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Visualization for supporting individual climate change adaptation planning: Assessment of a web-based tool

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Highlights

- Socio-cognitive factors constrain individual climate change adaptation planning.
- Targeted visualization advances adaptive capacity by addressing such constraints.
- VisAdapt™ combines specific and general visualizations of climate adaptation.
- The usefulness of VisAdapt™ in spurring homeowner reflection is analysed.
- Translating local climate change risks into a range of adaptation options is key.

Abstract

Homeowners are important actors in implementing climate change adaptation. However, individual socio-cognitive constraints related to risk perceptions and perceived capacity may hamper their action. Climate change visualization could help planning and management overcome such constraints by offering accessible information to increase individual adaptive capacity. Such visualization would require that information be perceived as legitimate and credible by emphasizing the diversity of impacts and alternative options, and simultaneously as salient by highlighting context-specific risks and measures. Based on focus group interviews and test sessions, we analysed how homeowners made sense of and discussed a specific interactive planning support tool – VisAdapt™ – integrating climate scenarios, local risk maps, and adaptation measures for various house types. The tool combines precise and general depictions in visualizing climate change to support adaptation among Nordic homeowners. Results reveal that the tool spurred reflection on concrete local risks and various adaptation actions. The tool was less successful in providing a framework for assessing the magnitude of anticipated changes, making these appear as generally small. Visualization aspects that are important for spurring reflection on adaptive action are specifying various climate parameters, relating climate impacts to established practices for managing weather risks, and emphasizing diverse concrete short- and long-term measures.

1. Introduction

Climate change calls for innovative adaptive responses if we are to seize opportunities and reduce negative impacts. Homeowners can be important actors in implementing adaptation measures to avoid impacts such as flooding, mould growth, storm damage, and heat stress, all of which could affect buildings and human health (Glaas, Neset et al., 2015 and Wamsler and Brink, 2015). This requires that climate-related risks be understood and recognized by homeowners and that adaptive concerns be considered in day-to-day management and in more forward-looking planning (Koerth et al., 2013; Porter, Dessai, & Tompkins, 2014; Smith et al., 2013). To do so, homeowners must be able to situate their own management relative to larger anticipated changes in the climate and landscape (Bartiaux, Gram-Hanssen, Fonseca, Ozoliņa, & Christensen, 2014). This entails overcoming a wide range of socio-cognitive constraints that could hamper adaptive actions (Kettle & Dow, 2014). Despite their potential importance, such constraints and facilitating factors for household-level adaptation remain under-researched (Elick-Barr, Preston, Thomsen, & Smith, 2014).

Adaptation constraints previously identified in the literature include structural aspects such as lack of resources, regulations, institutional systems, and technology (Engle, 2011). However, individual socio-cognitive aspects in the form of perceived exposure to climate-related risks as well as perceived ability and willingness to manage these risks also influence people's adaptation capacity because they are closely linked to their action space (Grothmann & Patt, 2005). Together with the structural aspects, socio-cognitive constraints embody individuals' adaptive capacity, which is an important precondition for adaptive action (Fleming, Dowd, Gillard, Park, & Howden, 2015).

As argued by Adger et al. (2009, p. 344), "actions are shaped in part by deeply-embedded (but not static) cultural and societal norms and values". In this context, climate change communication resources can strengthen individuals' adaptive capacity if they address the underlying norms, values, and local contexts that influence people's perceptions and behaviour (Adger, Quinn, Lorenzoni, Murphy, & Sweeney, 2013). Such communication should further provide meaningful information that can increase awareness, reflection, and a sense of relevance and thus support individual decision-making (Wibeck, Neset, & Linnér, 2013). Various climate visualization tools could generate the information needed in order to raise awareness of risks and opportunities and to stimulate adaptation (Lujala, Lein, & Rød, 2015). As argued by Foo, Gallagher, Bishop, and Kim in the 2015 special issue of this journal on landscape visualization, "visual outputs contribute to people's perceptions, feelings, and thoughts about the landscapes that they inhabit and shape over time" (Foo, Gallagher, Bishop, & Kim, 2015, p. 80). However, visualizing climate change and adaptation alternatives so that they appear credible and legitimate (i.e., presenting trustworthy scientific outputs without oversimplification and measures deemed reasonable or sensible) while simultaneously appearing salient (i.e., easy to understand and localized enough to spur local action) is far from straightforward (Lovett, Appleton, Warren-Kretzschmar, & Von Haaren, 2015; Nassauer, 2015). On one hand, general visualizations providing "a bird's-eye overview of a study area" can effectively facilitate homeowners' exploration of what climate change and adaptation could mean for them without promoting a specific measure (Lovett et al., 2015; p. 87). On the other hand, Sheppard (2015) argues that precise visualizations, highlighting local effects and tangible action alternatives, can effectively spur local engagement. Developing climate visualizations clearly calls for informed choices and sometimes mixed approaches to what and how information is displayed.

This paper analyses whether and how combinations of “precise and general depictions” (Foo et al., 2015; p. 81) can be combined in climate visualization to enhance individuals’ adaptive capacity. The study examines an interactive planning support tool, VisAdapt™, that targets Nordic homeowners. This tool collects information on general climate change trends in the Nordic region, combining it with more specific information on risks and measures and specific house types to facilitate individual adaptation planning and management. To date, visualization tools in this segment, connecting the global challenges of climate change to local tangible information on adaptation for laypeople, remain scarce (Neset, Opach, Lilja, Lion, & Johansson, 2016).

The study explores how homeowners in Denmark, Norway, and Sweden make sense of and discuss climate change risks, climate change adaptation, and their individual planning and management when using the VisAdapt tool. The study takes its starting point in previous literature on the socio-cognitive constraints on adaptation affecting individual adaptive capacity, and on criteria for meaningful adaptation communication, including visualization. Our definition of adaptation constraints (often synonymous with barriers, limits, and obstacles) is in line with the IPCC’s definition, i.e., “factors that make it harder to plan and implement adaptation actions” (Klein et al., 2014; p. 907).

The empirical material comprises transcripts of seven focus group interviews in the three countries. The study is structured around the following three sets of research questions:

- How do homeowners perceive climate change risks and their own capacity to adapt, and how can these perceptions act as individual constraints on adaptation?
- How do homeowners make sense of and discuss climate risk and individual capacity to adapt in the context of the interactive planning support tool VisAdapt?
- Does the assessed visualization tool help reduce perceived individual constraints on adaptation? If so, how?

2. Constraints and facilitating factors for climate change adaptation

A common departure point in assessing climate change adaptation constraints (and facilitating factors) in the scientific literature is the concept of adaptive capacity. As defined in the IPCC’s Fifth Assessment Report, adaptive capacity is “the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (IPCC, 2014). An assessment of adaptive capacity can reveal how well a system or actor is suited to reactively managing the effects of climate impacts, such as rescuing people from flooded areas and/or estimating a system’s or actor’s capacity to implement long-term measures, such as regulating where it is safe to build houses (Engle and Lemos, 2010 and Engle, 2011).

Studies of adaptive capacity have often concentrated on specific determinants in order to qualitatively analyse their importance in facilitating or hindering the implementation of adaptation. Though highly dependent on their context, such determinants generally include highly interrelated financial, institutional, technological, informational, and behavioural aspects (Smit & Wandel, 2006). In the literature, such determinants encompass universal societal preconditions that can influence the capacity of actors to implement adaptation (Keskitalo, Dannevig, Hovelsrud, West, & Gerger-Swartling, 2011), including the influence of institutional configurations on local government ability to

implement adequate adaptation (Storbjörk & Hedrén, 2011) and the influence of socio-economic stress on specific actor groups' ability to respond to specific climate impacts (Hjerpe and Glaas, 2012 and Sovacool and Linnér, 2015).

2.1. Individual constraints and adaptive capacity

When targeting individuals' adaptive capacity, analyses have often centred on how norms and values (i.e., behavioural aspects) related to, for example, place identity, perceptions of roles and responsibilities, knowledge, previous experience, and perceived risk severity, act as constraints on or opportunities for adaptation planning (Adger et al., 2013 and Moser, 2014). A key argument is that it is important to analyse underlying contextual factors that influence individuals' priorities and values, which in turn influence their adaptive capacity (Fleming et al., 2015). This involves analysing interdependencies between perceived individual adaptation constraints and how they develop, persist, and play out in order to assess how to facilitate adaptive action (Eisenack et al., 2014).

Individual constraints on adaptation that affect individual adaptive capacity are often divided into two interlinked types: 1) perceptions of the probability and severity of climate impacts (i.e., risk perceptions) and 2) the individual's own perceived role, efficacy, and adaptation costs (i.e., perceptions of responses) (Grothmann & Patt, 2005).

2.1.1. Risk perceptions

Individuals' motives for adapting to climate change are influenced partly by how probable climate change impacts are perceived to be and partly by how harmful they appear, both of which are in turn influenced by multiple contextual and personal factors (Grothmann & Patt, 2005). An important factor is the strength of confidence that climate change will generate local effects (Blennow & Persson, 2009), which is formed largely by the availability of information about local risks and impacts (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007). The global and expert-driven nature of climate change knowledge can inhibit such understandings by making climate change appear distant in time and space, reducing individuals' sense of urgency and their motivation for change (Shaw et al., 2009).

Another context-dependent factor is how severe climate change risks appear relative to other risks. As argued by Raymond and Brown (2011, p. 267), "because individuals cannot deal with the full complexity of risk and the multiple types of risks in their everyday life, individual and group values will determine the importance and severity of different risks". How people understand and conceptualize climate change risks is greatly influenced by how they perceive other issues and relate those to climate change (Wolf & Moser, 2011). One way to contextualize is to anchor climate change information to locally known places and other local issues (Shaw et al., 2009).

2.1.2. Perceptions of responses

Whether risk perception is transformed into adaptation implementation is further determined by two factors in particular: individuals' own perceived responsibility and capacity to adapt (Grothmann & Patt, 2005). First, perceptions of one's own versus the public sphere's responsibility to manage climate change affect individual willingness to implement adaptation actions (Adger et al., 2013). This willingness can be eroded, for example, by an "overreliance on public infrastructure" such as dykes, which can arguably lead to "a dangerous, false sense of security" (Lieske, Wade, & Roness, 2014, p. 84). Previous experience of impacts, such as floods, can affect these perceptions by generating an

acceptance of one's responsibility to protect one's own home, for example, against future flood events (Kreibich et al., 2011).

The second factor is perceptions of one's ability to mitigate climate risks. According to Blennow and Persson (2009), this relates to individuals' confidence in the appropriateness of various adaptation options. Accordingly, efforts to reduce uncertainty regarding how to adapt were found to be important in facilitating individual adaptation. However, even though it is fairly clear what measures would be appropriate, the perceived high cost and low efficacy of the individual implementation of these measures could constrain adaptation (Lorenzoni et al., 2007). Addressing this would require actionable information on "possible, effective and not too costly adaptation options" (Grothmann & Patt, 2005; p. 209).

2.2. Factors facilitating individual adaptive capacity

Social constraints on adaptation are "malleable barriers", meaning that "they can be overcome with sufficient political will, social support, resources, and effort" (Moser & Ekstrom, 2010, p. 22027). Climate visualizations can facilitate reducing social constraints on adaptation if presented so as to resonate with users. As with all forms of communication, important points of departure for meaningful communication about climate change risks and adaptation options are knowing one's audience, finding ways to recall established practices and values, and engaging users by relating information to existing implementation barriers and local contexts (Moser, 2014 and Nicholson-Cole, 2005). This is important, as people tend to pay more attention to messages that are emotionally charged and appear more personally relevant than to more classical forms of expert-based information (Lujala et al., 2015 and Wibeck et al., 2013). Nevertheless, the information should also be seen as credible and unbiased, placing other demands on the development of visualizations (Lovett et al., 2015). More specific criteria for how to meaningfully communicate climate change risks and adaptation in order to spur action have also been highlighted, as summarized in Table 1.

Table 1. Criteria for meaningful adaptation communication.

Socio-cognitive constraint to adaptation	Criteria for effective communication	References
Perceptions of risks	Climate change is framed as a phenomenon personally relevant to the target audience	Lujala et al. (2015), Shaw et al. (2009)
	Communication on risks and impacts resonates with local practices, values, concerns, and previous experiences	O'Neill & Nicholson-Cole (2009), Scannell & Gifford (2013)
	Communication provides opportunities to explore impacts by oneself	Bishop et al. (2013), Wibeck et al. (2013)
	Information is transparent: uncertainties are made understandable and are visualized to appear credible	Dockerty et al. (2005), Moser (2014), O'Neill & Smith (2014)
	Information is not over-simplified	Uggla (2008)
	Not only fearful messages are spread	Wolf and Moser (2011)

Perceptions of responses	Information relates to established implementation barriers	Moser (2014)
	Communication presents clear options and lists of alternative adaptation measures to choose from	Lieske et al. (2014), Scannell & Gifford (2009), Sheppard et al. (2011)
	Communication on actions is tailored to the needs and objectives of the target audience and relates to everyday concerns	O'Neill and Nicholson-Cole (2009), Vulturius & Gerger Swartling (2015)
	Adaptation options are visualized	Moser (2014)
	It is clear how individual adaptive responses can make a difference	Nicholson-Cole (2005), Niepold et al. (2008)
	Communication enhances engagement and discussion among users	Bohman et al. (2015)

Regarding overcoming the first type of individual constraints – i.e., risk perceptions – previous literature emphasizes that communication must address an often existing gap between changes perceived as occurring at a distance and those perceived as occurring within the personal realm of individuals. This entails framing climate risks as personally relevant phenomena by linking them to issues, impacts, or places to which users can relate (Lujala et al., 2015 and Scannell and Gifford, 2013). One emphasized way of contextualizing climate change in this manner is to allow “people to ‘encounter’ the possible impacts” of climate change, for example, by relating them to “iconic places”, for example, locally important and well-known agricultural land at risk of flooding or animal habitat threatened by storm surges (Shaw et al., 2009). Another way to convey messages about possible local climate change effects more effectively is to use “interactive landscape displays”, i.e., interactive climate visualizations in which landscape views change depending on user inputs (Dockerty, Lovett, Sunnenberg, Appleton, & Perry, 2005). Various abstract and realistic visualization techniques have the potential to help users relate to climate impacts in ways that make sense to them (Bishop, Pettit, Sheth, & Sharma, 2013) and increase engagement through reducing the “perceived distance to the problem” (Scannell & Gifford, 2013; p. 64). Another suggested way to put climate impacts on the individual agenda is to relate these to personal experiences of weather-related damage, an approach that influences people’s perceptions of climate change and its likelihood (Lujala et al., 2015).

Nevertheless, climate change communication material must be transparent in order to appear legitimate and credible and thereby avoid being counterproductive for its intended users (Dockerty et al., 2005). This can be done by presenting robust projections or scenarios from trusted sources in a clear and accessible format (Nicholson-Cole, 2005) and by offering various scenarios from which users can choose (Moser, 2014). As previous studies demonstrate, framing climate change as a single over-simplified story will not likely be productive in helping people to make sense of climate change or to consider individual actions (Uggla, 2008). The same also goes for representations of climate change that appeal solely to fear, as these might create distance from the problem, thereby reducing personal engagement (O’Neill & Nicholson-Cole, 2009). If messages that appeal to negative feelings

of hopelessness, fear, and guilt are emphasized, climate change communication could generate disengagement rather than spurring individual interest and action (Wolf & Moser, 2011).

Related to overcoming the second type of individual constraints, i.e., perceptions of responses, previous studies stress the importance of identifying response measures (Moser, 2014). Developing such a supporting framework includes presenting sets of alternative adaptation options that individuals feel personally responsible for implementing (Lieske et al., 2014), highlighting both short- and long-term choices, and demonstrating personal relevance (Scannell & Gifford, 2013). An important departure point for such a framework is that the communication should fit the practical objectives and needs of individuals, for example, being related to income, costs, and preventing damage (e.g. Vulturius & Gerger Swartling, 2015). It is furthermore important to communicate costs and benefits related to different types of adaptation measures (Moser, 2014). Empowering individuals in their own ability to implement such actions is key (Niepold, Herring, & McConville, 2008), and doing so entails presenting how individual adaptive responses can make a difference in preventing specific risks (Nicholson-Cole, 2005). However, as found by Bohman, Neset, Opach, and Rød (2015), the effectiveness of climate change adaptation communication in facilitating action is not necessarily limited to addressing communication deficits. Rather, effectiveness in adaptation communication may be found in its ability to enhance engagement, reflection, and discussion among its users. From this perspective, it is important that users be provided with several possible ways forward and that the information on actions not be biased or too limited (Lovett et al., 2015).

3. Method and materials

In this study, the role of climate visualization in addressing constraints on adaptation is understood from a communication perspective, communication being defined as a constitutive practice in which meaning creation is central. Meaning, in this sense, is defined as a process of interpretation influenced by cultural, contextual, and social factors (Fiske, 2011). In this view, audiences are conceptualized as active and central participants in the communication process, so we approach communication from an audience perspective, concentrating on how it is received and interpreted. To this end, this study used focus group interviews and test sessions with homeowners to explore how participants relate to climate risks and adaptation actions as presented in the visualization application VisAdapt™.

3.1. VisAdapt™

VisAdapt™ was developed through an interactive collaborative process involving Nordic researchers and representatives of four large non-life insurance companies and the national insurance organizations in Denmark, Norway, and Sweden, and was tailored to meet the profile of homeowners. A main aim of the tool was to increase homeowners' adaptive capacity by providing interactive information about climate change risks and adaptation alternatives relevant to planning and managing individual residential buildings. A web-based solution was designed to allow for easy navigation between setting a house profile, exploring climate change scenarios and risk data, and investigating related adaptation measures. The tool is available in English and the five major Nordic languages (i.e., Swedish, Danish, Norwegian, Finnish, and Icelandic) to ensure that homeowners have unconstrained access to the information provided.

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VisAdapt™ includes elements of geographic and information visualization and is designed to incorporate multiple linked views. The structure of the interface follows a three-step design (cf. Johansson et al., 2016) to guide the user and enable an iterative process in which various locations, house types, and parameters can be selected and local climate-related risks and adaptation measures can be explored (Fig. 1).

Fig. 1. Overview of the Visadapt™ tool.

In the first step, users are asked to specify their address and then to select the features of their house (e.g., the material of the roof and façade) and the topography that applies to their garden in the “House Builder” (Fig. 2). Based on the selected house features and the identified geographic location and situation of the house, the scope of the spatial data is demarcated and information on adaptation measures is sorted as presented below. When inserting the address of the house, a Google Street View image of the house is shown to reinforce the local anchoring of the information presented.

Fig. 2. House builder function.

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In the second step, users can explore climate change scenarios and risks at their location. Building on the RCP 8.5 emission scenario, implying business as usual and a time frame up to the 2051–2070 period, users are provided with downscaled climate scenarios highlighting anticipated changes in the four climate parameters (i.e., annual temperature, annual precipitation, heat waves, and cloudbursts) displaying the largest changes in the region (Fig. 3, left part). An explanation of the viewed climate parameter and a summary of the anticipated changes in the users' location are shown below the map. The yellow arches of the “gauges” indicate the projected changes and the scale applies to the entire Nordic region.

Fig. 3. Selected climate parameter (left) and flood risk map (right). The light blue area represents the flood zone for a 100 year flood. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Users are also provided with risk maps for climate risks deemed important for the region, including the risk of flooding stemming from sea level rise and freshwater runoff (Fig. 3, right part), which are collected from national authorities in the Nordic countries. The anticipated changes and risks were

matched with more specific risks facing residential buildings in the region based on a deeper literature review (Glaas, Neset et al., 2015 and Glaas, 2014). Based on the assessed literature, a list of specific climate- and weather-related risks affecting various house parts and materials was developed, which was used as the foundation for identifying existing adaptation measures, as presented below (Glaas, Neset et al., 2015).

In the third step, users can explore adaptation measures matching their house type and features in terms of materials and topography (Fig. 4). The measures are sorted under each specific climate parameter when the climate scenarios are viewed (Fig. 4, left part) or under each specific climate risk when risk maps are viewed (Fig. 4, right part). The adaptation measures are further sorted according to what changes are expected to be greatest at the user's selected location. The presented adaptation measures were collected from national authorities, research institutes, municipalities, insurance companies, and national insurance organizations in Denmark, Norway, and Sweden (Glaas, Neset et al., 2015). Generally, the adaptation measures present how houses can be adapted to changing weather conditions by, for example, managing or rebuilding drainage systems to avoid flooding, installing sun-blockers to lower indoor temperatures, and managing roofs and facades to prevent water leakage. At the top of the adaptation measures, a create report function allows users to print a PDF file containing all measures applying to their own house's features (Fig. 4).

Fig. 4. Adaptation measures sorted after climate parameters (left) and climate risks (right).

VisAdapt™ was designed as an interactive planning support tool with a medium to high level of interactivity. The level of interactivity allows users to swiftly compare different climatic parameters and risk maps for a specific location as well as to pan and zoom to investigate other locations for comparison. The tool does not allow users to pose their own hypotheses, but rather to search and assess predefined information on selected climate parameters, risks, and measures.

3.2. Focus group interviews

We applied a focus group methodology to explore how VisAdapt™ was perceived and used. The focus group interview is a well-established method for exploring the development of perceptions and ideas related to a particular subject (Kitzinger, 1995). The social setting of focus groups encourages participants to share and verbalize views, opinions, and ideas, which are developed as a result of the social and interactive nature of the focus group methodology.

To analyse how individual constraints on adaptation were addressed by the tool, the discussions explored, first, individual constraints from the participants' perspective and, second, how the participants made sense of climate visualization. To accommodate these aims, the focus group interviews were divided into three phases: 1) general discussion of climate change emphasizing risk perceptions and one's self-perceived adaptive capacity, 2) test sessions using VisAdapt™ in smaller groups of two or three people, and 3) a follow-up discussion of the participants' interactions with and perceptions of the tool. The first phase provided an understanding of the participants' preconceptions of climate change risks and adaptive capacity in order to contextualize their interpretations of VisAdapt™ and to gain insights into their perceived constraints on adaptation. In the test sessions, the participants could explore and familiarize themselves with the tool, and the subsequent follow-up discussion focused on the participants' perceptions of VisAdapt™, interpretations of its content and relevance, and discussion of climate change risks and individual adaptive capacity in relation to VisAdapt™.

We conducted a total of seven focus group interviews (Table 2). The first interview functioned as a pilot study used to adjust and refine the methodology. As an early version of VisAdapt™ was used in the pilot interview, we will refer to the insights and discussions from this particular focus group only when they are not directly related to the functionality of the current VisAdapt™ tool. The focus group interviews lasted approximately two hours and were audio recorded and subsequently transcribed for analysis.

Table 2. Description of the focus group interviews.

No	Group size	Participants	Place	Date
1	3	2 men, 1 woman.	Aarhus, Denmark	20 June 2013
2	7	5 men, 2 women.	Norrköping, Sweden	17 June 2014
3	5	3 men, 2 women.	Norrköping, Sweden	18 June 2014
4	5	3 men, 2 women.	Trondheim, Norway	3 Nov. 2014
5	7	4 men, 3 women.	Trondheim, Norway	4 Nov. 2014
6	6	2 men, 4 women.	Aarhus, Denmark	6 Nov. 2014
7	5	5 men.	Aarhus, Denmark	7 Nov. 2014

We held the focus group interviews in three locations: the towns of Aarhus (Denmark), Trondheim (Norway), and Norrköping (Sweden) were selected to obtain a range of exposure to climate change risks and of national and local policy contexts. This allowed for assessment of various risks and

management realities across the Nordic region. We recruited homeowners through social networks, invitations published on websites, and by contacting people through local housing associations. We strove to ensure a broad range of homeowners in terms of rural/urban location, age, and gender, allowing us to assess the “localization” of the contents of the tool from many perspectives.

For data analysis, we conducted a thematic content analysis in which we thematically categorized the transcripts of the focus group discussions (phases 1 and 3) (Krueger, 1998). Aligned with the themes of the framework (Table 1), we identified sequences and dialogue sections relating to the participants’ perceptions of risks and responses, defined as perceived adaptive capacity and responsibility. Driven by the data, we then condensed the meaning of the dialogues into the two categories (Kvale & Brinkmann, 2009), concentrating the analysis on identifying constraints on adaptation. The analysis of the follow-up discussions (phase 3) concentrated on the participants’ discussions of climate risks and individual adaptive capacity in the context of VisAdapt™. Following the same procedure as above, we identified sequences relating to the participants’ perceptions of risk, adaptive responses, and the features and usability of VisAdapt™. The analysis identified challenges and opportunities, arising from visualization tool use, for enhancing the participants’ adaptive capacity.

4. Results and discussion

The focus group discussions revealed various perceptions of climate change risks, ranging from distant in space and time to local and current. This spread mirrors the complexity of the climate change issue, and was itself an expected outcome. From a global perspective, the highlighted risks were largely the same as those addressed by the IPCC, while appropriate local adaptation measures were less discussed.

During the test sessions, participants experimented with the interactive functions of the tool, by exploring and comparing the different climate parameters and risk maps (Fig. 3). The pan and zoom functions of the tool were frequently employed to compare the selected house location with other areas in the same region or for comparison with the other Nordic countries.

Overall, five clusters of constraints on adaptation were identified in the transcribed material from the first phase of the focus group discussions. The following sections are structured according to these identified constraints, which are discussed in relation to our analysis of the participants’ views of the VisAdapt™ tool, resulting in several pathways for developing climate visualization tools to facilitate adaptation planning and management. The identified constraints played out in a similar way in most focus group discussions in the three countries, suggesting that they are not particularly sensitive to place attachment.

4.1. Climate change impacts are abstract

One identified constraint on adaptation is the perception of climate impacts as generally innocuous for the participants’ own local areas, based on a view of climate change impacts as abstract. This view influences the participants’ sense of the relevance of climate change adaptation and hinders individual action (cf. Glaas, Ballentyne et al., 2015). Interestingly, these views existed despite a quite well-developed understanding of climate change impacts at a global level. The follow-up discussions revealed that the visualization tool, presenting climate change trends over a period of 40–60 years,

clarified the anticipated trends of specific parameters such as precipitation, heat waves, and cloudbursts, making the discussions in the focus groups more specific in terms of likely local impacts. An important facilitating factor here seems to have been the tool's easily understandable overview of the specific climate parameters, which made comparisons of trends at various locations accessible. This also seems to have facilitated understanding of the connections between anticipated climate change trends and previously experienced weather impacts. The following quotations from a discussion among respondents from Aarhus exemplify this in relation to cloudbursts, emphasizing the importance of specifying various parameters individually in climate visualization:

P1: I think about how it rains a lot already. Occasionally there's a cloudburst, and we should be able to handle that. ... These things are already here and it's nothing new. This could mean that there will be two days more or less [of cloudbursts]. I mean, this is nothing new.

Interviewer: Because it's already here, you mean?

P1: Yes, and we should be able to handle that.

P2: It's only cloudbursts, but they will be stronger.

P1: Yes, so if there is more water in them, we may well need to do a little more.

(Focus group 6, authors' translation)

As exemplified by this quotation, and by discussions of the VisAdapt™ flood risk maps, the tool seemed to provide opportunities for participants to explore impacts related to specific climate parameters also regarded as important in previous research (cf. Bishop et al., 2013 and Wibeck et al., 2013). However, despite placing climate change impacts in a specific historical and management context, the presented climate change trends did not seem to make the impacts appear particularly more acute or pressing. The discussions instead highlighted that the level of anticipated change, which was perceived as generally small, could act as a barrier to action. This perspective was raised by respondents in all groups, for example, by a respondent in Norrköping:

I thought that the changes would generally be greater, and it's maybe a bit scary that you find out that it's not so bad, because then you may be less worried than before.

(Focus group 2, authors' translation)

One reason why participants perceived the climate changes to be small is, of course, the relatively short-term perspective of the presented scenario (i.e., the coming 40–60 years), which was selected to provide a timeframe relevant to homeowners. However, another reason is that participants found it difficult to understand what various levels of change actually implied in terms of climate impacts. Many participants asked for clearer links to be made between levels of change and degrees of impact, for example, what impacts a 2 °C increase in annual temperatures would have. This appears to be a general challenge in developing climate visualization tools, i.e., providing a scientifically sound basis while linking climate change scenarios to concrete anticipated impacts (cf. Neset et al., 2016). Finding better ways of connecting these two aspects would likely improve the tool significantly; this could be achieved through more localized assessments, by linking generic tools such as VisAdapt™ to local climate impact or adaptation projects, and by applying spatial analogues to exemplify possible future climates in other geographic places (Veloz et al., 2012).

4.2. Climate change happens somewhere else

Related to the perceptions of local impacts as abstract, participants in all focus groups perceived climate change impacts as somewhat distant in time and space, which could reduce their sense of urgency when other concerns appear more immediate and pertinent (cf. Glaas, Ballentyne et al., 2015 and Raymond and Brown, 2011). This constraint was nearly absent from the discussions after the sessions testing the tool, which centred more on local impacts, including various types of flood risks. An obvious reason for this focus was the flood risk maps included in the tool (Fig. 3), which were referred to frequently in the discussions, especially in the three Danish focus groups, in which flood risks were treated as the most pressing impact due to recent severe flood events. Such interactive displays of anticipated impacts appeared to encourage comparative analyses in the test sessions and provided common reference points in the follow-up discussions. In the future development of similar tools, further ways of linking climate change trends to local impacts would likely be useful for spurring reflection on local risks and impacts. As VisAdapt™ was developed in the intersection between general and precise depictions (Foo et al., 2015) and targets a wide audience (i.e., Nordic homeowners), linking to location-specific landscape displays (as suggested by, e.g., Bishop, 2015) would be beyond its scope. However, one way forward could be to link climate scenarios to generic images, visualizations of risks, and adaptation measures in residential buildings, as discussed by Sheppard (2015). When developing VisAdapt™, this could be done by visualizing the more specific climate risks underlying the identification of adaptation measures (Fig. 4, right part) and/or the presented adaptation measures (Fig. 4).

The entry point to the tool – i.e., where users search for their own address to determine their position on the map of the Nordic countries and to obtain a Google Street View image of their house – is another aspect that seemed to reinforce the relevance of local impacts. This was noted, for example, by a respondent in Trondheim:

The connection to Google Maps – when you type in your address and house type – it doesn't really matter what it looks like. But mentally it's easier to understand what is happening, as you can see your house (Focus Group 5, authors' translation)

Despite the risk that the Street View feature may be overemphasized (in many test sessions, participants spent more time than expected obtaining a good view of their house), the feature succeeded in providing a strong sense of place. As indicated by the above quotation, the feature seemed to have focused the discussions on local impacts and responses.

Limitations in the perceived relevance of the tool were also found. These seem to derive from the fact that both the climate and exposure data are aggregated by municipality (Fig. 3). Several participants commented that this data presentation did not correspond well to their knowledge of local differences, for example, due to topographical or microclimatic conditions, reducing the perceived relevance of the tool to their house. This problem could hypothetically be solved by including more local data on, for example, topography or previous local weather impacts, as suggested by some participants. On the other hand, many participants said that the present version of VisAdapt™ already featured too much data. Judging from these observations, a significant challenge that remains for this and many other similar web-based climate visualization tools (cf. Neset et al., 2016) is finding a good balance between the amount and level of detail in the information included. Adapting the level of detail to a broad audience presents developers of climate visualization tools with the challenge of ensuring sufficient flexibility to enable the initiated user to

retrieve sufficiently relevant information, while being selective enough to help the novice user retrieve introductory climate change adaptation information. A way forward that was discussed in the focus groups could be to provide information structured in multiple layers, allowing users to explore local risks and implemented adaptation measures in greater detail by linking to case studies, historical weather conditions, and municipal websites.

4.3. Climate change is someone else's responsibility

Another identified constraint was a weak sense of personal responsibility, with other actors being considered mainly responsible for taking action, as also found in previous studies (cf. Adger et al., 2013 and Lieske et al., 2014). Although acknowledging homeowners' responsibility for the day-to-day maintenance of their private properties, the focus group discussions of responsibility for long-term adaptation primarily concerned other actors, particularly state and municipal actors (cf. Glaas, Ballentyne et al., 2015). This perceived low individual responsibility for managing long-term effects was obvious in the initial discussions, but was less evident in the follow-up discussions. Generally, participants acknowledged their responsibility for managing weather and climate impacts affecting their properties, but stressed the importance of functioning municipal infrastructure, such as drainage systems, to guard against impacts such as flooded basements.

Although individual responsibility for managing private properties had already been discussed in the initial discussions, participants more clearly connected weather-related impacts to the anticipated impacts of climate change in the follow-up discussions, indicating that the visualization tool contributed to the discussion of greater responsibility on the part of individual homeowners. Specifically, the presented adaptation measures (Fig. 4) seem to have clarified for the participants the types of management or action needed from individual homeowners, directing the discussion away from broad global challenges towards local impacts and the management of residential buildings.

Nevertheless, how the discussions of responsibility evolved is difficult to assess as this matter was generally little addressed in the follow-up discussions, despite being explicitly requested. A lesson learned about visualizing climate change adaptation, however, is that it is important to explicitly emphasize various measures for managing the long-term impacts of climate change, to make adaptation alternatives appear more concrete and consequently make people more aware of their potential roles alongside other actors. This might specify what individual action can entail. The argument that visualizing climate risks, impacts, and adaptation measures could make action alternatives less abstract is also relevant to emphasizing personal responsibility. Such visualization would likely clarify personal responsibility for adaptation and thereby increase individual adaptive capacity (Adger et al., 2013).

4.4. Adaptation is not within the realm of individuals

Yet another identified constraint on adaptation relates to a lack of belief in the usefulness of individual adaptive action. There was general confusion on this matter in the discussions, indicating an artificial separation between measures for managing weather-related impacts – which were regarded as self-evident – and measures for managing climate change impacts – which were described as unusual, under-communicated, and abstract (cf. Glaas, Ballentyne et al., 2015). The follow-up discussions often centred on the actual adaptation guidelines included in the third section of the tool (Fig. 4). Here, the confusion about appropriate adaptive action was transformed into general frustration at the “everydayness” of the included guidelines, which many participants

considered common-sense measures that homeowners would naturally undertake, although acknowledging that it is good to be reminded about these issues. This is illustrated by a quotation from a participant in Trondheim:

This is a tool that might make us more aware that we must clean out our drains and ensure that we have waterproofed walls and a watertight roof. That's fairly self-evident. But it directs attention towards it, so the tool makes us aware that we must do something. (Focus group 5, authors' translation)

Though arguing for the obviousness of the guidelines included with the tool, participants in all focus groups initiated advanced discussions of how to prevent various climate change impacts from affecting specific house elements and materials, for example, protecting suspended foundations from mould and preventing water leakage through flat roofs. The fact that these discussions translated long-term adaptation into the perceived everyday practices of homeowners, making adaptation less abstract, may facilitate involvement, as also noted in previous studies (cf. O'Neill and Nicholson-Cole, 2009 and Vulturius and Gerger Swartling, 2015).

An issue repeatedly raised in relation to the claimed obviousness of the adaptation guidelines was a perceived lack of detailed information on implementation, which was perceived as a likely barrier to adaptation. In developing the tool, information on implementation had intentionally been limited, given the risk of overloading users with information and given that it is difficult to provide uniform information to heterogeneous users without misleading some of them. A positive aspect of this limited information provision, however, is the discussion and reflection it seemed to provoke among users. Several respondents presented examples of precise information on implementation and of specific materials (e.g., paint) that are particularly effective for preventing climate change impacts. A general conclusion is that information on adaptive measures need not be detailed or precise to spur engagement and reflection; it is likely more important that the information trigger reflection on alternative ways to manage climate change impacts and that it should relate to established user practices (cf. Bohman et al., 2015).

Nevertheless, to make the adaptation measures – and the tool – more useful, a few additional features were suggested by participants. These include separating short- and long-term measures, developing checklists for local risk management, and visualizing measures to make information more tangible. As suggested by the participants, the create report function presented in Section 3.1 was developed after the focus groups to add a checklist for individual planning and management.

To further develop the visualization tool, finding ways of separating information on day-to-day maintenance from more specific or “new” types of measures, such as how to install backwater valves and backflow blockers in basements, could improve its perceived usefulness. Such measures were seen as different from maintenance issues and not paid sufficient attention.

4.5. Adaptation is expensive

A final identified aspect, acting as both a limiting and a facilitating factor for adaptation, is the economics of implementation (cf. Glaas, Ballantyne et al., 2015). Opportunities to earn financial rewards (e.g., from insurance companies) were said to be among the main motivating factors for implementing adaptation measures, while high direct costs were considered a limiting factor (Lorenzoni et al., 2007). Several of the follow-up discussions concerned preserving capital through adaptation, rather than the actual cost of implementation, indicating that the tool increased the

attention paid to individual responsibility for adaptation, as discussed above. This can be exemplified by a quotation from a respondent in Trondheim:

As a homeowner, it is the value of my own property that is at risk here. And it's therefore, of course, my task to take care of my property. (Focus group 4, authors' translation)

Later in the discussions, the participants more frequently described the risks of damage-related costs and lower market values of houses as motivating factors for implementing adaptation, while focusing less on implementation costs as a limiting factor, versus early in the discussions. This shift in focus might be attributable to the clarification of specific adaptation measures, which were seen as straightforward, not too costly, and within the capabilities of individual homeowners.

The tool seemed to have inspired a sense of agency to adapt, found to be important in previous studies (cf. Grothmann & Patt, 2005). Nevertheless, participants argued that, to increase its usefulness, the tool should include more information on costs and various reward systems. The cost aspects of adaptation are not currently visualized in VisAdapt™, and incorporating these aspects could improve its perceived usefulness. However, it appears even more important to include information on available reward systems and on potential costs related to impacts. In some cases, rewards are offered by insurance companies for taking risk-prevention measures, and information on reward systems could be included if users were asked to specify their insurance company and the tool then linked to company-specific reward systems. Implementing this would require ongoing dialogue between the tool developer and the main insurance companies in the region. Visualizing the costs of weather impacts is less straightforward for general tools such as VisAdapt™ and would require more research.

5. Conclusions

This study set out to identify challenges and opportunities for enhancing individuals' adaptive capacity through climate visualization tools. Generally, the study supports previous findings that climate visualization tools should not tell a single climate change story, but instead provide the pieces of a puzzle, allowing people to piece together their own story (cf. Bishop et al., 2013, Uggla, 2008 and Wibeck et al., 2013). This is important because climate impacts, risks, and appropriate adaptation measures are highly context specific and because users possess different previous knowledge and attitudes, influencing how they will interpret the information presented to them. Nevertheless, enabling people to explore the information on their own requires that the information be situated, make sense, and boost people's agency and engagement. To address such requirements, VisAdapt™ was developed as an interactive planning support tool in the intersection between "precise and general depictions" (Foo et al., 2015, p. 81). It is intended to reach a broad target group (i.e., Nordic homeowners), providing it with information about general climate trends and impacts that is simultaneously context relevant by providing risk maps related to specific locations and suggesting adaptation measures applicable to the users' selected house features.

The initial focus group discussions revealed individual constraints on adaptation expressed when participants were asked about their general views of climate change risks, adaptive actions, and responsibilities, all of which influence individual adaptive capacity. These views included perceptions of climate change impacts as abstract and distant in time and space and of adaptation as "someone

else's" responsibility, i.e., not within the realm of individual action, and moreover as too expensive. These perceptions appeared rooted in a generally fuzzy understanding of climate change impacts as differing completely from weather-related risks and impacts. While climate change impacts and measures appeared abstract, irrelevant, and beyond the scope of individual homeowners, weather risks were considered "by default" in the hands of homeowners themselves.

After testing the VisAdapt™ tool, a more management-oriented picture of climate change adaptation emerged in which risk was discussed in accordance with impacts on participants' own houses. Generally, climate- and weather-related risks were more likely to be discussed as constituting a unified phenomenon in the context of VisAdapt™, as participants discussed more specific risks and measures and attributed more responsibility to themselves for practical management. This signals that the tool was successful in transforming climate change adaptation into a personally relevant and ongoing planning and management issue. Specifically, participants' perceptions of responses to climate change seem influenced by the information provided on adaptation measures, even though several measures were dismissed as common sense. However, even the perceived common-sense measures, i.e., cleaning out gutters and pipes to prevent water leakage, were set in a climate change context, indicating that adaptation had become more tangible, which could serve to increase individual adaptive capacity. To better support individual adaptive action, the adaptation measures suggested by the tool should be accompanied by more information on implementation.

One way of making adaptation appear more tangible while not limiting individual adaptive choices is to visualize a range of options for implementation. A lesson learned here is the importance of separating day-to-day maintenance from measures requiring long-term planning horizons and bigger investments, such as installing backflow blockers in basements or permanent flood walls in gardens. This was stressed in several of the focus group discussions.

Related to perceptions of risks as a constraint on, and basis for, building individual adaptive capacity, the participants' encounters with VisAdapt™ seem to have made climate change impacts appear more tangible. However, they did not seem to make climate change appear more acute or pressing, as the anticipated changes were seen as generally small. Identifying ways to improve the visualization of what, for example, a 2 °C increase in annual temperature could lead to in a concrete local context, stands out as key in future developments.

One facilitating factor that helped create a sense that climate change impacts were personally relevant was to explicitly specify various climate parameters individually in the tool (e.g., changes in precipitation, cloudbursts, and heat waves). Relating these parameters to well-known practices for managing weather-related risks was done to a great extent in the discussions, which seemed to facilitate perceived agency and confidence to implement action. As these links are seldom straightforward in practice, they are difficult to integrate into a visualization tool. The entry point into VisAdapt™, in which users are provided with a Google Street View image of their house, exemplifies a highly successful way of creating a sense of relevance to individual users. Another successful approach was to highlight the interactions between climate risks and established management practices for weather-related risks in the proposed adaptation measures, spurring discussion of current and future management practices among participants.

We conclude that climate visualization tools operating in the intersection between general and precise depictions, such as the tested VisAdapt™ tool, certainly still have limitations when it comes to addressing the adaptation constraints identified in the literature. However, the tool provided a

medium for exploring local impacts and spurring reflection on adaptation. We further found that it promoted reflection on potential climate change impacts and on concrete measures to implement in the participants' living environment. Content spurring such exploration and reflection can serve as a starting point for the future development of climate visualization intended to encourage household-level adaptation planning and management.

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