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Health

Prone to motion sickness? Your sex, diet and shoe size may be to blame

We are finally solving the mystery of why motion can make us queasy – just in time to help us deal with nausea-inducing VR headsets, driverless cars and space tourism

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IT STARTS behind your eyes, a niggling ache that heads down towards your stomach where it tumbles and turns before building towards a climax of vomit. Bleurgh! Motion sickness.

This has been a human affliction pretty much since we began travelling on anything but two legs. Most of us have experienced it, and it is likely to become even more prevalent when we all become passengers as driverless cars 🔗 /article/mg23531335-600-uks-first-public-autonomous-taxi-trial-to-begin-soon/ roll out, space tourism 🔗 /article/2182116-are-virgin-galactic-and-richard-branson-really-going-to-space-soon/ takes off and virtual reality headsets take over, both in the gaming industry and, increasingly, for virtual meetings. Even before covid-19, environmentally conscious businesses had started adopting VR technology to bring international clients together.

Motion sickness is clearly related to the movement of our body and head, but why this results in nausea has been a long-standing mystery. Now, however, evidence from brain imaging and genetics is helping scientists get to the bottom of it – as well as suggesting new ways to solve the problem. It turns out that there is far more to motion sickness than you might think. Your genes, gender and diet all have an influence. It might even come down to your foot size.

The word nausea derives from the Greek for "ship". But motion sickness goes way beyond the odd queasy sailor. Seasickness has had a big impact on history 🔗 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5378784/, influencing the outcome of several military conflicts, from the battle of the Red Cliffs, which marked the end of the Han dynasty in ancient China to the defeat of the Spanish Armada by the English in 1588. And, of course, motion sickness isn't confined to the high seas. There are reports of ancient Greeks and Chinese feeling nauseous while being carried aloft in Sedan chairs or travelling by horse and buggy. Their solutions included fasting, drinking the urine of young boys and hiding earth from the kitchen hearth in their hair.

Today, there are more ways to induce motion sickness than ever. One in three of us easily succumb, another third will experience it in rough seas or on a roller-coaster. Nobody is completely immune. We aren't the only species affected, either: cats, dogs, even a variety of birds and fish feel it 🔗 https://www.ncbi.nlm.nih.gov/pubmed/23000611. In fact, the only animals that don't are those without a vestibular system.

A new idea about motion sickness can explain why car passengers are more likely to feel nauseous than drivers

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This gives us our first clue as to what the cause might be. The vestibular system is a delicate assemblage of structures within the ear that detects motion (see diagram). It includes three semicircular canals filled with fluid that sit at right angles to one another. As the fluid sloshes around, the system sends signals about rotational movement to two places. The first is the brain's cerebellum – the region responsible for balance and movement – and the other is the brainstem, which links the brain to the rest of the body and includes areas that trigger nausea and vomiting. The vestibular system also transmits signals to the eyes, which stop the world from blurring as we move our head.

Early ideas about motion sickness put it down to overstimulation of the vestibular system https://www.ncbi.nlm.nih.gov/pubmed/12962599. However, if that were true, why would sailors experience nausea after returning to land? Why don't we suffer motion sickness when jumping around on a dance floor? And why is the driver of a car less likely to feel sick than the passengers?

Attempting to address such anomalies, a second idea posits that motion sickness results from conflict between different kinds of sensory information 🔗 https://pubmed.ncbi.nlm.nih.gov/30699041-the-neural-basis-of-motion-sickness/?from_term=sensory+conflict+motion+sickness&from_pos=8. When you read in a car, for example, your vision of the book and the dashboard tell your brain that you are stationary, but with all the bumps and turns, your vestibular system is convinced you are moving. These conflicting signals make it difficult for the brain to create a coherent sense of balance, which triggers nausea.

Something unexpected

This "sensory-conflict" idea has problems, too, however. If a novice and a seasoned sailor stand on the same deck, for example, they receive the same sensory signals but have different levels of nausea. There is a third possible explanation for why. Rather than resulting from conflicting signals between your eyes and ears, this idea frames motion sickness as a conflict between these signals and what your brain expects to happen 🔗 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1436193/.

This is the idea 🔗 https://www.nrcresearchpress.com/doi/abs/10.1139/y90-044?journalCode=cjpp#.XclDuJP7RE4 embraced by Charles Oman at the Massachusetts Institute of Technology. In 1990, he argued that when you make a movement, your brain subtracts the actual sensory input from the expected pattern of neural activity, and what's left is a "sensory-motor conflict signal". This is generally small, but it spikes when an unexpected obstacle or motion is encountered, resulting in a corrective response from the brain's motor systems. You then rebalance yourself and the conflict is extinguished. However, if the conflict signal is stimulated over a longer period, it triggers motion sickness.

This would explain why we don't feel nauseous when we jive around a dance floor, but do when we are swayed by high seas. It also explains why sailors get motion sickness on dry land – their sensory expectations don't fit with the stable environment. It even explains the mysterious immunity bestowed on the driver of a vehicle: being in control gives you more accurate expectations of your movements. There was just one problem with Oman's idea – nobody could find evidence for it in the brain. The required network of neurons was missing.

"Why don't we experience motion sickness when jumping around on a dance floor?"

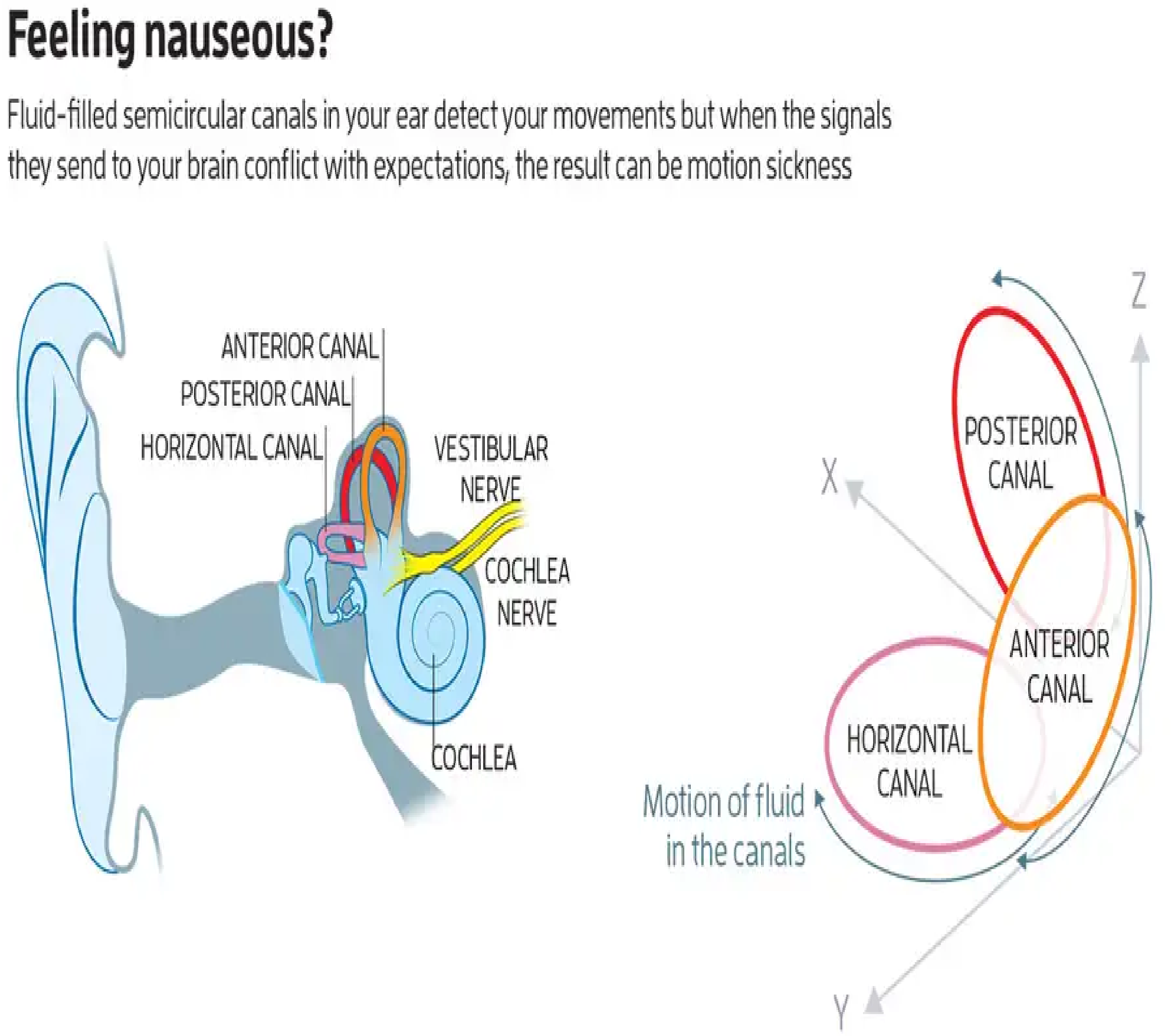
Meanwhile, Thomas Stoffregen, now at the University of Minnesota, had another idea. His research, measuring the subtle movements that people make to maintain their balance at sea, led him to believe that an inability to control our posture is to blame https://www.tandfonline.com/doi/abs/10.1207/s15326969eco0303_2. His studies also indicated a simple solution to motion sickness https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0066949: when sailors increased the width of their stance, making them more stable, they felt less nauseous.

Ginger stimulates the vagus nerve, which may explain why it can reduce nausea
Getty Images/Design Pics RF

The debate looked set to continue. Then, Kathleen Cullen, now at Johns Hopkins rsity in Baltimore, inadvertently discovered Oman's missing neurons //www.nature.com/articles/nn.4077. Her team had trained monkeys to move in a specific way to get a treat. Occasionally, the researchers would disrupt this movement – by placing a weight on top of the animal's head, for instance – causing a mismatch between the animal's expected and actual head motion. When this happened, there was a spike in the activity in some neurons in the cerebellum, cells that didn't seem to be active when the animal generated its own movement. "It suggests that the cerebellum can perform this amazing computation within a millisecond, in which it compares an internal model of sensory expectation based on prior experience with actual sensory information," says Cullen. Now her team has shown that when an animal subsequently adapts its movement, the internal model is updated 🔗 https://www.sciencedirect.com/science/article/abs/pii/S0960982219308516 and the neurons stop firing.

"I was startled when I saw their work," says Oman. "These neurons arguably play the critical role in motion sickness." But one piece of the puzzle is still missing, he says. Neurons are known to project from this region of the cerebellum to areas of the brainstem that trigger nausea. "It would be a clincher if we could establish that they are the same neurons Cullen's lab has been studying," he says.

Despite this progress in understanding motion sickness, questions remain about why some people are more prone to it than others. Why, for example, do female sailors seem more likely to be affected 🔗 https://www.ncbi.nlm.nih.gov/pubmed/10052571 than male ones? And why do women, especially pregnant women, consistently report more symptoms of motion sickness during VR experiments than men?



One possible explanation for this sex divide rests on a decades-old idea about why motion sickness exists at all. Vomiting is a handy reaction to ingesting bad food, but what is the purpose of being sick in reaction to movement? "Motion sickness is so physically disabling that if there were no positive reason for its presence, natural selection should have acted strongly to eliminate it," says Michel Treisman at the University of Oxford. Such thinking led him to suggest that it is a side effect of our robust reaction to poison 🔗 https://www.ncbi.nlm.nih.gov/pubmed/301659: the network involved in keeping us balanced is an ideal early warning system for detecting the unbalancing effects of toxins. Unfortunately, anything else that makes us unbalanced has … me result. If so, it would be beneficial for women to have a lower threshold for motion sickness so that, when they are pregnant, the fetus has increased protection from toxins.

It's in the balance

Stoffregen's research suggests 🔗 /article/2115648-posture-could-explain-why-women-get-more-vr-sickness-than-men/ another explanation for why women are more prone to motion sickness than men. "They have different distributions of body mass," he says. "Women carry weight lower in their hips and have smaller feet even when compared with men of similar height." As a result, women may be less physically stable, he says, so find it harder to balance when faced with unexpected movements.

Genes also seem to play a role. In 2015, consumer genetic analysis company 23andMe conducted the first genome-wide study on motion sickness in some 80,000 people and found 35 sections of DNA associated with the condition 🔗 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4383869/. The genes involved are related to the development of the eye and ear, and to glucose regulation – women who have particular versions of them are up to three times more prone to motion sickness than men who have them. How the genes influence motion sickness isn't known, but people who experience more motion-induced nausea tend to have lower levels of insulin than those who don't get sick. Because insulin helps us stabilise glucose levels in the body, the researchers suggest that stabilising glucose through your diet – by eating plenty of vegetables, fruits and whole grains, for example – might help to keep motion sickness at bay.

"Why do women report more symptoms of motion sickness in VR experiments than men?"

Closing the case on what causes motion sickness and why some people are more susceptible might lead to new pharmacological targets. Currently, the most effective drug 🔗 https://academic.oup.com/jtm/article/9/5/251/1854411 for it is called scopolamine, which works by blocking chemicals that transmit information from the vestibular system to nausea centres in the brain. However, it can cause dry eyes, drowsiness, headaches, palpitations and urinary retention. Antihistamines work too, and probably in a similar way, but they also have side effects.

Regardless of what might be making you susceptible, there are other things you can do to reduce sensory conflict that leads to nausea. Oman recommends staring at the horizon 🔗 https://journals.sagepub.com/doi/abs/10.1177/0956797610392927 to help synchronise visual information with motion, and keeping your head and body as still as possible to limit unexpected external forces. "Soldiers flying in transport planes found that strapping their head against the seat reduced their sickness," he says. Habituation training also works 🔗 https://www.ncbi.nlm.nih.gov/pubmed/26452639. Just as sailors eventually get their sea legs, so prior exposure to the sorts of motion you are likely to experience while travelling can reduce your chances of becoming seasick.

Few other traditional remedies have been tested. "Some people swear by things like pressure bands [worn on the wrist]," says Oman. "There's no good evidence for them, but any clinician will tell you that placebos can be useful." There is evidence the placebo effect alone can reduce motion sickness 🔗 https://www.ncbi.nlm.nih.gov/pubmed/12962599. "When I meet sailors who swear by these things, I say 'if you believe in it, do it'," says Oman.

Some ideas do have a little evidence behind them. Studies suggest that ginger can reduce nausea during pregnancy and chemotherapy, and although the jury is out 🔗 https://www.ncbi.nlm.nih.gov/pubmed/2062873 for motion-induced sickness, ginger activates the vagus nerve 🔗 /article/mg21929252-200-vagus-thinking-meditate-your-way-to-better-health/ – which runs between the brain and gut and controls aspects of nausea – and there is evidence that vagal nerve stimulation 🔗 https://clinicaltrials.gov/ct2/show/NCT02177890 can reduce motion sickness. Adam Farmer 🔗 https://www.linkedin.com/in/adam-farmer-49525438/?originalSubdomain=uk at Queen Mary University of London found this when he fitted volunteers with an epilepsy device called NEMOS – an earphone containing two electrodes that stimulate the vagus nerve as it passes behind the ear. Another way to stimulate the vagus nerve is by breathing slowly and deeply. This simple measure has been found to successfully decrease motion sickness 🔗 https://www.ncbi.nlm.nih.gov/pubmed/25280524.

Standing with a wide stance and staring at the horizon are two ways to reduce seasickness
piola666/Getty Images

The latest idea is a wacky-looking pair of glasses, which are claimed to stop motion sickness https://academic.oup.com/jtm/article/9/5/251/1854411 in 94 per cent of users. "Seetroën" spectacles, produced by carmaker Citroën, feature four rings – two framing the eyes and one at each side of the head – half-filled with a coloured liquid. "The liquid moves in the same way as the liquid in the inner ear," says Antoine Jeannin, CEO of Boarding Ring, the company that developed the glasses. "It's like a visual inner ear, which helps reduce sensory conflict." Jelte Bos at Vrije University in the Netherlands thinks it is a nice seasickness idea. But the glasses only give information about two of the three planes of motion, he adds. "So I'm a little bit sceptical," he says.

In future, the best solution for motion sickness might not be a pill or ginger or a pair of special glasses. There is a growing realisation that we need to improve the technologies that make us nauseous in the first place (see "Sexist technology"). "We don't design the oceans, but we do design VR and driverless cars," says Stoffregen. "We can't be held responsible for seasickness, but we are damn well responsible for the technology we ."

Sexist technology

Motion sickness is predicted to become more widespread with increasing use of nauseainducing VR headsets in gaming and for business meetings. Part of the problem is their size. Bas Rokers at the University of Wisconsin–

Madison has found that the lenses on the average VR headset are too far apart to work properly for the eyes of 5 per cent of men and 90 per cent of women, and that this results in **greater risk of nausea** **https://www.biorxiv.org/content/biorxiv/early/2019/01/11/488817.full.pdf**. "The technology is sexist," says Thomas Stoffregen at the University of Minnesota. "VR can be up to four times more nauseating for women."

Even a perfectly fitting headset can cause queasiness. This needn't be a "necessary evil", says Rokers. The technology could identify when users start to move their head more – a sign that they are starting to feel sick – and pause the game. It is also possible to help people adjust to the cues that make them nauseous by introducing these more slowly.

The easiest solution is to get rid of the most nausea-inducing aspects of an image altogether. Unfortunately, this involves reducing the image contrast. "The irony is that this makes the display worse," says Rokers. "It creates a tension between the engineers who want to make things look as good as possible, and the vision scientists who want to make VR more tolerable for more people."