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Under high tension

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2016

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Porsius, J. T. (2016). *Under high tension: Health responses to the introduction of new high-voltage power lines*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

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CHAPTER

8

Summary, general discussion, and
recommendations for future research and risk
management practice

Power lines are needed to transport electricity from the places where it is generated (coal plants, wind turbines, etc.), to electricity substations closer in the vicinity of users. Due to increased demand for reliable and sustainable energy, worldwide new overhead high-voltage power lines (HVPLs) are installed. In the Netherlands about 350 kilometres of new high-voltage lines will be constructed in the near future. The construction of these new lines can have disadvantages for local residents. For example when it comes to the disruption of the landscape and its impact on housing prices. Another important aspect are the potential effects on people's health perceptions.

The aim of this thesis was to investigate the effect of new overhead HVPLs on health perceptions of nearby residents. In addition, we aimed to study the psychosocial mechanisms through which health responses to a new HVPL may occur. To achieve this aim we conducted a prospective field study in the Netherlands in an area where a new HVPL was to be constructed. Residents living close to the new power line, as well as a control group of residents living farther away were included. Participants filled out questionnaires about their health and their perceptions of the environment, before and after the new HVPL was put into operation. In a separate study we interviewed residents about their experiences with the planning process of a new HVPL near their home, and identified dominant themes in these experiences. In the present chapter, we summarize and discuss the main findings presented in this thesis. At the end of this chapter, recommendations for future research and risk management practices are provided.

SUMMARY OF THE FINDINGS

The effect of a new power line on residents' health perceptions

In the prospective field study, residents filled out questionnaires two times during construction of a new HVPL in their vicinity, and two times after the new line was put into operation (**Chapter 2**). We found a larger increase from baseline in cognitive and somatic symptom reports and in the strength of the belief that these symptoms were caused by a power line for residents living within 300 m of the new line, compared to a control group of residents living farther away (500-2000 m) (**Chapter 3**). Such a larger increase was not found for residents living within 300-500 m of the new line. While symptom reports did not differ at baseline between the distance groups, the belief that a power line could cause these symptoms was already stronger at baseline for residents living close by (0-300 m and 300-500 m) compared to residents living farther away. Based on these findings we conclude that the introduction of a new HVPL can have a negative impact on health perceptions of nearby residents. When we looked closer at the change in reported somatic symptoms of residents living within 0-300 m, we found that this change was mainly due to reported musculoskeletal and gastrointestinal complaints (**Chapter 4**).

Explaining health responses to a new overhead power line

We found that the increase in reported somatic and cognitive symptoms in residents living closer to the new power line, was mediated by the strength of the belief that these symptoms were caused by a power line (**Chapter 5**). This finding suggests that

nocebo mechanisms operate during the introduction of a new HVPL. When we focused on those residents living within 300 m of the new power line, we found that subgroups of residents responded differently to the introduction of a new line. Only a small subgroup of residents began attributing health complaints to an overhead power line after its activation and reported a deterioration in general health. Other subgroups appeared more affected by the introduction of the new line as a whole, instead of putting the new line into operation. These subgroups of residents could be differentiated based on personality, perceived physical and mental health, and their perceptions of the environment. The subgroup of residents with a strong response to the activation of the new line, for example, evaluated the health effects of power lines more negatively, and they were more aware of the moment when the new line was put into operation (**Chapter 6**). This suggests that these factors play a role in health responses to a new HVPL.

In a qualitative study conducted in a different area in the Netherlands, we found that residents' experiences with the planning process of a new HVPL near their home, were mainly negative due to the expected negative impact of the new power line on their health, the aesthetic quality of their environment, and the value of their property. In addition, feelings of injustice regarding the planning process and its outcomes played an important role as well (**Chapter 7**). Contrary to residents' needs for personalized, concrete and timely information provision, they perceived provided information as too global, inconsistent and being provided too little, too late. These communication problems played a role in perceived injustice as well as negative health expectations.

DISCUSSION OF THE FINDINGS

Our findings contribute to research in environmental health, risk perception and psychological medicine, and raises important questions regarding the mechanisms through which residents report health complaints after exposure to an uncertain environmental health risk. In the next paragraphs we will discuss our findings in light of the potential psychosocial mechanisms known from the scientific literature that might explain health responses to uncertain health risks.

The role of causal beliefs

In Chapter 2, we described a conceptual framework (see Figure 1, Chapter 2), depicting psychosocial pathways through which the introduction of a new power line might lead to reporting more health complaints. These hypothesized pathways are based on a considerable body of evidence on nocebo responses, showing that symptom reports can increase after an inert treatment due to negative expectations of the treatment. Several researchers have suggested that such effects extend to environmental exposures [1-3] which is supported by experimental evidence [4-7]. Evidence from prospective field studies is rare though (for an exception see [8]), and was non-existent for exposure to the potential health risks of HVPLs.

In Chapter 5 we used longitudinal mediation models to test several of these pathways involving beliefs regarding the health effects of power lines. We found that

residents living close by had stronger beliefs regarding the negative health effects of power lines than residents living farther away, even before the new line was put into operation (Chapter 3, Chapter 5). There are several ways how these beliefs may explain the increase in reported symptoms. First, their stronger negative beliefs *before* the line was put into operation might have led to an increase in symptom reports of residents living within 0-300m. Second, the increase in these beliefs *after* the line was put into operation might have concurrently led to an increase in symptom reports. Third, both the stronger beliefs before the power line was put into operation *and* the increase afterwards, led to an increase in reported symptoms. Our results only support the second pathway, suggesting that putting a new power line into operation triggers beliefs and symptoms concurrently, amplifying each other. This supports the circular mechanism as proposed in our conceptual framework.

The role of somatosensory amplification

The reciprocal relationship we found between causal beliefs and symptom intensity (Chapter 5) is in line with symptom perception models (for an overview see [9]), and suggests that somatosensory amplification mechanisms were operating during the introduction of a new HVPL. Somatosensory amplification is the mechanism where somatic sensations get amplified and experienced as health complaints [10]. The experience of non-specific health complaints such as headaches, back pain and stomach aches, is very common in the general population [11,12]. Cognition, context, attention and mood have been suggested as important amplifying factors of somatic sensations [13]. Figure 1 displays how these factors might have played a role in our own findings.

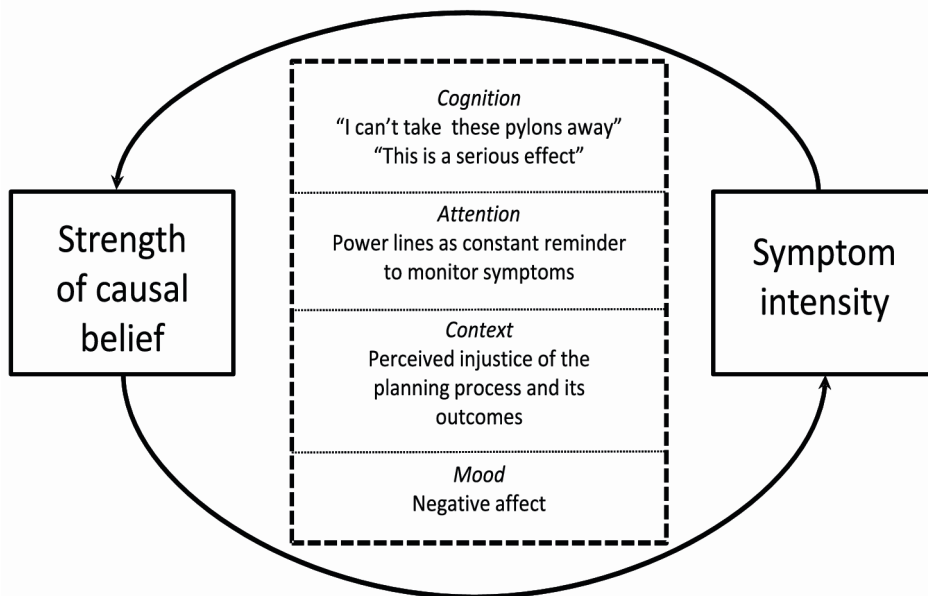


Figure 1. Hypothesized role of somatosensory amplification factors when a new HVPL is introduced in the environment.

It is likely that symptoms become intensified when one believes that they are caused by a serious factor that cannot be easily changed, like living close to an HVPL. In addition, an HVPL is an attention drawing object. It can provide a constant reminder to closely monitor somatic sensations, which has been shown to intensify symptoms in itself [14]. Our interviews with residents about their experiences with the planning process of a new HVPL provided more insight in the broader context that also plays a role in this somatosensory amplification. Other burdens of HVPLs like the visual intrusion and the negative effects on property values, appeared to interact and amplify concern about the health risks of exposure to electromagnetic fields (EMF). In addition, residents perceived the decision making process regarding the new power line as unfair, leading to feelings of injustice (Chapter 7). All these experiences may provoke negative affect, which is closely linked to somatic health complaints [15]. The increase in symptoms after the new line was put into operation might in turn further strengthen the belief that the new power line is causing these symptoms, illustrating the reciprocal character of this relationship.

Such a reciprocal pattern is in line with theories regarding the development of idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF); an etiologically neutral description of the condition where people report to experience non-specific health complaints when exposed to EMF [16]. Case reports suggest that reported symptoms worsened when self-diagnosed patients became more convinced that they were suffering from IEI-EMF [17]. In addition, an experiment with healthy participants also suggested a dynamic relationship between symptom intensity and causal beliefs involving environmental exposures [18].

Because the increase in beliefs and symptoms was concurrent, the exact starting point of a somatosensory amplifying mechanism remains unclear. A scenario where such a mechanism started with an increase in experienced symptoms after a power line is put into operation, instead of an increase in beliefs, is also possible. A potential driving factor in this process is social modeling. Recent experimental evidence demonstrates the role of social modeling in nocebo responses [19]. In one experiment, for instance, participants reported more symptoms after taking placebo medication only when they saw a confederate report more symptoms after taking the same medication [20]. This phenomenon of contagion by observation can also be observed in mass sociogenic illnesses, when the prevalence of reported symptoms suddenly increases if a group is exposed to a suspected toxin [21,22]. If residents in our study perceived symptomatic responses of others after the new power line was put into operation, this may have had a strong direct effect on one's own symptom reporting, resulting in a change in causal beliefs. In the presence of somatosensory amplification factors (Figure 1), this may in turn increase the intensity of experienced symptoms.

The role of risk perception and risk communication

If beliefs regarding the health effects of power lines play an important role in explaining symptomatic responses to power lines it is important to understand why we found that residents living closer to the new line had stronger negative beliefs regarding the health effects (Chapter 5). Previous research has indicated that lay people base their understanding of EMF on what they know about carcinogenic

ionizing radiation [23]. They believe that exposure to EMF from power lines can cause changes in mood, thought and behavior [24,25]. Within the Social Amplification of Risk Framework (SARF, [26]), the interpretation of a risk is in large part determined by communication with others through official (e.g. news media, official authorities) and informal personal networks (e.g. friends, neighbours, social groups in general). Content analyses of messages in the media regarding the health effects of EMF suggest that these messages are disproportionately negative and not in line with current scientific evidence [27,28]. These kind of messages portraying EMF to cause health effects, are in line with the lay understanding of EMF and could, therefore, easily further strengthen these beliefs.

In interviews with residents we found support for such an amplification process (Chapter 7). Although residents living close to the planned introduction of a new HVPL acknowledged the large amount of uncertainty regarding the evidence for health effects, most of them thought EMF emitted by power lines could not be completely harmless. This belief was strengthened by their perceptions of messages in the media, 'the word on the street', but also by messages of official authorities regarding EMF risk regulations. Saying there is only a small or even non-existent health risk, but offering residents to sell their home if they live very close to a power line, was perceived as inconsistent by residents and appeared to amplify health risk perceptions.

In line with previous work, suggesting negative effects of the media on symptom reporting of residents affected by an environmental incident [29], we found that subgroups of residents who responded more strongly to either the activation of the line or the construction, both reported to have heard more about the health effects through media or friends than those less affected by the introduction (Chapter 6). Based on our study we cannot tell *what* residents had heard from the media about the health effects of power lines. A recent study demonstrates how information on health effects provided by the media can increase symptom reports. In that study, adverse event reports increased after a change in the inert ingredients of pills used as treatment for Hypothyroidism [30]. Although the active ingredients of the new pills were the same, the look and taste of the pills were different. Media reports mentioned specific symptoms as potential side-effects of the new formulation and these specific symptoms were reported more often than other symptoms that were not mentioned in the media [31]. In our own work we found that residents reported more symptoms from several specific symptom domains, namely cognitive, musculoskeletal and gastrointestinal (Chapter 3, Chapter 4). To our knowledge no content analysis has been conducted into messages in the media specifically focused on EMF from power lines. However, content analyses of EMF health effects in general, indicate that messages in the media do not mention one specific symptom pattern, but rather several non-specific health complaints and illnesses [27,28]. This is in line with our own findings of the effects of a new HVPL on several symptom domains.

Strengths and limitations

The work presented in this thesis has several strengths. This is the first study to prospectively investigate the effect of a new HVPL on health perceptions of nearby

residents. Using a prospective design we were able to demonstrate how the introduction of a new HVPL lead to reporting more symptoms in nearby residents. In addition, we showed that the strength of the belief that symptoms were caused by a power line changed after the new line was put into operation, and this change explained the increase in reported symptoms. Because we presented our study to residents as a general environmental health study, asking questions about a broad range of environmental factors, we reduced the potential for response bias and demand characteristics to occur. The addition of a qualitative study, investigating perceptions of the planning process of a new HVPL, provided further insight into the mechanisms that could explain the findings in our quantitative study.

However, several limitations have to be addressed as well. One of the most important limitations of the findings described in this thesis considers the generalizability of our findings to the whole population of residents in our study area, to residents in other areas where HVPLs will be constructed, to other uncertain environmental health risks (e.g. mobile phone base stations and wind turbines), and to other cultures and times. Although the overall response rate in our study (19%) was comparable to other general population studies, it is still low. The group of residents who responded to our invitation might not be representative for the whole population of nearby residents. The higher response rate of residents living closer to the new HVPL further complicates the matter. Because we have no information about residents who did not respond, it is not possible to draw conclusions regarding this difference in response rate. Due to the construction of a new power line, environmental health issues might have been more salient to nearby residents leading to a stronger motivation to participate in our study. This saliency could have triggered the more concerned citizens to reply which would give an alternative explanation for the difference in beliefs regarding the health effects of power lines we found at baseline. If this was the case, it would be specifically limited to citizens concerned about power lines, because we found no differences in general health concerns, negative oriented personality traits or concerns about other environmental factors between the different distance groups. In addition, the differences we found in socio-demographic characteristics between the distance groups did not confound the effect of distance on beliefs about the negative health effects of power lines. On the one hand selection bias could have led to an overestimation of the effects of proximity on health perceptions, but on the other hand it could be an underestimation if strongly concerned residents had moved out of the area before construction of the new line started.

An additional related limitation of our study is the lack of an extra pretest before the construction of the new line started, and an extra pretest before the proposal for the new power line in this specific area was published in 2007. This would have ruled out selection bias related to knowledge about a potential future construction of a power line in the direct vicinity. It would have also provided the opportunity to study whether beliefs about the negative health effects of power lines changed after the new line was proposed, and investigate whether this change played a role in the increases in reported symptoms after the new line was put into operation. Future research with other new power lines is necessary to resolve these issues and to find out whether nocebo mechanisms operate with other power line introductions as well.

Although we found evidence for the role of nocebo mechanisms in health responses to a power line, this does not exclude the potential role of other mediating mechanisms. We did, for instance, not investigate the role of exposure to EMF. Exposure to EMF decreases rapidly with distance from a power line [32] and for the specific line we investigated, the expected magnetic field strength was below the suggested cut-off value of 0.4 μT for the elevated risk of childhood leukemia upwards of 55 meters of the new line [33]. Field measurements have confirmed that the modelled expected exposure is in line with the actual exposure after the new line was put into operation [34]. Only one resident in our study lived this close to the new line. Considering the rapid decrease in magnetic field strength, and the lack of a plausible biophysical mechanism for EMF to cause non-specific health complaints [35], we believe it is an unlikely alternative explanation of our findings.

RECOMMENDATIONS FOR FUTURE RESEARCH

Most nocebo research is conducted under laboratory conditions. To advance the field it is important to study these responses under more natural conditions as well. Findings from nocebo studies conducted in laboratory settings may not fully extend beyond the laboratory. Perceived exposure is easier to manipulate in an isolated laboratory setting where no other environmental stressors are present. It is important to know to what extent and under what conditions nocebo mechanisms operate in everyday life where a plethora of environmental and internal stressors is keeping our mind busy.

One way forward to find out more about these nocebo mechanisms in everyday life, is to combine risk perception research with research into nocebo responses. For example, the psychometric paradigm developed by Slovic and colleagues [36,37] can be useful as a guideline to predict which environmental risks are worthwhile to investigate in future studies. Their seminal work has shown that risks are perceived as high when a hazard is unknown (i.e. not observable, unknown to those exposed, delayed effects, new risk, unknown to science) and dreaded (i.e. uncontrollable, fatal consequences, involuntary, not equitable, high risk to future generations). New rapidly expanding EMF emitting technologies (e.g. WIFI, mobile phones), are therefore good potential candidates for nocebo studies. Outside of the EMF domain other technologies emerge with nocebo potential such as nanotechnology, genetically modified food, or renewable energy technologies (e.g. wind turbines). Several studies have shown that some people are indeed very concerned about the effects of such new technologies on their own health and these concerns are related to reporting more health complaints [38–40]. Further research into the mechanisms and conditions under which nocebo responses to new technologies occur is therefore warranted.

The psychometric paradigm also shows that risk perception is not only determined by the perceived health consequences of exposure. Aspects such as (perceived) controllability, the voluntariness of exposure, equity issues, and many more aspects also play an important role. This is in line with our own finding that negative experiences of residents with the planned introduction of a new HVPL are not only determined by negative health expectations, but also through interaction with other perceived burdens (aesthetic, financial) and the feeling of not being involved in the planning process. These are all factors playing a role in the ‘mental model’ that residents have of the introduction of an uncertain health risk in their environment. Although the importance of studying mental models of environmental risks has been acknowledged in risk research (e.g. [41,42]), the relationship with nocebo mechanisms is rarely studied. Nocebo research is generally focused on one aspect of the mental model, i.e. negative symptom expectations, which is studied in relation to health outcomes. However, the mental model that people have about an environmental exposure encompasses much more than symptom expectations and these other elements may, directly or indirectly, contribute to nocebo effects. In order to prevent nocebo responses it is therefore important to further study the relationship between different aspects of mental models and nocebo effects.

In line with this recommendation it is important to study factors that influence the mental model that people have of an uncertain risk. As suggested in our own work, as well as in others (e.g. [26]), the mental model of a risk is construed within a social context. Communications about environmental health risks with others through official networks (e.g. news media, official authorities), and informal personal networks (e.g. friends, neighbors, social groups in general), are therefore likely to play an important role. For instance, when public consultation, or risk mitigation strategies, are communicated by official authorities and residents try to interpret these messages through communications with their peers. More research is needed into the efficacy of risk communication and mitigation strategies to change mental models of residents during risk events (see [43]). An experimental laboratory study has shown that nocebo responses to infrasound from wind turbines could be counteracted when information was provided about the therapeutic use of infrasound to improve health [44]. However, the strategy to provide information about potential positive health effects of exposures may be difficult or unethical to implement in natural settings. In particular, when there is no evidence for positive effects of an exposure. Moreover, such communications can backfire if they are not in line with the mental model of local residents who are facing the risk.

A study comparing the mental model of experts and laypeople regarding the health risks of EMF has suggested three focal points to improve communication regarding these risks: providing more clarity regarding the uncertainty of evidence for health effects, illuminating personal EMF exposures in daily life and providing more accessible and transparent information on governmental policies [23]. Whether the implementation of such a mental models based communication strategy would lead to a reduction in nocebo responses to equipment emitting EMF is unknown. Future research should focus on the development of evidence-based risk communication strategies when residents face increased exposure to an uncertain environmental health risk.

Key recommendations for future research

- 1. Study nocebo responses, and the social context in which they occur, in natural settings. Particularly responses to risks that are perceived by the public as unknown and dreaded.*
- 2. Study how different aspects of the lay mental model of a risk is related to the development of health complaints after exposure to a risk.*
- 3. Study the efficacy of communication about exposure, risks and mitigation strategies, with regard to reducing nocebo responses to uncertain environmental risks.*

RECOMMENDATIONS FOR RISK MANAGEMENT PRACTICE

In addition to implications for research, our findings have practical implications. New HVPLs will be built in the near future. Our findings suggest that such an expansion will affect health perceptions, in particular those of residents living very close by (< 300 m). More research is needed to know whether our results generalize to other power lines (e.g. higher-voltage underground cables, lower-voltage overhead cables) and to get a better estimate of the effect size. For now, municipal health services might want to monitor residents' health perceptions during and after the planning process of new HVPLs, for instance through a website or mobile phone app where residents can fill out health perception questionnaires. Based on our findings described in Chapter 4 we would advise to use a symptom checklist which covers all relevant symptom domains, and include an assessment of causal beliefs. The outcome of such monitoring processes may provide valuable input for all involved stakeholders (e.g. residents and risk managers). A sudden decrease in perceived health, or a rise in the belief that health complaints are caused by a power line, signals the need to take action and communicate with each other about these results. This is in line with a participatory action approach to research, where research is conducted 'with' instead of 'on' people [45]. Using such an approach early on in the planning process, might reduce the negative experiences of residents facing increased exposure.

As far as we know, official communications with residents generally cease after a new HVPL is put into operation. While this may be in line with information needs of the majority of residents, our findings suggest that for a small subgroup of residents it is important to prolong communications, particularly after a new line is put into operation. Our finding that subgroups of residents may respond differently to the introduction of a new HVPL stresses the need for tailored information provision. We found that residents prefer personalized, concrete and timely information regarding the expected negative impact of a new power line on topics that matter for them (e.g. health, aesthetics and financial outcomes). Instead of only providing general information about the expected impact of an HVPL, one could present information in a personalized and concrete manner. For instance, by showing on a map the projected magnetic field zone associated with the elevated risk of childhood leukemia, relative to the home where the resident lives.

In order to tailor information to the needs of local residents modern communication technologies might be useful. Participatory geographic information systems, for instance, is a relatively new technique to combine spatial information with survey data from residents as a means to community-based participatory research [46]. Not only could this be a useful technique to involve and inform local residents during the planning process of new HVPLs, it might also be used to visualize the various information needs of residents spatially which could aid policy makers when distributing information. Such techniques can be used in combination with mobile phone apps, allowing even more refined tailoring of information provision.

Key recommendations for risk management practice

- 1. Apply community-based participatory research methods when introducing an uncertain environmental health risk to the environment.*
- 2. Assess the individual information needs of those exposed to an uncertain environmental health risk and tailor information provision accordingly.*
- 3. Communicate with residents in a timely, concrete, and personalized manner.*

CONCLUSIONS

The work presented in this thesis showed that the introduction of a new overhead HVPL can lead to symptom reporting in nearby residents. The increase in reported symptoms after a new HVPL was put into operation could be explained by the stronger belief of nearby residents that these complaints were caused by a power line. The relationship between beliefs about the negative health effects of power lines and reported symptoms suggests that nocebo mechanisms operate during the introduction of a new HVPL. A small subgroup of nearby residents with a stronger focus on the potential health effects of a nearby power line responded specifically to the new line being activated, while the majority of residents responded earlier during the construction process. In addition to nocebo responses, residents' overall experiences with the planned introduction of a new line were negative. On the one hand this could be explained by the expected negative impact of the new HVPL on their health, finances and the aesthetic quality of their living environment. On the other hand feelings of perceived injustice of the planning process and its outcomes contributed to these negative experiences. Residents' perception that communication was not tailored to their information needs played a significant role in these negative experiences. The negative impact of a new HVPL may be minimized by informing residents in a more personalized, concrete and prompt manner.

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