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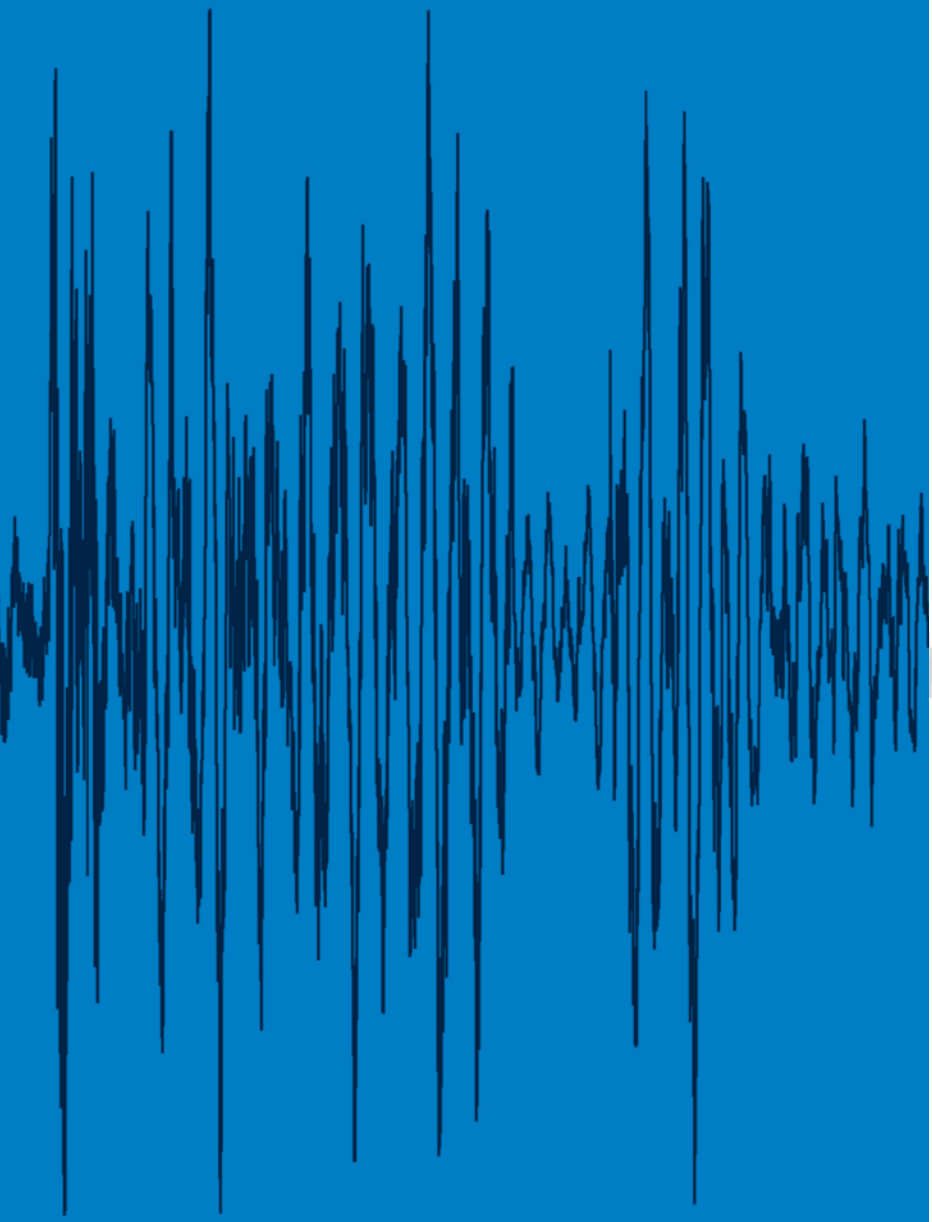

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Possible psychological mechanisms for "wind turbine syndrome". On the windmills of your mind

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Abstract

Throughout history, people have suffered from physical symptoms that they have attributed to modern technologies. Often these attributions are strongly held, but not supported by scientific evidence. Symptoms attributed to the operation of wind turbines (called "wind turbine syndrome" by some) may fit into this category. Several psychological mechanisms might account for symptoms attributed to wind turbines. First, the "nocebo effect" is a well-recognized phenomenon in which the expectation of symptoms can become self-fulfilling. Second, misattribution of pre-existing or new symptoms to a novel technology can also occur. Third worry about a modern technology increases the chances of someone attributing symptoms to it. Fourth, social factors, including media reporting and interaction with lobby groups can increase symptom reporting. For wind turbines, there is already some evidence that a nocebo effect can explain the attributed symptoms while misattribution seems likely. Although worry has not been directly studied, research has shown that people who are annoyed by the sound that turbines produce are more likely to report symptoms and that annoyance is associated with attitudes toward the visual impact of wind farms and whether a person benefits economically from a wind farm. Given that these mechanisms may be sufficient to account for the experiences reported by sufferers, policy-makers, clinicians and patients should insist on good-quality evidence before accepting a more direct causal link.

Keywords: Annoyance, expectations, nocebo effect, symptoms, wind turbine

Introduction

Throughout history, physical symptoms have been attributed to the introduction of new technologies. Wind turbines are the latest technology to be implicated.[1-4] Some have argued that symptoms can be caused by a direct effect from the infrasound produced by wind turbines,[5] a mechanism that is contentious.[6-8] A case definition for "wind turbine syndrome" has also been proposed[5] typified by symptoms that come and go depending on proximity to a wind turbine. In this review, we describe psychological mechanisms which might adequately account for the symptoms some people attribute to wind turbines without needing to invoke a direct effect of infrasound.

Methods

We searched Medline for papers containing the search terms (wind farm or wind turbine or infrasound) and (psych* or nocebo or worry or annoyance or misattribution or personality). This identified only 10 relevant papers. As well as discussing these, we have therefore generalized from the wider literature on the psychological mechanisms underlying symptoms attributed to environmental stimuli.

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"Wind turbine syndrome" and its historical context

The attribution of symptoms to wind turbines has been made by some of the residents who live close to some wind farms and by some research teams who have suggested that people who live close to a wind farm are more likely to report symptoms than people who live further away.[1-3] The symptoms that have been reported are diverse. At the time of writing, 223 separate adverse reactions are known to have been attributed to wind turbines, ranging from physical symptoms such as headache and fatigue, to reproductive and behavioral problems in livestock.[9]

In most instances, the noise produced by wind turbines as they operate has been suggested as the likely cause of the symptoms. Two main mechanisms have been discussed in relation to how a technology that generates noise can affect health.[10] The first is an "indirect" pathway whereby a noise may disturb sleep or cause stress or annoyance in some people, which in turn may result in other health effects. The second is a "direct" pathway, which does not involve

intervening psychological processes. In the case of wind turbines, proponents of a health effect have argued that not only do indirect effects occur, but that direct effects resulting from the infrasound produced by wind turbines also exist. Infrasound is sound that occurs at frequencies that are usually below the limit of human hearing, leading some to suggest that "what cannot be heard therefore may produce [adverse health effects]".[5] However, other experts who have reviewed this area have concluded that there is no clear physiological mechanism to explain how exposure to the infrasound from wind turbines might trigger adverse health effects.[6-8]

The case definition proposed for "wind turbine syndrome"[5] lists three criteria which can be used to identify people whose health has been affected by a wind turbine. To fulfill the first criterion, people must: Live within 5 km of a wind turbine, have experienced an "altered health status" since their exposure to it; experience amelioration of their symptoms when more than 5 km away from the turbine; and experience recurrence of their symptoms when they return. The second criterion requires that people experience at least three of the following which have occurred or worsened since the wind turbine began operating: Compromised quality of life; sleep disturbances; annoyance which produces increased levels of stress or distress; and a desire or preference to leave their home temporarily or permanently for sleep restoration or well-being. To fulfill the third criterion, at least three out of 18 other possible symptoms must have occurred or worsened since the operation of the wind turbine began (e.g., dizziness, anger or fatigue). The author of the definition also suggests that other stressors should be ruled out as possible explanations, specifically the presence of the wind itself, a stressful home environment and the presence of a mood disorder. In each case, however, he suggests that these alternative explanations would not explain why symptoms occur after the establishment of a wind farm and/or why they improve when time is spent away from the wind farm. According to the author "there are few, if any, alternative explanations" for how people could meet the case definition other than by an effect of wind turbines on their health. In our opinion, this is contentious.

Claims such as these are nothing new. Mysterious physical symptoms, ill-health in crops and livestock and adverse changes in the environment have often been attributed to the introduction of new technologies. Early examples include episodes of "persistent collapse" among workers in newly introduced cotton mills in the North of England during the 1780s that required treatment with reassurance that "the symptoms were merely nervous, easily cured and not introduced by cotton";[11] neurasthenia, a diagnosis given for fatigue-related conditions in the late 1800s that was seen as being caused by "steam power, the periodical press, the telegraph, the sciences, the mental activity of women and the erosion of religious faith";[12] fear in the late 1880s that early telephones produced "aural overpressure" causing "nervous excitability, with buzzing noises in the ear, giddiness and neuralgic pains";[13] concerns during the 1910s and 1920s that the proliferation of early radio signals were triggering outbreaks of nausea[14] and affecting weather patterns;[15] and reports in the 1980s, predominantly from Scandinavian workers that the visual display units that had been recently introduced into workplaces were causing skin problems and other subjective symptoms, reports that could not be validated by experiments over the subsequent 20 years.[16] As technology developed, these fears faded, only to be replaced by concerns about newer technologies. One contemporary example is "electrosensitivity," a condition in which sufferers report symptoms in connection with exposure to one or more everyday sources of weak electromagnetic fields such as mobile phone signals or Wi-Fi. Although this is a common condition in some countries, the results of experimental studies are broadly consistent.[16-20] People who report having electrosensitivity do indeed experience symptoms when exposed to electromagnetic fields, but only when they know that they are being exposed. No effects are apparent when exposures are repeated under double-blind conditions. A similar situation exists for other self-reported intolerances to everyday environmental exposures. For example, in the UK, around 20% of the population believe that they have some form of intolerance or allergy to particular foods or food additives.[21] In Germany, it is 35%.[22] Yet double-blind experiments testing large numbers of people who report food intolerance or allergy[21,22] have managed to verify adverse reactions in only a fraction of these people, leading to estimates that the true levels of food allergy or intolerance are 1.8% and 3.6%, respectively. Other conditions such as "multiple chemical sensitivity"[23] are similarly controversial, with sufferers often failing to react to chemical exposures during double-blind tests. For these conditions, it seems likely that the many of the symptoms reported are triggered by psychological mechanisms including nocebo effects, misattribution of symptoms and the role of negative emotions. It is possible that the same is true for "wind turbine syndrome."

Nocebo effects

Physicians have long known that administering an inactive or bogus treatment can improve a patient's well-being and provide relief from their symptoms. Impressive responses to inert "placebo" treatments have been observed for many forms of outcome across a broad range of clinical disorders. Several mechanisms have been implicated, though perhaps the best supported is the role of expectations. Many studies have demonstrated that when patients are led to expect a reduction in their symptoms following administration of an inert substance, the strength and type of their expectations can determine the effects of the treatment. Most commonly, these expectations are imparted explicitly. For example, simply telling people that a drug has been shown to reduce pain can dramatically reduce the level of pain that participants feel.[24]

Expectations can also form when people observe implicit indicators about whether and how a treatment will work. For example, observing that a sham treatment appears to reduce pain for other people can result in the treatment subsequently producing impressive placebo effects for you,[25] while expectations arising from our implicit knowledge of what is normal in our culture means that blue sleeping pills produce a stronger sedative effect than the same medicine colored orange.[26]

Nocebo effects are the logical flipside to placebo effects. Just as an expectation of benefit can be self-fulfilling, so too can an expectation of harm. Most commonly nocebo effects have been reported during double-blind clinical trials of new drugs, in which patients who are randomly allocated to receive an inert pill not only often report the beneficial effects of the genuine drug being tested in the trial, but around a quarter of them also report the side-effects associated with it[27] which they have typically been warned about in the accompanying study information leaflet.[28]

Many of the phenomena associated with placebo effects are also apparent for nocebo effects. Expectations, for example, are known to be important determinants of whether a nocebo effect will develop and can be induced simply by telling someone that a pill, procedure or exposure is harmful.[29] And although nocebo effects have been most studied in relation to medical interventions, they also occur in many contexts outside of the clinic. In particular, studies have demonstrated that symptoms associated with various forms of medically unexplained intolerance can be triggered by the belief that one is being exposed to the stimulus in question. Thus, people who report electrosensitivity have been found to experience their normal electrosensitivity-related symptoms after exposure to a fake mobile phone that they are told is emitting a signal[30] while double-blind tests of other forms of intolerance and allergy have also found that sham exposures can be sufficient to trigger severe reactions.[23,31,32] Such effects are also regularly found in real world settings.[33-36]

These effects are not only seen in people already suffering from a medically unexplained intolerance. People who have not yet developed the disorder can also be manipulated into developing symptoms following exposure to innocuous stimuli.[37-39] A series of experiments by Van den Bergh *et al.* has taken this a step further by testing whether a nocebo effect can become self-perpetuating.[40] By presenting healthy participants with a chemical odor and allowing them to breath in air enriched with carbon dioxide (which produces sensations such as fast breathing and headache), they showed that the participants quickly "learned" to associate the smell with the symptoms so that presenting them with the smell alone was soon sufficient to trigger their symptoms. These effects could be replicated when a thought, rather than a smell, was paired with the carbon dioxide. The association between the smell and the symptoms was persistent: A delay of a week did not affect the reproducibility of the effect. The symptoms also showed signs of starting to spread: those learned in response to one odor could also be triggered by other, similar smells. This paradigm, repeated across multiple studies, provides insight into how someone can develop intolerance to a set of related innocuous stimuli.

Given all this, nocebo effects would seem plausible as an explanation for many of the acute symptoms that people attribute to wind turbines and two recent experiments provide evidence that this may be the case. In the first, Crichton *et al.* randomly allocated 54 healthy volunteers to view television footage containing either first person accounts of symptoms attributed to wind farms (a "high expectancy" condition) or evidence from scientific experts stating that wind farms do not cause symptoms (a "low expectancy" condition).[41] Participants were then exposed to 10 min of infrasound (40 dB at 5 Hz) and to 10 min of a sham condition involving no infrasound. Participants were told, falsely that both sessions involved infrasound. Before and after each exposure, participants completed measures of 12 symptoms. No differences were found in symptom occurrence or intensity between the infrasound and sham conditions. However, participants in the high expectancy group experienced significantly more symptoms and a significantly greater intensity of symptoms than those in the low expectancy group. In the second study, the same team used a similar paradigm to test whether a negative portrayal of wind turbine-related infrasound might trigger increased symptom reporting while a portrayal of infrasound as having therapeutic effects might have the opposite effect. These hypotheses were largely supported: 77% of healthy volunteers who watched media footage of the possible negative health effects of wind turbines subsequently reported a worsening of their symptoms after experimental exposure to infrasound, while 90% of those who watched media footage which framed infrasound as a naturally occurring phenomenon reputed to have beneficial effects reported an improvement in symptoms following exposure.[42]

Misattribution of symptoms

While nocebo effects offer a good explanation for symptoms which occur rapidly following exposure to a stimulus, what about people with more chronic symptoms? Misattribution of symptoms that existed prior to a modern technology being encountered, or which have developed subsequently but for coincidental reasons, may be one explanation.

Even in the absence of a contentious environmental exposure, symptoms are common among the general population. Ihlebaek *et al.* surveyed 1240 Norwegians and asked about symptoms experienced in the last 30 days.[43] Only 4% had not experienced any symptom. Musculoskeletal pain (reported by 80% of the sample), pseudoneurological complaints (65%) and

gastrointestinal problems (60%) were most commonly reported. Similarly, when Eriksen *et al.* surveyed 4046 Scandinavians and asked about the presence of 10 specific symptoms in the past 30 days, 75% reported experiencing at least one of the symptoms.[44] And this high prevalence of symptoms is by no means restricted to modern Western populations — a survey of 221 aboriginal Mangyans from remote rainforest communities in the Philippines found that 100% of them reported at least one symptom in the past 30 days.[45]

Not only are symptoms common, very often they are not associated with any known biomedical cause. Among the minority of people who seek medical care for their symptoms, around a third will receive no adequate explanation from their physician.[46] Despite this, many people have an understandable need to find an explanation for their symptoms, particularly where the symptoms are troublesome or long-lasting. In one study of patients attending a neurology clinic in Edinburgh, the label "medically unexplained" was perceived as unacceptable and even offensive by a third of patients, who felt it carried an implication that their symptoms might be imaginary or feigned.[47] When a new environmental exposure occurs it is therefore natural for people who subsequently experience medically unexplained symptoms to consider whether the exposure might be responsible.

This effect can also result in people relabeling pre-existing symptoms as having been triggered by the exposure. Studies which have tracked the health of people over time suggest that this can be the case. For example, Petrie *et al.* asked 292 residents of West Auckland to complete a questionnaire 10 weeks before and 3 months after a controversial insecticide was sprayed over the area to combat the spread of a newly introduced caterpillar. One of the strongest predictors of whether people went on to attribute symptoms to the spraying was whether they had reported a higher level of symptoms before the spraying began.[48] This effect has also been found in other contexts.[49,50]

It is not just unexplained symptoms that can be misattributed to modern technologies or controversial interventions. Symptoms which are caused by a clear-cut organic or psychiatric illness can also be misattributed. For example, in three studies testing the effects of symptom-focused treatments for patients reporting electrosensitivity, a detailed examination of the people who volunteered for the studies revealed that between 14% and 33% were experiencing some other, more conventional illness that might account for their symptoms.[51-53]

We are not aware of studies which have tracked the health of residents before and after wind turbines have been erected near to their community, but given the high prevalence of symptoms in the general population, it seems likely that many of the residents who live near to wind farms will indeed have experienced symptoms prior to the turbines being erected. Misattribution is a plausible explanation for some cases of "wind turbine syndrome."

Worry and annoyance

Not everyone who is exposed to a contentious modern technology will report symptoms in relation to it. What differentiates those who do, from those who do not? One factor that has been explored in some depth is the role of worry. Several studies have observed that people who are worried, anxious or concerned by an environmental risk are more likely to report symptoms.[48,54-56] Several psychological mechanisms can account for this.[57] First, these emotional states are often associated with physiological changes (such as alterations in heart rate or gastrointestinal function) and behaviors (such as eating or sleeping habits) that can in turn lead to physical symptoms. Second, feeling anxious or worried about a particular risk may cause someone to increase the level of attention they pay to their health as they monitor themselves for any signs that they may have been affected. This can increase the chances of someone detecting a physical sign or symptom that might otherwise have gone unnoticed. Third, worry about a modern technology can increase recall bias for symptoms.[58] In the case of wind turbines, this might result in people who are worried about possible adverse health effects remembering more symptoms from the recent past than people who are not worried, even if the actual level of symptoms was the same in the two groups. Finally, people who are experiencing higher levels of worry or concern are more likely to "catastrophize," selectively focusing on the worst possible meaning of a symptom.[59]

For symptoms attributed to wind turbines, worry or anxiety as a concept has not been explored in any detail. However, the importance of annoyance caused by the sound generated from wind turbines as their blades turn has been studied. Annoyance caused by sound has been defined as "a feeling of resentment, displeasure, discomfort, dissatisfaction or offence when noise interferes with someone's thoughts, feelings or actual activities".[60] Several studies have suggested that annoyance plays an important role in predicting whether people who live near to wind turbines will report symptoms. For example, in one cross-sectional survey of 138 people living close to wind turbines in the UK, perceived levels of sound from the wind turbines, but not the objectively calculated levels of sound that the participants were exposed to, were associated with increased likelihood of reporting symptoms.[61] Similarly, in a study of 754 people in Sweden by Pedersen and Waye, annoyance from the noise produced by local wind turbines, but not objective markers of that sound, was associated with sleep disturbances and mood symptoms.[62] A 2011 analysis[63] comparing the data from this survey with two others by the same team[62,64,65] found that disruptions of sleep were associated with objectively assessed sound levels in two of the three surveys but that no other symptom showed

a consistent association with sound levels. Expressing annoyance about the sound of the turbines, on the other hand, was associated in at least two of the three surveys with most of the subjective symptoms that were asked about. More specifically, being annoyed about the sound was associated with increased sleep interruption, headache, feeling tense and stressed and feeling irritable.

Worry and annoyance are complex subjective phenomena. Whether someone will be worried or annoyed by a given stimulus depends on many factors. Some of these relate to properties of the stimulus itself. For example, in the series of surveys by Pedersen and Waye[62,64,65] annoyance from the noise generated by wind turbines was partly predicted by the objective level of sound that participants were exposed to. However, even under the worst case noise conditions identified in the surveys only a minority of respondents reported feeling annoyed.[65] It would be simplistic to suggest that the objective features of how a modern technology works are the only factors that are relevant.

Personality is one contributing factor determining who will be worried or annoyed by a stimulus. For symptoms attributed to wind turbines, personality variables including frustration discomfort ("an inability to cope with distressing stimuli"), negative affectivity and neuroticism have been variously shown to correlate with attitudes toward, and attributing symptoms to, wind turbines.[61]

How wind turbines are presented to the public may be another contributing factor. Decades of work on the "psychometric paradigm" of risk perception have resulted in a list of characteristics (sometimes called "fright factors") that help to determine whether a given modern technology is likely to cause public concern.[66] For example, risks are more likely to trigger concern if they are perceived by members of the public to be: Unfamiliar; invisible; inequitably distributed; capable of causing delayed or hidden health effects; poorly understood by science; involuntary; or posing a particular danger to children, pregnant women or future generations. The reactions to wind turbines and the infrasound they produce tick many of these fright factor boxes. Journalists are well aware that describing modern technologies in these terms attracts attention and sells newspapers. In the specific context of wind turbines, an analysis of 421 articles published in 17 newspapers available in Ontario found that 94% of them presented "negative, loaded or fear-evoking descriptions" of possible health effects.[67] The impact of such reporting should not be underestimated. Several studies have shown that exposure to sensationalist media reporting about a risk increases the likelihood that people will report symptoms following perceived exposure to it. For example, in the study by Crichton *et al.* testing whether a nocebo effect might trigger symptoms following perceived exposure to infrasound,[42] high expectations of symptoms were induced by showing people genuine television footage of people who were opposed to wind turbines. Similarly, in an experiment by Witthöft and Rubin,[39] participants were randomly assigned to watch either real television documentary footage of scientists, politicians and members of the public who were concerned about the health effects of Wi-Fi or footage about the importance of data security when using wireless connections. After watching the footage, all participants were exposed to equipment which was apparently emitting a new form of Wi-Fi signal and were asked to record any symptoms they experienced. In reality, the equipment was non-functional. Among participants who were already experiencing higher anxiety, watching the footage about purported health effects increased the chances that they would report symptoms following the exposure and also increased the chances that they would subsequently decide that they too might be sensitive to Wi-Fi signals.

Interaction with activists or lobbyists campaigning against a particular modern technology or with people who feel that their health has already been affected by it may produce a similar effect. For example, in an experiment by Winters *et al.*, volunteers asked to read leaflets produced by support groups for people with "multiple chemical sensitivity" were significantly more likely to experience a nocebo effect when exposed to an innocuous chemical odor than participants who did not read this information.[68] Recently, an analysis of the spatio-temporal distribution of health complaints regarding wind turbines in Australia has suggested that most complaints have only appeared since opposition groups began to publicize the possibility of health effects while 13 of the 18 wind turbine sites where complaints were registered had witnessed local campaigning by anti-wind turbine groups.[69]

A range of psychological and social factors therefore exist which may serve to increase worry in some people about wind farms and which may also increase the likelihood that they will report symptoms in connection to them. But what about annoyance? As with worry, several factors have been found which help differentiate people who find the sound from wind farms annoying from those who do not. Much of this evidence comes from surveys of people living close to wind farms. These have found that greater annoyance tends to be reported by people who have a negative attitude toward the visual impact of wind turbines on the environment,[63,64] who have a negative attitude toward wind turbines in general,[63] who can see a wind turbine from their dwelling[65] and who report being highly sensitive to noise.[2,64] Meanwhile receiving an economic benefit from the presence of a wind farm reduces the chances of someone being annoyed by their sound.[65]

Conclusion

Although it has been suggested that there are "few, if any" alternative explanations for the experiences of people who attribute symptoms to wind turbines, several plausible

alternatives exist. Nocebo effects, misattribution and increased symptom monitoring triggered by worry or annoyance can all help to increase symptom reports among communities which play host to a novel or controversial technology. In turn, these effects can be exacerbated by the social context that often accompanies a new technology, including sensationalist media reports, activist literature, interaction with others who describe adverse health effects, public disagreements between scientists and an unfair distribution of the risks and benefits from the technology.

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