Chapter 11
Human Perception of Urban Environment and Consequences for its Design

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11.1 Residential Satisfaction: A Theoretical Framework

In psychology, there is converging empirical evidence that it is necessary to differentiate between objective and subjective attributes of the environment and to take into account accompanying processes of perception and evaluation in examining the way humans interact with the environment. Amérigo (1990) and Amérigo and Aragonés (1997) proposed a conceptual framework to reflect residential satisfaction. We argue in favor of a much broader scope to this approach, namely studying the dynamic interaction between individuals and their residential environment, and analyzing the cognitive, affective and behavioral processes taking place in this interaction. The main tenets of this idea are illustrated in Fig. 11.1.

The objective attributes of the residential environment, once they have been evaluated by the individual, become subjective, giving rise to a certain degree of

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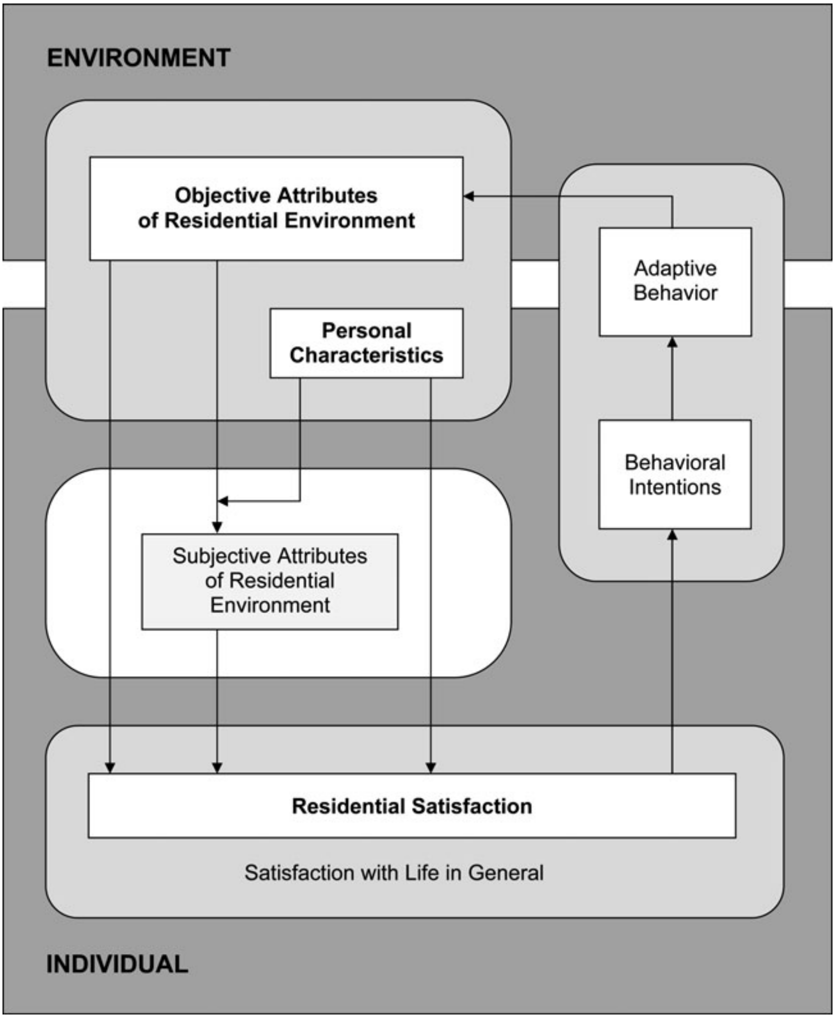

Fig. 11.1 Interactive model of residential satisfaction (Amérigo 1990; Amérigo and Aragonés 1997)

satisfaction. Thus, the subjective attributes are influenced by the individual's background, including socio-demographic and personal characteristics, as well as his or her previous knowledge of a given environment. The result of the evaluation, that is, residential satisfaction, is a more or less positive affective state regarding the environment experienced by the individual. This affective state is assumed to cause the individual to behave in certain ways intended to maintain or optimize congruence with that environment. The present article will use this model of residential satisfaction as a general theoretical framework for analyzing the perception and evaluation of different environmental attributes by applying it to recent developments in the urban environment.

In recent years city planners, developers, and policy-makers have increasingly directed their interest towards designing a more "compact city" in order to achieve an increasingly sustainable urban form. While European cities expanded rapidly during post-World War II reconstruction, ever since the 1970s, there has been a desire to slow down suburbanization and to optimize the use of inner-city spaces. As a recent vision of urban development the "model of the compact city" (e.g., Thomas and Cousins 1996) propagates higher building density along with the idea of multifunctionality, concentrated development in nodes, higher quality public spaces, and reduced traffic. This planning paradigm is regarded as providing many benefits compared to urban sprawl, which include a reduction in land and energy consumption and car dependency, while promoting a higher quality of life and the rejuvenation of existing urban areas. During the last two decades there has been a great deal of building measures aimed at increasing density including the development of empty lots, the addition of storeys, and the narrowing of streets, the last of which is linked to the master plan for inner city Berlin, "Planwerk Innenstadt". An important aim of the master plan is the reconstruction of the historic perimeter block structure, and consequently a considerable reduction of open space. As a result of this development the desirable mixture of urban functions increases, but at the same time the experience of limited spatial conditions for inhabitants of large cities is intensified. In the first experiment, we therefore investigated the perception and affective judgment of dense urban areas by human beings. We asked how specific objective attributes of the built environment (street width, building height, or greenery) correspond to an individual's specific evaluation of relevance and affective satisfaction, as well as overall residential satisfaction. At the same time, this evaluation is expected to serve as a criterion for future urban design.

To come to an important first point, take for instance the attribute "greenery", which can alleviate a pedestrian's negative affective judgments in dense urban streets. In general, urban green spaces enhance residential satisfaction (Bonaiuto et al. 1999) and contribute to physical and psychological health (Berto 2005; Mitchell and Popham 2008; Ulrich 1984). In the second experiment, we therefore investigated the perception and affective judgment of different types of greenery. We focused in particular on vegetation-covered urban wasteland areas, and asked which design measures might increase the appeal of these areas in order to supplement existing traditional green spaces.

Following Amérigo and Aragonés (1997), positively evaluated environmental attributes, residential satisfaction, satisfaction with life in general, and human health are closely interrelated. Thus, sustainable urban development should include the improvement of urban ecosystems, as well as strategies to optimize the quality of life for city dwellers (Bell et al. 2001; Evans 2003; Robin et al. 2007). In the third experiment, we therefore analysed the impact of environmental factors on residential satisfaction as an indicator of well-being in urban areas. To deepen our understanding of the dynamic interaction of environmental and individual factors we combined the conceptual framework of Amérigo and Aragonés (1997) and the cognitive-transactional stress theory of Lazarus (1991) which will be described in Sect. 11.4.1.

11.2 Perception and Affective Judgment of High-Density Metropolitan Areas

11.2.1 Density and Crowding

Crowding describes an affective and, in consequence, motivational state in which an individual experiences a certain degree of density as restrictive (Stokols 1972). In this case the term “density” refers to population density, describing the physical condition of spatial limitation, for example, the number of people per room, flat or acre (Stokols 1972; Desor 1972; Kaya and Erkip 2001). Experimental studies show that crowding is a function of various personal, situational, and cultural factors (Gillis et al. 1996; Sinha et al. 1995; Stokols et al. 1973). In the psychological model by Gifford (2002) three categories of parameters influencing the emergence of crowding are described as (1) the physical setting, (2) the social setting, and (3) personal factors. An own adaptation of his framework is illustrated in Fig. 11.2.

Within the “physical setting” category, Gifford distinguishes between quantitative and qualitative spatial factors. He furthermore points out that crowding is a psychological state yielding stress, which can lead to health problems if experienced over a long period of time. The relevant studies on crowding name physical factors as contextually important but define crowding itself as a social phenomenon. The present study focuses on a completely different aspect of crowding, namely when do people feel confined by the built environment itself, and how can environmental design alleviate these crowding phenomena? In the past, research on crowding has primarily focused on indoor long-term environments like private homes or dormitories. An important and largely ignored aspect of this phenomenon remains how crowding is perceived in public outdoor spaces like urban streets or squares. This study examines the perception and affective judgment of building density in public outdoor spaces – streets in particular – of large cities.

11.2.2 Research Questions

11.2.2.1 Crowding and Objective Measurements of Building Density

Our objective is to identify features of city streets that influence a person’s perception and judgement of building density, and which can at the same time be modified in planning processes. But which parameters do city planners use to regulate building density? Architects and city planners deal with objective, purely quantitative measurements like “coverage”, “floor area ratio”, “building height”, or “number of floors” to define the building density of an area. Coverage is defined as the ratio of the area covered by a building to the area of the site (expressed as a decimal fraction), while floor area ratio (FAR) is the ratio of the sum of the whole

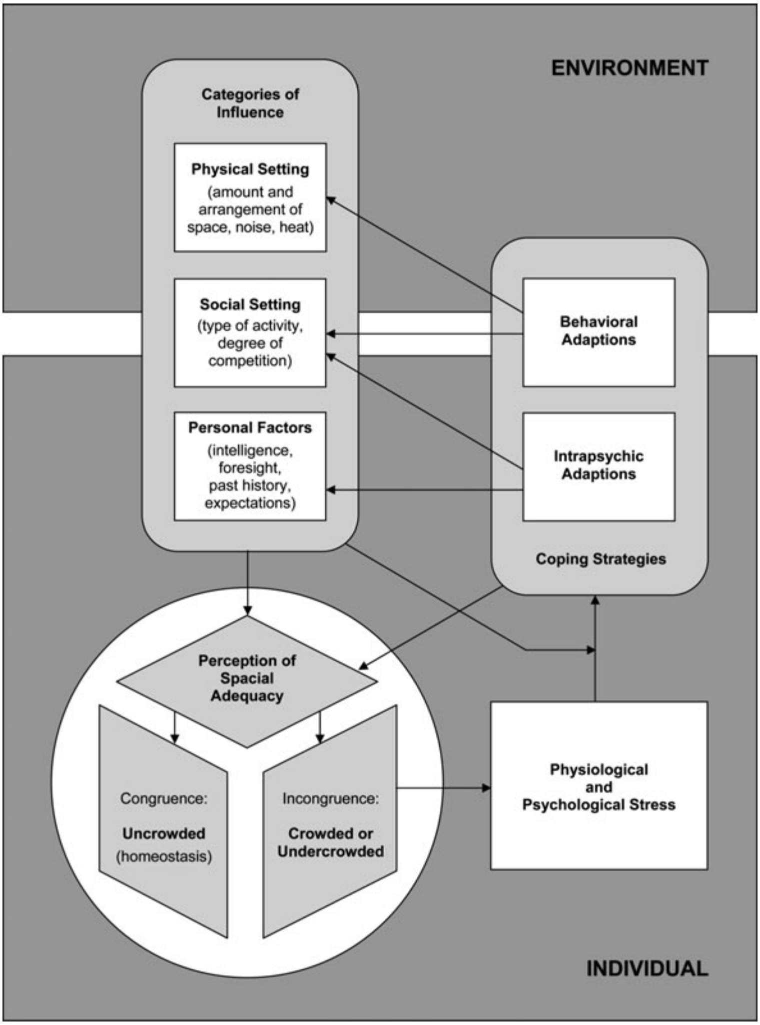

Fig. 11.2 Adaption of the crowding model by Gifford (2002)

built floor area to the area of the site. Another parameter is the specification of a minimal distance between buildings. The main purpose of all these measures is to regulate the intensity of permitted land use for a given area by providing objective criteria for the comparison of different areas. Our first research question is whether these objective measurements can predict the experience of crowding. The architectural features analysed for our study (i.e., street width, building height and storey height) are derived from the quantitative measurements used by city planners, as mentioned above.

11.2.2.2 Crowding and Qualitative Design Factors

In addition to quantitative spatial factors the psychological crowding model by Gifford (2002) also mentions qualitative environmental factors, that is, those aspects of the built environment which are not included in density measures. This includes, for instance, the character of a building or diversity of design. The impact of qualitative environmental aspects on crowding has not been sufficiently studied before. We asked, therefore, which design factors can alleviate a pedestrian's sense of crowding in urban streets and which might even intensify it. In our experimental study two qualitative spatial factors were analysed: the amount of parked cars as an aversive factor and the existence of trees in the street as a non-aversive one (cf., Husemann 2005).

11.2.3 Method

11.2.3.1 Participants

Ninety-five students of psychology, computer science, geography, and history took part in the first experiment. All students lived in Berlin, were native German speakers and had no specific architectural background knowledge. They received either course credit or 5 Euros as payment for their participation.

11.2.3.2 Stimuli and Materials

The study was conducted in a laboratory using computer-simulated pictures of high-density urban street scenes (see Fig. 11.3).

These pictures showed streets from a pedestrian point of view with houses lining both sides. Empirical evidence shows that participants' responses to simulations are surprisingly similar to real life settings. In one study, Bateson and Hui (1992) tested a theory of crowding and showed that using photographic slides to simulate environments evoked the same psychological and behavioral phenomena as the actual setting.

11.2.3.3 Design and Procedure

The following independent variables were used in the experiment (within subjects): street width (14 m vs. 17.5 m), building height (17 m vs. 22 m), storey height (3.10 m vs. 4.20 m), parked cars (7 vs. 14), and greenery (trees vs. no trees in the street).

The experiment took place in a quiet, averagely illuminated room. The participants received oral instructions. All pictures were presented by video projection.

Fig. 11.3 Example of computer-simulated pictures of high-density urban street scenes used in Experiment 1

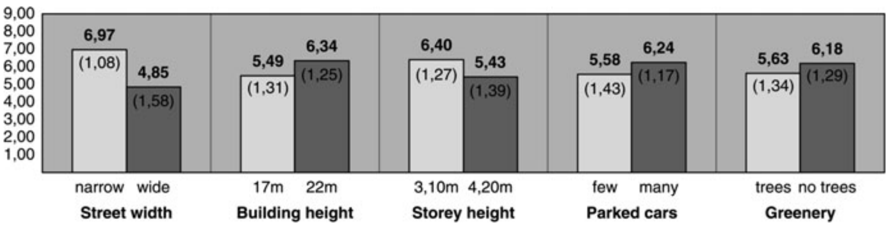

Fig. 11.4 Crowding judgments on design features. Means and standard deviations (SD, in brackets), 1 = not crowded at all, 9 = extremely crowded

The impression of a realistic scene was achieved by the projection size (7.00 m × 4.50 m) and by placing participants at an adequate distance to the projection surface. Participants were presented a sequence of 32 pictures, each shown for 10 s, followed by an interval of 10 s in which the participants rated the street scenes according to their personal experience of crowding. For this purpose a 9-point Likert-scale was used, with "1" corresponding to *not crowded at all* and "9" to *extremely crowded*. The pictures were presented randomly.

11.2.4 Previous Empirical Findings and Current Results

11.2.4.1 Impact of Architectural and Design Features on Crowding

Means and standard deviations (SD) of judgments are illustrated in Fig. 11.4.

Street Width. From the crowding definition mentioned above (Stokols 1972) we derive that spatial limitations due to the width of a street should influence a person's sense of crowding. Stokols et al. (1973) furthermore show that smaller rooms make people feel more crowded and restricted than larger rooms. The statistical analysis revealed a significant effect for street width [$t(94) = 19.176$, $p = 0.00$]. As predicted, participants rated narrow streets as more crowded than wide streets. The strong impact of street width on the participants' judgments is consistent with Stokols' (1972) assumption related to population density that crowding will result when "the restrictive aspects of spatial limitation are perceived by the individuals exposed to them" (p. 275). Thus, what Stokols points out for population density is also true for spatial limitation by physical features of the environment.

Building Height. Empirical studies have demonstrated that crowding depends on whether the setting provides an open view or not. In one such study, college students rated their dormitory rooms as larger and less crowded if they lived on higher floors and thus had a more open view from their windows (Schiffenbauer et al. 1977; Schiffenbauer 1979). Moreover, the importance of building height was tested in different studies. Gifford et al. (2000) identified building height as one of several important objective elements of a building exterior. The results of this study showed that building height indeed predicts arousal when lay-persons judge a building. Furthermore, Rapoport (1990) confirms that tall elements are likely to create high levels of enclosure. Therefore, we hypothesized that streets with high buildings will be judged as significantly more crowded than streets with lower buildings. This assumption could be confirmed by the results of our experimental study [$t(94) = -8.951$, $p = 0.00$].

Storey Height. Given a fixed building height, the number of floors within the building can vary. Apartment buildings from the end of the nineteenth century often have a storey height of 4.0 m or more, while contemporary apartment buildings have storey heights between 2.50 m and 3.00 m. Research in indoor situations has shown that men in particular perceive less crowding in rooms with higher ceilings (Savinar 1975; Walden 1981). In addition, there is a correlation between storey height and the floor area ratio measure (FAR) described above. Within a fixed building height lower storey heights are linked to a higher FAR and consequently to a higher degree of building usage. Thus, lower storey heights could be perceived as a cue for a higher degree of spatial limitation. Therefore, we hypothesized that a street will be judged as more crowded when a building has more floors within a fixed building height. The results of our study confirm this assumption [$t(94) = 8.951$, $p = 0.00$].

Parked Cars. Many studies have shown that people prefer downtown street scenes if there are fewer vehicles (Nasar 1987, 1988). Parked cars in a street reduce the space available to pedestrians and therefore – according to the definitions given by Stokols (1972) – influence pedestrians' perception and experience of spatial limitation. In other words, more parked cars will increase the experience of crowding. In our study a significant effect was observed for the amount of parked cars [$t(94) = -8.033$, $p = 0.00$]. Participants experienced streets containing numerous parked cars as more crowded compared to streets with only a few parked cars.

Greenery. As Zube (1973) proposes, trees can reduce a city's perceived scale, perhaps making it appear smaller or more comprehensible. These suggestions are not tested empirically, but various studies show that people prefer streets with trees or shrubs compared to non-vegetated urban settings (e.g., Sheets and Manzer 1991; Kuo et al. 1998). Vegetation can obviously alter people's experiences with urban places. Therefore it might also affect a person's sense of crowding. We assumed that streets without trees were experienced as more crowded compared to tree-lined streets. As predicted participants reported significantly less crowding as soon as trees were added along city streets [$t(94) = -6.187$, $p = 0.00$]. The positive influence of trees on the participants' judgments reflects the preference of natural elements in urban settings which has also been found in other studies (e.g., Kuo et al. 1998; Kaplan and Kaplan 1989).

11.2.5 Discussion: Consequences for Urban Planning

Summarizing the findings, it is evident that design factors affect the sense of crowding in street scenes. These results are interesting for several reasons. First, they support our basic assumption that architecture itself can make an individual feel crowded. Therefore, the assumption is confirmed that besides population density building density also has a substantial impact on crowding. These results can be explained by existing theories of human crowding (e.g., Gifford 2002). Our findings validate the practice of applying concepts of crowding to building density. Additionally, the findings provide further empirical support for the impact of design features on experienced crowding in an outdoor setting. It is also shown that variations in street design can alleviate crowding even if objective density is held constant. Finally, the results of the present study point to some necessary changes in city-planning in order to provide a user-friendly compact city structure. These include the suggestion that wide streets, greenery, and a fewer number of parked cars decrease the perception of crowding among residents.

In light of the results concerning the effects of street width on crowding, the contemporary urban development measures in Berlin to narrow streets must be seen critically. In addition, if streets are narrowed, measures to reduce the amount of parked cars need to be taken, for instance, by building parking garages. If storeys are added they should be set back in order to avoid a change in perceived building height from the pedestrian's point of view. Thus, from the perspective of environmental psychology, Berlin's inner city restriction of the building height to 22 m is useful.

The results concerning storey heights, however, do not answer the question of whether on one hand the variation of social cues or on the other hand structural variation of the façade influence the experience of crowding. In further studies the question of how the crowding effect of low storey heights can be compensated by an optimized façade design still has to be answered.

In conclusion, it appears that high urban densities can lead to an increased quality of life if combined with necessary changes in the design of street scenes.

11.3 Perception of Urban Green Spaces: The Example of Urban Wasteland Areas

Urban green spaces have a positive effect on residential satisfaction (Bonaiuto et al. 1999), and physical and psychological health (Berto 2005; Mitchell and Popham 2008; Ulrich 1984). They also affect urban climate – a function that will become increasingly important with the expected changes in climate (Endlicher et al. 2008). While the world is facing rapid urbanisation (United Nations 2008), urban green spaces are especially rare in cities with high growth rates. Given these circumstances, it seems economically and ecologically attractive to re-use vegetation-covered urban wasteland areas for purposes usually served by classic green spaces in ways that do not substantially interfere with flora and fauna. Thus, it is important to know how urban green space is being perceived and used by city dwellers, and how vegetation-covered urban wasteland areas may be sensitively altered to substitute for traditional green spaces where they are unavailable or rare.

11.3.1 Urban Green Space Perception and Use

In a pre-test, we aimed at identifying the visual features – or classification criteria – which are relevant to (a) the perception and (b) the preference of urban green spaces and urban wasteland areas. The participants ($n = 82$; landscape planners and city residents) sorted 24 photographs of parks and urban wilderness areas according to perceived similarity (Rosenberg and Kim 1975) and preference.

From the similarity rating, a number of classification criteria were derived including degree of canopy closure, artificiality, prospect (availability of wide views), and beauty, which have already been used in previous studies of rural nature (Im 1984; Özgüner and Kendle 2006; Real et al. 2000; Shafer et al. 1969). Additionally, the feature "physical accessibility," defined as the possibility to physically enter a site and not visual accessibility, was identified and is particularly relevant for urban wasteland areas. For residents, the degree of canopy closure was the most important classification criterion. For landscape planners, the degree of the human influence on a site was most important. These results indicate that not only simple visual features or basic shapes are important in the perception of urban green spaces and urban wasteland areas, but also higher-level characteristics like physical accessibility.

In regard to preference ratings, some differences between the two groups of participants were found. While the landscape planners preferred naturally developed areas with low accessibility and high species diversity, the residents preferred culturally shaped areas. The residents did not seem to disapprove of using urban wastelands as recreational areas per se, but a minimum level of maintenance and accessibility appeared to be necessary.

For urban wasteland areas to be redesigned as substitutes for green space, the ways in which urban green spaces are used should be considered in the redesign process. In a survey, we therefore analysed the actual use of urban green spaces ($N = 113$ city residents). The analysis revealed passive recreation (e.g., going for a walk, enjoying nature) as most important followed by extrinsically motivated activities like walking the dog, and social and sporting activities.

11.3.2 Increasing the Appeal of Urban Wilderness Areas

In his model of mental functioning, Grawe (2004) assumes four basic psychological needs that humans intend to meet: orientation/control, attachment, self-enhancement, pleasure/avoidance of pain. Adopting this model, urban wilderness areas are expected to be evaluated as increasingly attractive and to be used more frequently the more they match human needs. For example, if an area is designed to provide or convey safety (a key factor for the acceptance of public areas), it will more likely meet the users' need for pleasure/avoidance of pain and will consequently be used more often. Of the four psychological needs to be met, orientation and control can be regarded as one of the most important. There is empirical evidence that humans prefer a medium level of complexity (Berlyne 1970; Spehar et al. 2003). However, the visual input from urban wilderness areas is rather complex due to the high fractal dimensions of plants (Cutting and Garvin 1987; Höger 1997) and the natural, that is, unsettled state of these areas. This complexity is assumed to impair orientation and control. To increase the appeal of urban wilderness areas, we aimed at reducing its complexity by introducing visual structuring and thereby increasing the site's coherence (Kaplan and Kaplan 1989). For that reason, the following design measures were considered in the second experiment. First, mowing certain parts of a site was assumed to decrease the complexity of urban wilderness areas and, thus, to enhance the sense of orientation and control. Second, trails structure urban wilderness areas and facilitate wayfinding. Thus, they decrease the complexity of urban wilderness areas and enhance orientation and control. To test these hypotheses, a rating procedure was used in the current experiment.

A second aim of the study was to support these findings with psychophysiological data. In our study, this was the task-evoked pupillary response, which reflects an overall aggregate of mental resource allocation that is not limited to a specific part of the cognitive system (Aston-Jones and Cohen, 2005; Beatty and Lucero-Wagoner 2000; Just et al. 2003; van der Meer et al. 2010). In essence, the more difficult a task, the more the pupil dilates (Nuthmann and van der Meer 2005; Verney et al. 2004). For the current study, the following global hypothesis holds: Processing highly complex urban wilderness areas consumes more resources than processing less complex urban wilderness areas. Therefore, to test this hypothesis, peak dilation was measured in order to deduce the magnitude of the pupillary response. By measuring peak dilation during the first 3.5 s of stimulus presentation, we were able to compare the results of each participant. For highly complex urban wilderness areas, peak dilation was expected to have higher values than for less complex urban wilderness areas.

11.3.3 Methods

11.3.3.1 Participants

Sixty-eight participants took part in this experiment, 36 women and 32 men, with a mean age of 37.5 years ($SD = 12$). All of them were residents of Berlin and were native German speakers. They were paid for their participation.

11.3.3.2 Stimulus Materials, Design, Procedure

Computer-generated, photorealistic prototypes of urban wilderness areas were created. The following independent variables were varied in the experiment (within subjects): trail type – without trail, narrow unpaved trail, broad paved trail – and open spaces – annually mowed parts of a site vs. wild growth (cf. Fig. 11.5). This resulted in 6 images, three sets of which were used, yielding a total of 18 items. The images were each presented twice (block 1 and block 2). Within each block, images were presented randomly. The participants were instructed to rate each image according to their preference in the personal residential environment in block 1, and according to complexity in block 2. For this purpose 7-point Likert-scales were used with "1" corresponding to *very low preference* and "7" to *very high preference*

Fig. 11.5 Examples of the images used in Experiment 2

in block 1 and with “1” corresponding to *not complex* and “7” to *extremely complex* in block 2.

The experiment took place in a quiet, averagely illuminated room. The participants were seated comfortably in front of a 19″ computer monitor at a distance of 50 cm. Pupillometry was done with an iView system (SensoMotoric Instruments). Pupil diameter was sampled at 240 Hz and the luminance of the stimuli was controlled. In addition, we intended to control the experimental materials for the objective richness in detail. This was done by comparing the file sizes of the images using the JPEG-algorithm (International Telecommunication Union 1993). There were no significant differences.

Analyses of variance were performed to test the impact of the independent variables on the ratings of complexity and preference. Differences between conditions in peak dilation were analysed by subjecting the data to t-tests for every time frame (cf. Satterthwaite et al. 2007).

11.3.4 Results

Complexity ratings. Visually structured sites where annual mowing occurred on certain parts of the site were rated to be less complex than sites without such structuring [$F(1,396) = 5.752$, $MSE = 1.081$, $p = 0.017$]. Adding trails to a scene did not influence complexity ratings ($p = 0.593$). No interactions were observed ($p = 0.876$).

Preference ratings. Visually structured sites where annual mowing occurred on certain parts of the site were rated as more preferable than sites without such structuring [$F(1,396) = 13.907$, $MSE = 1.503$, $p = 0.001$]. Adding trails to a scene did not influence preference ratings ($p = 0.316$). No interactions were observed ($p = 0.890$).

Peak dilation. The pupillometric data showed a similar pattern. The peak dilation for sites with visual structuring was significantly lower than for sites without such structuring ($t = 120.974$, $p = 0.036$). The manipulation in trail design did not influence pupil diameter. The analysis by time frame yielded analogous results (cf. Fig. 11.6).

11.3.5 Discussion

The present experiment clearly suggests that urban wasteland areas with visual structuring – i.e., annually mowing parts of a site – are rated as being less complex. The pupillometric data points to the same results. Visually structured sites produce smaller pupil dilations indicating the presence of a less demanding visual input. Annually mowing parts of an urban wasteland area thus enhances the site’s coherence, leading to an increase in preference as predicted by Kaplan and Kaplan (1989). Similarly, Dörner and Vehrs (1975) argued that detail-rich visual input

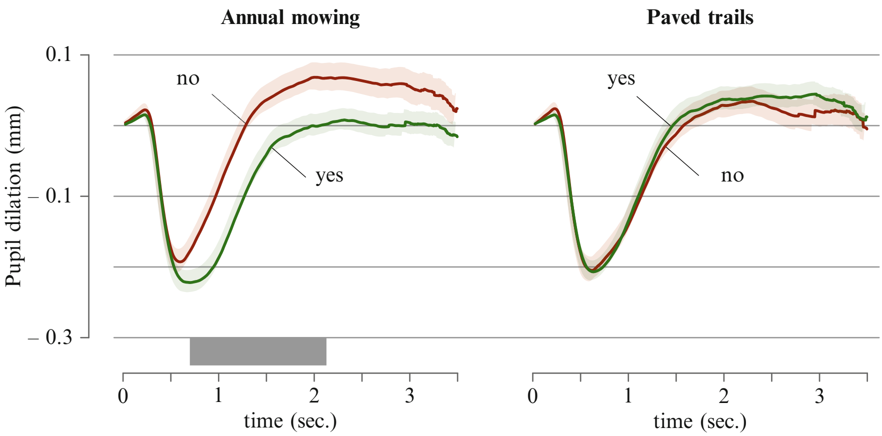

Fig. 11.6 Pupil peak dilation is lower for sites with visual structuring, that is, with annual moving (yes-condition) than for sites without visual structuring, that is, without annual moving (no-condition). This indicates the impact of specific visual structuring on the allocation of cognitive resources for processing the images of urban wasteland areas. In contrast, the manipulation of trails does not affect pupil peak dilation. The *grey* bar along the X-axis indicates significant differences between conditions, the envelopes of the lines indicate the SEM (standard error means)

is only preferred if its uncertainty can be reduced through ordering its details – i.e., structuring the site.

Our findings have a number of implications for the reutilisation of urban wasteland areas. It appears that these areas might prove a good substitute for traditional green spaces if they meet specific human needs (cf. Hofmann 2010). First, urban wasteland areas should be visually structured by, for example, annually mowing parts of the site. This design measure reduces the complexity of urban wasteland areas leading to an increase in orientation, control, and preference by residents. Second, urban wasteland areas must be recognisable as accessible to the public. Third, they should promote different possibilities of use – especially for passive recreation, the most frequent usage. Furthermore, a sense of orientation and control of urban wasteland areas also contributes to perceived safety in these areas. Perceived safety is a key factor in the acceptance of an urban wasteland area. Adding human artefacts like park benches, lanterns, waste bins, etc., or signs of human intervention – such as the annual mowing described above – to urban wasteland areas may signal the presence of helpful others enhancing perceived safety.

11.4 Environmental Stress in Urban Neighbourhoods

With regard to sustainable urban development it is of special interest to investigate if, and if yes, how abiotic and biotic environmental factors affect human health and well-being. This question has mostly been addressed within the field of epidemiology and environmental medicine rather than psychology. However, before city dwellers end up suffering from health consequences such as lung diseases caused by fine dust particles or heat strokes in urban heat islands, they may first experience stress induced by such critical factors. This applies to a much larger proportion of urban populations as severe diseases are usually caused by the concurrence of multiple and often independent risk factors rather than just one. In regard to human health, psychological effects do matter. Human health is defined as a "(. . .) state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 1946). At the end of the last century researchers began to put more emphasis on psychological processes as mediators in the relationship between objective environmental conditions and human well-being. This is partly due to the fundamental theoretical work of Richard Lazarus' research group outlined briefly in the following.

11.4.1 The Cognitive Stress Theory of Lazarus (1966, 1991)

The cognitive-transactional stress theory of Lazarus and colleagues (Lazarus 1966, 1991; Lazarus and Cohen 1978; Lazarus and Folkman 1984; Lazarus and Launier 1978) explains how stress reactions to environmental stimuli arise by cognitive processes and by a dynamic and interdependent interaction of objective attributes of the environment and personal characteristics. Thus, the theory is most suitable to explain inter-individual differences in reactions to or consequences of stressful environmental conditions. In short, stress is conceptualized as a perceived imbalance between environmental demands and resources to fulfill these demands.

According to the theory, a situation is perceived and evaluated in regard to one's own well-being (*primary or demand appraisal*). If it is perceived as potentially endangering well-being, an individual checks if there are sufficient personal and/or situational resources to cope with the situation. This *secondary* or *resource appraisal* is more strongly influenced by cognitive structures, personality traits and demographic variables like problem solving competences, optimism, self-confidence, age and education, and by the situational context, such as perceived control over the stimuli, social support or financial resources (Carp and Carp 1982; Robin et al. 2007). Only when resources are evaluated as insufficient will an acute stress reaction arise on different dimensions that are not necessarily corresponding. That is to say, stress is reflected in heightened physiological activation, changes in emotional states, at a cognitive-functional level – that is, in attention and performance – and/or in modified social behavior.

Subsequently, a strategy to cope with the actual stress is chosen. Coping strategies are cognitive, emotional or behavioral processes aimed at reducing the acute stress by adapting oneself or by changing the situation (Homburg and Stolberg 2006; Lazarus and Folkman 1984).

Finally, the success of the chosen strategy is evaluated in respect to stress reduction. We refer to this process as *reappraisal*. If stress was successfully mitigated, the same stimulus is less likely to cause a stress reaction the next time it appears. Otherwise, the stress reaction continues or follows should the stimulus reoccur. In the long run, this can result in various detrimental consequences such as mood disturbances, increased symptom reporting, elevated blood pressure, susceptibility to infectious diseases, use of psychotropic substances, or slower recovery from otherwise induced diseases (Adler and Hillhouse 1996; Cohen et al. 1986; Dougall and Baum 2001; Marsland et al. 2001).

11.4.2 The Cognitive Stress Theory in Urban Research

Urban research based on the cognitive-transactional model of stress is primarily focused on emotional rather than perceptual-cognitive appraisal. Unfortunately, the reactions studied in the field of "annoyance research" are varied and not clearly distinguished. Appraisal is surveyed using terms as diverse as *annoyance, disturbance, bother*, *anger*, *displeasure*, *discomfort*, *distress*, or even *concern* (Koelega 1987; Lima 2004). Thus, it is not surprising that research on the same environmental stressors comes up with enormously different results.

Another problem in this field of study is how to determine as to when a person can be considered affected. Do they have to be highly annoyed, or only moderately annoyed? As of yet, there is no conclusive answer in the literature.

Negative environmental appraisal is not only a prerequisite to the experience of stress, it is also associated with social or political actions that support the improvement of the environment (Prester et al. 1987), and with neighbourhood dissatisfaction (Amérigo and Aragonés 1997; Kearney 2006; Marans and Spreckelmeyer 1981).

As neighbourhood satisfaction is related to residential satisfaction and satisfaction with life in general (Amérigo and Aragonés 1997; Campbell et al. 1976), we operationalized it as an indicator of well-being in the urban environment. Besides physical factors, it is influenced by other environmental conditions (Francescato 2002; Hur and Morrow-Jones 2008), and by demographic variables (Galster and Hesser 1981).

One of the limitations of the cognitive-transactional stress theory is that predictions of "objective" environmental stressors are impossible. Hence, researchers attempt to identify stimuli that cause stress with a considerable probability in specific populations. The following stressor classification according to Lazarus and Cohen (1978) simplifies this issue. Environmental stressors can be classified as (1) *cataclysmic events* that affect large numbers of people overwhelmingly like natural disasters or war; (2) *personal stressors* with a powerful and sudden impact like illness or job loss, and (3) *background stressors* that bring about less severe and more gradual changes. The latter are subdivided into *daily hassles* – distinct "events" or instances affecting individuals rather than groups of people – and *ambient stressors*. Ambient stressors are environmental conditions that are perceptible (although they may go unnoticed), chronically present, negatively valued, non-urgent and intractable, meaning they cannot be altered structurally by an individual (Campbell 1983), and are the category of interest in the third experiment.

11.4.3 Empirical Findings and Research Questions

Noise from sources like traffic, industry, crowds, or a high population or building density, air pollutants and ozone, water pollutants, odorous substances, weather conditions like heat waves and cold temperatures, and aspects of visual pollution such as litter, billboards and unaesthetic urban design have empirically been identified as potential ambient urban stressors (Bullinger 1998; Cohen et al. 1986; Craik and Zube 1976; Evans 1982, 2003; Flade 1987; Glass and Singer 1972; Husemann 2005; Robin et al. 2007; Taylor 1982; Taylor et al. 1997; Walsh Daneshmandi and MacLachlan 2000; Zimring 1982). In the third study, we investigated which of these factors are perceived critically in the metropolitan area of Berlin. Moreover, we explored another, more subtle kind of urban pollution – the urban sky glow at night, or *light pollution*. Lately, the issue has gotten into scientific and public debate because of its ecological consequences and because it hinders astronomers' work. It is often argued that light pollution also impacts human well-being. Indeed, constant light exposure has been associated with health consequences such as altered immune functioning or breast cancer (Kloog et al. 2008; Navara and Nelson 2007; Stevens 2006). However, it is unclear whether these effects are due to physiological or psychological pathways, and epidemiological reports remain inconclusive (de Molenaar 2003; Langers et al. 2005; Padgham and Saunders 1995; van Ratingen 2001).

Most published studies on environmental stress have only investigated exposure to a single stressor. However, in real life people react to combinations of multiple stimuli. As suggested by the literature (Bell et al. 2001; Cohen et al. 1986), we hypothesize that the concurrence of several critical factors predicts neighbourhood satisfaction better than a singular factor alone. As there is no indication in the literature, we explore whether multiple factors concur in an additive, an exponential or in an alleviative way.

11.4.4 Method

In order to effectively obtain a geographically wide, demographically diverse and large sample, the third experiment was conducted as an online survey. The questionnaire was developed according to internet research guidelines (see e.g., Gräf 2002; Tuten et al. 2002; Sassenberg and Kreutz 2002) which dictated the questionnaire's instructions, item wordings and sequences, screen randomization, layout, and the general procedures. Data was collected from February to April 2009.

11.4.4.1 Questionnaire

We first assessed demographic variables, information about the housing situation and neighbourhood satisfaction by asking how satisfied participants were, generally speaking, with their proximate living environment on a 7-point Likert-scale, with "1" corresponding to *extremely unsatisfied* and "7" to *extremely satisfied*. Proximate living environment was defined as the area of a maximum two-minute-walk from participants' home. The second section of the survey focused on light pollution. Two 7-point scaled items asked for the actual and desired brightness in the proximate living environment, with "1" corresponding to *extremely dark* and "7" to *extremely light* Participants were further presented with a list of various lighting sources to indicate which ones were visible from their homes and to rate how much they felt disturbed by those on a 5-point Likert-scale, with "1" corresponding to *absolutely not disturbing* and "5" to *very disturbing*. We also assessed whether the term light pollution was known at all. In the final section the perception and appraisal of various factors was measured by similar 5-point Likert-scales. Appraisal was assessed by *impacted well-being* as a comprehensive measure for widely-used terms like annoyance, nuisance or disturbance. We also requested participants to indicate which factor disturbed them the most. At the end of the survey respondents were given more detailed information about the overall research project and the purposes of the study, as well as space for remarks.

11.4.4.2 Participants and Procedure

The survey was kept as short as possible to maximize return rates (Bosnjak and Batinic 2002). It could be completed in 10–15 min and it was possible to leave items unanswered. Participation was limited to Berlin residents with sufficient German language skills and internet access. Participants were recruited by emails distributed through personal networks or student and topic-related mailing lists, by notes in newsletters and on websites of local networks, authorities and initiatives. The only content-related information given was that it was a study on the perception and appraisal of environmental conditions in the urban area of Berlin. As an incentive for participation, participants were offered a report of the results via email. In addition, we promised to forward the outcomes to local authorities.

The survey was completed by $N = 763$ residents from all 12 administrative districts of Berlin. Most submissions were obtained from the central districts Friedrichshain-Kreuzberg (22%), Mitte (13%), and Pankow (13%) while residents of the peripheral districts Reinickendorf and Spandau are underrepresented with only 1% each. Sexes were almost equally represented (54% female vs. 45% male participants with 1% not indicating sex). The age range was 9–80 with an average age of 31 years. The sample was very well educated with 48% having a school qualification for university entrance and 44% holding a university or a similar academic degree.

11.4.5 Results

Light pollution. The term light pollution was known by 51% of the respondents. The mean perceived nocturnal darkness in the proximate neighbourhoods was somewhat higher than the desired ($M = 3.97$ vs. $M = 3.22$). Commercial lighting visible from rather few people's homes like illuminated advertisements/LCD-Displays ($M = 2.66$, $SD = 1.42$, $N = 128$) and laser lights ($M = 2.33$, $SD = 1.45$, $N = 72$) were perceived as the most disturbing. More widespread, unavoidable and safety-related light sources like street lighting ($M = 1.90$, $SD = 0.95$, $N = 558$), traffic lights ($M = 2.01$, $SD = 0.99$, $N = 303$) and interior illuminations ($M = 1.59$, $SD = 0.80$, $N = 586$) were least disturbing.

Environmental perception and appraisal. To explore how the quality or intensity of environmental factors was perceived, we computed the mean appraisals as well as the summed percentage of participants choosing the most and second most negative category of the 5-point scale. The results are displayed in Table 11.1. 32% reported to live in a neighbourhood with quite or very strong traffic noise while the mean perceived traffic noise level is 3.01. In regard to odors, we did not ask participants to rate the perceived intensity and/or frequency as a measure of environmental perception. Instead participants were merely asked if they regularly perceived unpleasant odors. Among the 35% who answered yes, most specified odors from litter and excretions in the public space (31% of this subsample), neighbours (28%), and traffic exhaust emissions (17%).

Among the factors rated by all participants, traffic noise and litter and dirt are the most critical, as shown by mean appraisal ratings and the percentage of participants who chose either of the two as *the most* disturbing one. When unpleasant odors are regularly present, however, they are on average rated even more negatively. Among

Table 11.1 Descriptive results of the perception and appraisal of environmental factors, correlation between mean perception and appraisal of each factor ($r_{\text{ep-ea}}$) and between appraisal and neighbourhood satisfaction ($r_{\text{ep-ns}}$)

Environmental factor	Environmental perception			Environmental appraisal			Correlations	
	M^a	*SD*	*Extent*[b]	M^c	*SD*	*Worst*[d]	$r_{ep\text{-}ea}$	$r_{ep\text{-}ns}$
Traffic noise	3.01	1.07	32%	2.64	1.13	26%	0.72**	0.17**
Cleanliness resp. litter/dirt	3.01	0.95	28%	2.55	1.13	20%	0.68**	0.29**
Cold temperatures in winter	n.a.+	n.a.+	n.a.+	2.47	1.19	11%	–	0.12**
Air quality	3.08	0.82	20%	2.37	1.05	6%	0.61**	0.21**
Noise by crowds	3.43	0.99	15%	2.31	0.97	11%	0.67**	0.15**
Heat in summer	n.a.+	n.a.+	n.a.+	2.29	1.05	6%	–	0.11**
Artificial lighting	n.a.+	n.a.+	n.a.+	2.09	0.99	3%	–	0.12**
Residential density	2.45	0.79	51%	1.96	0.94	3%	0.33**	0.22**
Industrial noise	4.58	0.69	2%	1.36	0.74	1%	0.61**	0.09*
Subsample								
Water quality ($N = 381$)	2.69	0.93	40%	2.18	1.03	1%	0.37**	0.12*
Unpleasant odors ($N = 269$)	n.a.+	n.a.+	n.a.+	2.98	0.99	4%	–	0.20**

$^{**}p < 0.01$; $^{*}p < 0.05$; +not assessed

[a]High mean perceptions indicate positive ratings in regard to noise sources, air and water quality and little population density

[b]Extent is the summed percentage of participants who chose the most and 2nd most negative/intense category

[c]High mean appraisals indicate strong impacts on well-being

[d]Worst is the percentage of participants disturbed most by the corresponding factor

the 27% who indicated that there were other factors in their proximate surroundings which impacted their well-being, most referred to noise from various sources (6% of the total sample), to a lack of public green space and the absence or the cutting down of trees (5%), and to dirt and canine excrements (4%).

As the correlations in the second last column of Table 11.1 show, environmental appraisal is to a large extent determined by the perceived quality or intensity of most factors except water quality and population density. This implies that the appraisal of these two latter factors is influenced stronger by non-perceptual factors. In other words, the perception of a poor quality of open urban waters or a high population density does not necessarily imply feelings of impacted well-being.

Neighbourhood satisfaction. The correlations of environmental appraisals and neighbourhood satisfaction are displayed in the last column of Table 11.1. While the majority of the sample (68%) indicated to be at least quite satisfied, 14% of the participants were extremely, very or quite unsatisfied with their proximate neighbourhoods, with another 17% neutral and 1% missing.

Concurrence of several potential stressors. Regression analyses were used to test if neighbourhood satisfaction can be better predicted by several concurring factors than by a singular factor alone (see Cohen et al. 2003). At first we examined the influence of several control variables including age, gender, education, parenthood, duration of residence, housing type, and time spent at home on average weekdays. Only gender was found to be significantly associated, with women less satisfied with their neighbourhoods ($M = 4.76$, $SE = 1.36$) than men ($M = 5.08$, $SE = 1.20$), $t(745) = -3.39$, $p < 0.01$. To reduce the amount of variables for hypothesis testing a multiple forced entry regression was performed with all eleven appraisal variables. We set $\beta = 0.15$ as the minimally required strength of influence. Accordingly, we ran a hierarchical regression with the appraisal of litter and dirt, and industrial noise. In the first step the two variables were entered simultaneously. In the second step the multiplicative term of the two variables was added to test for an interaction effect. The predictors were z-transformed to counterbalance different standard deviations and to reduce multicollinearity (Jonas and Ziegler 1999). We found a small main effect only for the appraisal of litter and dirt ($\beta = -0.29, p < 0.001; R^2 = 0.09$). It cannot be traced back to gender differences because the respective correlations do not differ significantly between the two groups ($Z = 0.465$). The interaction term was not significant, and therefore the main hypothesis of this study could not be confirmed.

11.4.6 Discussion

Traffic noise, litter and dirt, unpleasant odors, cold temperatures in winter and air pollution were rated the most critical ambient stressors in the urban area of Berlin. Moreover, insufficient public green space and near-by vegetation also seem to influence well-being in neighbourhoods. That is, the survey may have primed subjects to think of stressful conditions when they were asked for other negative factors. As we did not present urban greenery as a factor to be rated, we cannot compare it to ambient stressors at this time, but the indication in an open question should be weighed more than when respondents only react to presented factors.

Better educated people tend to evaluate the environment more critically (Marans 1976; Robin et al. 2007) and our respondents might have a rather high degree of awareness of pollution as voluntary participation attracts people with interest in a specific topic. However, we suppose that the extent of negative appraisals is rather underestimated here for several reasons: First, the variance in objective environmental loads in our participants' neighbourhoods may be reduced. The high education degrees in our sample suggest that our participants have a rather high socioeconomic status. However, as discussed in the environmental justice literature (cf., Bolte and Mielck 2004), it is the lower and middle class groups which usually live in areas with higher degrees of pollution. Second, individuals generally do not like to express negative feelings (Boucher and Osgood 1969). They might also correct their evaluations unintentionally to reduce cognitive dissonance (Festinger 1957). For instance, if it is easier for city dwellers to change their attitudes instead of their actions, they might correct their environmental appraisal rather than move away. Similarly, correction of the evaluation may occur when respondents cognitively habituate – that is they become accustomed to – stressful environmental conditions. Habituation – to be distinguished from physiological adaptation – is a mechanism that occurs when no suitable coping strategies are available for constant stress-inducing stimuli. It can also be interpreted as a cognitive reappraisal that the stimulus deserves less attention (Bell et al. 2001). Habituation may avoid breakdowns due to stressful stimuli, however it is problematic as it can deplete resources and result in stress disorders in the long run (e.g., Cohen et al. 1986; Craik and Zube 1976). The more predictable and the more regular stressful stimuli are, the easier it is to habituate to them (Glass and Singer 1972). This could be a reason for the highly negative appraisals of unpleasant odors and litter and dirt in comparison to, for example, constant air pollution.

For the same reasons, individuals usually indicate moderate or total satisfaction with their homes, relatively independent of the environment (Marans 1976). Hence, our finding that one third of the sample is not satisfied might be a conservative estimation, which is an undesirable outcome for Berlin: Neighbourhood satisfaction is not only a desirable state for individuals but also a societal issue. Unsatisfied residents behave less responsibly and are less likely to maintain semi-private areas, display less neighbourly behavior and are more likely to move away (see Flade 1987; Gärling and Friman 2002). This can contribute to the impoverishment of residential areas as the people with higher mobility are the ones with a higher income.

We could not confirm that the concurrence of more potential stressors predicts neighbourhood satisfaction better than one dominant factor. At this point we can only speculate why. Koelega (1987) supposed that coping with one stressor may increase vulnerability to other stressors. We intend to test his assumption with more direct stress and health indicators in further studies. As constant environmental loads may cause over-activation and thus enhance vulnerability on a physiological level, we will additionally apply a physiological stress measure and contrast the findings with more subjective stress indices.

11.4.6.1 Implications for Sustainable Urban Development

Neighbourhood satisfaction could be partly predicted by the appraisal of cleanliness of the proximate surroundings, which was also rated the most critical factor besides the well-known problem of traffic noise. Thus, litter and dirt in the public space is not only an aesthetic problem. We suggest that despite the economic problems Berlin is currently facing, the city should allocate more resources to this issue. Besides more frequent cleaning, more and bigger trash bins, or public campaigns and information, more research is needed to understand why people litter and how their behavior can be changed other than by implementing fines. At present, we are going to examine these aspects in more detail.

11.5 General Discussion

Adopting the conceptual frameworks proposed by Amérigo (1990), Amérigo and Aragonés (1997), and Lazarus (1991) we have reported three studies that investigated the relationship between objective attributes of residential environments and their subjective representations, including cognitive and affective judgements, and task-evoked pupillary responses as an indicator of cognitive resource allocation. The overarching goal of this work was to better understand the dynamic interaction between individuals and their residential environment by analysing the different processes – cognitive, affective and behavioral – which take place in this interaction. In addition we aimed at examining measures to design the urban environment according to the needs and preferences of residents. These design measures are expected to enhance residential satisfaction and satisfaction with life in general just as human health. Our study focused on Berlin as an example and prototype of a high-density residential environment.

The studies yielded the following main findings. First, besides population density building density also has a substantial impact on crowding. This was shown by manipulating specific attributes of the built environment, namely street width, building height, storey height, the number of parked cars, and greenery. Second, besides urban green spaces, vegetation-covered urban wasteland areas may have a positive impact on residential satisfaction. Third, and most importantly, specific variations in environmental attributes can reduce crowding of street scences or enhance preference of wilderness areas even if objective density or richness in detail is being held constant. The effective design measures are: reducing the amount of parked cars, adding greenery to street scenes, and visually structuring urban wasteland areas. Fourth, the following abiotic and biotic attributes of residential environment, namely traffic noise, litter and dirt, unpleasant odors, cold temperatures in winter, air pollution, insufficient public green space and nearby vegetation proved to be the most critical ambient stressors in the high-density metropolitan area of Berlin. Light pollution, in contrast, had a comparatively small impact on human well-being.

What do the results of our study tell us about needed changes in city-planning in order to provide a user-friendly city structure? From the perspective of environmental psychology, well-founded changes in the urban design or in current city planning like, for example, keeping wide streets and the inner city's restriction of the building height, providing a variety of greenery including nearby vegetation and structured urban wasteland areas, and building parking garages can lead to increased quality of life (cf., Wentz 2000; Thomas and Cousins 1996). Given these changes, living in a compact city could be conceived of as an attractive alternative to single-family housing in residential suburbs. Thus, the question of urban design is crucial in order to reduce rapid suburban expansion and its negative ecological and economical consequences. It is also crucial in enhancing residential satisfaction and human health.

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