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How does the individual perception of local conditions affect cycling? An analysis of the impact of built and non-built environment factors on cycling behaviour and attitudes in an urban setting

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ABSTRACT

The impact of local environment characteristics on individual cycling behaviour has been discussed in transport research for several years. Many previous studies have, however, primarily focused on the presence and distribution of built environment elements, considered using georeferenced or census data. This paper argues that not only is the objectively measured environment an influencing factor, but also the individual perception of this environment. Furthermore, besides built elements, the evaluation of perceived non-built attributes, such as discourses and policies, as well as the environment's impact on cycling attitudes, should be taken into account for a more comprehensive view. For this purpose, this study examines the responses to a household survey in the German city of Offenbach am Main (n = 701). The impact of the perceived local environment on cycling behaviour and cycling attitudes has been analysed using 21 perception items as well as socio-demographics, travel mode availability and general travel attitudes. For a more detailed view on cycling behaviour, this study applies the stage model of self-regulated behavioural change (SSBC) indicating a level of openness to use a bicycle frequently in everyday life. The results of the multivariate analysis show that the perceptions of built and non-built environment characteristics interrelate. Furthermore, certain perceptions encourage bicycle use and positive attitudes towards cycling, such as perceived cycling safety and pleasure. Primarily, these perceptions are safe and appropriate cycling infrastructures, cycling as a common practice and the absence of vandalism, dirt and high car pressure.

1. Introduction

Using a bicycle is not only a leisure and exercise activity, it also contributes to individual health and sustainability in transport. A shift from motorised means of transport to cycling has positive effects on auto-induced issues, such as air pollution, traffic noise, congestion and space requirements, especially in dense urban areas (Bernardo and Bhat, 2014; Gössling, 2013). Therefore, attempts are being made in many cities to improve conditions for cyclists and, thus, to foster frequent bicycle use (Lanzendorf and Busch-Geertsema, 2014; Pucher et al., 2010, 2011). In order to achieve this goal in the best possible way, it is essential to know how the local environment should be designed to meet cyclists' requirements. Research on this topic has increased significantly in recent years indicating that certain factors and characteristics are positively associated with non-motorised travel (Nello-Deakin, 2020; Yang et al., 2019). These include, for instance, the presence of cycling infrastructure, a high intersection density and diverse land use (Christiansen et al., 2016; Ewing and Cervero, 2010; Yang et al., 2019). However, most of these studies only consider the presence of objectively measured elements of the built environment. The impact of local non-built factors, such as marketing campaigns and discourses, has been neglected in many cases. Furthermore, some authors argue that only involving objective measures disregards actual individual perceptions that are subject to cognitive filtering processes (Golledge and Stimson, 1997; Ma and Dill, 2015; van Acker et al., 2010). Thus, perceptions of the presence and characteristics of local environment elements may differ from an objectively measured environment and even between individuals. Additionally, the vast majority of studies on the relation of environmental factors and cycling measure individual cycling behaviour based only on the frequency or duration of bicycle use in a certain period (cf. Arango et al., 2013; Craig et al., 2003; Ewing and Cervero, 2010). However, the implementation of cycling behaviour can be regarded as a process of individual decisions, involving attitudes, intentions and actions (Bamberg, 2012a). Previous research has hardly examined the

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environment's influence on these factors preceding actual cycling behaviour and on satisfaction when cycling.

On that basis, the aim of this study is to examine which perceived factors of the local environment, including built and non-built elements, contribute to the decision to cycle. Therefore, the perceptions' impact on cycling behaviour as well as on cycling-related attitudes are analysed. The former is done by applying the stage model of self-regulated behavioural change (SSBC), distinguishing four stages of openness towards frequent bicycle use. The attitudes towards cycling involve various associations and feelings. Additionally, the effects of socio-demographic attributes, travel mode availability and general travel attitudes are taken into account. For this purpose, a written household survey was conducted in the city of Offenbach am Main situated in the German Rhine-Main metropolitan region (n = 701).

The remainder of this paper is structured as follows. In the next section, I outline the theoretical background and previous research with regard to local environment perceptions, cycling and the SSBC model. Section 3 addresses the methodology comprising the case study in Offenbach am Main, the survey and the variables used for the analyses. The results of the empirical analyses are presented in section 4, followed by a discussion in section 5. The paper closes with some conclusions on implications, limitations and further research options in section 6.

2. Theoretical background

2.1. Local environment and travel

For several years, the impact of the local environment on individual travel behaviour has been an important subject in the field of transportation research (cf. Geurs and van Wee, 2004; Næss, 2015; van Acker et al., 2010). Especially with regard to non-motorised travel, built and non-built environment factors are considered to exert a decisive influence (Handy et al., 2002; Pikora et al., 2003; Saelens et al., 2003; Willis et al., 2015). In their often cited work, Cervero and Kockelman (1997) suggest land use diversity, density and street network characteristics as principal dimensions of the local environment. Studies addressing these "3Ds" indicate the positive effects of local dense and mixed land use as well as high street connectivity on the willingness to walk and cycle (Banister, 2011; Braza et al., 2004; Ewing and Cervero, 2010; Litman and Steele, 2018; Smith et al., 2017; van Wee, 2002). Some other studies refer to the presence of micro-scale factors or aesthetics of the environment, suggesting associations with the frequency and quality of walking and cycling in these areas. They include local amenities, such as greenery and trees, benches and street lighting, pleasing architecture and scenery as well as specific transport infrastructures, such as bike parking facilities and pedestrian crossings (Arango et al., 2013; Ewing and Clemente, 2013; Giles-Corti et al., 2013; Larsen et al., 2009; Milakis et al., 2017; Mitra et al., 2015; Moniruzzaman and Páez, 2012; Ramezani et al., 2018). Less attention has been paid to non-built characteristics of the local environment. These involve social and political factors, such as local regulations, policies, information services, marketing campaigns and media reports as well as the behaviours of the surrounding people, e.g. concerning travel, social conventions and crime (Heath et al., 2006; King et al., 2002; Klinger et al., 2013; Pucher and Buehler, 2008; Rech et al., 2012; Ståhl et al., 2001; van Acker et al., 2010; Willis et al., 2015).

Most of the recent studies analysing the impact of the local environment involve objectively measured design elements, primarily based on georeferenced and census data (Blitz and Lanzendorf, 2020; Ding and Gebel, 2012; Ewing and Cervero, 2010; Fraser and Lock, 2011; Kärmeniemi et al., 2018; van Acker et al., 2010). Thus, possible associations with travel behaviour are often only explained by the factual existence of certain local circumstances without questioning whether the individuals examined are even aware of these circumstances. Seen from a social sciences perspective, however, the stimulus of the objective environment is processed individually by emphasising and neglecting certain elements resulting in subjective filtered perceptions that form a decisive basis for behaviour (Flade, 2013; Golledge and Stimson, 1997; Lynch, 1977; Mehrabian and Russell, 1974; Norman, 2013; Stokols, 1977; van Acker et al., 2010). Thus, even though individual perception is constituted mainly by the actual attributes of the environment, it is also affected by cognitive capabilities, socio-demographic characteristics, preferences and experiences (Kremers et al., 2006; Nathan et al., 2012; Orstad et al., 2017; Wen et al., 2006). For instance, the study by Roosa et al. (2009) shows that an individual's social and cultural background as well as gender influence the perception of the quality of one's own neighbourhood. As a consequence, the impression of the environment may differ from the objectively measured reality, which has been illustrated in several studies (Ball et al., 2008; Gebel et al., 2011; McGinn et al., 2007; Orstad et al., 2017; Prins et al., 2009; van der Waerden et al., 2004). Moreover, associations identified between travel behaviour and local environment factors may vary depending on whether objective or perceived measures are taken into account (Hoehner et al., 2005; Lee et al., 2017; Ma and Dill, 2015; Prins et al., 2009). Therefore, several authors suggest the use of individual perceptions within studies rather than corresponding objective data only (Ma et al., 2014; Sugiyama et al., 2014; van Acker et al., 2010; Weden et al., 2008). Common approaches of acquiring information on individual perceptions involve surveys, questionnaires and in-depth interviews (Seamon and Gill, 2016).

2.2. Studies on perceived local environment and cycling

Although most of the studies on local environment and travel behaviour involve objective measures, in recent years, some research also relates to individual perceptions. In their study investigating which of these two evaluation approaches better explains the impact of the local environment on cycling, Ma et al. (2014) reveal that objective factors only have an indirect effect in terms of influencing individual perceptions. Thus, perceptions mediate the relations between the objective environment and behaviour. Therefore, the authors point out the decisive and immediate impact of environment perceptions on cycling. Based on previous research involving such perceived elements, this study identified four main perception dimensions of the local environment for cycling. These are used for the classification of perception items: (i) cycling infrastructures, (ii) public space quality, (iii) traffic environment and (iv) non-built cycling environment.

(i) Cycling infrastructures include the presence and condition of cycling facilities. In this regard, several studies show that the perception of appropriate cycle paths and cycle lanes contribute to bicycle use (e.g. Hoehner et al., 2005; Iwińska et al., 2018; Moudon et al., 2005; Porter et al., 2018b; van Dyck et al., 2012), as these increase efficiency and the feeling of safety while cycling. In turn, Frater and Kingham (2020) identified the lack of perceived safe bicycle parking facilities as an important barrier to cycling. Similarly, Wahlgren and Schantz (2012) argue that red traffic lights preventing continuous movement discourage cycling.

(ii) Research on the perceptions of public space quality involves aesthetics and the pleasantness of public spaces. In some studies, the perception of attractive and aesthetically appealing places and greenery turns out to be positively associated with cycling (D'Haese et al., 2015; Forsyth and Oakes, 2015; Heesch et al., 2014; Kerr et al., 2016; Liao, 2016; Milakis et al., 2017; Porter et al., 2018a; van Dyck et al., 2012). In their work on commuting route environments in the metropolitan area of Stockholm, Wahlgren and Schantz (2012) claim that perceived beautiful, green and safe environments stimulate the willingness to cycle. Additionally, high levels of exhaust fumes turned out to be hindering factors. By contrast, Mertens et al. (2016) found perceived high air pollution and unpleasant environments positively correlated with a high frequency and duration of transport-related cycling in five European urban areas. The authors assume that regular bicycle users are more exposed to these negative aspects of the local environment

compared to non-users and are, thus, more aware of these factors.

(iii) Traffic environment perceptions refer to local traffic volumes and the travel behaviours of the surrounding people. For instance, Liao (2016) found positive associations between individual cycling and the perception of others being physically active nearby. On the contrary, the analysis of Hoehner et al. (2005) indicates no such effect on the surrounding people. Manton et al. (2016) point out the negative effect of perceived motorised traffic on individual safety resulting in major concerns about cycling. Kerr et al. (2016) support these findings by identifying perceived high car traffic volume and speed as hindering cycling for transport. In addition, the respondents of a study conducted by Forsyth and Oakes (2015) cite motorists as the highest threat when cycling.

(iv) Few studies also involve non-built environment factors, such as discourses, a city's reputation or local social cohesion. For instance, by means of focus group discussions, Frater and Kingham (2020) ascertained that adolescents' perception of positive media images of the car favours positive attitudes towards driving, which might negatively affect bicycle use. In their research on cycling enablers and barriers in Warsaw, Iwińska et al. (2018) point out that the perception of automobility domination in the city's mobility culture and a lack of respect from road users towards cyclists lead to feelings of discrimination and unsafety hindering cycling. Compared with this, Xing et al. (2010) show that the perception of cycling as a common mode of transportation in the neighbourhood increases bicycle use. Furthermore, Titze et al. (2007) show that feeling unsafe due to a perceived high risk of bicycle theft discourages students from cycling regularly. According to Carver et al. (2005) as well as Timperio et al. (2006), the cycling frequency of children and adolescents is positively affected by high social interaction within a neighbourhood as well as the positive perceptions of their parents regarding safety and the quality of facilities and areas in public space.

2.3. The stage model of self-regulated behavioural change (SSBC)

In order to evaluate cycling behaviour in more detail, this study applies the stage model of self-regulated behavioural change (SSBC) (Bamberg, 2013). It facilitates classification according to people's openness to maintaining a certain behaviour (e.g. the intention to use the bicycle frequently) instead of only considering an actual implemented behaviour. Thus, it enables investigations on influencing factors in the implementation process. Recently, the model was employed in several travel behaviour studies (Blitz et al., 2020; Keller et al., 2019; Kirschner and Lanzendorf, 2020). It is based on the 'transtheoretical model' by Prochaska and DiClemente (1983) and describes the process of rejecting previous behaviour (e.g. car use) and implementing a new behaviour (e.g. cycling) by means of four stages illustrated in Fig. 1: (i) 'predecision', (ii) 'preaction', (iii) 'action' and (iv) 'postaction' (Bamberg, 2012b, 2013; Keller et al., 2019). Transition points characterised by the existence of certain individual intentions, attitudes and actions define the shift from one stage to another. Thus, the current affiliation of an individual to one of the SSBC stages can be measured by identifying which transition points have been exceeded at the time. However, in the SSBC process, it is not necessary for all stages to be passed linearly. Transitions can be reversed or even skipped (Bamberg, 2012b).

Individuals in the stage of 'predecision' indicate no evidence for questioning current behaviour, for instance, due to perceived social obligations, and, thus, suggest no willingness for behavioural change at all. In the second stage of 'preaction', an individual's evaluation of the practicability of adopting a new behaviour is a key aspect. It can be identified by attitudes towards and perceived behavioural control over this behaviour, which are also affected by environmental features (Bamberg, 2012a). A positive assessment of both of these significantly contributes to the willingness to adopt the behaviour (Ajzen, 1991; Bamberg, 2012b; Bamberg and Schmidt, 1993). Individuals in the stage of 'action' show the first attempts of implementing the new behaviour or state explicit plans for this intention. In the last stage of 'postaction', the implementation of the new behaviour could be maintained in everyday life resulting in regular actions. Depending on the affiliation to a certain stage, different requirements emerge that can be supportive for proceeding within the process. For instance, interventions providing information about alternative behaviours may contribute to individual choices in the stages of 'predecision' and 'preaction' or certain policies and infrastructures may facilitate the implementation (the 'postaction' stage) of a behaviour in everyday life (Bamberg, 2012a, 2012b).

2.4. Conceptual framework

According to the recent studies presented above, the perceived local environment affects individual cycling. In order to give a detailed explanation of how these perceptions contribute to cycling, this study analyses cycling behaviour by means of the SSBC model and, additionally, by involving individual cycling attitudes. For this purpose, variables of the previously described four local environment dimensions are taken into account. As illustrated in this paper's conceptual framework (Fig. 2), further factors recognised in previous mobility research as significant for cycling (cf. Piatkowski and Marshall, 2015; Willis et al., 2015) are considered as additional variables for the analyses: the respondent's objective characteristics concerning socio-demographics and bicycle and car availability as well as individual general travel attitudes. As mentioned before, such individual characteristics may affect the subjective perceptions in addition to the objective attributes of the local environment themselves. The dashed lines in Fig. 2 illustrate these relationships.

However, the focus of this study is the influence of these factors and individual perceptions on individual cycling (illustrated by the solid lines). Certainly, as indicated by previous research as well as the SSBC model's concept, cycling-related attitudes play a key role in the actual use of a bicycle (Bamberg, 2012a; Gatersleben and Appleton, 2007; Heinen et al., 2010; Willis et al., 2015). In particular, the perceived immediate benefits of cycling, such as positive emotions and practicality, as well as a good assessment of safety, strongly contribute to the decision to use the bicycle (García et al., 2019; Heinen et al., 2011). Therefore, previous studies show that people with positive views about cycling are more likely to cycle frequently (Willis et al., 2015). According to recent research on the constitution of attitudes, this paper argues that the local environment may contribute to specific cycling attitudes and feelings, such as behavioural control over cycling or enjoyment when cycling (Bamberg, 2012a; de Vos et al., 2020; Fernández-Heredia et al., 2014; van Wee et al., 2019). In this regard, attitudes involve an individual evaluation of the perceived environment (van Acker et al., 2010). For instance, in environments with high traffic, cycling is more often associated with unsafety (Ewing and Dumbaugh, 2009; Simpson, 2017). Therefore, this study also focusses on the impact

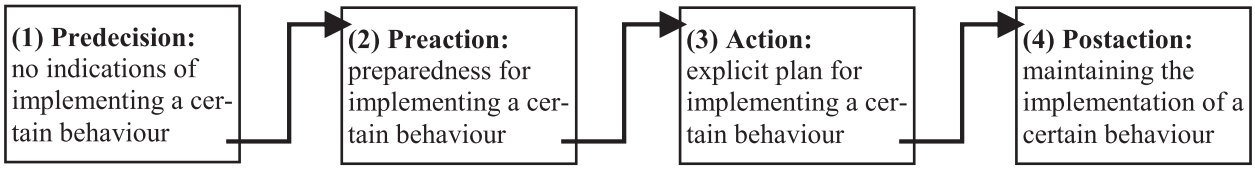

Fig. 1. Stages and underlying indicators of the SSBC model (own illustration based on Bamberg 2012b and 2013).

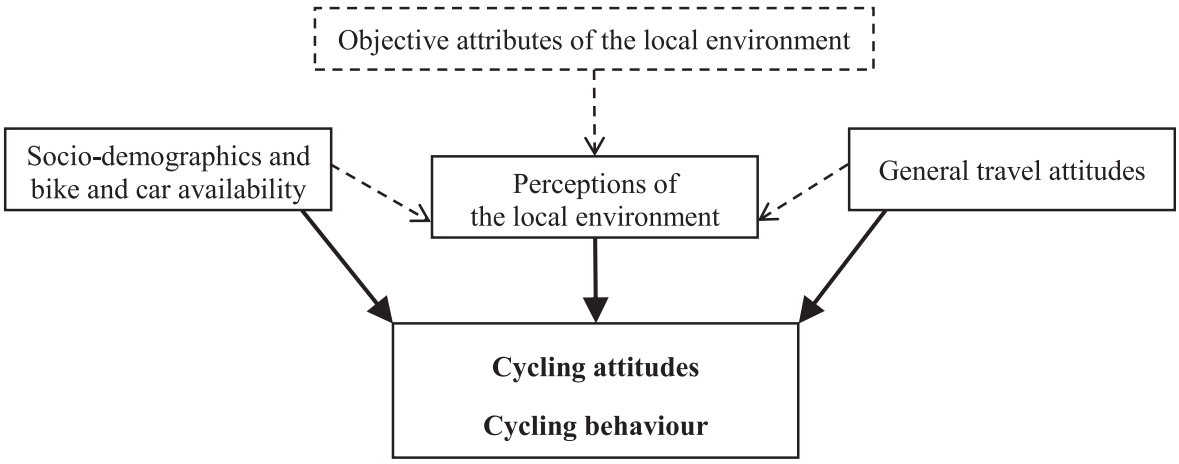

Fig. 2. Conceptual model of factors affecting cycling attitudes and behaviour (own illustration).

on cycling-related attitudes. The following sections provide more information on all of these variables.

3. Methods and data

3.1. Case study and survey

This study applies data from a written household survey in Offenbach am Main, a German city close to Frankfurt am Main in the urban Rhine-Main metropolitan region. The cross-sectional survey was conducted in March and April 2019 addressing 4,014 households in the city's populous downtown area. This area is characterised by a high housing density with only limited public and green spaces. On-street parking is permitted in a large part of the investigation area and there are several high-frequented arterial roads in its vicinity. Some streets in the area are part of the city's designated bicycle route network in the form of marked on-street bicycle lanes and a recently introduced cycle street.

Within the investigation area, every household received the survey documents requesting one adult member to participate. In order to randomly select this member, the last birthday method was applied (cf. Binson et al., 2000). The twelve-page questionnaire included items on travel behaviour and travel attitudes, on socio-demographics as well as on the evaluation of several of the city's and the neighbourhood's built and non-built environment factors, focussing on cycling-related elements. An enclosed envelope provided the opportunity to return the questionnaire free of charge. Participation was promoted by means of distributed pre-announcements, a press release as well as personal contact and reminder notes (for details, see Blitz, 2020). Altogether, 706 questionnaires were returned (17.6% response rate). Five cases were excluded due to a high amount of missing values, resulting in 701 cases for further analyses.

Table 1
Variables for bicycle use, cycling intention and attitudes (n = 701).

Variable	Percentage of agreement
Bicycle use	
U1: frequent bicycle use in summer	59% [1]
U2: frequent bicycle use in winter	31% [1]
Behavioural Intention	
BI: I have planned to ride my bicycle more often in everyday life.	50% [2]
Cycling attitudes	
A1: The bicycle is the ideal means of transport for me.	40% [2]
A2: Riding my bike is fun for me.	66% [2]
A3: When riding a bicycle, I am flexible and free.	54% [2]
A4: I am able to reach all relevant everyday destinations by bicycle.	42% [2]
A5: When riding a bicycle, I feel unsafe.	29% [2]
A6: For me, riding a bike is exhausting and uncomfortable.	14% [2]
A7: I enjoy riding my bicycle in Offenbach.	36% [2]

[1] agreement: bicycle use is "1–3 days per week" or "(almost) daily"

[2] agreement: "strongly agree" or "somewhat agree" to the attitude statement on a five point Likert scale

3.2. Variables for bicycle use, cycling intention and attitudes as indicators of the SSBC stages

To examine cycling behaviour, this study applies the SSBC model (section 2.3) adapted for frequent bicycle use. The model describes the implementation of regular cycling by means of four stages. To specify the respondents' stage in the SSBC, several items of the survey concerning individual bicycle use as well as cycling intention and attitudes that address the model's underlying assumptions are taken into account (table 1, see also Blitz et al., 2020). The stage assignment as well as the cycling attitudes are used as outcome variables in the further analyses. They allow a broader perspective on the possible effects of local environment perceptions on the diverse facets of cycling.

The respondents stating regular use of a bicycle in everyday life (at least once a week in summer (U1) or winter (U2)), are assigned to the fourth stage of 'postaction', as they have already implemented

Table 2
SSBC stage assignments of the sample.

SSBC Stage	Description	Percentage of assignment
Stage 1: Predecision	no indications of frequent bicycle use	26% [1]
Stage 2: Preaction	preparedness for frequent bicycle use	8% [2]
Stage 3: Action	explicit plan for frequent bicycle use	7% [3]
Stage 4: Postaction	implemented frequent bicycle use	59% [4]

[1] respondents with no indications; not assigned to stages 2, 3 or 4

[2] respondents with agreement to variables A1, A2 or A3 and agreement to A4 or neither agreement to A5 nor to A6; not assigned to stages 3 or 4

[3] respondents with agreement to variable BI; not assigned to stage 4

[4] respondents with agreement to variables U1 or U2

Table 3
Variables of the perceptions of the local environment.

Variable [1]
Cycling infrastructures
I1: In Offenbach, cycle paths are usually in good condition.
I2: In Offenbach, cycle paths are often blocked by parked cars or other obstacles.
I3: In Offenbach, bicycle parking facilities are convenient and safe.
I4: In Offenbach, a cyclist has to wait for a long time at traffic lights.
I5: In Offenbach, bicycles can be taken onto public transport easily.
Non-built cycling environment
N1: In Offenbach, there is a lot of advertising for cycling.
N2: In Offenbach, media reports on cycling are mostly positive.
N3: In Offenbach, there is a lot of information related to cycling.
N4: In Offenbach, not enough is being done for bicycle traffic.
N5: In Offenbach, they do not take you seriously as a cyclist.
N6: In Offenbach, I think bicycle theft happens frequently.
Public space quality
P1: In my neighbourhood, public space has nice areas I like.
P2: In my neighbourhood, there is enough greenery and trees.
P3: In my neighbourhood, public space has adequate lighting.
P4: In my neighbourhood, there is vandalism.
P5: In my neighbourhood, I often see dirt or rubbish.
Traffic environment
T1: In Offenbach, everyone rides a bike – young and old alike.
T2: In my neighbourhood, I see many cyclists.
T3: In my neighbourhood, car traffic is too heavy.
T4: In my neighbourhood, public space is characterised by parked cars.
T5: In my neighbourhood, there are frequent conflicts between cyclists and other road users.

[1] Variables measured on a five-point Likert scale: (0) "I strongly disagree" – (4) "I strongly agree"

maintained cycling behaviour. Those of the remaining participants who state an explicit plan for increasing their use of a bicycle (agreement to BI) are assigned to the stage of 'action'. An agreement to this statement indicates a distinct behavioural intention. Of the remaining respondents, those with positive attitudes towards cycling (agreement to A1, A2 or A3) as well as behavioural control over cycling (agreement to A4 or neither agreement to A5 nor to A6) are classified in the 'preaction' stage, indicating positive associations with and preparedness for frequent bicycle use. All other respondents are assigned to the first stage of 'predecision'. They show no indications of the intention of frequent bicycle use. Table 2 gives an overview of the resulting sample's stage classification.

As table 2 shows, 59% of the participants have already implemented frequent bicycle use ('postaction' stage) and about a quarter are in the stage of 'predecision'. The middle stages, 'preaction' (8%) and 'action' (7%), show the lowest shares, which can be explained by the status of transition between habitual behaviours represented by these stages. Respondents of both stages indicate a certain openness towards regular bicycle use without having it implemented. Usually this status only persists for a certain period (Bamberg, 2012b).

3.3. Variables for the perceptions of the local environment

The individual perceptions of the local environment are derived from 21 statements (table 3) with a five-point Likert scale ranging from 0 ("I strongly disagree") to 4 ("I strongly agree"). With additions and modifications, these statements are mainly based on items in the "cycling climate" survey, a nationwide survey regularly conducted by the German cycling association (ADFC) in German communities (ADFC, 2019). The statements address various local conditions comprising built and non-built environment elements of the neighbourhood and the entire city. They include: (i) specific bicycle infrastructures (cycle paths, bicycle parking facilities, traffic lights and public transport carriage), (ii) non-built cycling environment factors (related to communication, policies and bicycle theft), (iii) general public space qualities (aesthetics, greenery and lighting) and (iv) the traffic environment (bicycle traffic, car traffic and traffic conflicts). Thus, the items not only address the cycling-related practicability of the local environment, but also aesthetic and symbolic characteristics. A Principal Component Analysis (PCA) was conducted with all of the variables at once in order to identify possible interrelated perceptions involving different local environment aspects (section 4.1).

3.4. Variables for travel attitudes

Three general travel attitude factors are included as variables in the analysis. They have been extracted by means of a PCA (eigenvalue ≥ 1) involving six items (table 4). Factor 1 "preference for safe, pleasant and sustainable travel" describes the importance of the respective positive feelings and associations while travelling. Factor 2 "travel enjoyment and openness" outlines the pleasure of travelling and travel flexibility. Factor 3 "preference for efficient travel" emphasises the importance of the mobility's practicability in terms of travel time.

Table 4
Factor loading results of the Principal Component Analysis (PCA) regarding travel attitudes (n = 701).

Items measured on a five-point Likert scale: (0) "I strongly disagree" - (4) "I strongly agree"	Mean	SD	Factors of travel attitudes (PCA) 1 Preference for safe, pleasant and sustainable travel	2 Travel enjoyment and openness	3 Preference for efficient travel
When choosing the means of transport, I attach particular importance to safety.	2.64	1.152	.782	-.085	.095
It is important to me to travel in a pleasant environment.	3.23	.841	.617	.235	.159
Because of my own values, I feel obliged to travel in an environmentally-friendly way.	2.85	1.017	.572	.086	-.559
I am not committed to a particular means of transport.	2.72	1.177	.017	.769	-.265
I like to travel a lot.	2.89	.966	.104	.710	.291
It is important to me to reach my destination as quickly as possible.	2.94	1.003	.261	.036	.784
Cronbach's alpha			.393	.241	/

Principal Component Analysis with varimax rotation; only factors with eigenvalues ≥ 1 were considered; loadings ≤ 0.4 are shown in grey; N = 701; Kaiser–Meyer–Olkin = 0.585; Bartlett's test of Sphericity: $\chi^2 = 150.623$ df = 15 p = .000; Total variance explained: 61.4%

3.5. Variables for socio-demographics and travel mode availability

In addition, six socio-demographic items are applied as control variables: gender, age, level of education, employment status, income and migrant background (table 5). While the sample's share of female respondents is similar to that of the entire city of Offenbach, significant differences exist regarding age, migrant background and employment status. The former is caused by the survey's limitation to adults, while Offenbach's respective value includes all ages. The sample's lower proportion of people with a migrant background is an issue also familiar from other written surveys. It can be explained by linguistic and cultural barriers that might be a deterrent for this population group (El-Menouar, 2019; Fick and Diehl, 2013). Furthermore, the sample shows a higher proportion of people employed or in education compared to the city's entire population. However, it should be noted that the reference value is from 2011, thus not representing the current situation. In addition, the questionnaire included two items on bicycle and car availability ("Do you have a roadworthy bicycle / a car at your disposal?") indicating that the vast majority has access to both means of transport.

4. Results

4.1. Factors of local environment perceptions

To extract the most important factors of the perceived local environment and to identify interrelated perceptions, a PCA with the 21 initial items (section 3.3) was performed, resulting in six factors with an eigenvalue ≥ 1 (table 6). Surprisingly, only three factors (factors 3, 4 and 6) are in line with the element dimensions shown in table 3. The compositions of the factors 1, 2 and 5 show that evaluations of physical and intangible elements can be interrelated. Factor 1 'low political priority for the cycling mode in Offenbach' includes assessments of the city's cycling infrastructures' conditions and its cycling reputation, indicating perceived discrimination against bicycle traffic mirrored in both built and non-built elements. Factor 2 'vandalism, dirt and high car pressure in my neighbourhood' outlines perceived disorder and car traffic dominance in the neighbourhood. Thus, it comprises negative assessments of the quality of public space along with traffic environment issues. Factor 3 'pro-cycling marketing campaigns in Offenbach' describes the perceived presence of cycling-supporting (non-built) communication activities in the city. Factor 4 'high quality public space and greenery in my neighbourhood' indicates positive evaluations of the surrounding public space in terms of appealing aesthetics including sufficient lighting and greenery. Factor 5 'safe and appropriate cycling infrastructure in Offenbach' relates to positive assessments of the city's cycling facilities and a feeling of safety, also with regard to bicycle theft, indicating that a city's perceived cycling suitability and safety consists of built and non-built elements. Factor 6 'cycling is a common practice' outlines the perception of an omnipresence of cycling in the urban area's traffic environment.

4.2. The impact of local environment perceptions on cycling behaviour and attitudes

In order to understand the effect of the perceived local environment on cycling behaviour, I conducted ten logistic regression analyses including the six extracted factors of perceptions as independent variables (table 7). Cycling behaviour is specified by the assignment to the SSBC stages (see table 2). Assignments to at least stage 2 (preaction/action/postaction: indicating at least a basic openness towards frequent bicycle use), at least stage 3 (action/postaction: indicating at least the explicit plan for frequent bicycle use) and stage 4 (postaction: indicating implemented frequent bicycle use) are used as binary dependent variables for the first three regression models. Additionally, seven regression models analyse the perceptions' effects on cycling attitudes. For these, the agreement to the attitudinal statements are used as binary dependent variables (see table 1). They enable a separate consideration of cycling-related assessments and their influencing factors. General travel attitudes, travel mode availability and socio-demographics are included as further variables in all regression analyses. All calculated models are significant on the basis of the Omnibus Test ($p = .000$) and reveal different coefficients of determination mostly indicating an acceptable (≥ 0.2) or a good (≥ 0.4) goodness of fit based on Nagelkerke's R^2 measure (Rohrlack, 2009).

The results show that the perception of low political priority for the cycling mode in Offenbach (factor 1) is strongly associated with SSBC stages 2, 3 and 4 as well as with several positive attitudes towards cycling (A1-A4). Furthermore, the feeling of unsafety when cycling (A5) seems to be related to this perception. Perceiving vandalism, dirt and high car pressure in the neighbourhood (factor 2) reduces the probability of being at least in stage 2 or in higher stages. In addition, this perception seems to lower perceived cycling fun (A2) as well as enjoyment when riding in Offenbach (A7), while the feelings of unsafety (A5) as well as exhaustion and discomfort (A6) increase.

On the contrary, the further perceived dimensions of the local environment all seem to be related, to a greater or lesser extent, to cycling behaviour and referring positive attitudes. The perceived presence of pro-cycling marketing campaigns in Offenbach (factor 3) is positively associated with the enjoyment of cycling in this city (A7). Respondents who perceive high quality public space and greenery in the neighbourhood (factor 4) are more likely to regard the bicycle as an ideal means of transport (A1) and to be able to reach all relevant everyday destinations by bicycle (A4). Moreover, they show a stronger sense of flexibility and freedom (A3) as well as enjoyment (A7). The same attitudes are correlated with the perception of safe and appropriate cycling infrastructures in Offenbach (factor 5). In addition, this perceived dimension supports the affiliation to at least stage 2 of the SSBC and seems to contribute to the reduction of feeling unsafe (A5) as well as exhausted and uncomfortable (A6). The perception of cycling being a common practice as well encourages the probability of being at least in stage 2 of the SSBC, moreover also implementing frequent bicycle use (stage 4). Furthermore, perceived cycling traffic seems to positively affect the senses of fun (A2), enjoyment (A7) and safety (A5).

Some further variables also contribute to the regression models. Regarding general travel attitudes, the preference for safe, pleasant and sustainable travel is not associated with the SSBC stages, but seems to increase the likelihood of considering the bicycle as the ideal means of transport (A1) as well as having fun (A2), feeling flexible and free (A3) and feeling unsafe (A5) when cycling. In contrast, travel enjoyment and openness appear to positively affect advancing to further SSBC stages. In addition, cycling-related fun (A2), the feeling of flexibility and freedom (A3) as well as the enjoyment when riding in Offenbach (A7) seem to be positively influenced by this general attitude. Respondents indicating a preference for efficient travel, on the other hand, do not belong to the SSBC stages 2, 3 or 4. Furthermore, they show negative attitudes towards the positive aspects of cycling (A1-A4, A7), while the feeling of unsafety (A5) and exhaustion and discomfort (A6) when cycling is higher for them. Therefore, this general attitude seems to discourage cycling.

The availability of a bicycle strongly supports the assignment to at least stages 2, 3 and 4. Furthermore, having a bicycle is strongly associated with all the positive attitudes towards cycling (A1-A4, A7). On the contrary, it seems to reduce the feeling of unsafety and exhaustion and discomfort (A6). The availability of a car has no influence on the SSBC stage assignments. However, negative associations can be seen regarding cycling-related flexibility and freedom (A3) and the ability to reach all relevant everyday destinations by bicycle (A4).

None of the socio-demographic variables has an influence on the SSBC stages and only two of them contribute to the cycling attitudes: gender and age. Accordingly, females tend to have less fun (A2) and feel rather unsafe (A4) when riding a bike. Furthermore, younger people tend to feel free and flexible on a bike (A3), while older respondents consider cycling rather exhausting and uncomfortable (A6).

Table 5
Variables of socio-demographic attributes and travel mode availability in comparison with the city's population.

Variable	Description	Sample	City of Offenbach
Socio-demographics			
Female	gender: female (1); male (0)	51%	49% [1]
age (mean value) *	age in years (18–96)	46 years	40 years [2]
higher education entrance qualification	Abitur/ high school degree: yes (1); no (0)	74%	*no data*
employed/ in education *	employed (full-time/ part-time) or in education/ school/ college: yes (1); no (0)	77%	63% [3]
monthly net income (mean value)	income in Euro [4] (139–5500)	2,113 €	*no data*
migrant background *	with a migrant background [5]: yes (1); no (0)	26%	63% [1]
Travel mode availability			
bicycle availability	bicycle available: yes (1); no (0)	85%	*no data*
car availability	car available: yes (1); no (0)	83%	*no data*
N		701	138,853 [1]

* significant difference between total sample and city of Offenbach's total population (binomial test, $p < .010$)

[1] source: Stadt Offenbach am Main, 2019b

[2] including the population under the age of 18 (source: Stadt Offenbach am Main, 2019a)

[3] data from the year 2011, including the population aged between 15 and 17 (Hessisches Statistisches Landesamt, 2014)

[4] quotient of the mean value of the stated monthly net household income (queried using the levels: less than 1,000€; 1,000€ to less than 2,000€; 2,000€ to less than 3,000€; 3,000 € to less than 4,000€; 4,000€ to less than 5,000€; 5,000€ and more) and number of household members adjusted according to the OECD-modified scale (OECD, 2013: 1 adult valued 1.0 members, further adults 0.5 members, children under 14 0.3 members)

[5] respondent's country of birth or his/her parent's country of birth different to Germany

5. Discussion

5.1. Individual perceptions of the local environment

According to the PCA of various local environment perceptions conducted (section 4.1), it can be concluded that, from the residents' point of view, the four different examined dimensions of the environment are apparently interrelated. In particular, this can be seen with regard to the cycling infrastructures and non-built factors as well as related to the public space quality and the traffic environment. The former indicates a connection between the bicycle's political and social significance in the city and the presence and development of the cycling infrastructure on the one hand as well as its condition, maintenance and acceptance on the other hand. Additionally, the assessments of the infrastructure interact with the perceived risk of bicycle theft. The latter reveals the negative effect of high car traffic and traffic conflicts on the evaluation of orderly and clean spaces. Thus, a strict distinction between local environment dimensions – as implemented in previous studies (e.g. Hoehner et al., 2005; Porter et al., 2018a; Stronegger et al., 2010) – is not in line with the actual individual perception. Therefore, a joint consideration of various elements appears to be more appropriate.

Furthermore, the consideration of individual perceptions provided the opportunity to evaluate data not only on the presence of certain elements but also on the conditions assessed by the residents in terms of their own needs and opinions. For instance, the majority of respondents do not think the existing bicycle parking facilities are convenient and safe. This is a fact that could not be discussed using georeferenced data on the locations of such facilities alone. In addition, aspects of the local environment have been investigated, which are generally difficult to measure objectively, such as discourses and perceived safety, but also contribute to a city's overall mobility appearance (Aldred and Jungnickel, 2014; Klinger et al., 2013). The results show that the respondents in particular negatively evaluate the significance of the cycling travel mode compared to other modes and the dominance of car traffic. Thus, the analyses confirm previous investigations describing the city of Offenbach am Main as rather auto-oriented (Klinger et al., 2013).

5.2. The impact of the perceived local environment on cycling behaviour and attitudes

The regression models indicate an impact from the perceptions of the local environment on cycling behaviour and attitudes. Differences can be found regarding the extent and direction of the six factors examined. With reference to previous research, these correlations are discussed in the following in more detail.

Firstly, perceived low political priority for the cycling mode in Offenbach is associated with frequent bicycle use and positive attitudes towards cycling. In particular, respondents in SSBC stages 2 and 3 as well as those specifying the bicycle as the ideal means of transport show that perception. Similar findings can be found in a recent study on the cycling cultures in Stockholm and Copenhagen (Haustein et al., 2020) indicating that lower perceived prioritisation of cycling is positively associated with time spent cycling. These results may be explained by cyclists feeling disadvantaged compared to and possibly caused by other road users. Respondents who do not ride a bicycle may not be aware of this disadvantage seen from a cyclist's perspective or even perceive disadvantages of their own preferred mode of transport instead. Mertens et al. (2016) describe the impact of this higher awareness of negative aspects by those exposed to it as 'reverse causality'. In addition, it is also possible that those respondents used the survey to draw attention to their dissatisfaction and hope that in doing so improvements could be initiated.

Secondly, the perception of vandalism, dirt and high car pressure in the neighbourhood negatively affects frequent bicycle use and the enjoyment of cycling. Furthermore, this local environment factor increases the feeling of unsafety and discomfort when riding a bicycle. These conclusions can be supported by previous studies involving these kinds of factors. In particular, high car traffic volumes have been identified as a hindering determinant for non-motorised travel (e.g. Carver et al., 2005; Duncan et al., 2005; Wahlgren and Schantz, 2012). Car traffic may evoke feelings of unsafety, especially if there are no separated infrastructures for these modes. The same applies to perceived vandalism and dirt. Related public space does not give the impression of being suitable for parking one's own bicycle and may be associated with crime and the fear of bicycle theft (Fernández-Heredia et al., 2014; Rapoport, 1990). Previous research shows that pedestrians and cyclists, in particular, are exposed to these risks of traffic and crime, resulting in a decrease in walking and cycling levels in environments perceived as dangerous (Jacobsen et al., 2009).

Thirdly, pro-cycling marketing campaigns show a low effect on cycling behaviour and attitudes. Regarding the regression models, only the enjoyment of cycling in Offenbach is associated with this factor. Despite the lack of research on this specific local environment factor, it can be assumed that cycling-related advertising, information and positive media reports might contribute to an increased interest in cycling and improved capabilities (Pucher and Buehler, 2008). For instance, information on existing bicycle infrastructures may be helpful for finding appropriate cycling routes and, thus, improve cycling enjoyment. Moreover, it cannot be precluded that enthusiastic cyclists are

Table 6
Factor loading results of the Principal Component Analysis (PCA) regarding local environment perceptions (n = 701).

Items measured on a five-point Likert scale: (0) "I strongly disagree" - (4) "I strongly agree"	Mean	SD	Factors of perceived dimensions of the local environment (PCA) 1 Low political priority for the cycling mode in Offenbach	2 Vandalism, dirt and high ca pressure in my neighbourhood	3 Pro-cycling marketing campaigns in Offenbach	4 High quality public space and greenery in my neighbourhood	5 Safe and appropriate cycling infrastructure in Offenbach	6 Cycling is a common practice
N4: In Offenbach, not enough is being done for bicycle traffic.	2.47	1.144	.674	.037	-.335	-.034	-.059	-.194
I4: In Offenbach, a cyclist has to wait for a long time at traffic lights.	2.09	1.020	.666	-.146	.073	-.202	-.192	.278
N5: In Offenbach, they do not take you seriously as a cyclist.	2.40	1.209	.625	.180	-.113	-.094	-.216	-.040
I2: In Offenbach, cycle paths are often blocked by parked cars or other obstacles.	2.78	1.079	.607	.280	-.074	-.025	-.015	-.110
P4: In my neighbourhood, there is vandalism.	2.65	1.100	-.041	.740	-.035	-.210	-.175	.119
P5: In my neighbourhood, I often see dirt or rubbish.	3.30	.930	.052	.723	-.015	-.156	-.124	.088
T3: In my neighbourhood, car traffic is too heavy.	3.05	.962	.461	.576	-.069	.027	.062	-.005
T5: In my neighbourhood, there are frequent conflicts between cyclists and other road users.	2.46	1.121	.197	.566	.163	-.048	-.141	.037
T4: In my neighbourhood, public space is characterised by parked cars.	3.45	.803	.432	.459	-.078	.085	.203	-.120
N3: In Offenbach, there is a lot of information related to cycling.	1.63	.958	-.169	.003	.796	.049	.154	.157
N1: In Offenbach, there is a lot of advertising for cycling.	1.94	1.095	-.187	.083	.786	.064	.012	.139
N2: In Offenbach, media reports on cycling are mostly positive.	2.06	1.027	.006	-.056	.753	.111	.156	.001
P1: In my neighbourhood, public space has nice areas I like.	1.78	1.044	-.069	-.081	.126	.782	-.007	.126
P2: In my neighbourhood, there is enough greenery and trees.	1.73	1.165	-.221	-.211	.247	.665	-.107	-.047
P3: In my neighbourhood, public space has adequate lighting.	2.42	1.026	.030	-.086	-.085	.578	.286	.122
I5: In Offenbach, bicycles can be taken onto public transport easily.	1.69	1.022	-.116	-.011	.125	-.045	.701	-.024
I1: In Offenbach, cycle paths are usually in good condition.	1.70	1.009	-.292	-.130	.219	.084	.517	.233
I3: In Offenbach, bicycle parking facilities are convenient and safe.	1.46	.952	.057	-.272	.074	.147	.495	.304
N6: In Offenbach, I think bicycle theft happens frequently.	2.65	1.106	.103	.234	-.083	-.179	-.405	.401
T1: In Offenbach, everyone rides a bike – young and old alike.	2.06	1.063	-.131	.019	.119	.090	.116	.778
T2: In my neighbourhood, I see many cyclists.	2.46	.938	-.053	.197	.280	.256	.116	.587
Cronbach's alpha			.659	.755	.692	.556	.485	.594

Principal Component Analysis with varimax rotation; only factors with eigenvalues ≥ 1 were considered; loadings ≤ 0.4 are shown in grey N = 701; Kaiser–Meyer–Olkin = 0.816; Bartlett's test of Sphericity: $\chi^2 = 3172.624$ df = 210 p = .000; Total variance explained: 55.4%

more likely to pay attention to information about cycling, which could also be the reason for the observed correlation. However, the results of the other regression models, for instance concerning implemented regular use of the bicycle (stage 4), cannot confirm this causality.

Fourthly, high quality public space and greenery in a neighbourhood encourage several cycling attitudes, including the characterisation of the bicycle as being the ideal means of transport and enjoyment when cycling in Offenbach. These results correspond to several previous studies that highlight the stimulating effect of aesthetic environments on cycling (Kerr et al., 2016; van Dyck et al., 2012; Wahlgren and Schantz, 2012). From a psychological perspective, an appealing design of public spaces positively affects individual well-being (Flade, 2008; Rapoport, 1990; Stamps, 2011). In particular, greenery is considered as being associated with feelings of pleasure and reduction of stress and anxiety (Gubbels et al., 2016; Smardon, 1988; White and Gatersleben, 2011). Furthermore, the findings are in line with the analyses of Weber Corseuil et al. (2012), which indicate that perceived street lighting in a resident's own neighbourhood encourages cycling and walking. The authors suggest that the perception of adequate illumination of the public space contributes to a feeling of safety.

Fifthly, the perception of safe and appropriate cycling infrastructure reveals a strong impact on cycling behaviour and attitudes. Notably, this factor positively affects the transition to the SSBC stage of preaction (stage 2) indicating at least the preparedness for frequent bicycle use involving perceived behavioural control over cycling. This is also apparent from the resulting associations with cycling attitudes suggesting that perceived safe and appropriate infrastructures favour the feelings of safety and comfort when riding a bike as well as the ability to reach all relevant everyday destinations and considering the bicycle as the ideal means of transport. Therefore, the good condition of cycle paths, convenient bicycle parking facilities and the opportunity to take a bicycle onto public transport seem to be important factors for an environment favourable to cyclists. The relevance of perceived adequate infrastructures has also been identified within other studies, primarily emphasising the importance of related safety (Kerr et al., 2016; Titze et al., 2008; van Dyck et al., 2012; Wahlgren and Schantz, 2012). This connection is not surprising, as safety concerns are generally a decisive aspect when choosing a means of transport, especially for certain groups (Pucher and Buehler, 2008). For instance, Gatersleben and Appleton (2007) as well as Engbers and Hendriksen (2010) point out that safe bicycle facilities represent important environmental factors for increasing the willingness to cycle to work regularly. In addition, well-developed and maintained bicycle infrastructures foster fast and easy, thus, efficient cycling.

Finally, perceiving cycling as a common practice is also positively related to bicycle use and several favourable attitudes towards cycling. Similar to the perception of safe and appropriate cycling infrastructure, the preparedness for frequent bicycle use (stage 2) as well as the feeling of safety when riding a bicycle are associated with this factor. This relationship could be explained by a higher sense of security evoked by surrounding cyclists, which increase the visibility for all individuals (Aldred and Jungnickel, 2014). Jacobsen (2015) affirms this suggestion by showing that the likelihood of cyclists colliding with a motorist declines with an increased number of cyclists in a certain area. Furthermore, the perception of cycling as a common practice favours the implementation of frequent bicycle use (stage 4) as well as perceived fun and enjoyment. A reason for this could be the additional motivation and social contacts when encountering like-minded people or covering a distance together. This association can be confirmed by the study of Engbers and Hendriksen (2010), which indicates the opportunity of cycling together as the second most important perceived facilitator for starting to cycle to work – after saving travel time. Moreover, people tend to adopt the behaviour of those around them and of perceived norms in the environment (Willis et al., 2015). Yet, the perception of cycling behaviour within one's immediate environment could also result from one's own cycling behaviour. Dill and Voros (2007) argue that people who cycle regularly may just be more aware of other cyclists around them. This causal relationship could be supported by the correlation of implemented frequent bicycle use (stage 4) and the perception of cycling as a common practice. However, this perceived factor is

Table 7
Binary logistic regression models for the SSBC stages of frequent bicycle use and cycling attitudes (n = 701).

	SSBC stage of frequent bicycle use			Agreement to cycling attitudes							
	at least stage 2 (Preaction[1]/ Action[2]/ Postaction[3])	at least stage 3 (Action[2]/ Postaction[3])	at least stage 4 (Postaction[3])	A1 The bicycle is the ideal means of transport for me.	A2 Riding my bike is fun for me.	A3 When riding a bicycle, I am flexible and free.	A4 I am able to reach all relevant everyday destinations by bicycle.	A5 When riding a bicycle, I feel unsafe.	A6 For me, riding a bike is exhausting and uncomfortable.	A7 I enjoy riding my bicycle in Offenbach.	
	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	Exp(β)	VIF[4]
Perceived dimensions of the local environment											
low political priority for the cycling mode in Offenbach	1.539***	1.899***	1.760***	1.922***	1.594***	1.591***	1.578***	1.221**	0.885	0.965	1.127
vandalism, dirt and high car pressure in my neighbourhood	0.810*	0.767**	0.786**	0.980	0.838*	0.873	1.038	1.175*	1.262*	0.732***	1.056
pro-cycling marketing campaigns in Offenbach	1.075	1.114	1.044	1.138	1.014	0.999	1.103	1.111	1.137	1.260**	1.042
high quality public space and greenery in my neighbourhood	0.978	0.850	0.852	1.222**	1.093	1.164*	1.460***	0.871	1.018	1.417***	1.041
safe and appropriate cycling infrastructure in Offenbach	1.214*	1.035	1.057	1.215**	1.112	1.336***	1.413***	0.681***	0.772**	1.671***	1.027
cycling is a common practice	1.237*	1.172	1.210*	1.170	1.223**	1.138	1.100	0.755***	0.995	1.909***	1.093
General travel attitudes											
preference for safe, pleasant and sustainable travel	1.035	1.092	1.030	1.202*	1.210*	1.343***	1.095	1.343***	0.976	0.979	1.105
travel enjoyment and openness	1.213*	1.258**	1.283**	1.169	1.207*	1.318***	1.139	0.863	1.037	1.268**	1.069
preference for efficient travel	0.581***	0.496***	0.541***	0.501***	0.736***	0.633***	0.690***	1.290***	1.309**	0.770***	1.166
Travel mode availability											
bicycle availability (1 = yes, 0 = no)	27.697***	31.869***	63.427***	13.097***	12.492***	9.637***	4.780***	0.357***	0.116***	30.376***	1.199
car availability (1 = yes, 0 = no)	0.665	0.815	1.124	0.787	1.249	0.451***	0.471***	1.114	0.995	0.798	1.124
Socio-demographics											
female (1 = yes, 0 = no)	0.919	0.937	0.971	0.980	0.576***	0.894	0.783	1.641***	1.054	0.776	1.064
Age	0.990	0.990	0.998	0.989	0.988	0.981**	0.993	0.988	1.019*	1.010	1.913
higher education entrance qualification (1 = yes, 0 = no)	1.376	1.302	1.192	1.437	1.148	1.185	1.211	0.929	1.043	1.094	1.262
employed/ in education (1 = yes, 0 = no)	1.295	1.102	1.210	0.998	1.378	0.989	1.045	0.910	1.032	1.578	1.692
monthly net income	0.917	0.941	0.965	0.988	0.921	1.002	0.879	0.932	1.091	0.960	1.176
migrant background (1 = yes, 0 = no)	1.058	0.769	0.947	1.031	0.966	0.853	0.875	0.852	1.213	1.008	1.117
Constant	0.437	0.224	0.030	0.087	0.404	0.782	0.571	1.463	0.222	0.013	
−2 Log-Likelihood	524.707	589.052	660.737	721.912	687.765	755.133	797.194	754.149	466.918	709.080	
R^2 Nagelkerke	0.473	0.488	0.453	0.364	0.361	0.348	0.271	0.177	0.254	0.352	
Omnibus Test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
N	701	701	701	701	701	701	701	701	701	701	

Each column represents one logistic regression model; odds ratio values' (Exp(β)) significance: * p less than 0.10, ** p less than 0.05, *** p less than 0.01

[1] preparedness for frequent bicycle use

[2] explicit plan for frequent bicycle use

[3] implemented frequent bicycle use

[4] variance inflation factor

also associated with the affiliation to at least stage 2, thus with a stage not necessarily involving frequent cycling.

Altogether, all of the examined perception factors of the local environment contribute, to a greater or lesser extent, to individual cycling. They involve elements addressing either practical concerns, such as cycling infrastructures; aesthetic characteristics, such as the quality of public space and greenery; or symbolic or normative conditions, such as the non-built and traffic environment. Foremost, positive perceptions of safe and appropriate cycling infrastructure and cycling as a common practice as well as the absence of vandalism, dirt and high car pressure suggest an encouragement of cycling indicated by the positive association of these factors with several cycling attitudes and with the assignments to SSBC stages 2, 3 and 4. The reason for this can be seen in the contribution of the above-mentioned factors to a positive evaluation of cycling, in particular related to behavioural control, safety and enjoyment. On the contrary, the negative perception of these aspects prevents openness towards bicycle use and, thus possibly, even the attempt to cycle. A difference in the influence of the perceptions regarding the assignments to stages 2, 3 and 4 is that the perception of appropriate infrastructure seems only to play a role for the transition to the stage of preaction (stage two). Thus, this factor shows no influence as regards the explicit planning and implementation of frequent bicycle use but appears to be important for the assessment of cycling as appropriate travel mode. Although not all of the perceptions encourage the actual use of a bicycle, all of them at least affect individual cycling attitudes and satisfaction when riding a bicycle. Therefore, the results support recent assumptions that local environment conditions might influence certain individual attitudes (de Vos et al., 2020; van Wee et al., 2019).

5.3. *The impact of general travel attitudes, travel mode availability and socio-demographics on cycling behaviour and attitudes*

As suggested in the conceptual framework (Fig. 2), besides the perceptions of the local environment, certain other factors regarding general travel attitudes, travel mode availability and socio-demographic characteristics affect individual cycling behaviour and attitudes. The results show that the preference for safe, pleasant and sustainable travel positively influences the affective cycling-related attitudes of perceived fun, flexibility and freedom as well as the consideration of the bicycle as the ideal means of transport. This is not surprising, since sustainability and pleasure are usually associated with the mode of cycling (Rosen et al., 2016). However, the correlations indicate that respondents attaching importance to safety tend to evaluate cycling as unsafe. The positive impact of travel enjoyment and openness on bicycle use and several cycling attitudes show that the general pleasure of being on the move can be experienced by cycling. For people who, on the contrary, in general do not like to travel, the bicycle seems to be particularly unattractive. The same applies for those respondents who prefer efficient travel. Even if the travel time compared to other means of transport varies depending on the route, cycling seems to be considered as a rather slow and impractical way to travel.

Not surprisingly, the availability of a bicycle contributes to cycling behaviour and positive cycling attitudes. In particular, the implementation of frequent bicycle use requires bicycle access. Furthermore, only the possibility of experiencing cycling seems to result in positive associations. On the contrary, not having this opportunity increases negative cycling attitudes including unsafety and discomfort. The availability of a car only affects two cycling attitudes indicating that for the ability to reach all relevant everyday destinations no car is required, similar to the feeling of flexibility and freedom. The results show that the lack of a car is not decisive for the actual use of a bicycle.

Regarding socio-demographics, gender and age affect some of the cycling attitudes. Firstly, women tend to have less fun and feel rather unsafe when cycling. This result is in line with several previous studies, which argue that especially women have safety concerns in public spaces (Dalton, 2010; Heesch et al., 2012; Schintler et al., 2000). Secondly, significantly older respondents characterise cycling as being exhausting and uncomfortable. Additionally, they perceive less flexibility and freedom when travelling by bicycle. Both associations can be explained by their decreasing physical condition and level of fitness, which typically occurs with ageing. Therefore, other means of transport become more appropriate for travel. However, electric bicycles could be a suitable alternative.

6. Conclusions

The impact of local environment characteristics on individual travel behaviour has been an important subject of research in the field of mobility for decades. Although relevant studies have provided substantial findings on the encouragement of non-motorised travel (e.g. the "3Ds" concept), research has mostly been restricted to objectively measured elements of the built environment and their related impact on travel mode use. However, on the one hand, several social sciences approaches argue that subjective perceptions of the environment form a relevant basis for individual behaviour. On the other hand, mobility research studies recognise the importance of non-built conditions of the environment. Therefore, the aim of this paper was to investigate whether the perceived local environment affects cycling behaviour, involving built and non-built elements. Additional variables involve general travel attitudes, bicycle and car availability and socio-demographics. The SSBC model of frequent bicycle use was adopted to specify individual behaviour. Furthermore, the impact of the environment on cycling-related attitudes was analysed. The evaluations are based on a written household survey conducted in Offenbach am Main located in the urban Rhine-Main area.

The results indicate that individual perceptions of the local environment in terms of cycling infrastructures, public space quality as well as the non-built and traffic environment interrelate and affect cycling behaviour and attitudes in a number of ways. In particular, perceived safe and appropriate cycling infrastructures, the perception of cycling as a common practice and the perceived absence of vandalism, dirt and high car pressure in a neighbourhood encourage individual cycling. According to the SSBC stages, all of these perceptions positively influence a basic openness towards cycling and individual preparedness for frequent bicycle use. Furthermore, these factors increase perceived safety when cycling. In addition to these perceptions, those related to high quality public space and greenery as well as pro-cycling marketing campaigns, are associated positively with the enjoyment of cycling. Thus, related interventions might contribute to promoting cycling and enhancing cyclists' well-being, but only where the residents perceive such improvements. Therefore, interventions should involve strategies providing information or even the opportunity to experience the changes made, for instance via local events (cf. Forsyth and Oakes, 2015; Ma et al., 2014). In particular, the positive effects of perceived high quality public space and pleasant traffic environments have, so far, been neglected in urban planning processes revealing further potential for improvements (Marquart et al., 2020). In addition to individual perceptions of the local environment, several other factors included in the analyses show an influence on cycling. Foremost, the availability of a bicycle is decisive for frequent bicycle use and positive cycling attitudes. Making bicycles available, for instance via bike rental systems, could therefore serve as an incentive for those who do not own a bicycle. Regarding general travel attitudes, overall travel enjoyment and openness particularly encourage bicycle use and positive cycling attitudes. A preference for efficient travel, however, counteracts cycling. Moreover, female respondents tend to have less fun and to feel less safe while cycling. Also, elderly people tend to feel more exhausted and less flexible when riding a bicycle. As a consequence, individual factors, such as socio-demographics, general travel attitudes and bicycle availability, should always be taken into account when promoting cycling.

The application of the SSBC model of frequent bicycle use allowed a more detailed look at cycling behaviour and related individual

assessments than just investigating the frequency or duration of cycling. However, additional items, for instance concerning precise uses and intentions, such as certain travel destinations and purposes like cycling to the workplace or for recreation, could have strengthened the model and made results more conclusive. Another limitation of this study, but at the same time one of its strengths, can be seen in the inquiry of individual perceptions. The interpretation and assessment of some questionnaire items are very subjective, which on the one hand makes it difficult to compare the analyses with those conducted in other studies and to transfer the results into interventions. For instance, the question about pleasing, nice areas in a neighbourhood might be associated with different specifications depending on the respondent's preferences. On the other hand, this study argues that perceptions per se are the result of individual interpretations based on cognitive capabilities and further individual attributes (Flade, 2008; Golledge and Stimson, 1997; Lynch, 1977; van Acker et al., 2010). The objective environment contributes to that final perception as an initial stimulus. However, more research is needed to show in what way and to what extent different factors, such as individual characteristics, affect subjective perceptions (see conceptual model in section 2.4) and how they interact with the objective conditions (Orstad et al., 2017). Moreover, whether implemented behaviour itself or specific situations influence individual perceptions should be explored further. An interesting approach to this has been applied by Kazemzadeh et al. (2020), who compared cyclists' perceptions mentioned in "in-traffic" interviews on the street with those stated in an online questionnaire. Additionally, new technical methods, such as camera recordings from the cyclist's viewpoint and eye tracking, could provide new information on the perception of local environment stimuli when riding a bicycle (Berger and Dörrzapf, 2018; Liu et al., 2020; Oliver et al., 2013). Moreover, further research on perceptions in other environment settings and the impact of local environment changes due to interventions might contribute to a better understanding of cycling behaviour, attitudes and promotion. In conclusion, the individual perceptions of cyclists should form the basis for planning an appropriate cycling environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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