Understanding Age-Related Differences in Privacy-Safety Decisions: Acceptance of Crime Surveillance Technologies in Urban Environments

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Abstract. Although crime surveillance technologies (CST) are incrementally used in cities all over the world to improve safety, critics and data privacy specialists fear a rising violation of urban residents' privacy. So far, research on CST neither focuses in-depth on their acceptance nor addresses different user diversity factors. To reach a high degree of CST acceptance, not only technical parts are of importance but also human aspects and the way in which CST meet the residents' needs. In this paper, we present the results of a conjoint analysis (CA) study regarding the acceptance of CST with special focus on the residents' age and including the attributes *locations, reduction in crime rates (safety), handling of recorded footage (privacy),* and *camera type*. Age-specific similarities and differences in respondents' preferences were revealed.

Keywords: Crime surveillance acceptance · Aging · Safety · Privacy · Conjoint analysis

1 Introduction

In recent years, the use of CST for the purpose of crime surveillance in urban environments has been controversially discussed: on the one hand, more and more different types of CST are installed in cities all over the world to enhance safety, driven by increasing numbers of terrorist attacks and criminal offenses [1–3]. On the other hand, critics and data privacy specialists fear a rising violation of the urban residents' privacy [4, 5]. In the course of urbanization processes and demographic change, by 2030 more people will live in cities than in other regions [6]. Thus, it will be an increasingly important challenge of modern societies to meet the complex requirements of urbanization processes as well as wishes and needs of future residents and to do justice to the trade-off between individual needs for safety and privacy. For this reason, research concerning acceptance of CST is required to determine at which locations and on what terms they are accepted and which conditions may lead to changes in needs for privacy and safety.

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1.1 Crime Surveillance Technologies (CST)

Aiming for increasing safety in terms of higher rates of crime prevention and detection, a rising number of CST is currently used in almost every city in the world [7, 8]. This is heavily criticized by data protection specialists, who view the recording and storage of data as a violation of a human's privacy and personal rights [5, 9]. In particular, an absence of transparency is raising concerns pertaining to usage or processing of recorded data material, because, in most instances, it is unclear what exactly happens with recorded data. Thus, the relationship between privacy and safety is often understood as conflict or trade-off [10] and leads to central questions regarding the implementation of CST in urban areas: at which locations and on what terms is privacy or safety more important and to what extent do the requirements of city residents differ depending on individual characteristics? So far, it is a common practice to use CST without considering the requirements and needs of city residents [e.g., 11, 12]. A long-term acceptance and adoption of surveillance technologies in urban environments will only be achieved if residents are included into implementation processes and their wishes, fears, and needs are taken into account.

1.2 Acceptance of CST

Previous research essentially focuses on technical and functional features of CST such as localization and detection technologies or drones [13, 14] as well as the effectiveness of CST [5, 15]. These technologies are usually implemented into urban environments without considering opinions and needs of city residents and acceptance of CST is, if anything, comparatively superficially addressed. Attempts were made to understand crime surveillance acceptance by means of theoretical models or to determine whether crime surveillance is generally accepted or rejected [e.g., 16, 17].

So far, potential impact factors in terms of user diversity factors were only sporadically investigated: e.g., perceived safety [18], perceived crime threat [19], and gender [20] were emphasized to be important impact factors on the acceptance of CST and safety measures. Facing demographic change and aging societies, it is of great importance to examine if residents' age influences the acceptance of crime surveillance, which – to the best of our knowledge - has not been specifically examined yet. Besides user diversity factors, an understanding of determinants that affect technology acceptance is essential for a successful adoption and integration of innovative technologies [21]. Perceived safety and protection of one's own privacy [5, 22] as well as locations of surveillance and the type of inserted technologies [22] were proved to be influencing determinants for crime surveillance acceptance. Thus, an empirical approach is necessary, that investigates the acceptance of CST as a function of important determinants (locations, type of technology, and different needs for privacy and safety) and age as possible influencing user factor. Previous models like TAM or UTAUT are well-established theoretical approaches to explain and predict the adoption of technologies [23, 24]. However, they are not transferrable to the context of crime surveillance: questionnaires, designed on the basis of TAM and UTAUT, since they do not allow to holistically portray complex decision

scenarios, in which several decision criteria are weighted against each other. Moreover, it is not possible to draw conclusions about relative importance, relationships, and interactions of factors concerning crime surveillance acceptance. By combining a conjoint analysis with a traditional questionnaire, more information can be obtained and different attributes' acceptance as well as their interrelations can be analyzed in detail.

2 Methodology

In this study, we assumed that the acceptance of CST is especially influenced by age. Thus, the results of a conjoint analysis study were analyzed with a particular focus on the respondents' age. The conjoint analysis approach included four attributes that had been identified as important impact factors on crime surveillance acceptance in a preceding study [22]: locations of surveillance, increase in privacy operationalized as reduction in crime rates, privacy in terms of different handlings of the recorded data material, and different camera types. The aim of this study was to examine whether and to which extent crime surveillance scenario decisions based on these attributes were linked to age.

2.1 Conjoint Analysis

Conjoint Analyzes (CA) combine a measurement model with a statistical estimation algorithm. They were developed in the 1960s and first deployed for assessments of products and product configurations as well as the determination of product prices [25]. Within a CA, respondents evaluate specific product or scenario configurations that consist of multiple attributes and differ from each other in the attribute levels.

Using CA data, simulations of decision processes as well as fragmentations of scenario preferences into separate part-worth utilities of attributes and their levels are enabled [26]. Relative importance of attributes provides information about the proportion an attribute contributes to the decision for or against a scenario and which attribute influences the respondents' selection most. Part-worth utilities indicate which levels are accepted or rejected most. Preference shares can be interpreted as indicator of acceptance. For this study, the choice-based-conjoint (CBC) analysis approach was chosen, because it mimics a complex decision process in which several attributes influence the final decision [26].

2.2 Attributes and Levels

Based on a literature analysis and a preceding quantitative study, we selected relevant influencing factors for video-based crime surveillance acceptance [22]:

- *Location:* private home environment was contrasted to public and semi-public locations as place for camera installation.
  - *Levels:* train station, market, department store, and home.

- *Reduction in crime rate (safety):* increase in safety as major benefit of crime surveillance, which was operationalized as a reduction in crime rate.
  - *Levels: 0 %, 5 %, 10 %,* and *20 %.*
- *Handling of recorded footage (privacy):* violation of one's own privacy as major barrier to crime surveillance, which was operationalized as different intensities of handling of recorded data material.
  - *Levels: archiving by police, storage in profile databases, location determination,* and *face recognition.*
- *Camera type:* refers to different camera types, which differ in features of size, visibility, and conspicuity.
  - *Levels: large & tracking, dome, mini-dome,* and *hidden & integrated.*

2.3 Experimental Design and Questionnaire

The questionnaire was composed using the SSI Web Software [27] and consisted of four parts. First, demographic data was assessed, e.g., age, gender, experience as a victim of crime. Second, respondents had to evaluate their needs for privacy and safety as well as their perceived crime threat (PCT) at different places (each four items on a six-point Likert-scale). For further analysis, sum scores were calculated relating to privacy needs, safety needs, and PCT (each: min = 4; max = 24). In a third step, the attributes and their levels were introduced. Afterwards, the scenario was presented and participants were to imagine that they would be alone during the day at one of the introduced locations. Then, participants should select the scenario that meets their needs for safety and privacy best and most. In the fourth part, the CBC choice tasks with four attributes and four levels each (see Sect. 2.2) were presented.

Since a combination of all corresponding levels would have led to 256 (4×4 4×4) possible combinations, the number of choice tasks was reduced. Thus, each respondent rated 10 random tasks and one fixed task. A test of design efficiency confirmed that the reduced test design was comparable to the hypothetical orthogonal design (median efficiency of 99 %).

2.4 Sample

Data was collected in an online questionnaire in Germany. Participants were invited via e-mail and were forwarded to the questionnaire that took approximately 15 min to complete. In total, 273 participants took part in the study. Since only complete questionnaires could be used for further analysis (i.e., no missing answers especially in the choice tasks), 162 data sets were analyzed (return rate: 59.3 %). The mean age of the participants was 35.5 years (min = 16, max = 80, SD = 14.6) and gender was evenly spread with 49.4 % males and 50.6 % females. Concerning their type of residence, the majority of participants (53.7 %) indicated to live in an apartment building, 28.4 % specified to live in a detached house, 11.1 % in a row house and 6.8 % in a semi-detached house. Regarding their residential area, 37.0 % of the respondents reported to live in the city center and 22.8 % on the outskirts, 22.2 % in suburbs and

17.9 % in a village. In terms of previous experiences with crime, 67.1 % have already fallen victim to *"slight offenses,"* e.g., theft or burglary, and 11.3 % to *"serious offenses,"* e.g., assault, robbery, rape. Altogether (each: min = 4; max = 24), an average need for safety (M = 12.2; SD = 4.7) and an average perceived crime threat (M = 11.2; SD = 4.4) were present. Needs for privacy were generally on an markedly higher level (M = 19.1; SD = 6.8).

2.5 Data Analysis

Data analysis was carried out by using Sawtooth Software [27, 28]: In a first step, relative importance of attributes and part-worth utilities were computed on the basis of Hierarchical Bayes estimation. In a second step, preference simulations were calculated, which estimate the influence on preferences if certain attribute levels change or are consciously kept constant within a specific scenario [26, 28]. The simulation of preferences allows for specific "what-if"-examinations, e.g., the influence of the privacy-safety trade-off on respondents' preferences can be analyzed in detail within a predefined scenario.

3 Results

This chapter presents the results of the conjoint analysis, differentiating between age effects among respondents. General results of the conjoint analysis have already been published [29]. In the present study we focused on the impact of age on scenario decisions in terms of crime surveillance preferences.

3.1 Segmentation and Characteristics of Age Groups

In order to understand age-related differences perceptions as well as diverse needs for safety and privacy depending on the age, we especially focus on a younger group (up to 25 years; n = 55; M = 22.6; SD = 2.5) and on an older group of participants (50 years and older; n = 34; M = 58.9; SD = 8.4). The results of the middle age group (between 26 and 49 years; n = 73) were also analyzed, but they are not reported here in detail, since they did not differ from the results of the "young group".

As the group characterization in Table 1 shows, both age groups did not differ significantly in terms of gender. However, they differed with regard to respective living circumstances: the majority of the "young group" lived in an apartment building and, for the most part, in city centers while on the other hand, the majority of the "old" group lived in houses (detached, semi-detached, row) primarily in rather rural areas outside the city center. Younger and older adults reported the same experiences with crime (i.e. have already become victims of "slight" or "serious" offenses). The same applied to safety needs, which did not differ significantly among young and older adults. In contrast, both groups differed strongly in their needs for privacy and perception of criminal threat: the participants of the "young" group had a significantly

Table 1. Characterization of both age groups

	"young" group (n=55)	**"old" group (n=34)**	P
age (M,(SD))	22.6 (2.5)	58.9 (8.4)	<.01
gender (male; female in %)	45.5% m ; 54.5% f	64.7% m ; 35.3% f	n.s.
type of residence in %	detached house 20% semi-detached house 9.1% row house 12.7% apartment building 58.2%	detached house 47.1% semi-detached house 5.9% row house 14.7% apartment building 32.4%	<.01
residential area in %	city center 49.1% outskirts 23.6% suburbs 16.4% village 10.9%	city center 5.9% outskirts 23.5% suburbs 35.3% village 35.3%	<.01
exp. "slight offenses"(%)	65.5% yes; 34.4% no	61.8% yes; 38.2% no	n.s.
exp. "serious offenses" (%)	12.3% yes; 87.7% no	9.1% yes; 90.9% no	n.s.
need for safety (M,(SD))	12.0 (4.2)	13.6 (5.5)	n.s.
need for privacy (M,(SD))	20.8 (4.1)	14.8 (9.0)	<.01
perceived crime threat (M,(SD))	9.5 (3.5)	13.9 (5.1)	<.01

higher need for privacy than the participants of the "old" group whereas the participants of the "old" group showed a clearly higher perception of criminal threat than the "young" group.

3.2 Importance of Attributes for Scenario Selection

By means of Hierarchical Bayes analysis, the importance of attributes was determined and, thus, main factors influencing the acceptance of crime surveillance acceptance were discovered depending on age groups (see Fig. 1).

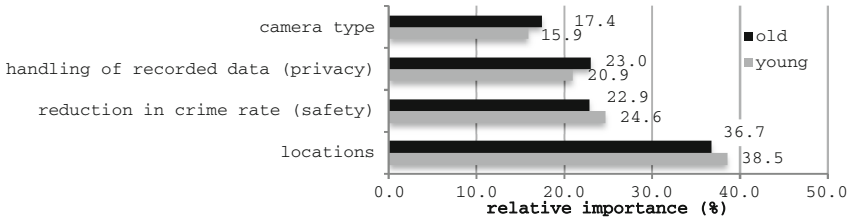

Fig. 1. Relative importance of attributes depending on age groups

In total, there were differences between the age groups regarding attributes and levels, but not very strongly pronounced. For both groups, *locations* was the most important attribute and influenced the decisions for or against a scenario the most. For the "young" (38.5 %) this attribute was slightly more important than for the "old" group (36.7 %). In contrast, the attribute *camera type* was least important for both groups and had the lowest impact on scenario decisions, whereas it was a little more important for the "old" (17.4 %) than for the "young" group (15.9 %). Interestingly, the importance of the attributes *reduction in crime rate (safety)* and *handling of*

recorded data (privacy) showed comparatively unexpected results: although the "young" group was characterized by a stronger need for privacy, the *attribute reduction in crime rate (safety)* (24.6 %) was more important for the scenario decisions of this group than the attribute *handling of recorded data (privacy)* (20.9 %). In contrast, the "old" group showed an almost equal importance of *handling of recorded data (privacy)* (23.0 %) and *reduction in crime rate (safety)* (22.9 %). Accordingly, the privacy-attribute was slightly more important to the "old" group, while the safety-attribute was a bit more important to the "young" group. A more accurate idea of differences and similarities between the age groups can be demonstrated by the results of the utilities of attribute levels.

3.3 Utilities of Attribute Levels

In Fig. 2, the average part-worth utilities are shown for all attribute levels. Based on the part-worth utilities, attribute levels with highest positive and negative evaluations and, therefore, scenarios with highest and lowest potential of acceptance can be identified. The best scenario configuration for both age groups would be: crime surveillance at a "train station," with a "reduction in crime rate of 20 %," "archiving by police" as way of data handling, and using a "large & tracking camera."

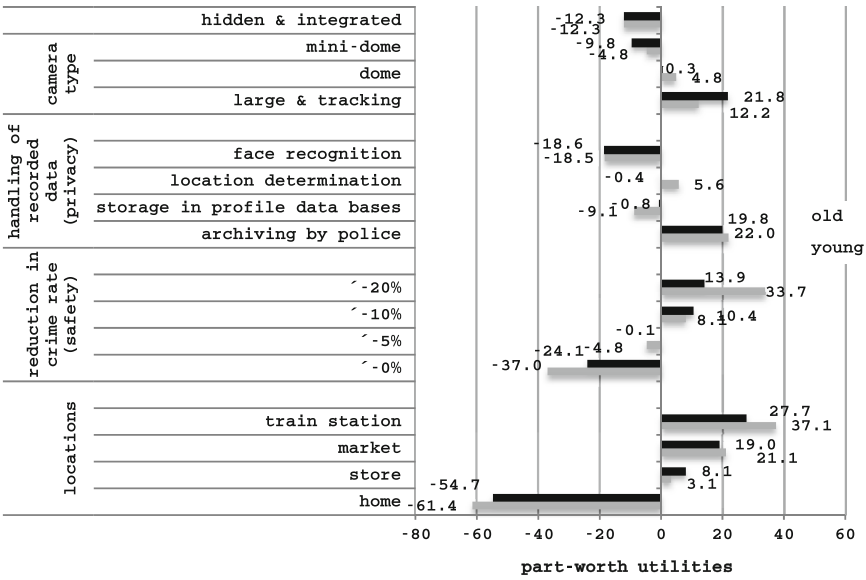

Fig. 2. Part-worth utilities of all attribute levels depending on age groups

Concerning absolute utility values, the levels of the attribute *locations* reached the largest span and, thus, the highest and lowest utility values for both age groups, which is explained by the high relative importance score of this attribute. Within this attribute,

crime surveillance was rejected at "home," with the "young" group (–61.4) declining it a bit more strongly than the "old" group (–54.7). All public locations were rated positively and, therefore, they contributed to a favorable decision for a scenario, but to varying degrees. Surveillance at a "store" reached slightly positive utility values in the "young" group (3.1) and only marginally higher values in the "old" group (8.1). "Market" received clearly higher positive values from both groups ("young": 21.1; "old": 19.0). Crime surveillance at a "train station" reached the highest positive utility values in both groups, but it was unexpectedly (see Sect. 4.1) more important to the "young" (37.1) than to the "old" group (27.7). The safety-attribute *reduction in crime rate* received the second largest span and a nearly linear function of utility values (from the young group). The higher the reductions in crime rate (gain in safety), the higher were the utility values. A "reduction in crime rate of 0 %" was rated worst and it was more strongly rejected by the "young" (–37.0) than by the "old" group (–24.1). "5 % reduction in crime rate" was slightly rejected by the "young" group (–4.8) and evaluated as almost neutral by the "old" group (–0.1). A reduction of "10 %" resulted in positive evaluations by both groups ("young": 8.1; "old": 10.4). This positive evaluation quadrupled for a crime reduction of "20 %" in the "young" group (33.7), but 20 % less crime it was only rated slightly higher than 10 % by the "old" group (13.9). Within the privacy-attribute *handling of recorded data,* initial similarities of both age groups existed in relation to the worst and best evaluations: "archiving by police" was perceived as best option of handling recorded data ("young": 22.0; "old": 19.8); "face recognition" was clearly rejected by both ("young": –18.5; "old": –18.6). The groups' evaluation of "location determination" and "storage in profile data bases" was more diverse: on the one hand, the old group evaluated "location determination" (–0.4) as well as "storage in profile data bases" (–0.8) neutrally. On the other hand, the young group accepted "location determination" (5.6), but rejected "storage in profile data bases" (–9.1). Concerning the attribute camera type, the "hidden & integrated" camera was identically rated the worst by both groups (–12.3). The "mini-dome" camera received negative utility values by both groups, although it was rated worse by the "old" group (–9.8) than by the "young" group (–4.8). The "dome" camera was evaluated slightly positive by the young group (4.8), and seen neutrally by the "old" group (0.3). The "large & tracking" camera received the best ratings of both groups, but it was clearly more important to the "old" (21.8) than the "young" group (12.2).

3.4 Simulation of CST Preferences

In a next step, sensitivity simulations were carried out by using the Sawtooth market simulator [27]. In the simulation, we examined to which extent the relative preferences of respondents for a scenario vary when single levels of an attribute change while other attribute levels are kept constant. We used this type of analysis to investigate the relationship between safety and privacy for both age groups in more detail, because the relative importance of the attributes *reduction in crime rate (safety)* and *handling of recorded data (privacy)* were rather similar. Based on the findings in previously reported part-worth utilities, two constant safety and privacy scenarios of attributes levels were constructed: (1) "high safety" (and low privacy) with the levels "crime reduction of 20 %"

and “face recognition”; (2) “high privacy” (and low safety) with the levels “archiving by police” and “crime reduction of 0 %”. These levels were kept constant while the levels of the other attributes (locations and camera type) changed. Outcomes are pictured in Fig. 3 for the “young” group and in Fig. 4 for the “old” group. In the “young” group, the “high safety” scenario reached a higher average preference (62.5 %) compared to the “high privacy” scenario (37.5 %) (see Fig. 3). For all single attribute levels, the “young” group’s preference for “high safety” was clearly higher than for “high privacy.” The acceptance of the “high safety” scenario (max. at train station +16.4 %) and, even more so, of the “high privacy” (max. at train station: +32 %) scenario rose, when surveillance was provided and carried out at public locations. There was only a small difference between the various public locations. However, at the private location (home), there was the largest difference between both scenarios and “high safety” was clearly preferred. Concerning all camera types, the “young” group favored the “high safety” scenario consistently by at least 21 %.

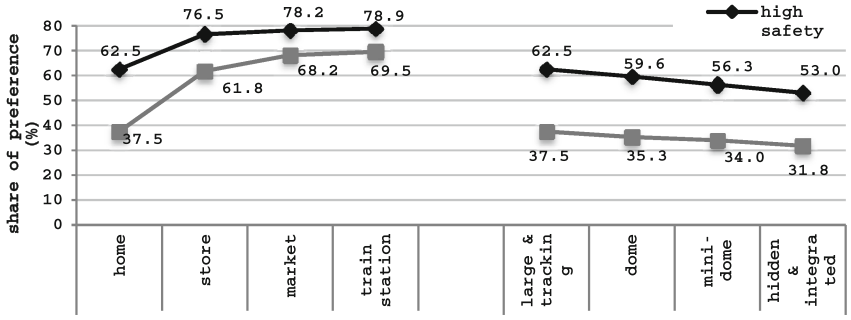

Fig. 3. Relative preferences for the scenarios “high safety” vs. “high privacy” (“young” group)

In contrast, the “old” group’s decisions were not as explicitly unambiguous, because the preference ratings of both scenarios were closer together (see Fig. 4). Also in the “old” group, there was a higher average preference for the “high safety” (54.2 %) than the “high privacy” (45.8 %) scenario. The acceptance of the “high safety” scenario reached a maximum of 67.9 % for surveillance at a market (+13.7 %) and of the “high privacy” scenario a maximum of 72.3 % for surveillance at a train station (+26.5 %). Both scenarios were rated better when surveillance was carried out at public places. The “old” group preferred the “high safety” scenario (54.2 %) to the “high privacy” scenario at their home. At more public locations (store and market), the “old” group slightly favored the “high privacy” scenario. At a “train station” the “old” group preferred the “high privacy” scenario (72.3 %) clearly more than the “high safety” scenario (64.5 %). However, the “high safety” scenario was slightly preferred for all camera types.

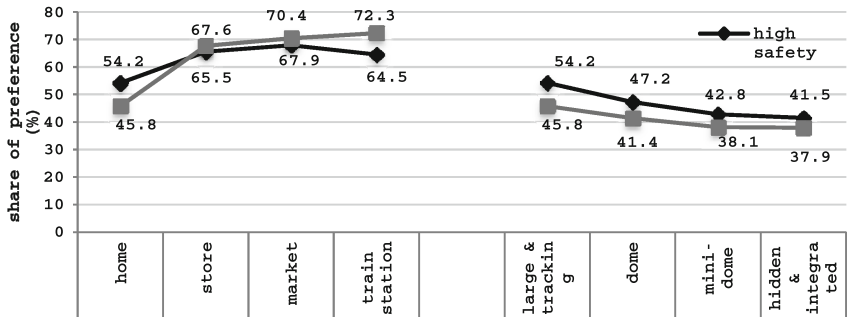

Fig. 4. Relative preferences for the scenarios "high safety" vs. "high privacy" ("old" group)

4 Discussion

Facing the challenges of a growing and aging society, the implementation of CST at public and private locations seems to be a promising way to improve safety in future cities. However, diverse demands and needs of urban residents have to be considered.

4.1 Age and Privacy-Safety-Decisions

The investigation of age groups showed that younger participants differ from the elderly, in particular in their living circumstances, but also in various needs for privacy and perceived crime threat. Contrary to previous research results [30], where older people had higher safety needs than younger people, this sample's elderly did not differ significantly from the younger generation in this regard. In general, results showed that crime surveillance decisions differ only slightly with respect to the participants' age. Crime surveillance seems to be such a central and engaging scenario that similar decision patterns occur regardless of age and are presumably driven by motives such as perceived threat and self-protection. When it comes to surveillance in urban areas, the location of surveillance is of great importance regardless of age.

Crime surveillance is accepted at public locations and rather rejected at private locations, although this could be driven by motives such as a greater perceived need for protection at public locations. In detail, younger participants rejected surveillance at home even more strongly than the elderly, which may be due to the fact that the elderly indicated a significantly stronger perceived crime threat "at home" ($p < 0.01$). Contrary to our expectations, surveillance at a "train station" was more important for younger participants. This was inasmuch unexpected as the elderly's total perceived crime threat was significantly higher and, thus, we assumed that all locations but especially public locations were favored by older participants. The camera type was of minor importance to both age groups and, thus, technical features of *cameras* such as visibility or conspicuity were comparably unimportant. However, if camera technology is used for surveillance, it should be visible and striking. Nowadays common seamless integration of surveillance systems into the private or public environment is not desirable from the

users' perspective. Overall, participants' feedback showed that it comparatively does not matter how data is collected, it is more important what happens to the data and how long it is stored. Besides the location of surveillance, the trade-off between safety and privacy is important for crime surveillance acceptance and holds the most obvious differences between the age groups. Unexpectedly, for the younger group, the attribute safety was more important for scenario decision than the privacy-attribute, although this group was characterized by a higher need for privacy and a lower perceived crime threat. Using sensitivity analyzes in the market simulator, a direct decision situation between safety and privacy could be simulated, in contrast to previous findings, in which safety and privacy were usually evaluated in isolation [10]. The sensitivity analysis showed that younger participants decided clearly in favor of safety in a direct comparison between safety and privacy. Therefore, privacy is becoming less important and is abandoned to some extent in favor of safety, if it has to be explicitly decided between both. For the elderly, privacy and safety hold a similar importance. Only when considering the trade-off in the sensitivity analysis, trends are detectable: privacy is favored at home while safety is preferred at public locations. The elderly's decisions between safety and privacy are clearly more influenced by the location of surveillance than by the camera type. Results show the importance of considering safety and privacy in the context of urban crime surveillance: safety and privacy are both of great importance and the right balance between those aspects is different for diverse groups of urban residents.

4.2 Limitations and Further Research

The applied conjoint analysis approach was useful for evaluating preferences of different crime surveillance scenarios. However, it has some limitations in methodology and content, which should be considered in future studies. For example, the limited number of attributes has to be criticized. Participants' feedback showed a request for integrating other privacy aspects into the study, e.g., duration of data storage. In this study, a compromise had to be made between an economic research design with a limited number of attributes and the complexity of the research issue. Thus, in future studies, we will use adaptive conjoint approaches (e.g., ACBC) allowing for bigger attribute numbers. Furthermore, a comparatively young sample was under study, and thus, the size of the older group was slightly smaller than the younger group's size. This could have possibly resulted in an underestimation of barriers, concerns, or preferences. Thus, the study should be repeated in larger and regarding age, more representative samples. Additionally, the results mirror a European perspective with only one cultural context. Thus, we aspire a replication in other countries to compare crime surveillance needs and wishes of city residents depending on their cultures and backgrounds.

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