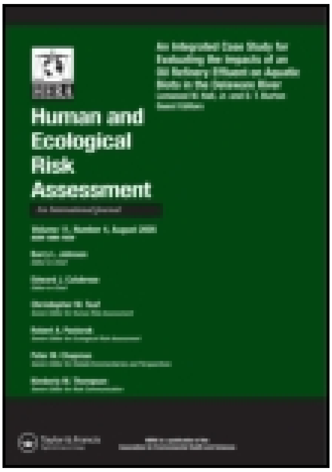

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Health Concerns Versus Mobile Data Needs: Conjoint Measurement of Preferences for Mobile Communication Network Scenarios

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RISK PERCEPTION/COMMUNICATION ARTICLES

Health Concerns Versus Mobile Data Needs: Conjoint Measurement of Preferences for Mobile Communication Network Scenarios

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ABSTRACT

As demands for mobile broadband services and ubiquitous network coverage in our societies are increasing, the mobile communication network infrastructure has to be expanded. Concurrently, the technical infrastructure of mobile communication technologies (base stations) raises the public's concerns about health risks due to electromagnetic fields (EMF). By applying conjoint analyses, the study empirically investigates the relationship between mobile data demands, different base station locations, the prevalence of perceived health complaints, and the impact of compensation payments. Findings show that health concerns are the most critical factor for mobile network communication scenario preferences, followed by data rate availability. In the decision scenarios, base station location and compensation payments played a minor role. Two user groups, cellphone and smart phone users who differ in their sensitivity regarding health concerns and data demands, were identified by segmentation analysis. By means of a sensitivity analysis, different mobile communication network scenarios were analyzed. Outcomes show the importance of integrating users' preferences into the design of mobile communication networks. This especially refers to an increased sensitivity regarding health concerns in cellphone users and minimum requirements for data rates at least sufficient for the usage of mobile Internet services for smart phone users.

Key Words: mobile communication technology, base stations, health concerns, data rate, compensation payment, conjoint analysis.

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INTRODUCTION

In the last decade, the usage of mobile communication technologies for mobile phoning, texting, or mobile Internet services has become an integral part of our life. The global mobile penetration has increased to 85% in 2011 (Ericson 2012) and a further doubling of mobile subscribers is expected until 2016 (ITU 2011). Recent technical developments in network performance (mobile broadband), mobile devices (*e.g.*, smart phone with high-resolution displays), and mobile services and applications (*e.g.*, Web streaming, video conferencing) suggest increasing mobile demands of end-users in the future. According to market research, mobile data traffic is expected to grow 10-fold in the next 5 years (ITU 2011). To provide requested mobile broadband services and ubiquitous network coverage, mobile communication network infrastructure has to be expanded (*i.e.*, the number of deployed base stations will have to increase).

However, the technical infrastructure of mobile communication technologies raises the public's concerns about health risks due to electromagnetic fields (EMF) emitted from base stations and mobile phones (Siegrist *et al.* 2005; Wiedemann and Schütz 2005). Reactions of those affected range from rejection or negative attitudes regarding base stations or mobile phone usage to medical conditions such as headaches, dizziness, sleeping problems, and so on (Cousin and Siegrist 2010a). As a consequence, the construction of base stations in residential areas, especially near sensitive areas, such as kindergartens, schools, or hospitals, often raises protests or law suits against network providers. The upcoming expansion of the mobile communication network infrastructure (*i.e.*, the rising number of deployed base stations), might lead to further protests among citizens and to aggravated acceptance problems in the society.

The growing mobile demands of our society on the one hand and the public's health concerns related to the technical infrastructure of mobile communication technologies on the other hand illustrate a dilemma that has important implications for network providers and public authorities. Even though technology acceptance and risk perception research thoroughly studied influential factors on acceptance of mobile communication technologies (van Kleef *et al.* 2010; Arning *et al.* 2010), an investigation of users' preferences in the described "dilemma scenario" with regard to mobile communication network demands on the one hand and health concerns on the other hand was not found in real choice situations.

The present study therefore simultaneously focuses on the relationship between existing mobile demands of users in terms of data rate availability, preferences regarding base station locations, and the prevalence of perceived health complaints due to EMF in the population. Moreover, we consider the impact of compensation payments for base station location on preferences in our study and identify user groups who differ in their preferences. As methodological approach conjoint analyses was applied.

Risk Perception of Mobile Communication Technologies

Research on risk perception has become increasingly important in recent years for the successful design and rollout of large-scale technologies. Risk perception research investigates the subjective assessment of the probability and the outcomes of negative events such as natural hazards or environmental threats (Slovic 1987) and tries to explain, predict, and influence perceptions of and attitudes toward technologies and related risks (Kasperson *et al.* 1988).

One dominating research approach is the psychometric paradigm that aims at the identification and quantification of factors that determine lay peoples' (non-experts) perception of hazards (Slovic at al. 1982). The psychometric paradigm explicitly considers the subjective, perceptual nature of lay peoples' risk perception. Based on psychophysical scaling and factor analytic studies two main factors of risk perception were extracted: "dread risk," defined by perceived lack of control, dread, catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits, and "unknown risk," defined by hazards judged to be unobservable, unknown, new, and delayed in their manifestation of harm (Slovic 1987). Highly relevant in the context of mobile communication technology risk perception is the perception of dread, which can even evoke feelings of fear (Frick at al. 2002). Health risks due to EMF emitted from mobile devices and base stations were identified as major source of dread (Arning *et al.* 2010; Siegrist *et al.* 2005).

Risk perception is also higher for unknown and new risks, but decreases when a risk is present for a long time due to habituation processes (Slovic *et al.* 1986). For risk perception of mobile communication technologies it was found that frequent usage experiences of mobile phones reduces perceived risks (Siegrist *et al.* 2005). Apart from risk perceptions, benefit perceptions also play an important role in explaining the overall evaluation of a specific technology. Risk and benefit perceptions were found to be inversely related (*i.e.*, the higher the perceived risks of technology, the lower the associated benefits). This relationship was explained by an underlying affective evaluation (like or dislike) of an activity or technology (Alhakami and Slovic 1994; Finucane *et al.* 2000). Further research suggests that people weigh or "tradeoff" perceived benefits against risks in making usage decisions or adopting a technology (Arning *et al.* 2013; Schenk *et al.* 2008). Considering the rising mobile data traffic and the growing number of mobile subscribers worldwide, benefits of mobile communication technology usage seem to outweigh risk perceptions. However, as far as we know, a systematic empirical evaluation of the relationship between benefit and risk perceptions of mobile communication technologies by applying the conjoint measurement approach has not been conducted yet.

Conjoint Analysis

In the present study the conjoint measurement approach was applied to measure the direct influence of health risk perceptions, mobile data demands, and compensatory payments on the acceptance of base station locations. Compared to surveys, which are still the dominating research method in information system (IS) acceptance and risk perception research, conjoint analyses (CA) allow for a holistic evaluation of ecologically more valid decision scenarios, the weighting of single factors against each other, and the possibility of direct simulations. Conjoint analysis methods, which were developed in the 1960s by the psychologist Luce and the statistician Tukey (Luce and Tukey 1964), are a combination of a measurement model with a statistical estimation algorithm.

In CA, respondents evaluate product profiles or scenarios that are composed of multiple attributes and differ from each other in the levels of the attributes. The main objective is to simulate decision processes and to decompose the preference of a product or scenario as a combined set of attributes into separate part-worth utilities of the attributes and respective attribute levels. It is assumed that the utility value of a product or scenario is the result of its added part-worth utilities. CA thus gives information about which attribute influences the respondents' choice the most and which level of an attribute is valued highest. Preference judgments and resulting preference shares are interpreted as prediction of the likelihood or indicator of acceptance.

In the present study, choice-based-conjoint (CBC) analysis was applied. The key characteristic of CBC, in comparison to other types of CA, is that respondents express preferences by choosing from sets of concepts rather than by rating or ranking them. Thus, CBC choice tasks in CA studies are simple and natural tasks that are easily understood by respondents and closely mimic complex decision processes in which more than one attribute has an important impact on the final decision (Ericson 2012; van Biljon and Kotzé 2007). CA were predominantly applied in market research (Green and Srinivasan 1990), but nowadays they are also widely used in other disciplines for studying preferences, for example, in environmental research (Farber and Griner 2000), healthcare and medicine (Shackley *et al.* 2001), and pharmaceutics (Fraenkel *et al.* 2001).

In IS research, conjoint analyses are mainly applied for evaluating technical innovations (Pagani 2004) or novel services and applications (Wehmeyer 2005; Kowalewski *et al.* 2013). In mobile communication network acceptance research, there are hardly any studies using conjoint analysis. One exception is the study of Dohle and Siegrist (2010) in which the factors base station siting preferences, base station appearance, type of building, and decision processes were investigated using conjoint analyses. However, the present study has a different focus since it investigates the interaction of mobile communication network demands or benefits (in terms of data rate availability, which allows for the usage of different functionalities) and risks (in terms of health complaints) in combination with different base station locations in relation to one's own living and work environment. Moreover, apart from utility analysis and user group segmentation, a simulation of preferences for different scenarios is presented.

METHODOLOGY

Selection of Attributes

In this study, we assume that mobile phone users' acceptance is influenced by a set of attributes that possess the highest utility. In order to select relevant impact factors on mobile phone users' preferences, we analyzed relevant literature, interviewed mobile network planning experts, and used the results of a previous study in which focus-group interviews yielded relevant benefits and barriers of mobile communication network system acceptance (Arning *et al.* 2010).

In the context of mobile phone usage, people frequently report concerns about *health risks* due to EMF emitted from base station and mobile devices (Arning *et al.*

2010; Cousin and Siegrist 2010a). Empirical studies in different countries (Korpinen and Pääkkönen 2009; Schreier *et al.* 2006) showed that people attribute a broad range of health complaints (such as sleep disorders, headaches, dizziness, muscle pains) to EMFs emitted from base stations. Even though prevalence rates of self-reported symptoms were generally low (1.5–5%), some studies (Baliatsas *et al.* 2011; Bortkiewicz *et al.* 2012) report high symptom prevalence rates (*e.g.*, up to 57% for headaches) for people living close to base stations. This suggests that the location of base stations is another topic that raises concerns and leads to protests among citizens (Cousin and Siegrist 2010b).

People prefer base station siting to be as distant as possible from central and residential areas (Dohle *et al.* 2010). Since efficient mobile communication networks require centrally located base stations close to the living environment of mobile phone users, the present study aimed for studying preference differences for base station locations close to one's own living environment. Technically, most of the transmission power of a radio antenna is emitted in a predominant direction (*i.e.*, in direction of the main transmission beam). The signal strength at short distance increases with a higher antenna downtilt but at the cost of a shrinking cell footprint (*i.e.*, decreasing cell coverage). Since cell coverage is a major objective for radio network configuration, the typically applied downtilt is low rather than high. Hence, the EMF strength directly under the shadow of a base station (*i.e.*, on the own house) can be expected to be lower than in neighboring areas of the antenna (*i.e.*, neighboring house) (Revermann 2003). We assumed that most of the people are not aware of that technical fact and just prefer a larger distance to the base station antenna. The building type was identified as a further influential factor on base station sitting preferences (Dohle *et al.* 2010): industrial estates or commercial buildings were perceived as more adequate siting areas. Since a mix of residential and commercial buildings typically characterizes densely populated urban environments, we also investigated preference differences for base station siting on two different building types in neighboring areas.

Apart from risks associated with mobile phone usage, people do perceive benefits (Arning *et al.* 2010) due to the multitude of functionalities mobile devices offer. While mobile phones were initially used for low *data rate* functions such as telephony and text messages, they are nowadays used for a much broader variety of functions such as surfing the Internet, using social media, playing music, playing games, watching videos, sending and receiving e-mails, and so on. Future services and applications (*e.g.*, Web-base e-mail, video-download or -conferencing in the "mobile cloud") will continue this trend (Taylor *et al.* 2012). From a technical point of view, this development implicates that data rate demands and mobile data traffic will increase (ITU 2011).

To meet growing data demands, mobile communication network infrastructure will have to be expanded in the future. Different measures, such as information and communication strategies or participation in decision processes, were recommended to react to concerns of residents who are affected by base station siting (Dohle *et al.* 2010). Another approach to react to the public's risk concerns refers to monetary *compensation payments,* which are quite common in the siting of locally undesirable land uses such as waste disposal facilities (Swallow *et al.* 1992). While in some studies direct monetary payments raised acceptance (Groothuis *et al.*

Table 1. Attributes and levels used in the CBC studies.

Attribute	Levels			
Attributes used in conjoint study 1				
Base station position	Own house	House next door	Neighboring office building	
Available data rate	Phoning/texting	Surfing the internet	Downloading HD-videos	
Frequency of subjective health complaints (SHC)	Never	Rarely	Sometimes	Often
Additional attribute used in conjoint study 2				
Compensation payment	€0	€250	€500	€1000

2008), the majority of studies found no effects or even adverse reactions as people felt "bribed" by monetary payments (Claro 2007). However, to the best of our knowledge, an empirical investigation of the effects of compensation payments on risk perception and preferences regarding mobile communication network system scenarios has not yet been carried out.

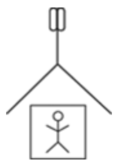
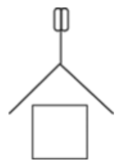
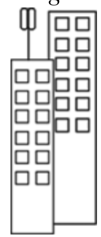
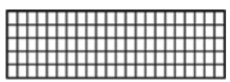
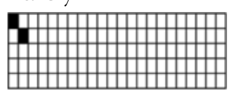
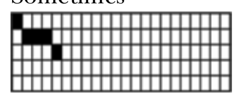
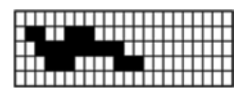
Accordingly, mobile communication network infrastructure planning processes could be improved if providers knew about mobile communication network preferences of citizens. The goal of our study was, therefore, to measure the impact of perceived health risks, base station locations, and mobile demands in terms of available data rate on users' preferences. Moreover, we investigated the impact on preferences of compensation payments offered by providers.

Experimental Design

Four attributes and relevant levels were chosen for the CBC studies (Table 1). No prohibitions for level combinations had to be included as all chosen attribute levels were combinable. In the CBC tasks, three sets of product configurations plus a "none option" were presented. In order to improve comprehensibility, all attribute levels were presented in verbal and pictorial form (see Table 1 for attributes and levels and Table 2 for respective icons).

"Base station location" described the siting of the base station. We distinguished between three different levels: "on top of one's own house," "on the neighboring house," and "on the neighboring office building" (see icons in Table 2). We assumed a discrepancy would be found between the technical fact of lower EMF directly beneath a base station ("on top of one's own house") in comparison to neighboring areas ("on the neighboring house" and "on the neighboring office building") on the one hand and people's preferences of more distant base station locations on the other hand. Moreover, we were interested in preference differences based on the type of building (office vs. residential building).

Table 2. Icons used in the CBC studies.

Attribute	Base station position			
Levels	Own house	Neighboring house	Neighboring office building	
Icons				
Attribute	Available data rate			
Levels	Phoning/texting	Surfing the internet	Downloading HD-videos	
Icons				
Attribute	Frequency of subjective health complaints (SHC)			
Levels	Never	Rarely	Sometimes	Often
Icons				

"Available data *rate*" referred to data-rate-dependent functions used on the mobile phone (see Table 2 for respective icons): "calling/texting" (low data rate), "surfing the internet" (medium data rate), and "downloading HD-videos" (high data rate).

"*Frequency of subjective health complaints (SHC).*" We operationalized perceived health risks due to EMF as frequency of subjective health complaints such as headaches, dizziness, and so on among the population. We explicitly focused on subjectively perceived, self-reported health symptoms that people attribute to EMF—independent of the public and scientific debate if EMF causes objectively measurable adverse health effects (Wiedemann and Schutz 2005). Due to the high variance in health complaints prevalence, the attribute levels ranged from "never" over "rarely" and "sometimes" to "often." The examination of this broad span of SHC frequencies also allowed for an analysis of the "maximum acceptable health risk" in the context of mobile communication network scenarios, that is, to what extent do people accept health risks in order to satisfy their mobile needs? Icon arrays (Table 2) were used to symbolize the different levels of health complaint frequencies (Lipkus and Hollands 1999). The graphical visualization of health risks is especially helpful for people who have difficulties using numbers and processing elementary probability expressions (Galesic *et al.* 2009).

"Compensation payment," with the four levels "€0," "€250," "€500," and "€1000," was added in study 2 in order to evaluate the effects of monetary compensation on preference judgments.

All participants took part in studies 1 and 2 (dependent measurement design), thereby allowing to directly interpret the effect of compensation payments.

Because a combination of all corresponding levels would have led to 36 ($3 \times 3 \times 4$) possible combinations for study 1 (the first part of the questionnaire) and 144 ($3 \times 3 \times 4 \times 4$) combinations for study 2 (the second part of the questionnaire), the number of stimuli was reduced. Each respondent was presented with only 10 random tasks and 1 fixed task for each part of the questionnaire. The reduction meant that some levels of attributes might not appear together in one set. Therefore a test of design efficiency was applied to examine whether the design is comparable to the hypothetical orthogonal design (Sawtooth Software 2008a,b). Design efficiency regarding a total of 115 respondents was confirmed with a median efficiency of 99% relative to a hypothetical orthogonal design.

Questionnaire Design

For the questionnaire design, SSI Web Software was used (Sawtooth Software 2012). The questionnaire consisted of four parts: First, participants received a description of the scenario. They were to imagine that a network provider plans to improve and extend network coverage by deploying new base stations in the neighborhood (the instruction and a complete example of a choice task is presented in the Appendix). Participants were asked to decide about these base station locations while also considering available data rates and potential health complaints. In study 2, which contained compensation payment as an additional attribute, participants were instructed that the network provider had already decided to deploy a base station in the immediate vicinity due to optimal network coverage reasons, but also offered a compensation payment to affected residents.

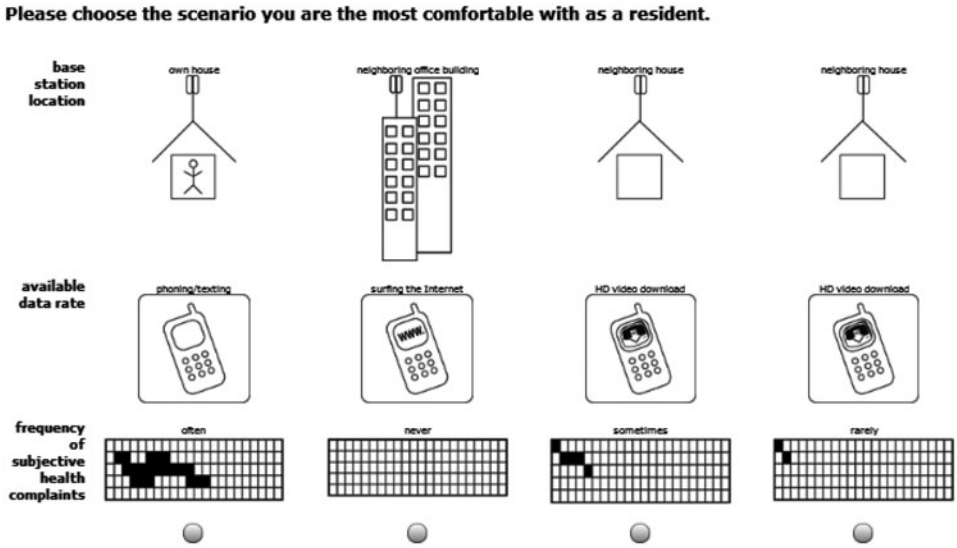


Figure 1. Screenshot of a choice task in study 1.

To ensure participants correctly understood all attributes and levels as well as the icons used in the choice tasks, they were defined and comprehensively described in the introduction (Table 2).

In the CBC tasks, verbal descriptions and icons were presented simultaneously (see below) and respondents were asked to choose the scenario they would be most comfortable with if they were a local resident (Figure 1). Second, in study 1, participants rated different scenarios composed of the attribute levels of "base station location," "available data rate," and "frequency of SHC."

Third, the following part of the questionnaire (referred to as study 2) also started with a short introductory text in which the new attribute "compensation payment" was presented to the respondents. It was explained that the provider had decided to place the cell tower in an area near to the respondents but was willing to pay compensation. Participants were then asked again to choose the scenario with which they would be most comfortable (Figure 2).

Fourth, after completing the CBC tasks, respondents were asked to answer demographic questions regarding gender, age, type of residence, and place of residence. They were also asked questions about their mobile phone usage behavior, that is, the type of mobile handset they use, their self-reported mobile phone technology expertise as well as their knowledge about EMF transmission directions and field intensity relations.

Data Collection and Participants

Data were collected in an online survey conducted in Western Germany between November 2011 and February 2012. Participants were invited to participate in the study via e-mail and were forwarded to the questionnaire. Completion of the questionnaire took approximately 15 min. In total, 190 participants participated in the

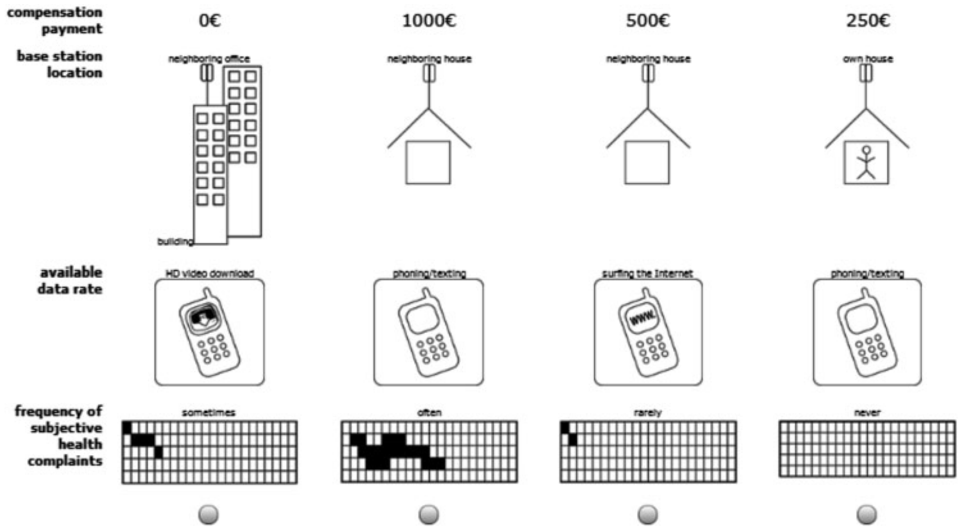


Figure 2. Screenshot of a choice task in study 2.

study. As only complete questionnaires (no missing answers) could be used for further statistical analyses, only 115 data sets were analyzed.

The mean age of the participants was 28.6 years (SD = 8.0) with 59% females and 41% males. Twenty-four percent reported to live in a detached, semi-detached, or terraced house, and 76% reported to live in an apartment building. Regarding their area of residence, 63.5% live in a city, 23.5% in a small town, and 13% in a village. The majority (65%) were smart phone users, 33% were mobile phone users, and 2% reported not to use any mobile handset at all. The mean level of mobile phone technology expertise of the participants on a Likert-scale ranging from 1 (very low) to 6 (very high) was 3.8 (SD = 0.98). Thirty-five percent rated their level of expertise with "rather low," 23% rated it with "rather high," and 17% with "high"; 12% judged their own level of expertise with "very high," 8% with "low," and 5% with "very low." Knowledge about EMF transmission characteristics was also rather low. The majority of respondents stated that EMF would be highest on the top of one's own house (84%), whereas only 16% chose "neighboring houses" or "neighboring office building."

Data Analysis

Data analysis (*i.e.*, the estimation of part-worth utilities, segmentation, and preference simulations), was conducted using Sawtooth Software (SSI Web, HB, SMRT). First, part-worth utilities were calculated on the basis of hierarchical bayes (HB) estimation and part-worth utilities importance scores were derived. In the HB estimation approach, all part-worth utilities are individually computed for each respondent rather than computing importances from average part-worth utilities over the whole sample. The relative importance of an attribute was calculated by taking the part-worth utility range for each factor and dividing it by the sum of the utility ranges for all factors. Thus, they provide a measure of how important the attribute is relative to all other attributes. Part-worth utilities are interval-scaled data that are scaled to an arbitrary additive constant within each attribute, that is, it is not possible to compare utility values between different attributes (Orme 2010a). One way to compare differences between attribute levels is to use zero-centered differentials part-worth utilities that are scaled to sum to zero within each attribute. Finally, preference simulations (SMRT) estimate the impact on preferences if certain attribute levels change within a specific scenario (Orme 2010b). This allows "what-if" considerations in order to investigate the consequences of, for example, changing base station positions or raising compensation payments on respondents' preferences.

RESULTS

The root likelihood (RLH) indicates the goodness of fit for a HB model. The RLH varies between 1.0 as best possible value and the probability of the different choices in the average task (*i.e.*, a minimum RLH of 0.3 for model 1). In the HB model for study 1, RLH was 0.5, for study 2, the RLH was 0.4, indicating a moderate, but still satisfying goodness of fit.

First, the relative importance scores of attributes are presented, followed by part-worth utility estimation results, the results of the user group segmentation, and the simulation of preferences.

Relative Importance Scores

Shown in Figure 3 are the relative importance scores of the attributes examined in both conjoint studies. In study 1 (grey bars), the attribute "frequency of subjective health complaints (SHC complaints)" had the highest importance score by far (60.9%), followed by "available data rate" (25%) and "base station location" (14.1%). The results indicate that health complaints are the most dominant attribute to influence acceptance among users. Available data rate had a far lower impact and—most interesting—base station location had the lowest importance.

Adding "compensation payment" as fourth attribute into the analysis in study 2 led to the following results (black bars): The attribute "frequency of subjective

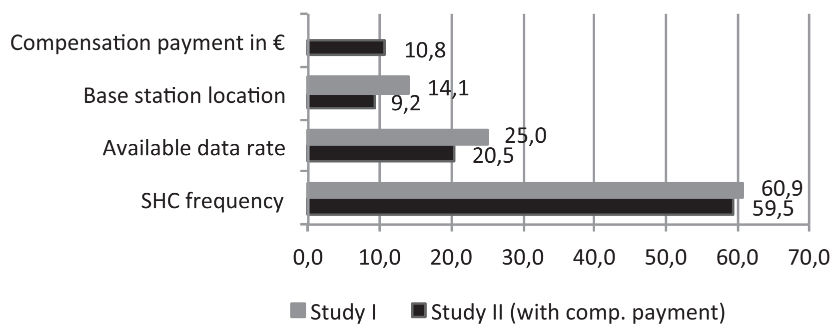


Figure 3. Importance scores in studies 1 and 2 (with compensation payment).

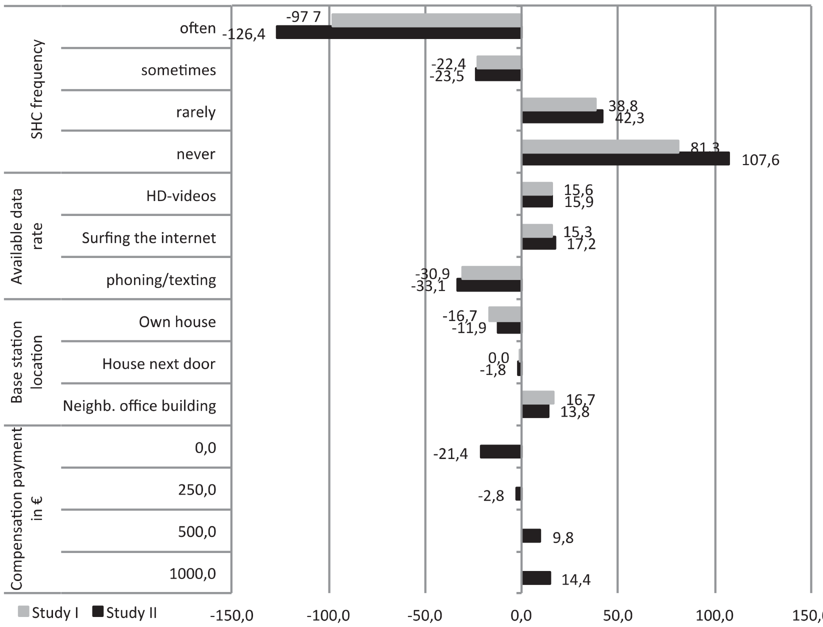


Figure 4. Part-worth utilities (zero-centered diffs) for all attributes and levels in studies 1 and 2.

health complaints" had the highest importance score (59.5%), followed by "available data rate" (20.5%), "compensatory payment" (10.8%), and "base station location" (9.2%). Interestingly, compensation payment was rather unimportant for respondents—comparable to the importance of base station location. However, the inclusion of the compensation payment attribute decreased the importances of base station location and of available data rate whereas the importance of SHC remained rather constant.

Part-Worth Utility Estimation

Shown in Figure 4 are the average zero-centered diff part-worth utilities for all attribute levels in study 1 and study 2. Looking at absolute utility values, the attribute levels of "*frequency of SHC*" reached the highest and lowest utility values in both studies (which explains the high importance scores of this attribute): "never" received the highest utility in both studies, followed by "rarely," whereas "sometimes" and "often" resulted in far lower utility scores. Regarding *available data rate*, participants in both studies preferred middle-to-high rates and rejected low data rates, which only allowed for phone calls or text messaging. Looking at *base station location*, the neighboring office building was preferred to the neighboring house and the own house, both of which had clearly lower utility values. For *compensation payment*, the €500 and €1000 options were evaluated higher than €250 or €0.

The most preferred scenario in study 1 (grey bars) was "no SHC, a middle-to-high data rate with a base station located on a neighboring office building." The most preferred scenario in study 2 (black bars) was: "no SHC, medium data rate,

Table 3. Group characteristics after segmentation.

	Group 1 (n = 57) M (SD)	Group 2 (n = 58) M (SD)	P
Age	28.09(6.83)	29.21(8.98)	n.s.
Subjective expertise	3.86 (1.30)	3.66 (1.34)	n.s.
Gender (F/M in %)	52.6%/47.4%	66.7%/33.3%	n.s.
Device type in % (smartphone/cell phone/no device)	77.2%/22.8%/0.0%	54.4%/42.1%3.5%	$p < 0.01$
Residency in % (city/small city/village %)	61.4%/22.8%/15.8%	64.9%/24.6/10.5%	n.s.
Residential building ([semi]detached house/apartment building)	24.6%/75.4%	24.6%/75.4%	n.s.

base station on the neighboring office building and a high monetary compensation (€1000)."

Segmentation of User Groups

Latent class segmentation analysis was applied to data of study 2 (*i.e.*, with the additional attribute "compensation payment") in order to detect segments of respondents having similar preferences based on their choices in the CBC questionnaires. A two-group solution showed the best data fit according to the criteria percentage certainty, consistent Akaike information criterion (CAIC), and relative Chi square. Group 1 (N = 57) consisted of smart phone users and group 2 represented mobile phone users (Table 3). No expertise difference regarding mobile phone technologies or knowledge differences about EMF transmission characteristics were found for the two groups. Further group differences in demographic characteristics missed statistical significance in ANOVAs and Mann-Whitney-U-Tests.

Group comparisons revealed different importance patterns (Figure 5): Even though SHC frequency is the most important criterion for both groups, it is less important for group 1, which puts stronger emphasis on data rate availability. Group 1 also states a lower importance of base station location but a higher importance of compensatory payment. In contrast, for group 2, data rate availability and compensatory payment are less important whereas SHC and base station location reach the highest importance scores.

Looking at average zero-centered diff part-worth utilities in both groups for all attribute levels revealed that both groups differed in their optimal scenario configuration with respect to preferred data rate availability and utility differentials for SHC frequency, base station location and compensation payment (Figure 6): Group 1 (smart phone users) preferred "never SHC," the neighboring office as base station location, maximal compensation payment (€1000), and a high data rate (HD-video

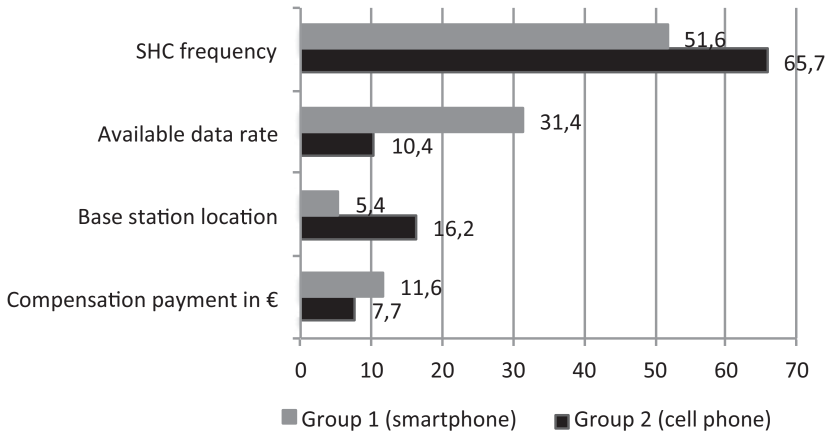


Figure 5. Importance scores for group 1 (smart phone users) and group 2 (cell phone users).

download). Group 2 (cellphone users) also preferred "never SHC," the neighboring office as base station location, maximal compensation payment (€1000), but low data rates allowing only calling and texting.

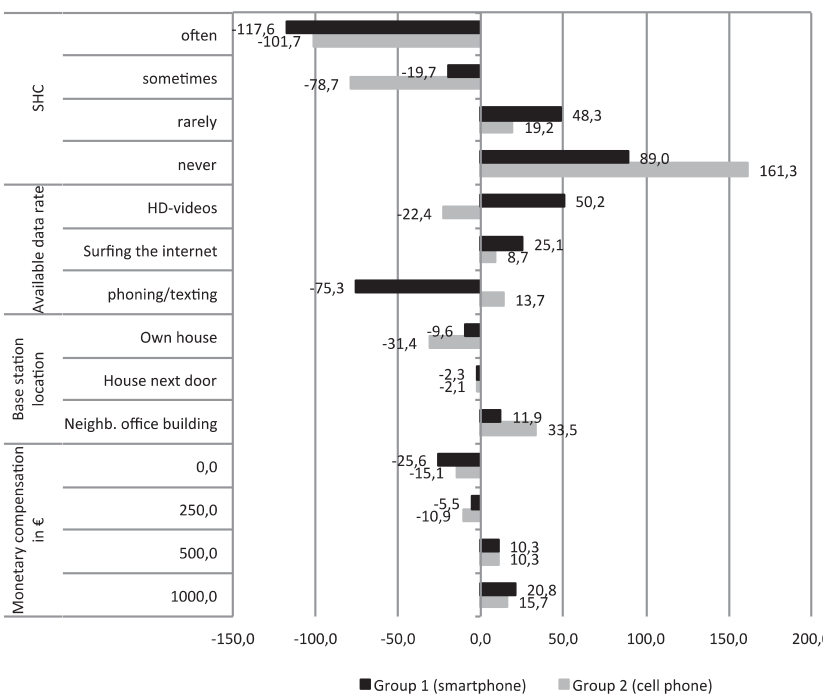


Figure 6. Part-worth utilities (zero-centered diffs) for all attributes and levels in study 2 for group 1 (smart phone users) and group 2 (cell phone users).

Table 4. Attribute level settings of hypothetical scenarios used in sensitivity analysis.

	Attribute level settings			
	Compensation payment	Base station location	Data rate availability	Frequency of SHC
Best case	1000€	Neighboring office building	HD video download	Never
Average case	500€	Neighboring house	Surfing the Internet	Rarely
Worst case	0€	Own house	Phoning/texting	Often

Simulation of Preferences

Based on the finding of user segmentation, sensitivity simulations were applied. The simulations test the extent to which the relative preferences of a respondent change when single levels of an attribute change while all other attributes are kept constant. Referring to the preference patterns identified in previously reported part-worth utility analysis, three scenarios of attribute level settings were constructed: a best case, an average case, and a worst case (Table 4).

Best case scenario

The hypothetical "best case scenario" with the attribute level settings "compensation payment of €1000," "base station location on the neighboring office building," "HD-video download," and "absence of SHC (SHC frequency never)" reached the highest relative preference of 96.9% (group 1) and 97.8% (group 2), mainly due to the absence of SHC (Figure 7). The strongest decrease of preferences was reached by an increase of SHC (group 1: –61.0%, group 2: –54.9%) and by decreasing data rate availability to "calling/texting" for group 1 (smart phone users, –26.9%).

Four findings seem to be especially noteworthy: First, for group 2 (cellphone users) a higher sensitivity regarding SHC frequency in comparison to group 1 (smart

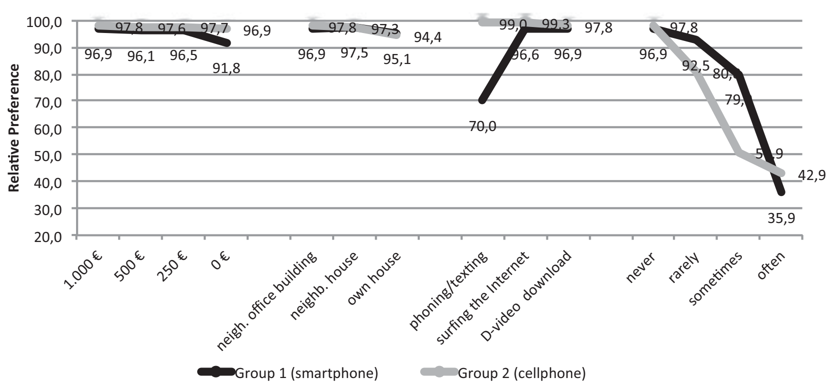


Figure 7. Relative preference simulation for the "best case scenario" for group 1 (smart phone users) and group 2 (cell phone users).

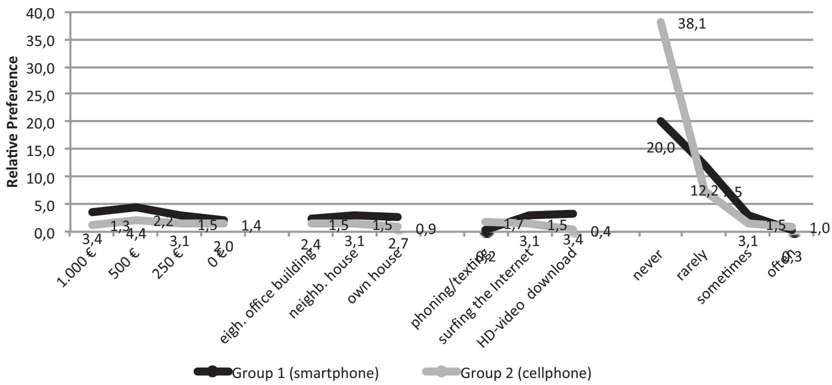


Figure 8. Relative preference simulation for the "average case scenario" for group 1 (smart phone users) and group 2 (cell phone users).

phone users) was revealed, that is, a faster drop of preferences with increasing SHC indicates a lower tolerance for SHC. Second, reducing compensation payments to €0 in the best case scenario had almost no effects on preferences in group 2 (cellphone users, –1.0%) and only minor effects in group 1 (smart phone users, –5.1%). Third, given the absence of SHC in the best case scenario, the base station location did not strongly affect preferences—even if the base station was located on the own house (group 1: –1.8%, group 2: –3.4%). Fourth, reducing the data rate from "surfing the internet" to "calling/texting" is perceived to be worse, that is, leads to a stronger decrease of preferences, in group 1 (smart phone users, –26.6%) than an increase of SHC frequency from "rarely" to "sometimes" (–17.8%). For group 2 (cellphone users) this pattern is reversed.

Average case scenario

The hypothetical "average case scenario" (Figure 8) with the attribute level settings "compensation payment €500," "base station location on the neighboring house," a "data rate availability allowing for surfing the internet," and "rarely SHC" reached a relative preference of 3.1% (group 1) and 1.6% (group 2). A reduction of SHC to "never" would increase the share of preference to 20.0% (group 1) and 38.1% (group 2). Changes in other attribute levels would not lead to a substantial increase of preferences in either group.

Worst case scenario

The hypothetical "worst case scenario" (Figure 9) with the attribute level settings "compensation payment €0," "base station location on the own house," a "data rate availability allowing for calling/texting," and "often SHC" reached a relative preference of 0.6% (group 1, smart phone users) and 0.0% (group 2, cellphone users).

Preference shares would only rise—at least for group 2 (cellphone users)—if the frequency of SHC would decrease to "never" (+28.4%). This does not apply

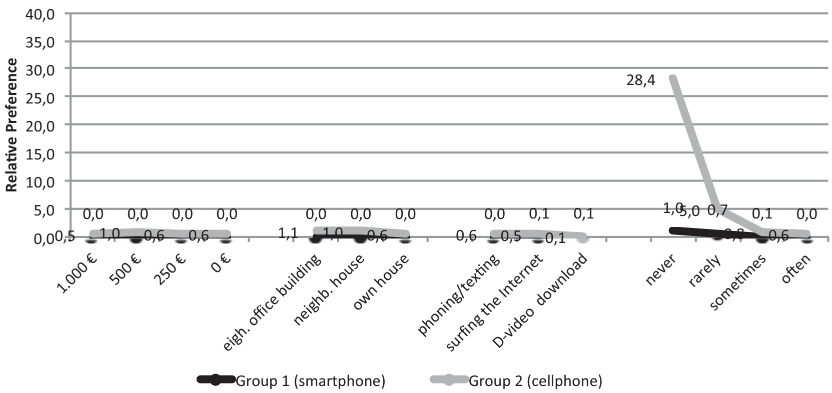


Figure 9. Relative preference simulation for the "worst case scenario" for group 1 (smart phone users) and group 2 (cell phone users).

for group 1 (smart phone users) whose preference share remains low, even in the absence of SHC, due to their preference of higher data rates. Most importantly, compensation payments have no effect at all on preferences shares in the "worst case scenario."

DISCUSSION

Future mobile communication networks need to be expanded in order to satisfy the growing mobile data demands of our societies. In contrast to that, there are concerns in the public about health risks due to EMF emitted from base stations and mobile phones, which might even increase with the upcoming expansion of mobile communication networks. Thus, planning processes for mobile communication network infrastructure could benefit from knowledge of citizens about mobile communication network preferences. The goal of our study was therefore to measure the impact of perceived health risks, base station locations, and mobile demands in terms of available data rate on users' preferences. Moreover, we investigated the impact of compensation payments offered by providers on preferences. By using conjoint analysis it was possible to determine the impact of each of these aspects on the respondents' preferences. All results were further analyzed according to specific user profiles that turned out to differ in their preferences.

First, general results of both conjoint studies are discussed. Second, the impact of each aspect (*i.e.*, data rate availability, perceived health risks, base station location, and compensation payments) as well as implications of findings for the identified user profiles are evaluated in detail.

General Results

Health concerns and data rate availability are the most important criteria in respondents' decisions for or against a mobile communication network scenario, whereas base station location and—as study 2 showed—compensation payments play only a minor role. Interestingly, a compensation payment does not have great impact on the importance of the other aspects except for the preferred base station location. When adding a monetary incentive to the choice tasks, the importance of the base station location diminished and the monetary aspect becomes slightly more important. As a first summary, the findings demonstrate that preferences for mobile communication network scenarios are not based on the location of a base station or a monetary incentive but on the tradeoff between a benefit (available data rate) and a potential health risk (frequency of subjective health complaints).

Impact of Health Concerns on Mobile Communication Network Preferences

At first sight, the high number of mobile subscribers and mobile or smart phone users in the population and in the present study (98%) might contradict the finding of the enormous importance of health concerns on mobile communication network scenarios. Respondents' preferences regarding mobile communication network scenarios are strongly influenced by perceived health risks. A total exclusion of SHC ("never") achieves the highest possible approval; a "rare" prevalence of SHC is tolerated, whereas higher prevalence rates ("sometimes" and "often") are strongly rejected. We assume that cognitive dissonance theory provides an explanation for this finding (Festinger 1957). In the study's scenarios, respondents were "forced" to include health-related factors in their decision processes. One possible explanation is that in everyday usage situations mobile phone users blind out potential health risks because the human cognitive system seeks to reduce cognitive dissonance, which causes a feeling of discomfort when two or more conflicting cognitions are being held simultaneously in mind. Instead, potential benefits of mobile phone usage outweigh potential risks or barriers in the decision to use technologies (Melenhorst *et al.* 2006). We assume that due to the design of the presented decision scenarios, respondents explicitly considered health risks in their decision which resulted in a higher importance of health concerns.

One might critically object that this "forced inclusion" of decision criteria led to an overestimation of perceived health risks compared to daily usage decision situations. Bearing that objection in mind, the study's design and results demonstrates the significance of health risks in direct relation to benefits in the acceptance of mobile communication network scenarios. Moreover, individual "risk thresholds" or a maximum acceptable risk, which users are willing to take in mobile communication network scenarios, can be determined, for example, a minor raise in health issues (to "sometimes") already leads to a significant decrease of acceptance. In this context, it is important to emphasize that we put our study focus on *subjectively perceived* and not objectively proved health risks. A definite proof of negative health effects could even result in a total rejection of mobile communication services ("acceptance killer"), as the simulation of the worst-case scenario showed. However, the reverse argument that a definite exclusion of negative health effects would lead to increased preferences in the whole population is also a fallacy as some people tend to maintain suspicions regarding the trustworthiness of sources (Renn and Levine 1991). Accordingly, the credible communication of risks is a separate, highly relevant research area in the context of mobile communication network acceptance.

Impact of Data Rate Availability

Looking at preferred data rates, we found that users prefer a data volume that supports at least mobile Internet. Lower data rates, which allow only calling or texting services, are insufficient for the actual needs of mobile communication network users. This finding corresponds to the identification of "internet generation," in contrast to the "computer-" or "TV generation" (Sackmann and Winkler 2013), which is characterized by different usage patterns (*e.g.*, social media usage) and mobile data demands. In contrast to the general findings over the whole sample, the subgroup of smart phone users puts an even higher emphasis on data rate availability compared to cellphone users. For smart phone users, data-rate availability was the second most important attribute whereas for cellphone users the base station location was the second most important criterion in their decision. These findings again demonstrate the growing demands of mobile device users for mobile broadband services and ubiquitous network coverage. Accordingly, providers need to expand their mobile infrastructure in the future, and they can benefit from knowledge about acceptance-relevant factors in the public and their integration into technical planning processes.

Impact of Base Station Location

Surprisingly, compared to the other decision criteria in the investigated scenarios, the base station location had a rather minor impact on respondents' preferences. However, this finding does not imply that base station siting is irrelevant for users' preferences of mobile communication network scenarios. It shows that the research focus, that is, the type and interrelation of selected attributes, has a considerable impact on the evaluation of decision criteria and—as shown in the present study—that the inclusion of further decision-relevant criteria (such as perceived health risks), can cause a shift in users' judgments in comparison to other findings (Dohle *et al.* 2010). In the present study, respondents preferred a base station on a neighboring office building compared to a location on a neighboring house or the own house, the latter of which was most strongly rejected. The decrease in preference with increasing proximity to the base station location contradicts technical facts about transmission characteristics of EMF, which are typically higher directly beneath than in neighboring areas of the antenna. Instead, respondents' preferences are in line with the "not in my backyard" (NIMBY) phenomenon, which describes the phenomenon of residents rejecting new developments or building projects such as base stations, new roads or schools in their immediate vicinity although they perceive them as necessary for the society. Future studies will have to investigate if expert information or knowledge about antenna transmission characteristics changes base station location preferences.

Another interesting aspect is that the building type affected respondents' base station location preferences: they prefer the base station on a neighboring office building compared to a neighboring house. Although both buildings are located in the neighborhood, the office building is perceived as more suitable as a base station location. A similar finding was reported by Dohle *et al.* (2010): a factory as building type was favored as base station location compared to a church or a residential area. We assume that the work-related context of base station siting is perceived as less threatening because the exposure time is limited in comparison to a location near one's own home. The inclusion of compensatory payments also led to an interesting finding in the evaluation of base station locations. When compensation payments are offered, the base station on the house next door is perceived slightly more negatively. We assume that the compensation payment activates a more uncompromising attitude in respondents who want the base station to be located further away.

Impact of Compensation Payments

For compensation payments in the context of mobile communication network scenarios we found that they are not perceived as an incentive to raise acceptance. The inclusion of compensation payments decreased the importance of base station location (–35%) and available data rate (–18%), whereas the importance of SHC (–2%) remained rather constant. Accordingly, offering compensation payments cannot reduce the high significance of health concerns. On the contrary, the inclusion of compensation payments in study 2 caused higher utility gains when SHC are reduced (Figure 5) (*i.e.*, compensation payments led to a higher sensitivity regarding health concerns). Moreover, in both extreme scenarios (*i.e.*, the best and the worst case scenario), the amount of compensatory payments did not influence respondents' preferences. Thus, compensatory payments are not suitable to affect or positively influence decisions in mobile communication network scenarios. Looking at the different amounts of payment we found a diminishing marginal utility, that is, the highest amount of €1000 was preferred but yielded only minor utility gains in comparison to smaller amounts of money. This implies a nonlinear relationship: higher payments do not automatically lead to higher preferences. Nevertheless, future studies will have to investigate the effect of higher compensation payments and their effect on preferences. To sum up, based on the present findings, network providers should refrain from offering compensation payments to local residents as they do not enhance acceptance but might even cause the exact opposite.

Impact of Different User Groups

We identified two user groups in latent class analysis that differed in their evaluation of decision-relevant attributes. The first group mainly consisted of smart phone users whereas the second group mainly contained cellphone users. Smart phone users have higher demands for data rate availability and a higher tolerance towards public health concerns. In contrast, cellphone users have a higher sensitivity regarding health concerns but lower demands for data rate based functions. The preference simulations demonstrate this finding: a decrease of data-rate leads to a stronger decrease of preference for smart phone users than an increase of SHC does. Thus we can conclude, the technical factor "data-rate availability" affects preferences of smart phone users more than health-related issues (SHC), unless SHC do not occur more often than "sometimes." In contrast to that, for cellphone users, SHC frequency was always the most important decision criterion and only a frequency of never (or rarely) was acceptable.

Results do not seem surprising with regard to the data-demanding usage behavior of smart phone users. Yet, the emerging question is whether in the future, when nearly everyone will own a smart phone instead of a cell phone, if health concerns will become less important in favor of a high data rate for every mobile device user. Therefore we suggest the variable "data volume demands" as an appropriate user segmentation criterion in future studies. By using this criterion we will be able to analyze the direct effect of health concerns in mobile communication network scenarios on acceptance.

LIMITATIONS AND FUTURE RESEARCH

The conjoint analysis approach has proven in the present study to be a valuable analysis and simulation tool for assessing preferences of different technology scenarios. However, the methodological approach has several limitations which should be considered in future studies.

The assessed preference ratings of our respondents do not mirror actual behavior, that is, the public's concerns or protests might be lower or higher in real mobile communication network planning situations. This discrepancy between attitudes and behavior is a challenging issue with a long research tradition (Ajzen and Fishbein 1977). Although theoretical models exist that explain the gap between attitudes and behavior (*e.g.*, Theory of Reasoned Action [TRA], Ajzen and Fishbein 1980), researchers and developers should be aware that actual usage behavior might deviate from conjoint analysis findings. A further limitation refers to the limited number of attributes and the small sample size in the study. Our findings and the derived implications only apply to the investigated attributes and levels; further extrapolations beyond the examined level range are not feasible. Researchers have to find a tradeoff between including a certain number of decision-relevant criteria and respondents' ability to validly evaluate complex scenarios with (too) many attributes. We therefore suggest conducting further conjoint analyses that include a broader set of attributes (*e.g.*, participation in decision processes, type of risk communication strategy) and levels (*e.g.*, more detailed health risk levels, higher compensation payments) that could not be considered in the present study. As such, key attributes could be the tradeoff between connectedness on the one and privacy and security issues on the other hand (Wilkowska and Ziefle 2012), especially when focusing on persons with a lower experience with technical devices or higher anxiety levels regarding health hazards (Crawford 2004).

Our findings should be replicated in larger and more representative samples that also contain a higher number of non-users (Warschauer and Matuchinak 2010). The usage of icon arrays for displaying risk information should also be critically evaluated in further studies (*e.g.*, by controlling for numeracy skills) to exclude biases due to comprehension problems. Finally, our approach and findings could be transferred to other areas of technology acceptance (*e.g.*, the acceptance of power-lines or other renewable energy technologies). The inclusion of users' preferences into technical planning processes, especially in early stages of the planning process, could improve acceptability of large-scale technologies.

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APPENDIX

Instruction of scenarios in studies 1 and 2 (translated from German) (General instruction study 1)

Dear participant, please imagine the following scenario:

A cellular operator would like to improve and expand its mobile network. To do so, new cell towers need to be sited very close to your residence. The mobile phone operator would like to incorporate the residents' needs and preferences when mounting the towers. Therefore, you are asked for your opinion as a resident.

Hereafter, different scenarios will be presented which include information about the base station site, available data rates, and possibly occurring health problems.

You, as a resident, are called upon to decide where these new base stations should be build. Apart from choosing the base station location you are asked to consider your personal needs concerning available data rates and possible health issues in your decision.

(Attribute introduction)

Here are the criteria and corresponding icons* you are meant to consider in the following scenarios. (*the respective icons are illustrated in Table 2, in the study introduction they were placed next to the verbal descriptor of the attribute level)

Base station location:

The installation site of the cell towers offers three possible places on which to erect the cell tower:
– on top of your own residential house
– on top of a residential house in your neighborhood
– on top of an office building in your neighborhood

Data rate availability:

The available data rate depends on the actions one would like to perform with the mobile or smart phone, namely
– making phone calls/writing SMS, which requires a low data rate
– surfing the Internet, which requires a medium data rate
– downloading HD videos, which requires a high data rate

Frequency of subjective health complaints (SHC):

Subjective health complaints, which are perceived to be related to base station siting and EMF, such as headaches or dizziness, are differentiated by the frequency in which they occur in the population, namely
– never
– rarely
– sometimes
– often

(Choice task study 1)

(For a complete example of a choice task see Figure 1.)

(General introduction study 2)

Now imagine the following:
Unfortunately, the mobile network operator has decided there is no way around a base station in your direct vicinity. For planning reasons it is the best location. The cellular operator would be willing, however, to reimburse you and other residents with a compensation payment.

Hereafter, you are asked to include the amount of compensation payment, namely 0€, 250€, 500€, or 1000€ with regard to the base station site, the available data rate, and possibly occuring health issues into your considerations.

Please choose the scenario you are the most comfortable with as a resident.
(Choice task study 2)

(For a complete example of a choice task see Figure 2.)