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Original article

Visual processing of green zones in shared courtyards during renting decisions: An eye-tracking study

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A R T I C L E I N F O

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A B S T R A C T

We used an eye-tracking technique to investigate the effect of green zones and car ownership on the attractiveness of the courtyards of multistorey apartment buildings. Two interest groups—20 people who owned a car and 20 people who did not a car—observed 36 images of courtyards. Images were digitally modified to manipulate the spatial arrangement of key courtyard elements: green zones, parking lots, and children's playgrounds. The participants were asked to rate the attractiveness of courtyards during hypothetical renting decisions. Overall, we investigated whether visual exploration and appraisal of courtyards differed between people who owned a car and those who did not.

The participants in both interest groups gazed longer at perceptually salient playgrounds and parking lots than at greenery. We also observed that participants gazed significantly longer at the greenery in courtyards rated as most attractive than those rated as least attractive. They gazed significantly longer at parking lots in courtyards rated as least attractive than those rated as most attractive. Using regression analysis, we further investigated the relationship between gaze fixations on courtyard elements and the attractiveness ratings of courtyards. The model confirmed a significant positive relationship between the number and duration of fixations on greenery and the attractiveness estimates of courtyards, while the model showed an opposite relationship for the duration of fixations on parking lots. Interestingly, the positive association between fixations on greenery and the attractiveness of courtyards was significantly stronger for participants who owned cars than for those who did not. These findings confirmed that the more people pay attention to green areas, the more positively they evaluate urban areas. The results also indicate that urban greenery may differentially affect the preferences of interest groups.

1. Introduction

For thousands of years, courtyards have been a key element of houses in many parts of the world. People garden, cook, work, play, and even sleep in their courtyards ("Courtyard Housing: Past, Present, and Future, " 2005). Nowadays, in large agglomerations, such as Shanghai or Mumbai, a large number of people live in multistorey residential buildings and share relatively large courtyards. Importantly, people not only consistently report a strong preference for green neighborhoods, but the mere presence of trees nearby also increases house prices (e.g., Saphores and Li, 2012). Nevertheless, in developing countries, there are plenty of large courtyards dominated by parking lots. To explore the role of parking lots and greenery on tenants' appraisal of courtyards, we used an eye-tracking technique to investigate the effect of green zones and parking spots on the perceived attractiveness of large courtyards during renting decisions.

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An online survey (n = 4956) in four Dutch cities showed that trees strongly influenced residents' preferences (Van Dongen and Timmermans, 2019). Many studies have clearly demonstrated that people are ready to pay more for a property with trees or if the property is located close to urban parks (Anderson and Cordell, 1988; Pandit et al., 2014). Conservative estimates suggest that trees may add 5% to the average value of a single-family residence (Anderson and Cordell, 1988). Thus, trees make adjacent properties more valuable financially. Since free urban space is limited, urban greenery competes with other uses of urban space. For example, residents require a substantial number of free parking spots; the availability of on-street parking attracts car owners (Guo, 2013), whereas pedestrians prefer streets with fewer parked cars (Isaacs, 2000). Further, a large number of parked cars make the street look child-unfriendly and unsafe (Mullan, 2003), as a high number of parked cars is dangerous for children (Jacobsen et al., 2000). A recent study used photographs of street scenes where the number of parked cars and street trees was digitally manipulated (Staats and Swain, 2020) and demonstrated that both the neighborhoods and the residences were less attractive when the street was overcrowded by parked cars. Moreover, the participants' estimated prices for residences on a green street and ratings for neighborhood attractiveness were higher. Here, we further study how people who own a car and those who do not own a car perceive the green elements of courtyards during hypothetical rental decisions.

Previous studies have shown that access to green spaces produces various health benefits (WHO, 2017). For example, greenery may improve air quality, enhance physical activity and social interactions, and reduce stress (Hartig et al., 2014). Importantly, nature provides profound mental health (Hartig and Mang, 1991) and cognitive benefits (e.g. Kaplan and Kaplan, 1989). A typical courtyard of a residential building may have multiple and often competing functions: it provides entrances to the building and parking spots; contains children's playgrounds, sport facilities, and recreational zones; provides a special bin area and space for pets and their owners; and provides a green space with trees, flowers, and bushes. Some countries traditionally regulate the structure of courtyards (Knuth, 2005). Nevertheless, residents of newly built districts often complain about the quality of their courtyards (e.g. Becker et al., 2012) and demand more green spaces. However, urban green spaces exist in connection with other urban elements, but not in isolation.

In the current study, we used eye tracking to investigate how people perceive the key elements of the courtyard of a multistorey residential building: (a) green zones, (b) parking lots, and (c) children's playgrounds, which are present in all local courtyards. Eye tracking has been successfully used in urban and natural environment studies (Berns et al., 2005; Berto et al., 2008; De Lucio et al., 1996; Dupont et al., 2014, 2015, 2017; Li et al., 2020; Nordh et al., 2013; Staats and Swain, 2020). The use of the eye-tracking technique allows for monitoring gaze location, specifically tracking where, when, and what people are looking at. With this method, we could monitor the number and duration of fixations—periods of time during which an area of the visual stimulus is gazed upon. Thus, eye tracking could offer insights into which specific parts of a courtyard attract attention during the renting decision. In the current study, we analyzed whether people who did not own a car visually processed courtyards differently from those who owned a car (Hypothesis I). We also investigated whether the observation patterns of these two interest groups were associated with different appraisals of courtyards (Hypothesis II).

To check our hypotheses, two interest groups (people who owned a car vs. people who did not own a car) were asked to observe images representing different courtyards of multistorey residential buildings. The presence and positions of green zones, parking lots, and children's playgrounds systematically varied across the images. The participants were instructed to make hypothetical renting decisions and indicate the attractiveness of each courtyard. During the experiment, the eye movements of the participants observing courtyards were continuously recorded, and gaze patterns were then analyzed. First, we compared the number and duration of fixations on three regions of interest (green zones, parking lots, and children's playgrounds) between people who owned cars and people who did not. Second, we used a regression model to investigate the relationship between fixations on three regions of interest and the attractiveness of courtyards in both interest groups. Overall, this approach allowed us to investigate the processing of urban greenery and other key urban elements by different interest groups.

2. Methods

2.1. Participants

To attract people with diverse socioeconomic backgrounds, a sample of 40 participants (average age = 29.6 ± 3.7 years, 20 females) was recruited via social media and online advertisements (see Staats and Swain, 2020, for the same approach). All participants had previous real renting experience. The participants were required to fill out a pre-screening questionnaire and confirm that they had normal vision. None of the participants reported having any visual problems, which ensured that they did not suffer from visual disorders that might affect eye-tracking recordings.

Since various studies have shown that younger households are more likely to rent privately (Mah, 2014; McKee et al., 2020) the age of the sample was restricted to 18–35 years. Since the study investigated the effect of car ownership on the visual processing of courtyards, we recruited 20 participants who did not own a car (*NoC-interest group*; average age = 28.25 ± 3.26 years, 10 females) and 20 other participants who owned a car (*C-interest group*; average age = 28.8 ± 4.1 years, 10 females). This allowed us to compare the gaze patterns and preferences of the two interest groups. Using various statistical analyses, we contrasted the eye tracking and behavioral patterns of people who owned a car (*C-interest group*) and those of people who did not own a car (*NoC-interest group*).

An additional sample of 12 participants (average age = 29.1 ± 4.1 years, 6 females) with normal vision was recruited as a *control group* for a manipulation check. The participants in the *control group* did not receive a specific task, but they were exposed to the same experimental stimuli. We expected that participants in the *control group* and two experimental interest groups (*C-interest group* and N*C-interest group*) would show significantly different gaze patterns, indicating that the experimental groups indeed followed the instruction to make hypothetical renting decisions. The study protocol was approved by the local ethical committee, and informed consent was obtained from all participants before the start of the experiment.

To avoid additional confounders (age, socioeconomic status, etc.), we invited participants with no children. Households with children tend to own homes (Kurz, 2004). Since our study focused on renting decisions, we invited people without children who were more interested in renting than people with children. Further, tenants with children who rent privately are more likely to be older and have a lower socioeconomic status than other tenants (Bailey, 2020). Therefore, to better control for the socioeconomic status and motivation of the participants, we excluded people with children from the current study.

2.2. Stimuli

In total, 36 color images representing nine versions of a multistorey apartment building's courtyard were used as stimuli (for details, see Supplementary Table 1). The images were created using 3 ds Max software (Autodesk 3 ds Max) to control for low-level physical features and the sizes of the key elements of courtyards. The 24 *experimental* pictures depicted three regions of interest (ROIs) of equal sizes: children's *playground*, *parking slot,* and *greenery* (see Fig. 1 for a representative example of the stimuli). The remaining small fractions of the courtyards (outside the main ROIs) were arranged into an additional ROI—the *area of no*

Table 1
The effect of the number of fixations (FT) at greenery, playgrounds, and parking lots on attractiveness ratings. Results of the generalized linear mixed-effects model.

ROI	Estimate	Std. Error	Z- value	Significance
Greenery	0.13	0.02	7.62	p <.0001***
Parking lots	−0.02	0.02	−0.95	p = .34
Playground	0.05	0.02	3.81	p <.005**
AIC = 1190.1; BIC = 1214.4				
Greenery × *Group*	0.02	0.04	0.50	p = .62
Parking lots × *Group*	0.03	0.03	0.8	p = .41
Playground × *Group*	−0.04	0.03	−1.3	p = .20
AIC = 1164.5; BIC = 1208.3				

Note: here and below * p <.05; ** p <.05; *** p < .001.

interest. Twelve *control* pictures depicted only the two ROIs and were used to determine the participants' preferences for the ROIs. The position of the ROIs in the picture was counterbalanced such that each ROI was equally likely to be presented on the left or right side of the courtyard in the foreground or the background of the image (for details, see Supplementary Table 1). The size of all pictures was 3840 × 2000 pixels. Cars and playgrounds varied across pictures. To control for the systematic spatial asymmetry of the images, half of the stimuli represented the mirror versions of the other half of the stimuli. Rendered images were used as stimuli to control for the physical characteristics of the stimuli and to avoid unnecessary confounding factors. Taking participants to the real environment creates many limitations for controlling the basic settings of the experiment, including the sizes and positions of the ROIs. Various studies have demonstrated that photographs are valid surrogates for real landscapes (Coeterier, 1983; Palmer and Hoffman, 2001). Thus, we could assume that our eye-tracking results are fundamentally similar to the tracking results obtained in the real world. Each stimulus was administered only once and in counterbalanced order to all participants. The average duration of the intertrial interval across all trials was 4,000 milliseconds.

2.3. Eye-tracking apparatus

The eye-tracking data were collected using a nonportable desktop eye tracker (EyeLink 1000 Plus, SR Research). The eye-tracking method is based on detecting infrared light reflected by the eyes of the observer and signaling the x- and y-coordinates of the observer's center of the eye (pupil) position. Thus, this type of eye tracking allowed continuous registration of the participants' fixation points while they observed the images of courtyards.

The experiment was programmed using SR Research Experiment Builder v1.6.121 software (SR Research Ltd., Ottawa, ON, Canada). Eye movements were recorded from the right eye only with a 1000 Hz sampling rate. Stimuli were delivered by the eye tracker PC to a 17-inch display with a refresh rate of 60 Hz. The participants were seated 60 cm away from the monitor, with their head position controlled by a chinrest.

We used standard (velocity- and acceleration-based) methods to segment the gaze trajectories into a sequence of fixations and saccades. If the velocity or acceleration exceeded a certain threshold, the eye movements were marked as saccades. All fixations outside the range of 50–600 milliseconds were removed as outliers. Thus, less than 5% of the data were deleted.

For each interest group, we calculated the following eye movement measures:

1 Fixation time (FT) – the total time of all gaze fixations for a specific ROI
2 Fixation count (FC) – the total number of gaze fixations on a specific ROI

2.4. Procedure

Before the experiment, all participants provided their demographic information and signed consent forms. After reading the experimental instructions, the eye tracker calibration procedure began (standard 9-

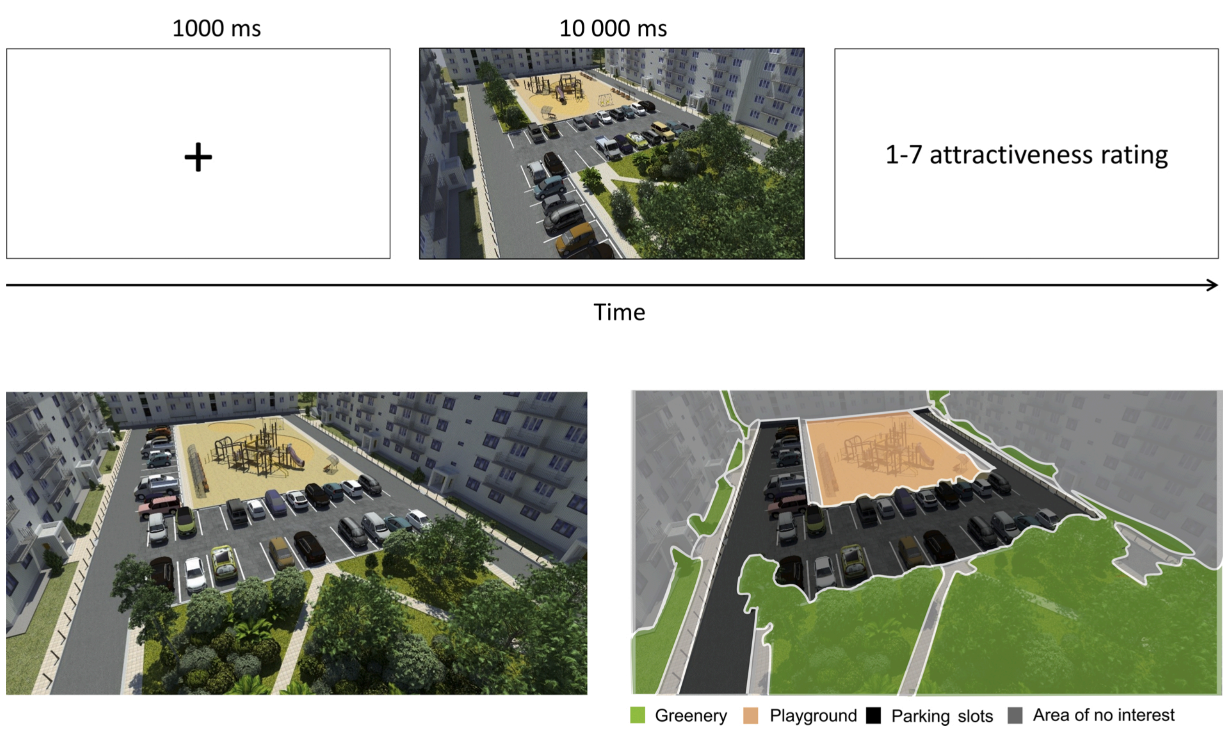


Fig. 1. (Upper part) Trial structure. Each trial began with a fixation cross, followed by an image of the courtyard (courtyard #0). At the end of the trial, the participants provided self-paced attractiveness ratings of the courtyard using a 7-point Likert scale. (Lower part) Classification of courtyards elements/ROIs (courtyard #10).

point calibration, average calibration error below 0.5 °). Upon completion of the calibration session, the participants received instructions for the main part of the experiment. The participants were told that in every trial, they would be exposed to an image of a courtyard; the view would be from the window of a hypothetical apartment that they were planning to rent. In each trial, they had to rate the attractiveness of the courtyard while assuming that other characteristics of the apartment were satisfactory.

Each trial had the following structure: it began with a fixation cross presented for 1,000 milliseconds, followed by a stimulus presented for 10,000 milliseconds (during which eye-tracking data were collected). At the end of the trial, the *attractiveness of the courtyard* was measured. For this, the participants were asked to provide attractiveness ratings of the courtyard using a 7-point Likert scale in a self-paced manner with the anchors "very unattractive" and "very attractive" (see Fig. 1, upper part).

The eye-tracking session lasted approximately 13 min. Presumably, the experiments evoked no fatigue, which was confirmed by the participants during the debriefing session. To avoid a demand effect—experimenter-induced expectations that may influence participants' behavior—the participants reported their personal preferences for the three courtyard areas (children's playground, parking lot, and greenery) at the end of the experiment: "For me, the presence of a parking slot in my courtyard is important/not important/I don't know"; "For me, the presence of a green area in my courtyard is important/not important/I don't know"; "For me, the presence of a children playground in my courtyard is important/not important/I don't know". The participants were also asked to fill in another sociometric questionnaire, which was not used in the current study, except for two questions, which additionally verified car ownership and the number of children in the family.

The participants in the *control group* observed the same experimental stimuli but with no specific task. They also completed the same questionnaires on courtyard preferences and sociometrics.

2.5. Data analysis

2.5.1. Analysis of variance (ANOVA)

We used ANOVA to compare eye movements (fixation time, fixation count) across four elements of courtyards: playground, parking slot, greenery, and area of no interest. To compare eye movements in the two interest groups, we used a two-way ANOVA with the factors *ROIs* (playground, parking slot, greenery, area of no interest) and *Group* (C-interest group vs. NoC-interest group). Eye-tracking data for the four most attractive and the four least attractive courtyards were compared using a two-way ANOVA with the factors *Group* and *Attractiveness* (most attractive courtyards vs. least attractive courtyards). See Supplementary materials for details of the ANOVA results.

2.5.2. Nonparametric ANOVA-type statistics

Due to a mild violation of the assumptions for ANOVA in eye tracking data and attractiveness ratings (see Supplementary materials), we reanalyzed the data using the *nparLD* package, which provides robust, rank-based nonparametric ANOVA-type statistics (Noguchi et al., 2012). The nonparametric analysis was also replicated with the standard parametric ANOVA (for details, see Supplementary materials) and showed very similar results compared with the nonparametric statistics.

2.5.3. A regression analysis (with random effects)

To study the relationship between gaze fixations and the attractiveness of courtyards in depth, we used regression analysis, which is a standard method for identifying variables that have a significant impact on the dependent variable. The generalized linear mixed-effects model was performed using R software (R Development Core Team, 2011) with the software package *lme4* (Bates et al., 2015) and *lmertest* on the following dependent variable: the attractiveness of the courtyard. Thus, our analysis investigated the relationships between the total number/duration of fixations (FC, FD) at different ROIs (independent variables) and the attractiveness ratings of the courtyards (dependent variable), taking into account random effects at the subject level. We also investigated the relationships between car ownership (C-interest group vs. NoC-interest group) and the attractiveness of courtyards.

Each regression model was estimated separately for each eye-tracking metric (fixation time and count). The model included three categorical predictors: fixations (fixation time or count) on (1) the children's playground, (2) parking spots, and (3) greenery. To account for possible group differences, the NoC-interest group (participants without a car) was used as a reference group for each effect associated with fixations at different ROIs. The models were compared based on the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). We also tested the regression variables for multicollinearity using variance inflation factors (VIF). Multicollinearity indicates that the independent variables in a regression model are correlated, which creates a problem because the independent variables are not really independent. Usually, VIFs greater than five indicate critical levels of multicollinearity. In the current study, all VIFs were below five, suggesting that the correlation was moderate; hence, the results were not questionable.

3. Results

First, we compared the preferences of the two interest groups. As expected, the perceived level of importance regarding parking lots in the courtyards differed among participants who did not own a car (the NoC-interest group) and those who owned a car (the C-interest group): 5% of the NoC-interest group versus 65 % of the C-interest group stated the importance of the parking lots in their courtyards (Pearson chi-square statistic, $\chi 2 = 15.82$, and $p = 0.0001$). However, both groups indicated a similar importance of the greenery in courtyards: 100 % of the NoC-interest group versus 95 % of the C-interest group stated the importance of the green area in their courtyards (Pearson chi-square statistics, $\chi 2 = 1.02$, and $p = 1$).

Next, we used control stimuli to assess whether both interest groups showed a stronger preference for courtyards with greenery than for courtyards without greenery. We compared the attractiveness ratings of the control pictures that included only greenery and playgrounds (M = 5.55, SD = 1.19) with the attractiveness ratings of the control pictures that included only parking spots and playgrounds (M = 2.13, SD = 0.97). Participants in both interest groups preferred courtyards with greenery to courtyards without greenery. Nonparametric ANOVA-type statistics indicated that the participants strongly preferred courtyards with greenery to courtyards without greenery: the main factor *Greenery* ($F(1, 80) = 230.665$, $p < 0.0001$). We found no significant effect of the factor *Group* ($F(1, 80) = 0.014$, $p = 0.9$) and no significant interaction between *Greenery* and *Group* ($F(1, 80) = 0.8$, $p = 0.37$).

A further analysis of the control pictures showed that the participants rated courtyards with parking lots as significantly less attractive than courtyards without parking lots (main factor *Parking*, $F(1,80) = 175.47$, $p < 0.0001$). Interestingly, we found a significant interaction between *Parking* × *Group* ($F(1,80) = 6.223$, $p < 0.05$): the participants who owned a car rated courtyards with parking lots less negatively than the participants who did not own a car.

4. Eye-tracking results aggregated across interest groups

We subjected two indicators related to gaze (fixation count and duration) for 24 experimental pictures that depicted playground, parking lot, and greenery to further statistical analysis.

Number of fixations at greenery, playgrounds, and parking lots. Across both interest groups, the participants made 218.15 (*SD* = 44.9), 245.85 (*SD* = 54.8), and 244.38 (*SD* = 61.6) gaze fixation s (FC) on greenery, playgrounds, and parking lots, respectively. Since the areas of no interest (NI ROI) attracted a very small number of fixations (M = 1.9, *SD* = 1.38), we did not report further descriptive or statistical results for this area of courtyards. Nonparametric ANOVA-type statistics indicated that participants made more gaze fixations on playgrounds and parking lots than on greenery: main factor *ROIs* ($F(3, 120) = 4.371$, $p = 0.012$) (for details, see Fig. 2).

4.0.1. Fixation duration at greenery, playgrounds, and parking lots

We found a statistically significant difference in gaze duration (FTs) among the greenery, playgrounds, and parking lots: main factor *ROIs* ($F(3, 120) = 4.47$, $p = 0.011$) (for details, see Fig. 2). Overall, the participants gazed longer at playgrounds (M = 62665, *SD* = 11155, $p = 0.012$) and parking lots (M = 62052, SD = 12920, $p = 0.023$) than at greenery (M = 55010, *SD* = 11144).

4.0.2. Control group

In the control group, in which participants received no specific task, we found no difference in the number of gaze fixations ($F(3,36) = 1.12$, $p = 0.339$) and for the gaze duration ($F(3,36) = 1.30$, $p = 0.287$) between greenery, playgrounds, and parking lots.

4.1. Between-group comparison of eye-tracking results

4.1.1. All interest groups versus control group: manipulation check

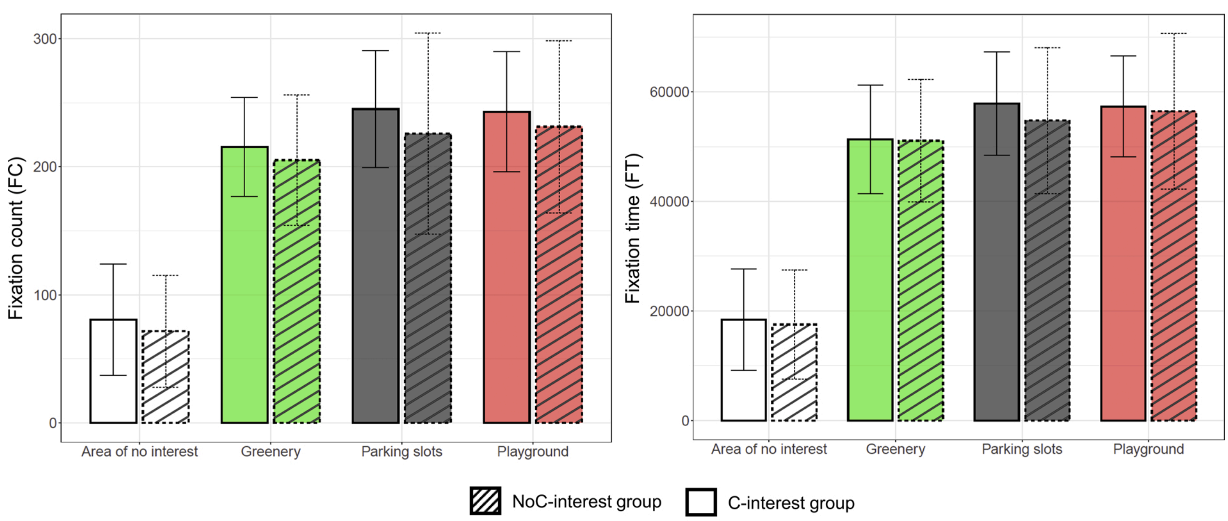
To verify the effect of the instruction, we compared the eye-tracking data of the two (experimental) interest groups that performed hypothetical renting decisions with those of the control group that did not receive a specific task. Two-way nonparametric ANOVA-type statistics showed a significant difference between both interest groups and the control group regarding the gaze duration (FT: factor *Group*, $F(3, 160) = 6.39$, $p < 0.05$) and number of gaze fixations (factor *Group*, $F(3, 160) = 5.34$, $p = 0.02$). The participants in both interest groups gazed longer at parking lots (M = 62052, SD = 12920) than those in the control group (M = 50202, SD = 11863). The participants in the control group gazed longer at ROIs of no interest (M = 35354, SD = 20056) than those in the interest groups (M = 18713, SD = 9535). Moreover, the participants in the control group (M = 155, *SD* = 103) had more gaze fixations on ROIs of no interest than those in the interest groups (M = 79, *SD* = 44). Thus, as initially hypothesized, the participants in the experimental and control groups used different visual strategies during the processing of the courtyards.

4.1.2. NoC-interest group versus C-interest group

We tested Hypothesis 1 and found no significant difference between the NoC- and C-interest groups both for the gaze duration (factor *Group*, $F(3, 120) = 0.468$, $p = 0.50$; *ROIs* × *Group*, $F(6, 120) = 0.174$, $p = 0.84$) and the number of gaze fixations (factor *Group*, $F(3, 120) = 0.838$, $p = 0.36$; *ROIs* × *Group*, $F(6, 120) = 1.518$, $p = 0.47$). Therefore, there was no significant difference between the visual processing of courtyards by people who owned cars and by people who did not, which disconfirmed Hypothesis 1.

4.1.3. Results for the least attractive and most attractive courtyards

Two-way nonparametric ANOVA-type statistics (factors *Courtyard*



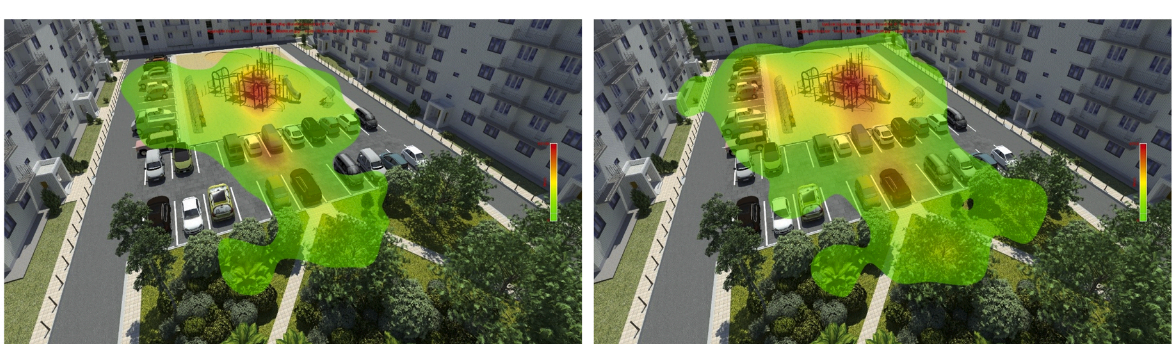


Fig. 2. Aggregated eye-tracking results. (Upper part) The total number of fixations (FC) and fixation duration (FD) for the four ROIs. The error bars represent the standard deviation of the eye-tracking data.
(Lower part) Representative heatmaps for the NoC-interest group (left) and the C-interest group (right) illustrate the location and duration, FD, (from low in green to high in red) of the fixations when the subjects made renting decisions (courtyard #10).

and *Group*) revealed that participants differently rated 24 courtyards: factor *Courtyard* ($F(24, 960) = 5.63$, $p < 00001$). Therefore, we selected the four most attractive (Set 1) and four least attractive courtyards (Set 2). Set 1 included four courtyards (courtyards #21, #22, #23, and #24; see Supplementary Table 1) that were ranked the highest by both interest groups (M = 4.6, SD = 1.25), while Set 2 included four courtyards (courtyards #10, #11, #18, and #19) that were ranked the lowest by both interest groups (M = 3.55, SD = 1.32).

Participants gazed longer and made more gaze fixations on greenery when they observed the most attractive courtyards (Set 1) than when they observed the least attractive courtyards (Set 2). Across both interest groups, we observed more gaze fixations (FC) on greenery in the most attractive courtyards (Set 1, M = 46.95, SD = 10.18) than for the least attractive courtyards (Set 2, M = 31.3, SD = 11.1, $p < 0.05$). Similarly, gaze duration (FT) was longer for greenery in the most attractive courtyards (Set 1, M = 11683, SD = 3672) than in the least attractive courtyards (Set 2, M = 7919, SD = 3007, $p < 0.05$).

On the contrary, participants gazed longer and made more gaze fixations on parking lots when they observed the least attractive courtyards (Set 2) compared to the most attractive courtyards (Set 1). For the least attractive courtyards (Set 2, M = 49.475, SD = 10.5), we observed significantly more gaze fixations (FC) on parking lots than for the most attractive courtyards (Set 1, M = 30.6, SD = 14.0), $p < 0.05$. Similarly, the gaze duration on parking lots for the least attractive courtyards in Set 2 (M = 12842, SD = 4124) was significantly longer than the gaze duration on parking lots for the most attractive ones in Set 1 (M = 7863, SD = 3017, $p < 0.05$). Overall, the most attractive courtyards triggered more attention to greenery, whereas the least attractive courtyards triggered more attention to parking lots.

4.1.4. Regression analysis–the effects of the faze fixations on attractiveness of courtyards

We used a generalized linear mixed-effects model to study the relationship between the fixations and attractiveness of courtyards in more detail. The results are reported in Tables 1 and 2.

The regression model confirmed that the more the participants' gazes were fixated on greenery, the more attractive the courtyards were rated (Table 1). Across both interest groups, we found a significant positive relationship between the number of gaze fixations (FC) on greenery and the attractiveness of courtyards: estimate = 0.13, $p < 0.0001$. We also observed a similar but weaker positive relationship between the number of gaze fixations on playgrounds and the attractiveness of courtyards: estimate = 0.05, $p < 0.005$. Next, we extended the analysis by adding the factor *Group* into the model and found no significant interaction between the predictor *Group* and the number of gaze fixations for all elements of courtyards. Thus, in both interest groups, the more the participants fixated on greenery or playgrounds, the more they perceived the courtyards as attractive.

We analyzed the relationship between gaze duration and the attractiveness of courtyards. The preliminary analysis of the gaze duration showed a high correlation between gaze duration at playgrounds and gaze duration at greenery and parking lots ($r = 0.71$ and $r = 0.69$, respectively). Therefore, we excluded the fixation time (FT) data for playgrounds from the main regression model. Across both interest groups, we found a substantial and significant positive relationship between the gaze duration at greenery and the attractiveness of the courtyards (estimate = 0.3, $p < 0.0001$, Table 2). We also observed a significant opposite relationship between the gaze duration at parking lots and the attractiveness of the courtyards: estimate = -0.31, $p < 0.0001$. Thus, across both interest groups, the longer the participants fixated on greenery, the more they liked the courtyard, while the opposite behavioral pattern was observed for parking lots. We also estimated the effect of gaze duration at playgrounds on the attractiveness of courtyards and found no significant effect (estimate = -0.08, $p = 0.23$, Table 2).

Finally, we found that the participants who owned a car showed a stronger positive association between the duration of the gaze on greenery and the attractiveness of the courtyards than the participants who did not. For the fixation duration, adding the factor *Group* to the models (Table 2) revealed a significant *Greenery* × *Group* interaction (estimate = 0.33, $p < 0.05$) and a trend for *Parking lots* × *Group* interaction (estimate = 0.33, $p = 0.05$).

Table 2
The effect of the duration of fixations (FD) at greenery, playgrounds, and parking lots on attractiveness ratings. Results of the generalized linear mixed-effects model.

ROI	Estimate	Std. Error	Z- value	Significance
Greenery	0.3	0.07	4.06	$p < .0001$***
Parking lots	−0.31	0.08	−4.2	$p < .0001$***
AIC = 1215.6; BIC = 1235.1				
Greenery × *Group*	0.33	0.15	2.02	$p = .03$*
Parking lots × *Group*	0.33	0.17	1.94	$p = .05$
AIC = 1181.6; BIC = 1215.7				
Playground	−0.08	0.07	−1.21	$p = 0.23$
AIC = 1265.2; BIC = 1279.8				
Playground × *Group*	−0.23	0.14	−1.64	$p = 0.10$
AIC = 1238.6; BIC = 1262.9				

Note: Due to a high correlation of the fixation time (FT) for playgrounds with fixation time for greenery and parking lots, separate models were conducted for the effects of fixation time on playgrounds and for the effects fixation time on greenery and parking lots on attractiveness of courtyards (for details, see the results section).

5. Discussion

5.1. Interpretation of the results

We investigated the visual processing of green zones in the courtyards of modern multistorey residential buildings. We focused on the differential visual processing of the key courtyards' zones, specifically, playgrounds, parking spots, and greenery. Overall, during imaginary rental decisions, the participants gazed longer at playgrounds and parking lots than at greenery. Importantly, both bright, colorful cars and outdoor playground equipment were visually salient. In general, people's attention is driven either intentionally in a (top-down) goal-related manner or unintentionally in a stimulus-driven manner (e.g., Egeth and Yantis, 1997). Perceptually salient items, including urban objects (Dupont et al., 2015, 2017; García et al., 2006), may drive attention in a bottom-up fashion in the absence of an intention to look somewhere or even against current intentions and goals (e.g., Wolfe, 1994). Thus, visually salient cars and playgrounds may automatically attract the stronger attention of residents and potential tenants. Our results suggest that playgrounds and occupied parking spots might guide visual attention in shared courtyards distracting attention from green zones.

We also examined the relationship between the participants' gaze fixations and their ratings of attractiveness for different courtyards. We compared eye movements during the observation of the most attractive and least attractive courtyards. Across both interest groups, the participants demonstrated more gaze fixations and longer gazes on greenery during the observation of the most attractive courtyards than during the observation of the least attractive courtyards. Importantly, during the observation of the least attractive courtyards, the participants paid more attention (more fixation count and longer fixation time) to parking spots compared to the most attractive courtyards. Thus, our results support the view that greenery strongly shapes people's preferences for urban environments (e.g., Li et al., 2020; Staats and Swain, 2020). Our findings were further supported by the regression analysis, which demonstrated a significant positive relationship between the time or count of fixations on greenery and the perceived attractiveness of the courtyard. Even though the opposite was true for the fixation time on parking spots, here, the longer the participants fixated on the parking lot, the less attractive the courtyard was.

Our results are consistent with those of previous studies that showed vegetation was evaluated positively, whereas cars and parking spots were evaluated negatively (e.g., Wang et al., 2019; Wherrett, 2000). Various studies have shown that green urban environments bring vital health, social, and economic benefits (for a review, see Hunter and Luck, 2015), particularly health benefits (McCormack et al., 2010) and mental restoration (Nordh et al., 2009). Recent reviews have clearly demonstrated that complex factors underlie such benefits, including perceptions of aesthetic attractiveness and safety (Kabisch et al., 2015; McCormack et al., 2010). Trees lining the street not only increase preferences for streetscapes (Stamps, 1997) but also increase participants' house price estimations (Staats and Swain, 2020). Green large-scale courtyards are particularly important in densely populated metropolitan areas, where city dwellers' experiences of nature are becoming rare (Cox et al., 2017). People often have an opportunity to experience urban greenery only during daily activities in the streets and courtyards. Our results suggest not only that salient urban elements, such as playgrounds and cars, can destruct people's attention from green zones but also shows that parking lots devaluate the attractiveness of the urban environment.

Our results are in line with previous findings showing that people who pay more attention to trees than to other urban elements evaluate an urban environment more positively (Li et al., 2020). Contrary to other studies, we investigated the allocation of gaze during hypothetical renting decisions. It has been previously shown that the allocation of gaze plays a significant role during choices: a longer gaze directed at one option is often associated with stronger preferences for that option (e.g., Shimojo et al., 2003). However, it is also noteworthy that people tend to look longer at the items that are chosen (Orquin and Mueller Loose, 2013). In a seminal eye-tracking study, Shimojo et al. (2003) demonstrated such "gaze bias" and suggested the gaze cascade model, in which eye movements may create a loop: exposure to an object increases preference, and preference increases the likelihood of looking at this object, in turn increasing exposure. Such a "gaze bias" was also demonstrated for faces and natural scenes (e.g., Mitsuda and Glaholt, 2014). Thus, in our study, a longer look at greenery could boost participants' attractiveness ratings for courtyards compared with the other trials when participants focused more on playgrounds or parking spots. Alternatively, attractive courtyards may simply attract more visual attention (more and longer fixation) than less attractive courtyards.

It is also important to consider the motivations of various interest groups during their decisions to reside in a particular urban area. Interest groups could have quite different reasons for preferring a green area or one with a large parking space. For example, the results obtained in different cities have shown that visits to green areas are underlined by various motivations, from a motivation "to relax" in Amsterdam (Chiesura, 2004) to striving for "fresh air and beautiful scenery" in Guangzhou (Jim and Chen, 2006). Further, people have quite diverse preferences for green urban area attributes, including their structure, functionality, cleanliness, naturalness, or presence of adequate facilities (e.g. Adinolfi et al., 2014; Giles-Corti et al., 2005; Voigt et al., 2014). Thus, responses to urban green spaces may differ among social, cultural, and other interest groups with different motivations and preferences. In the current study, we compared the gaze patterns of people who owned cars (the *C*-interest group) with those of people who did not own cars (the *NoC*-interest group). Contrary to Hypothesis 1, we found no significant difference between the two interest groups in overall gaze fixations (count and duration). However, we confirmed Hypothesis 2, which suggested that the patterns of fixations of the two interest groups could be associated with different evaluations the courtyards. The regression analysis showed a stronger positive association between fixation duration on greenery and the perceived attractiveness of the courtyards in the *C*-interest group than in the *N*C-group. We also found a trend of a reduced negative association between fixation duration on parking lots and the perceived attractiveness of the courtyards in the *C*-interest group compared with the *NC*-group. Second, an analysis of the 12 control courtyards with two ROIs supported the last finding, showing a strong difference between the interest groups. The negative association between fixation duration in parking spots and preferences for courtyards was significantly stronger for the *NC*-interest group than for the *C*-group; this indicates that the people owning cars responded to parking lots more favorably. Our results may indicate conflicting cognitions in the *C*-interest group. We can speculate that the participants who owned cars reacted to large parking spots less negatively, but, in turn, overvalued greenery in the courtyards compared with the participants who did not own cars.

Eye tracking has been extensively used in studies of differential visual processing by various categories of people. Previous studies have focused on visual and cognitive expertise: landscape experts versus laypeople (Dupont et al., 2015), advanced versus novice drivers (e.g., Mourant and Rockwell, 1972), and professional chess players versus novices (Reingold et al., 2001). We observed no significant differences between the interest groups in overall gaze fixations (count and duration) on greenery, parking spots, or playgrounds. Normally, the between-group profound differences in eye movements are observed for stimuli for which one group of participants is highly trained: chess variants for professional chess players or road signs for professional drivers and landscapes for landscape experts. Courtyards are highly complex visual stimuli that are more or less relevant to most interest groups. To find a difference in the global visual processing of courtyards by car owners compared with other interest groups, a follow-up study should investigate more specific stimuli, such as road signs or road surface marking, which are processed daily mainly by car owners.

Importantly, our results indicate that despite a vast similarity in cognitive processing, the interest groups interpreted urban environments differently. The current study showed that car owners reacted less negatively to salient parking spaces than people who did not own cars. Indeed, car users often demand more parking spots (Shoup, 2006). Particularly in developing countries, the number of vehicles is growing, and the need for parking spots is increasing. For example, India faces dramatic growth of nearly 400 % in its motor vehicle population (Open Government Data (OGD) Platform India, 2018). However, other interest groups have less interest in maximizing the number of parking spots, which can create conflicts between different resident groups. Our results call for further research to reveal the differences in interest groups and how this may affect the evaluation of urban environments.

5.2. Implications for participatory landscape planning and management

Our findings suggest that visually salient playgrounds and cars attract tenants' attention more than greenery. Thus, playgrounds and parking spots in a multistorey building's courtyard may tunnel residents' attention and distract them from customary greenery. Nevertheless, stronger attention to cars and trees affects the evaluation of the urban environment but in opposite directions. It suggests that the introduction of trees in between car spots can lead to a more positive evaluation of the urban area. Importantly, our study confirmed that the longer people looked at green areas, the more positively they evaluated urban areas. Thus, not only the mere presence of greenery at courtyards but also the particular designs of green areas that make greenery more visually salient can effectively influence tenants' decisions and preferences. Our results also show that the effects of parking spots and greenery on tenants' preferences may differ among interest groups. Thus, landscape planners and managers should carefully address the conflicting motivations of various social groups. For example, the negative impacts of cars on courtyards can be largely ignored by car owners. The study also suggests that eye tracking could help to study the visual processing of urban environments by various interest groups.

5.3. Limitations and recommendations for further research

We used 3D renders to control the basic features of green zones, parking lots, and children's playgrounds (size, position, etc.). This allowed us to create ROIs of exactly the same size and to fully counterbalance their spatial positions. However, object recognition is often enhanced with respect to real objects relative to pictures, a phenomenon called the real-object advantage (e.g., Chainay and Humpreys, 2001). Therefore, further studies should investigate the differences between the processing of real urban environments and images. Nevertheless, given that our results are very much in line with previous results (e.g., Li et al., 2020), it seems unlikely that the artificiality of the 3D renders significantly reduced the ecological validity of the study.

In the current study, the participants observed images of courtyards for 10,000 milliseconds. Several studies have demonstrated that the scenes can be accurately processed in a few hundred milliseconds (e.g. Biederman et al., 1983). Thus, future studies should investigate the effect of stimulus duration on courtyard assessment. Further, the extension of our results to other interest groups and cultures should be made with caution.

A follow-up study could replicate our experiment by including more detailed questions on car usage behavior and car ownership. Such a study might also use real photos of courtyards to investigate real renting decisions. In addition to attractiveness of courtyards, future studies should also investigate the relationship between fixations on the courtyard and prices that tenants are ready to pay (for a similar approach, see Li et al., 2020). Further studies should be carried out to determine whether other interest groups (parents, elderly, etc.) show different patterns of eye movements and preferences during renting decisions. Follow-up studies should also recruit participants with children, since a person with a child or children may pay more attention to the safety of the courtyards and to children's playgrounds than participants of the current study.

In the current study, participants were recruited via social media, which is increasingly used, given its ability to reach diverse audiences. The potential biases and differences in participants due to the recruitment source are still not well understood. Therefore, in future studies, the effects of offline or online recruitment on participant characteristics should be addressed. Finally, the attractiveness of courtyards could be heavily affected by residential identification in renting an apartment. Thus, further studies might set residential identification as the inclusion criterion.

6. Conclusions

In the current study, both interest groups indicated the importance of the presence of greenery in the courtyards of multistorey residential buildings. The participants who owned a car indicated a significantly higher importance of parking spots in courtyards than the participants who did not own cars. The participants in both interest groups rated courtyards with greenery as significantly more attractive than courtyards without greenery. Although courtyards with parking spots were rated as less attractive than those without parking spots, car ownership significantly attenuated the negative effects of parking spots.

Our eye-tracking results indicate that playgrounds and parking spots capture visual attention in large shared courtyards. During hypothetical renting decisions, the participants fixated more on visually salient playgrounds and parking spots than on greenery. We found no difference between the participants who owned a car and those who did not in the overall number and total duration of fixations on playgrounds, parking spots, or greenery. Importantly, the more participants fixated on the greenery, the more positively they evaluated the courtyards. However, a longer total fixation duration on parking lots was negatively associated with the attractiveness of courtyards. The relationship between the attractiveness of the courtyards and the duration of fixations on the greenery was modulated by car ownership. The results further demonstrate that eye tracking is a promising research tool for studying the cognitive processing of urban environments by various groups of residents.

Author statement

Nadezhda Kerimova: Conceptualization, Methodology, Writing. **Pavel Sivokhin:** Investigation, Data Curation, Formal analysis, Visualization, Writing - Original Draft**. Diana Kodzokova**: Investigation, Conceptualization, Methodology. **Karine Nikogosyan**: Investigation, Conceptualization, Methodology**. Vasily Klucharev**: Supervision, Conceptualization, Methodology, Writing- Reviewing and Editing, Funding acquisition.

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Data availability

Data will be made available on request.

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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Appendix A. Supplementary data

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