedal.

Figure 2

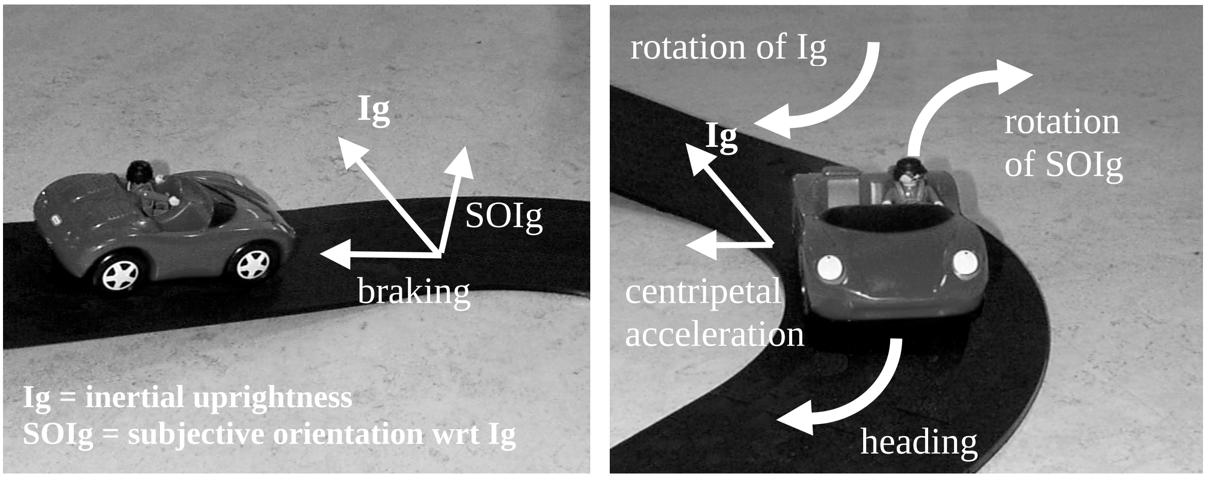

Figure 2 Changing orientation of driver with respect to ‘inertial upright’ during descent of a hill and braking into a corner. See explanation (iii) in text.

Two kinds of situations arise with subjects suffering MDS. Either they have become aware of illusory motion, which they accept as true, or they respond to an incident on the road which is inappropriate given the true configuration of what is happening. In the latter circumstance, the real situation may be consciously apparent to the driver but he still makes an inappropriate manoeuvre because of a pre-conscious percept. Some of the perceptions described above may occur at a pre-conscious level but may still provoke apprehension in normal drivers. Unconscious mechanisms have been shown for other behavioural modalities [8], for example being disturbed by a subliminal presentation of a word such as “cancer”. Here we propose that a similar phenomenon may exist for ambiguous motion stimuli. We may consciously perceive one possible interpretation but others, held in reserve at an unconscious level, may also affect our behaviour.

MDS disorientation is difficult to rehabilitate. Furthermore approximately 30% of patients with proven vestibular disease are difficult to rehabilitate. A common feature is that the sufferer has been made over-aware of, overreacts to, or reacts inappropriately to quotidian instabilities of the environment such as moving crowds, traffic and using vehicles. Environmental motion makes them dizzy in the sense of feeling unstable and accompanying the dizziness is malaise with nausea which may be motion sickness. The malaise may include an element of headache. Psychological consequences may be anxiety, depression, panic and phobia.

Hypothesis: the mechanism of chronic susceptibility to spatial disorientation

A potent current theory of how orientation in space is organised proposes that somatosensory and visual signals of body movement are referenced to vestibular signals of orientation and movement of the head in space [9,10,11]. This is sensible, even necessary, in terms of the physical properties of the senses since vision and somatosensory inputs give relativistic information; on the basis of a visual signal of motion or somatosensory signals of force or changing position one cannot determine how much oneself or the external object or contact surface is moving. In contrast, vestibular signals render self motion in space. Given this parameter one can interpret other sensory input and apportion relative amounts of self and object motion.

In order to explain susceptibility to disorientation a further key factor should be considered; the vestibular system needs calibrating [12]. Its gain and phase settings are highly plastic at both the level of perception and reflex motor functions (see appendix for a detailed account of vestibular plasticity). The problem arises in that calibration is referenced back to visual and somatosensory input. This threatens circularity and all the problems of circular reference, including ambiguity and instability. Most features of a simple world without machines are stable so that the vestibular system maintains appropriate calibration. In a world involving vehicular transport the potential ambiguity of sensory cues to motion increases so that when a subject is disoriented he may find it difficult to establish stable features to which he can ‘anchor’ his perceptual estimates. Once this inherent ambiguity is recognised it is difficult for the sufferer to return to his naïve state of perceptual certainty, in part because instability is the true nature of the world and he finds himself in a state of chronic susceptibility to disorientation. Things are made worse if there is also a disorder such as a vestibular lesion because the subject finds greater difficulty in establishing a reliable frame of reference.

The key which unlocks the escape route from the vicissitudes of circular reference is the perception of what is stable and reliable in the world. This is attained through identifying reliable, invariant patterns in the consequences of our actions. This is classical 'Gibsonian ecological psychology' [13]. Unfortunately, before resolution of perceptual uncertainties is achieved a final pitfall threatens. Because of its teleceptive and panoramic attributes the obvious perceptual route to which we would tend naturally to have first recourse in any attempt cognitively to identify stable referents in the world is vision. Hence the patient who is challenged by some experience of disorientation tends to become visually dependent [15-18] and such tendency is probably enhanced if the observer was initially, already visual dependent [19] (eg susceptible to making errors of the visual vertical against a tilted frame or rolling background). The pitfall is that vision is arguably the most potent source of illusory motion; viz railway train illusions, waterfall illusions, parallax illusions, induced motion illusions, orientation illusions such as the "tilted" landscape seen from a tilting train [20]. Accordingly the visually dependent patient also begins to experience, and suffer from, visual vertigo. The patient originating idiosyncratically as a visually dependent subject is doubly jeopardised.

Reconciliation in therapy

Our 'model' for rehabilitation of disorientation assumes the following sequence of events.

i) An episode of disorientation or a sensory impairment causes dysfunctional behaviour in an intrinsically unstable ambiguous environment.
ii) The subject finds difficulty in re-establishing a working algorithm for interpreting sensory inputs (eg compensating gains and asymmetries; re-establishing rules of reference between somaesthetic and vestibular signals). This process is at an unconscious level but is manifest in consciousness as a feeling of disorientation or detachment.
iii) They recourse to a cognitive appraisal of world events: acting and perceiving consequences.
iv) The first choice of sensory input for evaluating the environment is vision which may be the worst choice in a complex environment because of visual relativism; eg causing vection illusions; visual vertigo. The longer symptoms remain untreated the more patients suffer visual vertigo.

The only resolution of the problems arising at stages (ii) and (iv) is cognitive reappraisal of environmental stability. Therapy should comprise cognitive behavioural therapy incorporating desensitisation to motion and commencing with simple stable structured environments.

Appendix

Evidence that vestibular system 'gains' are highly plastic and calibration is referenced to the other sensory inputs and cognition. Canal signals probably rely on vision and input from the neck for calibration [21,22]. The otoliths may use vision and multiple sources of somatosensory signals for reference. The calibration 'gain' and offset of otolith and canal signals may change quickly: eg, the gain of vestibular-ocular reflexes can adjust in seconds to spectacle corrections [23] or to contextual somatosensory input [24,25] and asymmetrical gains may be induced by manipulation of external visual motion [26]. Many normal subjects in the dark have offsets in the resting activity from their semi-circular canals [27,28]. Divers underwater who must rely on otolith signals to verticality become disoriented [29,30]. Vestibular 'perception' of self motion is highly plastic being subject to context, sensory input and mental set [31-37]. Finally, even vestibular 'reflex' gains are influenced markedly by cognitive 'set' [38,39].

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