Understanding "Symptoms Associated with Environmental Factors" (SAEF) in buildings; e.g. "sick building syndrome", "electromagnetic hypersensitivity" and "multiple chemical sensitivity"

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ABSTRACT

The field of buildings, health and human experiences may be divided between conditions (a) with scientific support for causal relations between exposure and health effects, e.g. dampness in buildings and asthma exacerbation; (b) lacking such scientific support, e.g. "sick building syndrome" (SBS). b) conditions are often disregarded as imaginations, psychogenic etc. Traditional ideas are (1) the brain registers what happens in- and outside the body, thus reports of symptoms and experiences "objectively" reflect the underlying biological processes; (2) all symptoms and experiences result from biological processes in the body, often due to external causes. Emerging knowledge indicates that the brain instead creates all consciously experiences. In principle, experiences are "integrations" of (I) previous experiences (i.e. acting as models to generate predictions on future events) and (II) what actually happens (i.e. inputs to the brain, e.g. from senses); (I) and (II) themselves not being consciously experienced. In this "integration", factors (I) vs. (II) may have any distribution. If (II) dominates, the traditional model may fit, i.e. experience is rather equivalent to what actually happens. If (I) dominates, the traditional model fails, experience has limited relevance to what actually happens and may be understood as a "copy" based on previous experiences; e.g. still getting asthma(like) symptoms in a building long time after proper renovation of water-damages. This new knowledge offers plausible explanations for learned phenomena like SBS, "multiple chemical sensitivities", "electromagnetic hypersensitivity" and other conditions with limited scientific documentation for causality between associated environmental factors, e.g. "building", "electromagnetic" and "chemical", and experiences like symptoms. Important implications are (A) the symptoms and experiences in e.g. "SBS" are just as real as in any other medical condition; (B) as the symptoms and experiences in such conditions are not caused by the associated factor (e.g. "building"), nor through mechanisms like "syndrome", "(hyper)sensitivity" etc.; such misleading terms should be abandoned. The new concept and phenomenon description "Symptoms Associated with Environmental Factors" (SAEF) offers a paradigm shift. SAEF opens for a better understanding of such phenomena, including prevention, treatment and the need for interdisciplinary approaches.

INTRODUCTION

The field of buildings, health and human experiences includes a spectrum from conditions/issues with rather well-established causal connections between exposure and health effects to those that most likely have no such interconnection. Asthma exacerbation caused by water-damaged buildings is an example of the first end of the spectrum; where dampness is a proxy exposure, as the causal agent not yet has been identified, despite the widespread idea that moulds are established as the causal agents (Mendell et al., 2011; Quansah et al., 2012; Kanchongkittiphon et al. 2015). An example from the other end may be "electromagnetic hypersensitivity" (EHS), a condition characterized by persons experiencing symptoms (e.g. headache, dizziness and fatigue) as caused by exposure to sources of EMF (e.g. cell phones and Wi-Fi). A number of double-blind experimental studies do not support that symptoms are caused by EMF exposure. However, fMRI indicates that perceived (sham)exposure may elevate signals in relevant parts of the brain, i.e. perceived exposure alone can trigger symptoms (Landgrebe et al., 2008; Schmiedchen et al., 2019; Dieudonné, 2020).

Conditions like asthma, hypersensitivity pneumonitis, rhinosinusitis and infections that may causally be associated with "building-related factors" (BRF) can be labelled as "building-related illness" and belongs to the same part of the spectrum as the asthma-example. Symptoms from airways, skin, mucosae and other common symptoms with sparse scientific grounding for such a causal association are sometimes labelled "non-specific building related symptoms" (NBRS; Nordin, 2020). NBRS may be seen as belonging to approximately the same part of such possible spectrum as EHS. Despite NBRS being more frequently reported in e.g. buildings with dampness and water-damaged buildings, knowledge of precise mechanisms for a causal relation is sparse. However,

there are published hypotheses and models on how such symptoms may arise. Neurogenic inflammation is a model seeking to explain the symptoms as an interplay between the nervous system (mainly peripheral nerves) and local inflammatory mechanisms triggered by exposure originating from BRF. Models like neural and central sensitization focus on neural mechanisms (mainly in the brain) that over time lead to amplified responses to stimuli. As the scientific grounding for the relevance of these models is quite limited, it may be argued that they are not (yet) to be used in the field of practice. In addition to these models exploring the physiological and structural mechanisms involved, models describing phenomena (experiences, thoughts, feelings, behaviour etc., i.e. the experienced final results of the actual biological processes of the body) are frequently discussed, e.g. learning like conditioning and nocebo. For a review, see Nordin (2020).

PREDICTIVE CODING

In addition to e.g. neurogenic inflammation, neural and central sensitization, models like predictive coding (PC)/ processes (Van den Bergh et al, 2017a; Pezzulo et al., 2019) seek to explain how the body (brain) generates experiences, e.g. symptoms. Of the models mentioned here, only PC aims to give an account on the creation of all conscious experiences. On the other hand, PC does not deal directly with what biologically happens outside the nervous system, e.g. mechanisms in peripheral tissue caused by exposure.

PC models contradict "traditional" ideas like (1) the brain registers what happens in- and outside the body, thus reports of symptoms and experiences "objectively" reflect the underlying biological processes and exposures; (2) all symptoms and experiences result from biologic processes in the body and/or external causes; (1) and (2) may be distorted by psychologic phenomena, reduced precision etc. (Wade & Halligan, 2004). Emerging knowledge indicates that the brain instead should be seen as creating all our consciously experiences. PC models are described more detailed in another conference paper (Haanes, 2020). Citation from an interim summary of that paper: All conscious experiences are in principle "integrations" of (a) our previous experiences (i.e. acting as models to generate predictions on future events by the brain) and (b) what actually happens (i.e. the inputs the brain gets, e.g. from our senses). Only the "end-product" is consciously experienced, not (a) and (b) themselves. In this "integration", factors (a) and (b) may be of equal importance, one factor may dominate or even constitute the total. If (b) dominates, the traditional model may be acceptable, i.e. what is experienced is rather equivalent to what actually happens, e.g. reporting an unpleasant smell in a newly water damaged building. If (a) dominates, the traditional model fails, what is experienced in the actual situation has limited relevance to what actually happens. Instead, the experiences may be understood as "copies" based on previous experiences; e.g. still getting symptoms in a building long time after proper renovation of water-damages.

Models like PC are based on emerging understanding of (a) anatomic structures and physiologic functions of the nervous system, and (b) phenomenon descriptions like placebo, nocebo, conditioning and other learning processes. Despite quite substantial scientific support for the models, more documentation is needed. However, the scientific support for alternative, e.g. more commonly used, models is more limited. Hence, a possible conclusion is that in the lack of any better, and based on the available documentation, models like PC should be used to understand human experiences, including e.g. perception of symptoms and associated causes (Barrett & Simmons, 2015; Van den Bergh et al, 2017a; Haanes, 2020).

SYMPTOMS ASSOCIATED WITH BUILDINGS (SAEF-BUILDINGS)

As elaborated (above and Haanes, 2020), previous experiences are a crucial part in models like PC. Accumulation of information is an important element in forming previous experiences. Van den Bergh et al. (2017b) describes how this may happen when symptoms are associated with factors in the environment, with special focus on conditions lacking grounding of a casual association between perceived exposures and symptoms, e.g. "idiopathic environmental intolerances" (IEI), "sick building syndrome" (SBS), "multiple chemical intolerances" (MCS) and EHS. Information may elevate risk perception, i.e. how risks are interpreted, irrespective of the objective risk (Sandman, 1993). This information may originate from social and ordinary media, direct social relations, organizations etc. Information may fuel nocebo mechanisms, i.e. expectations that a given exposure, or just a clue perceived to indicate such exposure, will cause one or more symptoms associated with the belief. Information may also influence the other way, i.e. symptoms experienced as related to environmental factors may be confirmed as such if there are clues indicating ongoing exposure. The latter can be characterized as association or attribution bias, and will generate new previous experiences. Most of the described processes are unconscious, i.e. not manipulation etc. The models explain possible mechanisms for the creation of symptoms associated with environmental factors, even when there is no causal connection between exposure and symptoms. This illustrates an important distinction between (a) models like PC applied to describe environmental conditions; and (b) neurogenic inflammation, neural and central sensitization. The first ones primarily

focus on enhanced responsivity, while the others postulate an exaggerated sensitivity to exposures, which may not exist. It may be relevant to pinpoint that causality often is impossible to observe directly, i.e. it has to be inferred; the first models account for this. If further research confirms such models, it will constitute a paradigm shift regarding these kinds of conditions. Fig. 1 illustrates the concept SAEF-buildings based on models like PC.

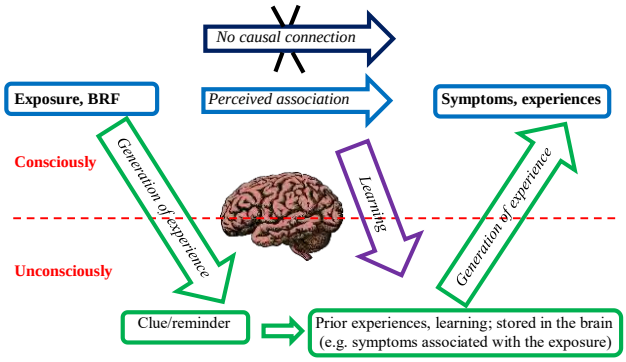

Figure 1. Highly simplified illustration of symptoms associated with environmental factors (SAEF), e.g. building-related factors. Blue arrow indicates the association between exposure (e.g. subtle smell in a formerly water-damaged, now renovated, building) and experience (e.g. headache and fatigue), as this is consciously perceived, e.g. "the building gives me symptoms". Black arrow, over-crossed, underlines that the exposure itself does not have a potential to cause biological processes that give such symptoms, i.e. the association is not causal. Green arrow indicates what, according to models like predictive coding, in reality happens in the brain. Unconscious processes, based on prior experiences (e.g. symptom-experiences from a time when a building was severely water-damaged), generate the experiences activated by stimuli acting as hints or other reminders (e.g. a subtle smell). Purple arrow shows the next step, perceived association between exposure and symptoms reinforce the learning of such an association. As the number of such learning-episodes increase, the perceived association appears more and more convincing.

Haanes et al. (2020) elaborates on consequences of such a paradigm shift and propose a new term, "Symptoms Associated with Environmental Factors" (SAEF). SAEF maybe applicable when symptoms are perceived caused by environmental factors, but without indications for a causal association between symptoms and the exposure, i.e. no documentation supports that properties of the exposure *itself* cause biological processes explaining the symptoms. These characteristics, including no objective way of confirming the relationship, do not fit with principles on construction of diagnoses; hence, SAEF may be used as a *phenomenon description*, not a diagnosis. A person may have both characteristics of SAEF and a disease where a medical diagnosis can be identified, e.g. asthma where diagnostic criteria exist regardless of verified or perceived exposure (Janssens et al., 2009).

There are already enough terms and confusion –Why introduce SAEF? Terms like IEI, SBS, MCS and EHS are misleading: (a) "intolerance" and "hypersensitivity" may be associated with mechanisms like allergy; (b) terms including an exposure (e.g. "building", "electromagnetic" and "chemical") are indicative of a causal connection; (c) "idiopathic" and "syndrome" imply medical understandings with limited relevance for these phenomena; and (d) "sick building" is inappropriate as a building is not a living creature and though may not be sick or healthy. SAEF is supposed to give as neutral description as possible of these kinds of conditions. One of the reasons for proposing this overarching term, is that there tends to be a large overlap in symptoms irrespective which environmental factor the (non-causal) association is directed against (Palmquist et al., 2014). However, for practical reasons SAEF may be sub-divided according to the, or group of, environmental factor in focus, e.g. SAEF-buildings for symptoms associated with buildings. SAEF-buildings and NBRS (non-specific building related symptoms) at least partly describes the same phenomena. However, depending on what may be included, a proportion of NBRS may include conditions with limited support for a potential causal association between exposure and symptoms. If instead linking terminology to SAEF may underline that attributions related to buildings are part of a more global phenomenon. In addition, using the label "non-specific" symptoms will be avoided. It can be argued that there is no such thing as "non-specific" vs. "specific". All symptoms and possible perceived causes are equally objective and real accounts for the person experiencing those. If instead taking the physicians' perspective, it may be argued that e.g. asthma or headache are equally "non-specific" for exposure to BRF, both conditions may be caused by a number of exposures and other factors. The aforementioned also applies to the term "building-related illness"; i.e. none of the conditions included under that label are caused by BRF only.

POSSIBLE IMPLICATIONS FOR THE FIELD OF BUILDINGS, HEALTH AND HUMAN EXPERIENCES

On one hand, it is essential to continue the efforts to reveal mechanisms of how BRF causes symptoms and diseases, i.e. the physiological and structural mechanisms taking place in the body as results of the exposure itself. On the other hand, this paradigm should not be the only, or the ultimate, goal. As discussed in this paper, a substantial fraction of symptoms and other experiences associated with BRF are most likely not caused by the exposures themselves. This should be implemented, e.g. utilizing the knowledge emerging from models like PC and confronting the prevailing cultural ideas that finding causal relations between exposure and symptoms are just a matter of efforts. The last idea is closely linked to another problematic one; that symptoms lacking

such causal relationships tends to be evaluated as "not real", "wrong perceptions", "psychogenic" etc. Such ideas may hamper research and knowledge-based practice in the field, e.g. not considering that some symptoms are perceived as linked to BRF, even though objectively not being so. This harbours potential for meaningless and destructive discussions of what is real or not as to both symptoms and perceived causes (Huiberts et al, 2013).

Use of terms like IEI, SBS, MCS and EHS may accentuate the problems. As discussed, such terms give wrong messages regarding causes and tend to be perceived as medical diagnosis. One of the wrong messages may be that avoidance is the main cure, i.e. in SBS avoid using the building, in MCS stay away from chemicals etc. Such behaviours may be regarded as logical, and unfortunately sometimes also encouraged by health practitioners, but according to PC models, the most likely effect is the opposite (Van den Bergh et al., 2020). Avoidance usually aggravate SAEF (Guglielmi et al., 1994), building-related interventions not addressing exposures that are causal for symptoms of the occupants may have the same effects, or at best have a placebo effect. This illustrates a crucial dilemma when dealing with BRF and health: (a) in conditions aggravated by the exposures themselves, e.g. non-allergic asthma with bronchial hyperreactivity in a water-damaged building or allergic asthma with medically confirmed dust mite allergy, avoidance and proper renovation may be the cure; but (b) in conditions like SAEF-buildings none of these actions may be part of a cure. Therefore, in each specific case, the troublesome task is to decide what mechanisms seem to prevail, as the question often is not if it is assumed to be condition a) or b) only, but what kind of mix it seems to be. Often factors like social climate, organization and handling of the situation adds to this mix (Sandman, 1993). Although initially apparently being the main issue of a case, technical BRF not seldom turn out to be of minor relevance in cases ongoing for a period, i.e. situation a) may be less frequent than b) for cases not quickly sorted out. Often dialogues, investigations and evaluations reveal that SAEF-buildings and other factors are more important. This leads to some fundamental questions relevant for the practice field: Is the starting point really BRF causing symptoms, or is the true origin SAEF-buildings, organizational or other non-BRF factors attributed to BRF? Are there systematically differences in BRF in these two kinds of cases or is it bias effects? The answers may be both yes and no; sometimes symptom reports are associated with BFR, e.g. water-damages, sometimes the associations are weak. However, causality of the associations is often unclear, see fig. 2 for examples of the diversity of factors that may be relevant.

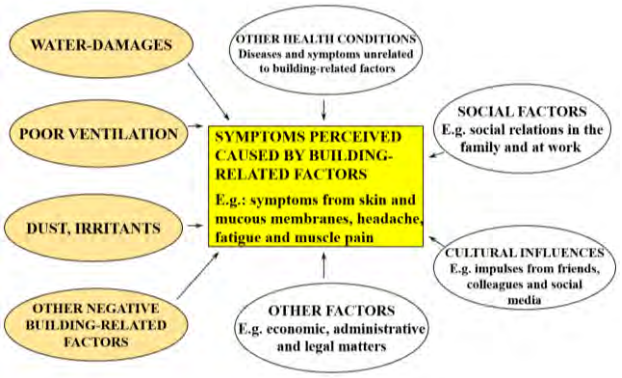

Figure 2. Examples of factors that may underly perceived building-related symptoms. Beige ellipses illustrate possible building-related factors, white ones point to examples of other components. In each case, one or more elements may be relevant, i.e. there are numerous different combinations. Regarding causality and mechanisms of the associations, see the text, including models like predictive coding and symptoms associated with building-related factors (SAEF-buildings).

If symptoms, perceived associations with, and shortcomings of, BRF all are self-reported, there may be a substantial bias. This may be explained by a combination of mechanisms like PC and SAEF and the fact that most buildings have at least some sort of shortcomings regarding BRF. The same kind of biases may also influence professionals looking for e.g. water-damages or shortcomings of the ventilation system based on symptom reports from occupants or vice versa, i.e. search for occurrence of symptoms after revealing technical defects. Possible consequences may be that e.g. questionnaires gathering information on frequencies, symptoms and associations have limited value and potentially strengthen the SAEF effects. In addition, it should be mentioned that symptoms and discomfort without disease, e.g. smells, often are confused with more serious conditions, i.e. diseases like asthma.

An important implication of the discussed issues is to use interdisciplinary approaches, e.g. not attempting to solve what in reality are mainly SAEF and organizational problems through purely technical evaluations and interventions. Such monodisciplinary approaches may exaggerate the situation, as persons involved experience that their problems neither are understood nor solved. Interdisciplinary approaches may include dialogues with those involved, one-to-one or in most cases preferably in groups, customized according to each case. Dialogues may reveal discomfort, symptoms, perceived associations to environmental and other factors, other elements of risk perception, social climate, technical issues and other relevant factors. Opposed to questionnaires, dialogues allow to adjust the collection of information during the process, clarify and check interpretations, and importantly, opens for two-way communication, i.e. starting the process of "treatment", that may be

based on elements discussed in this paper. If such dialogues disclose technical issues that are evaluated to be of significance or such issues are discovered without reports of discomfort and symptoms, proper assessments and actions may be conducted. When performing such interventions communication is important, from the start it should be stressed that technical assessments usually not reveal exact causes of symptoms and discomfort. Instead, they show factors that may elevate risks on a group level.

Although treatment of SAEF-buildings is beyond the scope of this paper, it may be mentioned that the main principle is to override previous experiences by new ones that are more beneficial. Behavioural interventions seem to be most efficient, e.g. exposure to the factors associated with symptoms in a setting creating neutral or positive experiences (Van den Bergh et al., 2020).

CONCLUSIONS, TAKE HOME MESSAGES

1. *All* perceived symptoms and their associations to building-related factors are both *real and valid* for that *person*, i.e. experiences are neither wrong nor give an objective account of e.g. building-related factors.
2. Symptoms and other experiences associated with building-related factors *may or may not* be causally linked to the attributed exposure. In cases lacking causality, models of the brain's function like *predictive coding* can explain the underlying mechanisms. The concept and phenomenon description *symptoms associated with buildings* (SAEF-buildings) operationalize such mechanisms in the field of buildings and health.
3. As the field of buildings and health consists of a broad spectre from technical to medical, cognitive and behavioural aspects, *interdisciplinary* approaches are often required.
4. Terms like "sick building syndrome", "multiple chemical intolerances", "electromagnetic hypersensitivity" and "idiopathic environmental intolerances" should be avoided as they give misleading messages and may create unnecessary problems and disputes. Such labels and related ideas indicate that the cure is avoidance of the associated factor. However, such behaviour often deteriorates the health condition.

ACKNOWLEDGMENTS

Many thanks to Martin Tondel, Sweden for valuable inputs and interesting discussions; and Tove Linda Haanes, Norway for useful comments on language issues.

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