Correspondence

Trains with a view to sickness

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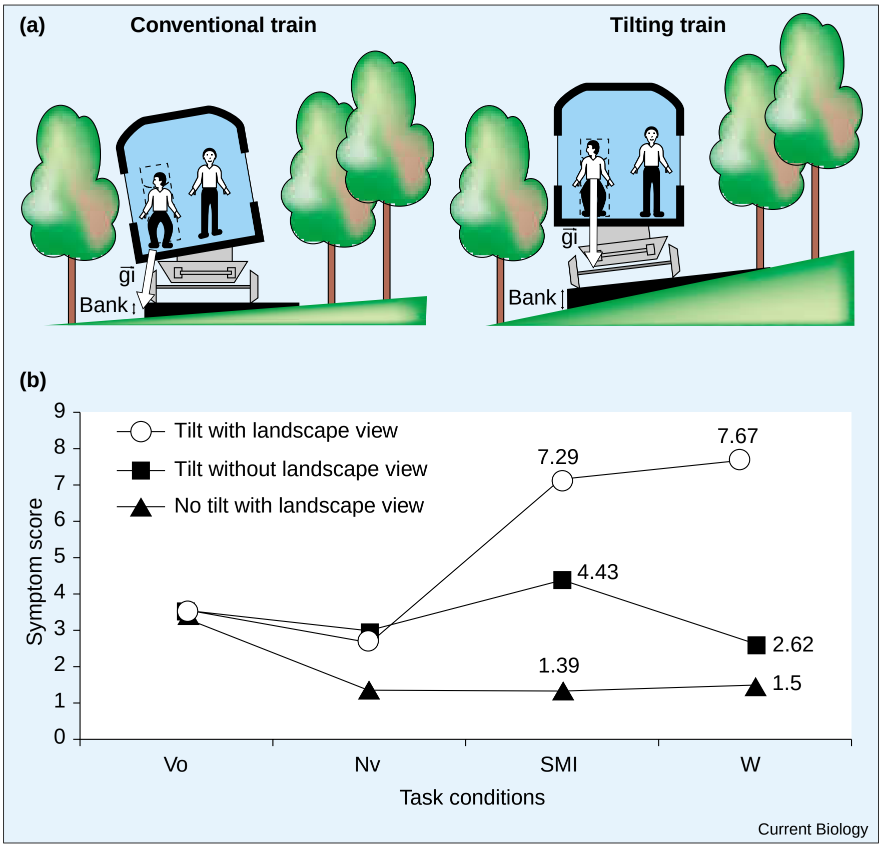
We report the findings of a pan-European study on the factors which provoke motion sickness on tilting trains. The findings also highlight tactics passengers may use to ameliorate their malaise.

Some readers may recall that the tilting train programme under development in the UK some 30 years ago was halted because of a combination of technical problems and reports of high levels of motion sickness which were not subject to a scientific study at that time. Currently, there is limited use of tilting trains in France and Italy but their imminent widespread deployment throughout Europe, scheduled for 2002 in the UK, threatens the situation that unacceptable numbers of passengers may become ill. Whereas passengers are rarely motion sick on conventional trains [1], it is estimated that between 5% and 30% may become sick on tilting trains [2].

The symptoms develop specifically on winding tracks when the compensatory suspension maintains the coaches inertially upright (Figure 1a). Our study investigated features of tilting trains that provoke motion sickness and identified how passengers may protect themselves. The particular aspects of train motion selected for study were suggested from established features of motion sickness which suggested that provocative situations may develop when the coach tilts inwards on curves to align with the inertial vertical ‘gi’ (Figure 1a). Firstly there is a provocative conflict [3] that the passenger feels upright whereas the external scenery appears to tilt; a phenomenon known to be nauseogenic. Secondly, as in an aeroplane during banking, when rounding bends the passenger feels only a variation of gi intensity, mixed

Figure 1



(a) Illustration of what a passenger may perceive on tilting versus conventional trains when rounding a bend at speed. In a tilting train the coach tilts inwards on the curve so that the passenger perceives that he and the coach remain approximately aligned with the inertial vertical, gi. Thus the passenger feels upright and the coach also looks to be upright, whereas the external landscape appears to tilt – when looking outwards from the curve the horizon appears to tilt downwards. Consequently the passenger experiences an inertial–visual as well as a visuo–visual conflict. This is not the case in a conventional train which tilts outwards on bends. A passenger looking outwards from the curve may observe that the horizon tilts appropriately upwards as he perceives he and the coach tilting outwards. **(b)** The graph shows the findings of the study which was performed on both conventional (no tilt) trains and trains with active suspensions which compensated for 60% of tilt from earth upright of gi. On both types of train the following behavioural conditions were dispensed. Journeys were undertaken in a lit coach both with and without a view of the landscape. Subjects behaved at will throughout the journey or performed tasks: sitting still blindfolded, Vo; sitting still with vision, Nv; map interpretation with scanning and writing, SMI; walking about on the train, W. Each task lasted 20 min with 10 min rest intervals. Conditions were dispensed in a balanced within-subjects design and task sequences rotated between subjects. The graph shows the key results to understanding tilting train sickness which are the comparative sickness scores with different tasks. The interaction ‘train conditions by activities’ is significant at p = .008 (F 6/114 = 3,081). A full description of the study is available in Neimer *et al.* [5].

with marked roll motion which may induce an 'otolith–canal conflict'. (Otoliths are directionally sensitive inertial force detectors of the balance organs of the inner ear which can signal tilt from the inertial upright; canal refers to the directionally sensitive semicircular canals of the organ which signal angular velocities of the head and therefore indicate roll motion of the coach.) In addition, whole body movements, particularly those made during faster motion on tighter corners, could cause unusual 'coriolis' stimulation of the labyrinth, inducing vestibular-vertigo [4].

Participants methods

The study involved test rides over winding track in two distinct mountainous regions (Massif Central and Alps) where tilting trains could increase their speed on curves up to 30% — 156 km/h instead of 120 km/h speed limit for conventional trains. Journeys were undertaken in both a conventional train and in a tilting train. The passengers studied were 21 volunteers, 10 male, 11 female, aged 24–56 years with an even distribution of motion sickness susceptibilities on questionnaire assessment [5]. On each journey subjects were given tasks varying from quiescence to walking about (Figure 1b). After each task, motion sickness symptoms of headache, pallor, sweating, somnolence, vertigo and nausea were rated on a simplified version of the Graybiel scale [6] and scores were accumulated.

Provocative factors and individual susceptibility were also evaluated in laboratory studies. Half of the subjects exhibited a high sensitivity to motion sickness induced in the laboratory by continuous whole body rotation about an 15° earth-tilted axis in the dark (OVAR) and also by exposure of the seated subject to a visual field which rotated obliquely about an axis which was tilted 45° from the vertical (O-OKS). Susceptibility to spatial disorientation was also assessed with the Rod and Frame Test (RFT) in which a luminous rod is set to earth vertical against a surrounding frame which is tilted misleadingly.

Results

Incidence of sickness was low when subjects remained seated and still and rose when interpreting a map (Figure 1b). The short periods of walking about were highly provocative of sickness: 5 subjects (and 1 technical staff) vomited, of whom 3 were completely disabled. However, even when walking about, exclusion of the view of the landscape suppressed sickness to below the levels obtained when subjects were seated and interpreting a map (Figure 1b). The protection afforded by excluding a landscape view together with the low levels of sickness obtained in blindfold subjects (Figure 1b) indicate that the primary source of motion sickness on the tilting train is visual conflict.

The levels of motion sickness which developed in the tilting train were predicted by the sickness triggered by OVAR which provides a sinusoidally modulated, primarily otolith stimulation (Bravais–Pearson $R > 0.53$, $p < 0.05$ for tilt with landscape and $R = 0.6$, tilt without landscape). The motion sickness which was induced for tilt with the landscape view was predicted by the levels of motion sickness provoked by O-OKS (visual stimulation) ($R = 0.75$, $p < 0.05$) and by the amount of disorientation in the RFT ($R = 0.65$, $p < 0.05$). The RFT has a similar geometric configuration to the relative tilt between the gi-upright cabin and landscape and thus may reflect a specific sensitivity to the conflict between the visual references of the cabin and landscape (Figure 1a). Its specific predictive value for tilting train sickness could be considered in railway personnel selection.

Comment

The study showed that nausea and vomiting on tilting trains is provoked primarily by exposure to a view of the external, tilting, landscape and removal of this perceptual conflict protects against the development of motion sickness. Susceptible passengers on the tilting train should be advised that sickness might be avoided by pulling the blinds and sitting quietly.

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