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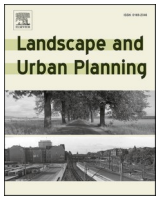

# Planning for fear of crime reduction: Assessing the impact of public space regeneration on safety perceptions in deprived neighborhoods

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## HIGHLIGHTS

- We assess the impact of low-income public space regeneration on safety perceptions.
- A photo-simulation experiment combined with a geotagged image survey is proposed as a method.
- Neighborhood safety perception is lower for women and clusters in specific locations.
- Public space regeneration significantly improves safety perceptions for both genders.
- Effective safety-enhancing interventions in public spaces are gender-specific.

## ARTICLE INFO

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## ABSTRACT

Fear of crime significantly reduces people's time–space access to and use of public space, notably in high-crime neighborhoods where concerns around personal safety are more acute. One widely used strategy to reduce fear of crime is the regeneration of the built environment. However, tension remains on whether this strategy is effective, and if it is, then where, which and for whom public space interventions work. This research, incorporating a gender perspective, assesses whether neighborhood-level regeneration of public space significantly enhances or reduces residents' perceptions of safety in deprived urban areas with a gender perspective. To test these impacts, we run a randomized control trial with 100 residents in a high-crime neighborhood in Santiago de Chile. A series of geotagged photographs of the area and ten treatment photo simulations of proposed interventions were rated by residents according to their perceived safety related to crime. The results suggest that: highly unsafe perceptions cluster in specific neighborhood locations and are particularly acute for women; the regeneration of public spaces significantly increases perceived safety for both men and women; and the effectiveness of different interventions is gender-specific. The results suggest, while an effective technique, public space regeneration in deprived neighborhoods can be further optimized through urban design and planning policy that are space- and gender-specific. The technique presented could support researchers and practitioners to understand the spatial distribution of perceptions of safety, to select effective interventions to make deprived neighborhoods feel safer, and to assess the impact of regeneration strategies.

## 1. Introduction

People's fear of crime and sexual violence in public spaces reduces their freedom to access opportunities and move throughout cities (Tandogana & Simsek, 2016). When left unaddressed, fear of crime can influence decisions around where to live (Hale, 1996), compromise transportation options and decrease walkability (Lee & Contreras, 2020), determine the social use of parks and squares (Ceccato, 2016; Ceccato & Nalla, 2020), alter paths of mobility (Loukaitou-Sideris, 2012), and impact residents' satisfaction with their neighborhoods (Lee

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et al., 2016). This presents a basal cause of inequality, as vulnerable populations' concerns about crime further reduce their access to alternative options for employment, schooling, socializing and recreation (Blöbaum & Hunecke, 2005; Cattell et al., 2008). The poorer and more marginalized neighborhoods are, the more pronounced the resident's concerns are for their personal safety in public spaces, along with a greater reduction in their rights to access urban opportunities. Among these communities, studies have shown that women experience higher levels of fear of crime, and that sexual violence is predominantly a threat faced by women – increasing their likelihood of exhibiting fear-related preventive crime behaviors (Fahnganel, 2018; Ferraro, 1996). The importance of access to safe public space is gradually being recognized, and in 2017, it was made a global priority as Target 11.7 of the UN's Sustainable Development Goals. However, if we are to attain this objective by 2030, it is necessary not only that citizens *are* safe, but also *feel* safe in public spaces, to ensure that all people can fully reap the benefits of accessing the public realm (Blöbaum & Hunecke, 2005; Valentine, 1990).

The challenge of making cities feel safe for all has increasingly become a focus of international and local public policy efforts (Wynne, 2008), with the transformation of the built environment becoming one of the most widely adopted and advocated strategies used to tackle feelings of fear in public spaces. These environmental strategies have generally been based on crime prevention theory, and thus focus on curtailing offenders' motivations and opportunities to commit a crime (Brantingham & Brantingham, 1981; Cohen & Felson, 1979), and are intended to affect, by extension, people's perceptions of fear. Crime Prevention Through Environmental Design (CPTED), the most widely used strategy, while becoming more sophisticated over time, remains a technique focused on the offender, targeting their advantage of environmental awareness in a determined urban landscape, and aiming to increase their perceived risk of detention and apprehension (Jeffrey, 1971).

The CPTED approach, which has guided various strategies, is based on different theories of criminology and urban planning. For instance, defensive space techniques aim to block opportunities for crime and foster guardianship through built environment design (Reynald, 2011; Uittenbogaard & Ceccato, 2014), while broken window theory (Wilson & Kelling, 1982) identifies environmental signs of disorganized neighborhood, such as physical dilapidation, as a leading factor to an area increasingly becoming a magnet for further crime and disorder. The 'eyes on the street' approach instead aims to bring more windows, light and people in the streets for increase opportunities of interventions and deter crime (Jacobs, 1961). Likewise, and as Jiang et al. (2018) point out, the routine activity theory notes that it is not only the physical characteristics of a built environment but also its social uses and human activities that have an impact on perceptions of safety. More recent advancements include the incorporation of a neighborhood's social context, psychological aspects, and participatory community-led approaches and their capacity of guardianship, and the location of crime, along with facilitating and detracting factors (Brantingham & Brantingham 1995; Covens & Love, 2015). However, it is unclear whether built environment solutions generated to influence perpetrators' actions are suitable for interpreting and addressing people's feelings of fear of crime, particularly those of women in marginalized communities. Research has shown a weak correlation between actual crime rates and fear of crime in urban areas (Rader, 2017). Moreover, while men have a higher likelihood of being victims of crime, women are more concerned about personal safety and are more likely to take safety precautions measures (Dymén & Ceccato, 2012; Hale, 1996; Pain, 2000; Riger & Gordon, 1981). As feminist theories and gender-perspective studies have argued, crime prevention strategies in the built environment in particular, and urban planning and design in general, do not take into account women's mobility and their use of and experience in the public space (Loukaitou-Sideris, 2012; Pain, 2000; Valentine, 1990; Wrigley-Asante, 2016). Despite the vast amount of CPTED academic criminology literature to prevent, the effect of the built environment on fear of crime remains crucially understudied. For instance, Lorenc et al. (2013, p.2), in a systematic review and *meta*-analysis, show that although numerous built environment interventions have been theorized, limited empirical studies exist showing their effectiveness, while the few that do exist provide low-quality evidence due to many possible confounders from environmental, social and cultural factors. The authors conclude that even widely used strategies such as improving street lighting or installing CCTV have been backed up with little evidence.

While the detrimental role of fear of crime in restricting time–space mobility in and use of public space is widely recognized, it remains largely unaddressed in planning policy, and as a result we risk seeing profound impacts on a society's behavior, psychological wellbeing, and quality of life (Blöbaum & Hunecke, 2005; Dymén & Ceccato, 2012; Hale, 1996). This passive approach to fear of crime is further exacerbated by a lack of existing methodological tools that can determine which public spaces generate fear, find effective built environment interventions for a given public space, and incorporate demographic perspectives in the planning process.

In light of these gaps in understanding, our aim here is to assess whether neighborhood-level regeneration of public space, can significantly decrease residents' fear of crime in deprived neighborhoods, and to consider the differences in outcomes across gender. By doing this, we propose an image-based method to simultaneously identify clusters of fear of crime requiring improvement and to test ex-ante the impact of various public space interventions alternatives on residents' fear of crime. We build a platform to run an image rating experiment combining geotagged images with a randomized control trial (RCT) technique. Data was collected from 100 participants in 2019 in Marta Brunet, Puente Alto – a deprived and high-crime neighborhood located in the southern outskirts of Santiago de Chile – who stated their perceived feelings of safety when viewing a series of unmodified geotagged images of the neighborhood, as well as photo simulations of ten interventions – categorized according to their relationship to CPTED theory – drawn from a proposal by the Chilean Ministry of Housing and Urban Development (MINVU) for urban regeneration in Marta Brunet.

In the following section, we present an overview of the relevant literature on the relationship between and built environment strategies addressing fear of crime in the public space, and an outline of the pitfalls of current image-based methods. This is followed by a presentation of our proposed method to combine geospatial and image-based RCT analysis. We then present our findings, and conclude with a discussion of the policy implications and limitations of this study.

### 1.1. Fear of crime and its effects across demographics

Fear of crime is defined as the emotional response to the uncertainty or anxiety produced by real or imagined crime, or to the symbols that a person associates with it (Ferraro, 1996). Studies show that this emotional response to crime is not directly linked to the experience of being a victim, but rather depends on the subject's assessment of a physical environment and its potential risks based on their individual characteristics such as physical ability, age, gender, socioeconomic status, and ethnicity (Garofalo & Laub, 1979; Pain & Smith, 2008). It has been established that older adults, for instance, tend to express more fear than younger people (Ceccato, 2016; Ferraro, 1996; Jiang et al., 2017), and poorer individuals express greater fear of crime than wealthier socioeconomic groups (Boomsma & Steg, 2014; Jorgensen et al., 2013).

A burgeoning body of literature looks at gender differences of fear of crime and their associated consequences. Gender has been shown to be one of the key predictors of levels of fear of crime (Ferraro, 1996; Rader & Cossman, 2011). While men are overall more likely to be victims of crime, women experience higher worry about crime (Riger & Gordon, 1981), an effect mainly driven by women's fear of sexual violence (Fahnganel, 2018), and the spillover effects of this that increase fear of other crimes (Ferraro, 1996). Critical feminist research and current

studies on the politics of care emphasize that fear of crime leads to protective behavioral responses that result in profound gender gaps in the right to access and seize city opportunities. Women are more likely to adopt protective mobility patterns, including restricting their destinations, routes, times and modes of transport used, and also face increased likelihood of confinement in the home, thus restricting space–time access to opportunities for education, work, and personal wellbeing (Dymén & Ceccato, 2012; Ferraro, 1996; Pain, 2000; Valentine, 1989). Pain (1997) further highlights the importance of considering women's individual characteristics, such as socio-economic status, as factors that influence perceptions and therefore affect behavioral responses. Studies in developing countries show that poorer women present higher levels of fear than their higher-income counterparts, notably in homogenously low-income neighborhoods, and that women living in these areas can even lead lives of immobility as a result (Wrigley-Asante et al., 2021; Wrigley-Asante, 2016). Therefore, urban planning and infrastructure bodies should account for the experiences of fear within this particular population – women in low-income neighborhoods – as a central point when making public investment decisions (Gargiulo et al., 2020; Owusu et al., 2016; Whitzman et al., 2013).

### 1.2. Theoretical approaches to fear of crime

Criminology theory has proposed that the physical environment contains clues that trigger people's fear, and that therefore, by modifying the built environment, public policies could reduce the perception of fear of crime (Costamagna et al., 2019; Jongejan & Woldendorp, 2013). Jane Jacobs (1961), in what is now known as the 'eyes on the street' theory, argues that urban areas with high levels of activity, or with building configurations that favor street observation, provide a form of informal surveillance where passers-by feel that others are more able to witness, report and act on crime, making them feel safer. Thus, levels of fear may be reduced through actions such as minimizing the presence of solid walls or increasing visibility of public spaces (Cozens et al., 2005). Another perspective comes from Appleton's (1975) prospect–refuge theory, which highlights that people feel safer in environments that offer a sense of enclosure, where the observer has a wide and downward-looking field of view, without nearby objects to conceal potential offenders, and without physical barriers preventing escape (Boomsma & Steg, 2014; van Rijswijk & Haans, 2018). Furthermore, Newman's (1972) defensive space theory states that fear of crime should increase in a location, for example, with an absence of escape routes for potential victims, and so modifying these spatial features would provide an effective strategy for tackling fear. Similarly, to Jacobs' concept outlined above, Newman also suggests that creating a physical layout that reinforces a sense of ownership over private spaces would reduce opportunities for crime and fear, while increasing residents' ability to casually observe the public areas around them. Specific physical designs to this end include clearly defining private communal areas (such as hallways, entrances, and shared gardens) in contrast to public spaces.

In addition to these approaches, broken windows theory (Wilson & Kelling, 1982) explains that exposure to disorder in the built environment in public spaces increases fear of crime. From this perspective, multiple physical signs of incivility in an area, such as the presence of litter, graffiti, broken windows, neglected gardens and dilapidated houses, foster a perception that residents are unable or unwilling to protect their neighborhoods from crime, which leads to a localized increase in fear (Loukaitou-Sideris, 2012). As Skogan (1984) points out, community-wide fear of crime leads to further withdrawal, and a decrease in social interactions and inter-subject coordination, resulting in a vicious circle of further urban decay and fear. Furthermore, routine activity theory or RAT (Cohen & Felson, 1979) proposes that crime and insecurity respond to the convergence of three social factors: a) the presence of a motivated offender; b) the presence of a victim; and c) the absence of a guardian or protector. As Jiang et al. (2018) note, people have the capacity to associate environmental changes with the risk of crime and predict functional uses likely to occur in public spaces.

CPTED strategies, over the course of more than 20 years, have seen these different environmental criminology theories incorporated into urban landscape design strategies, and have been widely used by urban planners to design public spaces (Cozens & Love, 2015). Fundamentally, CPTED seeks to curtail offenders' motivations and opportunities by modifying the design of streets, pavements, and public spaces (Chang, 2011). Here, city planners expect to reduce an offender's advantage of environmental awareness of criminogenic (crime-inducing) locations and increase their perceived risk of identification (Brantingham & Brantingham, 1981; Cohen & Felson, 1979) and apprehension (Jeffery, 1971). However, as such, in practice CPTED interventions have been focused on reducing crime itself, and their specific effects on fear of crime remain unclear.

Several CPTED principles of built environment design reflect the environmental criminology theories mentioned above. First, building on Newman's (1972) theories of defensive space, the natural control of access principle suggests that reinforcing the public–private delimitation of space and incorporating observable entrances will reduce opportunities for crime. The natural surveillance principle builds on Jacobs' (1961) 'eyes on the street' theory, suggesting that natural surveillance and guardianship can be facilitated through the design of windows, lighting, and landscaping. The maintenance principle relates to Wilson and Kelling's (1982) broken windows theory, and is based around the cleaning and improvement of dilapidated public spaces to increase the signals of an active and well-functioning community. These strategies place particular importance on bottom-up action, recognizing that it is the residents themselves who are most aware of the causes that generate environmental insecurity in their neighborhoods, and that it is the communities who hold the power to collectively decide on broader actions (Jeffrey, 1971; Cozens, 2014).

### 1.3. Methodological challenges of measuring fear of crime and its impacts

CPTED theories have indeed been embraced by urban planning departments in cities in the Global North and South (Cozens, 2014). However, there is little robust evidence regarding which types of CPTED-based interventions are effective in reducing people's fear of crime (Collins, 2016). Correlational empirical studies have shown that built environment strategies can have minor effects on reducing fear of crime, while leaving potential confounding factors unaddressed (Lorenc et al., 2013). There is also a generalized lack of causal studies, and the few that do exist have tested only a handful of built environment interventions in wealthy cities of the Global North (Navarrete-Hernandez et al., 2021).

Existing empirical evidence is also criticized on a number of counts. First, studies have failed to systematically measure important sociodemographic differences from an intersectional perspective to consider how, for instance, women, different ethnic groups, elderly people, people with disabilities or those using a pram might have very different experiences of fear in the public space (Gargiulo et al., 2020; Whitzman et al., 2013). Correlational empirical studies have also been criticized for not factoring place specificity in the configuration of fear (lack of ecological approach). Most studies do not set a baseline of the fear of crime perceived in each space (despite each space having unique characteristics), and therefore cannot accurately measure the perceptual changes produced by built environment interventions. This criticism has been made, for example, in studies measuring the impact of lighting, tree foliage, and blind walls, which makes it impossible to rule out the correlated effects that might occur (Van Rijswijk & Haans, 2018). In causal laboratory studies, subjects are typically presented with generic public spaces distant from those that they encounter in everyday life, and there is a tendency to focus on highly educated, wealthy populations (Farrall, 2004; Navarrete-Hernandez et al., 2021). This is despite the recognition from empirical studies that fear of crime is transitory and situational (Fattah & Sacco, 1989), and is highly influenced by the

specificities of each subject (Wisktrom, 2017).

There is therefore a clear need for empirical causal studies of fear of crime, with a specific focus on the places where this fear occurs, concentrating on those groups that are more exposed to it, and measuring spaces with which subjects are familiar.

### 1.4. Using images to measure fear of crime in public spaces: potential and limitations

Images are widely used in environmental psychology studies as a means of evoking emotions, including fear (Barke et al., 2012). Functional magnetic resonance imaging has also shown that urban photographs can activate areas of the brain including the amygdala, a center of fear control (Kim et al., 2010). The robust evidence connecting urban images and emotional responses has given rise to a number of empirical urban studies of fear of crime using photography and photo simulations, with two predominant approaches: mapping and impact assessment strategies.

A body of literature has focused on using images to map fear of crime (using perceptions of safety as a proxy) in the public space. Studies have attempted to address the unique particularities of built environment differences across cities by directly asking people to rate geotagged images that are then used to build maps of perceived safety by location. Rosseti and Hurtubia (2019), for example, use a large data set from PlacePulse to build a map of perceptions of safety for the Santiago de Chile metropolitan area, showing a strong correlation between the socio-economic status of an area and safety perceptions in public space. Acosta and Camargo (2018) built similar heat maps for neighborhoods in Bogotá using image ratings form their own online survey. This method, they argue, can serve as a low-cost tool to direct fear-reduction investment where it is most needed. These studies demonstrate two important points: 1) the existence of variations in safety perceptions across cities and neighborhoods is strong evidence that fear of crime is influenced by the built environment conditions; and 2) images allow us to map fear of crime in the built environment, which is typically highly concentrated in low-income neighborhoods. However, these studies have limitations due to the omission of important socio-demographic respondent data, and while they allow us to understand where fear of crime is concentrated, they provide no clarity around how we might change these perceptions (Solymosi et al., 2020).

A different body of literature has used photo simulations to measure fear of crime before and after changes were made to a built environment. Jiang et al. (2017) simulated an improvement of alleyways in Hong Kong, testing the effect of urban functions (e.g. cafes or bicycle parking) and vegetation on fear of crime. Jorgensen et al. (2013) simulated the presence or absence of people in public parks, showing an increase in safety perception, although with higher rates for women. Navarrete-Hernandez et al. (2021), in an RCT setting, used photo simulations of London streets with and without graffiti, public toilets and blind walls to measure the impact of these factors on fear of crime. While these studies have accounted for relevant socio-demographic diversity and measured changes in fear of crime driven by built environment transformations, they have not addressed the complex problem of place specificity.

In this study, we propose a method that combines the strengths of image-based mapping techniques and photo-simulation RCTs while overcoming previous limitations. We test this in our assessment of whether public spaces regeneration in deprived and high-crime neighborhoods decreases residents' fear of crime. The technique brings socio-demographic diversity to current mapping techniques while also detecting clusters of fear of crime, therefore identifying spaces that require transformation. The methods also allow to test and select effectively situated fear-reducing intervention and accounting for relevant place and socio-demographics specificity. Finally, combining the methods we to predict the impact of a proposed regeneration scenario on fear of crime in deprived urban areas.

## 2. Methods

To test our methodological approach, we use the case of Marta Brunet, in the commune of Puente Alto, Chile. Marta Brunet is a neighborhood containing 1,256 overcrowded social housing units, and is a high-crime urban area and one of the most stigmatized neighborhoods in Chile. For this reason, the Greater Santiago Regional Government, MINVU and the Ministry of Interior Affairs have designed the Marta Brunet Urban Regeneration Plan (*Plan de Regeneración Urbana Marta Brunet* or PRUMB), a series of built environment investments aimed at transforming residents' quality of life, reducing crime and increasing perceived safety.

Our proposed methodology is implemented through three steps. First, we aim to map locals' fear of crime in Marta Brunet through the evaluation of randomly assigned street views, while incorporating socio-demographic information. Second, we assess the impact of different project proposals (and classify them into CPTED approaches) on the community's fear of crime, and use this to select a portfolio of effective projects based on their fear-reducing performance in this neighborhood. Third, we explore the potential impact of selected high-performance projects on residents' fear of crime.

Throughout the study, we use 'perception of safety' as a proxy variable for fear of crime. As Yang and Hinkle (2012) propose, fear of crime is an abstract emotional construct that is difficult to measure directly and cannot be consistently compared across studies. Instead, large public sector surveys (such as the US National Crime Victimization Survey and Crime Survey for England and Wales) and academic literature tend to measure fear through the converse proxy measurement of perceived safety. In this sense, although the two phenomena are subtly different, we also measure perception of safety, so as to bring our results into a dialogue with the existing body of knowledge (Farrall, 2004; Hinkle, 2014).

### 2.1. Participants

We used the Urban Experiment platform (urban-experiment.com) to design a flexible instrument to collect data of participants' ratings of fear of crime for unmodified geotagged images, and simultaneously to run an RCT with photo simulations of the urban regeneration plan. Using a convenience sampling strategy, we collected data from 100 residents on January 18th and 19th, 2018, from a stall located in the central square of Marta Brunet. We specifically aimed to test this method in a realistic setting, allowing us to demonstrate its usefulness as an affordable complement to traditional participatory strategies. We also decided to restrict our data collection activity to two days and a single location, as this aligns with the regular participatory process used by MINVU. Within these constraints, we aimed to make our study as representative as possible. When the distribution of a population is unknown, the sample size is calculated with maximum variance, i.e., a default value of 50% heterogeneity is used. For this case, we do have access to the data of the population and its socioeconomic distribution, which was calculated at 6.3% heterogeneity. This neighborhood therefore has high socioeconomic homogeneity (due to it being a segregated social housing area), and given Marta Brunet's population of 4,842 (2017 Chilean Census), the sample size should be of at least 90 individuals. Thus, compared with our sample data, actual neighborhood data will be 95% of the time in the interval $\pm$ 5%.

At the stall, trained assistants approached passers-by and asked them to participate in a voluntarily survey to rate their perceptions of safety when viewing street images of the neighborhood. Participants were then assigned to one of five laptops, first signing an online consent form, then completing a registration form containing socio-economic questions, and finally rating a series of 25 randomly assigned images. To rate images, participants were instructed to imagine themselves walking in the presented street alone, and to state their perception of safety related to crime on a scale from 1 (not at all safe) to 10 (very safe). No personal

identifying information was collected, and no economic incentives or compensation were given. The average time to complete the survey was 4:32 min. Table 1 presents descriptive statistics.

### 2.2. Design strategy

The experiment contains two groups of images. The first comprises unaltered images of public spaces in Marta Brunet, which we refer to as 'mapping images'. The database of mapping images contains 103 geotagged photographs taken from the center of a street, spaced 40 m from one another, and covers all public spaces in Marta Brunet (Fig. 1.A presents the locations of the photographs). The second group contains 'experiment images', consisting of ten sets of photo-simulated images representing two conditions: the current public space (control image) and the same space with a fear-reducing intervention (treatment image). Two of these ten intervention sets contain two treatment images, representing different design approaches applied to the same intervention type. These ten interventions represent all the intervention types contained in the PRUMB (see Fig. 1.B).

Since the PRUMB was proposed by MINVU itself in dialogue with neighborhood organizations, rather than by academic researchers, CPTED theory did not directly form the basis of the interventions. However, to test the impact of different CPTED theoretical approaches, the interventions are arranged into four subgroups. Firstly, broken windows (BW) theory is represented by the renovation of run-down housing blocks, and the transformation of abandoned spaces into housefront parking, which aims to reduce perceptions of incivility by minimizing clutter and enhancing perceived maintenance (Fig. 1.B, Images A.1–2). Second, 'eyes on the street' (EOS) is represented by interventions that install windows into blind walls of buildings, and that introduce new public lighting, aiming to reinforce natural surveillance of public space (Images B.3–4). Third, defensive space (DS) theory is represented by interventions that see the fencing-off of housing lots, and create better definition of housing block entrances, reinforcing the access control of shared housing spaces (Images A.5–6). The remaining four interventions all improve dilapidated public space, enhance recreational activity and increase contact with nature by incorporating green infrastructure (GI): the addition of a park, building green pedestrianized streets, street reforestation, and the construction of a soccer pitch (Images D.7–10). This GI approach, while less widely discussed in CPTED theory, has still been considered and supported by empirical and exploratory studies as a means of affecting crime rates and fear of crime comparable to the other three categories, and may even carry the effects of several of these categories simultaneously (Jiang et al., 2018, Macdonald et al., 2019; Navarrete-Hernandez & Laffan, 2019).

Each participant rated 25 images in total: 15 randomly selected mapping images, and 10 experiment images, with random selection of either control or treatment conditions for each intervention type. This process of random selection allowed participants' covariates to be balanced for both the rating of different mapping images, and between control and treatment groups. We further controlled for potential spillovers for participant 'fatigue' on ratings from one image to the next, by randomly assigning the order of appearance of the 25 images. This generated a unique set of images and order of presentation for each participant.

**Table 1**
Descriptive Statistics.

| Variables | N | Percentage | Min | Max |
|---|---|---|---|---|
| Age | 1585 | | 1 | 3 |
| <30 | 592 | 37.4% | | |
| 31–50 | 540 | 34.1% | | |
| >51 | 453 | 28.6% | | |
| Gender | 1585 | | 0 | 1 |
| Male | 610 | 38.5°. | | |
| Female | 975 | 61.5% | | |
| Residence | 1,585 | | 0 | 1 |
| Local | 1,511 | 95.3°. | | |
| Other neighborhood | 74 | 4.7% | | |
| Having Children | 1,585 | | 0 | 1 |
| No | 285 | 18.0% | | |
| Yes | 1,300 | 82.0% | | |
| Date Test | 1,585 | | 0 | 1 |
| Day 1 | 574 | 36.2% | | |
| Day 2 | 1,011 | 63.8% | | |
| Time of Response | 1,585 | | 10:00 | 17:00 |
| 10:00–10:59 | 60 | 3.8°. | | |
| 11:00–11:59 | 120 | 7.6% | | |
| 12:00–12:59 | 151 | 9.5% | | |
| 13:00–13:59 | 164 | 10.3% | | |
| 14:00–14:59 | 189 | 11.9% | | |
| 15:00–15:59 | 403 | 25.4% | | |
| 16:00–17:00 | 498 | 31.4% | | |
| Image source | 1585 | | 0 | 1 |
| 0Mapping | 921 | 58.1% | | |
| 1Experiment | 664 | 41.9°. | | |
| Type of Interventions | 664 | | 1 | 10 |
| 1 Housing Upgrading | 101 | 15.2% | 0 | 2 |
| 2 Street Lighting | 56 | 8.4% | 0 | 1 |
| 3 New Park | 59 | 8.9% | 0 | 1 |
| 4 Fences | 96 | 14.5% | 0 | 2 |
| 5 Parking Spaces | 57 | 8.6% | 0 | 1 |
| 6 New Windows Openings | 59 | 8.9% | 0 | 1 |
| 7 Street Trees | 57 | 8.6% | 0 | 1 |
| 8 Green Pedestrian Street | 54 | 8.1°. | 0 | 1 |
| 9 Housing Block Entrance | 64 | 9.6% | 0 | 1 |
| 10 Football Pitch | 61 | 9.2% | 0 | 1 |

### 2.3. Data set

We used four data sources: 1) participants' socio-demographics; 2) experimental condition measurements; 3) images' geographical coordinates; and 4) participants' stated safety perceptions. Socio-demographics correspond to gender identity, age, municipality of residence, and whether the participant has children. Experimental conditions correspond to the ID of each image, mapping or experiment status of an image, treatment or control status for experiment images, order of appearance, and the test date. Geographical coordinates contain the X and Y coordinate of each mapping image. Safety perceptions are on a 1 to 10 scale as described above.

### 2.4. Empirical Strategy

#### 2.4.1. Mapping and cluster analysis

To map safety perception, we use a Kriging interpolation model of participants' image ratings. In this process (Wang et al., 2009), 1,842 evaluations were taken from 103 images, using an exploratory analysis to ensure the elimination of local trends, avoid high degrees of entropy and guarantee a normal distribution.

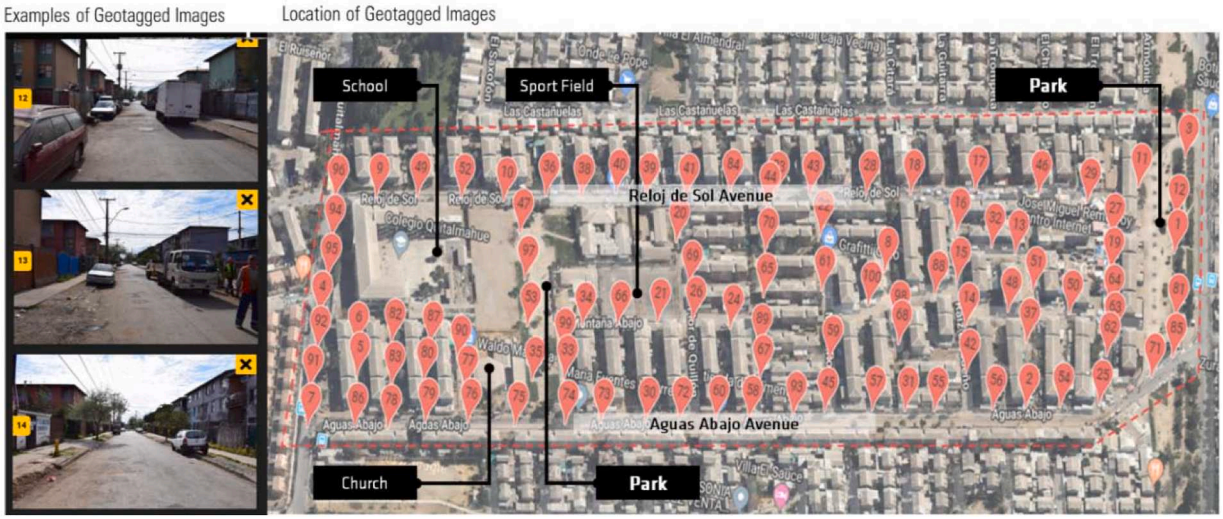
Once the exploratory statistical analysis was completed, a simple Kriging was calculated, for which the average size and number of spatial lags were established, also adjusting the parameters of the variography analysis. With the appropriate adjustment, the geostatistical prediction was obtained and exported after consistency testing by means of a cross-validation process. The mathematical expression of the Kriging used is defined as follows:

$$\widehat{Z}(S_o) = \sum_{i=1}^{N} \lambda_i Z(S_i)$$

where $Z(S_i)$ is the average value of perceived safety at location $i$, $\lambda_i$ is the unknown weighting for the value measured at location $i$, $S_o$ is the prediction location, and $N$ is the number of measured values.

From the results, the LISA spatial statistics (Anselin, 1995) was applied to highlight the safest and least safe agglomerations. For this purpose, a grid covering the study area was generated, which took the average value of the interpolation. Spatial statistics were applied with a

**A** Sample of mapping images, and a map showing geotagged locations in Marta Brunet.




**B** Simulated images of proposed regeneration projects

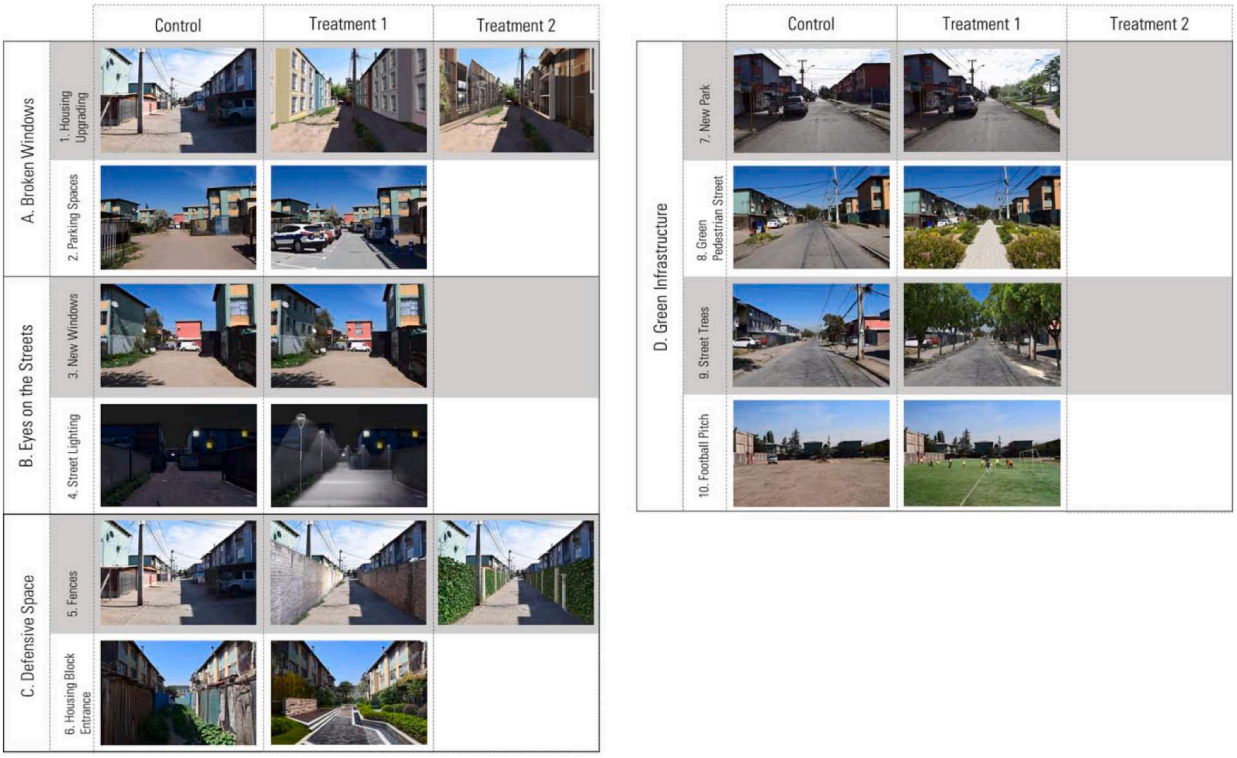



**Fig. 1.** Image inputs for the survey.

topology-based spatial weight matrix, specifically based on the Von Neumann neighborhood (Tower). The simplified mathematical expression of this statistical calculation is:

$$I_i = z_i \sum_j w_{ij} z_j$$

where $z_j$ is the original form of the safety perception variable standardized from a score $Z$, $w_{ij}$ is the spatial weights matrix configured between the observation and its neighbors, and $z_i$ is the variation of the sum of the neighbors, i.e. how different or similar the analyzed value is as a function of the sum of the values contained in its neighborhood (dependent on the spatial weights matrix).

We first ran Eq. (1) and Eq. (2) over all mapping image ratings to produce the result for the whole neighborhood. We then conducted Eq. (1) on each of the subsamples of women and men, to account for gender differences.

#### 2.4.2. Experimental assessment

To test the impact of the proposed interventions on participants' safety perceptions, e used a random intercept model with fixed effects at the image level. A random intercept model is used to control for the variability of a participant's predisposition to feel safe in any given space. The formal model is:

(3) $\text{Perception}_{ij} = \beta 1\text{Treatment}_i + \beta 2\text{Image}_i + U_j + E_{ij}$.

where *Perception*$_{ij}$ accounts for the declared safety perception of participant *j* for image *i*, *Treatment* is a categorical variable equal to 0 and a consecutive number if the *i*th image comprises a public space intervention (treatment), $\beta 1$ captures the impact of the intervention on the participants' reported safety, *Image*$_i$ is an image fixed effect for the *i*th image, $U_j$ is the random intercept for the *j*th individual, and $E_{ij}$ is the error term.

We analyzed Eq. (3) in two ways. We first ran it to estimate the impact of each of the selected regeneration interventions on perceptions of safety, and then on women and men subsamples to account for the impact of the interventions according to gender. We conducted additional robustness checks by running Eq. (3) with and without control variables.

## 3. Results

In this section, we present the main results of our study in three stages. First, we use residents' ratings of street images to build a fine-grained map of neighborhood-wide perception of safety and to assess the existence of spatial clusters where perceptions of low safety concentrate. Second, we evaluate causal estimates of impact of built environment modifications and different categories of CPTED approaches on safety perceptions, and from this provide insights on selecting effective PRUMB interventions to increase perceived safety. Finally, we use these evaluations to provide neighborhood-level estimates of the expected impact of a portfolio of the most effective investments on safety perceptions, and visualize this spatially. All results are reproduced by gender.

### 3.1. Mapping safety perception in Marta Brunet

Fig. 2, Panel A displays the safety perception map produced by running Eq. (1) for the whole data set. The map shows that, overall, Marta Brunet is perceived as an unsafe neighborhood across its entire area (mean: 3.84, S.D.: 2.38), with particularly low levels of perceived safety around housing blocks. Panel B explores the statistical significance of perceived safety within the neighborhood by running Eq. (2). It shows that low perceptions of safety are clustered in three degraded public spaces located between housing blocks (shown in blue, following the LL Anselin Local Moran Classification), while the areas perceived as safest are concentrated in the central neighborhood park. Hotspots of low safety perception (Low-Low Clusters as per Anselin Local Moran Cotype) are characterized by vacant land and informal housing extensions (as in image 6-Control in Fig. 1.B).

Panels C and D in Fig. 2 display the gendered safety perception of Marta Brunet without any interventions. As column 1 in Table A.1 (see Appendix) indicates, women perceive the neighborhood as significantly less safe than men (estimate: −0.582, S.D: 0.161, $p < 0.001$). A visual inspection indicates, however, that both genders coincide on the neighborhood spaces that they consider safe or unsafe, and so the gender discrepancy arises from women tending to feel less safe in those spaces compared to men.

### 3.2. Assessing the effectiveness of interventions and theoretical approaches

Here, we analyze the effectiveness of built environment interventions proposed in the PRUMB (Fig. 3, Panels A-K). Regarding CPTED theories, Panel A indicates that interventions of DS, BW and GI types all significantly increase perceived safety (DS-estimate: 3.008, S.D.: 0.439, $p < 0.001$; BW-estimate: 2.327, S.D.: 0.421, $p < 0.001$; GI-estimate: 1.576, S.D.: 0.553, $p < 0.001$). EOS strategies have a weakly significant impact. Of the specific interventions, improving housing entrances has the largest positive impact (estimate: 4.927, S.D.: 0.553, *p*

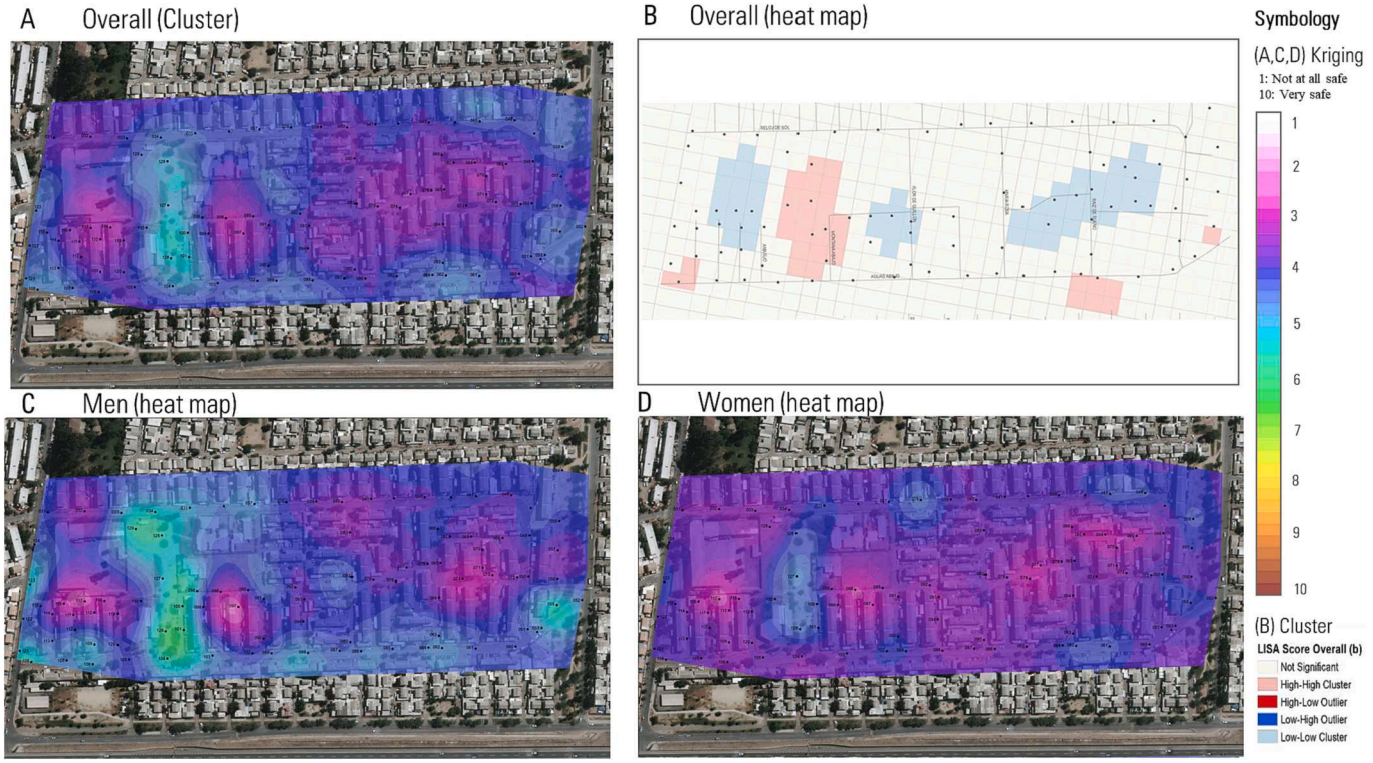



**Fig. 2.** Image-based safety perception heat maps and cluster analysis.

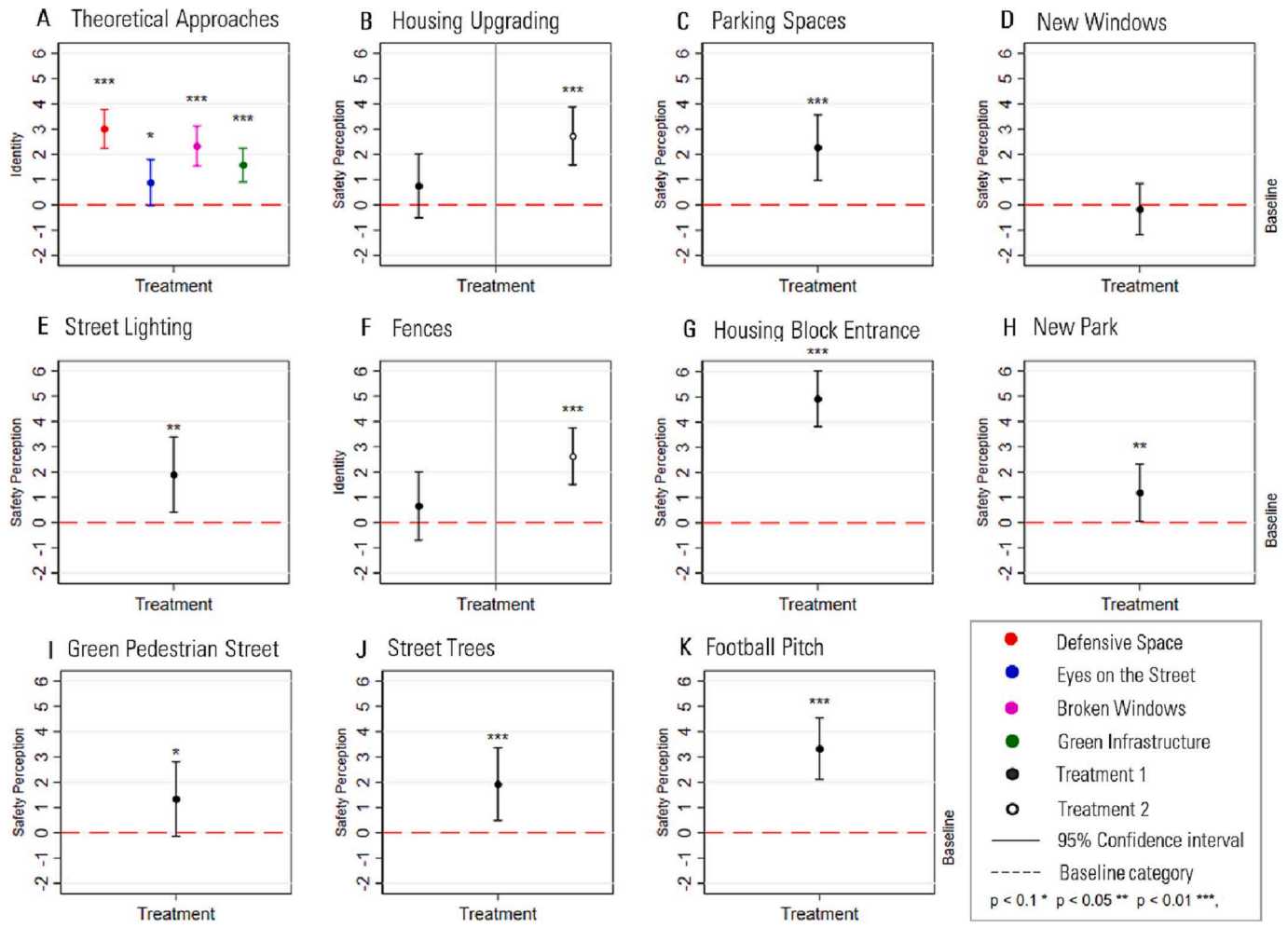



**Fig. 3.** Impact of PRUMB interventions on perceptions of safety (all participants) Note: Regression results are plotted with controls. Each point represents the average treatment effect compared with images with no interventions.

$< 0.001$), while fencing off houses – although only the treatment with greenery on fencing (estimate: 2.624, S.D.: 0.565, $p < 0.001$) – replacing vacant land with parking spaces (estimate: 2.264, S.D.: 0. 648, $p = 0.001$), constructing a soccer pitch (estimate: 3.322, S.D.: 0.607, $p < 0.001$), and planting trees in streets (estimate: 1.920, S.D.: 0.717, $p = 0.010$) strongly enhance safety perceptions. These interventions all have a relatively moderate cost with a large impact. Building a new neighborhood park (estimate: 1.184, S.D.: 0.564, $p = 0.040$), increasing street lighting (estimate: 1.901, S.D.: 0.742, $p = 0.013$), and renovating housing blocks– although only the treatment using a more detailed, modern style (estimate: 2.721, S.D.: 0.579, $p < 0.001$) – all have a significant impact on improving safety perceptions, but may require greater investment. Renovating housing using a more basic design, adding windows to housing blocks, and fencing off houses using brick walls had no significant impact on safety perception. Detailed results are presented in Table A.2 (in Appendix).

Fig. 4 illustrates the impact by gender. Regarding CPTED theories, Panel A indicates that all four categories produce a significant increase in perceived safety for males, with DS having the largest impact (DS-estimate: 3.599, S.D.: 0.606, $p < 0.001$; EOS-estimate: 1. 665, S.D.: 0.751, $p = 0.03$; BW-estimate: 1.541, S.D.: 0.560, $p = 0.011$; GI-estimate: 1.021, S.D.: 0.531, $p = 0.026$). For women (Panel B), DS, BW and GI approaches yield a significant increase, with DS and BW having the larger impacts (DS-estimate: 2. 618, S.D.: 0.600, $p < 0.001$; BW-estimate: 2.759, S.D.: 0.545, $p < 0.001$; GI-estimate: 1.852, S.D.: 0.450, $p < 0.001$), while EOS approaches produce non-significant results. Panels C to K show that, compared with men, a smaller set of interventions have an effect for women, but the impact of these interventions is bigger. For both women and men, the most effective intervention remains improving housing entrances (estimate-men: 6.00, S.D.: 0.821, $p = 0.001$; estimate-women: 4.237, S.D.: 0.761, $p = 0.001$), while adding parking spaces (estimate-men: 2.650, S.D.: 1.053, $p = 0.021$; estimate-women: 2.193, S.D.: 0.790, $p = 0.009$), renovating housing blocks – again, only the treatment using modern design (estimate-men: 2.231, S.D.: 0. 673, $p = 0.007$; estimate-women: 3.194, S.D.: 0.715, $p = 0.001$) – and constructing a soccer pitch (estimate-men: 3.376, S.D.: 0.966, $p = 0.002$; estimate-women: 3.338, S.D.: 0.833, $p = 0.001$) significantly enhance perceptions of safety for both genders. Building a new neighborhood park (estimate-women: 1.706, S.D. = 0.807, $p = 0.042$), and fencing off houses using green walls (estimate-women: 3.179, S.D.: 0.740, $p = 0.001$) only have a significant impact for women, while fencing off houses using solid brick walls (estimate-men: 2.733, S.D.: 0.801, $p = 0.002$) and increasing street lighting (estimate-men: 4.391, S.D.: 0.893, $p < 0.001$) have a significantly effect for men only. Regressions results are presented in Table A.3 and A.4 (in Appendix).

### 3.3. Assessing the impact of the Marta Brunet regeneration plan

In this section, we estimate the change in perceptions of safety in Marta Brunet after the implementation of the proposed PRUMB interventions. For this, we match the location of a proposed intervention

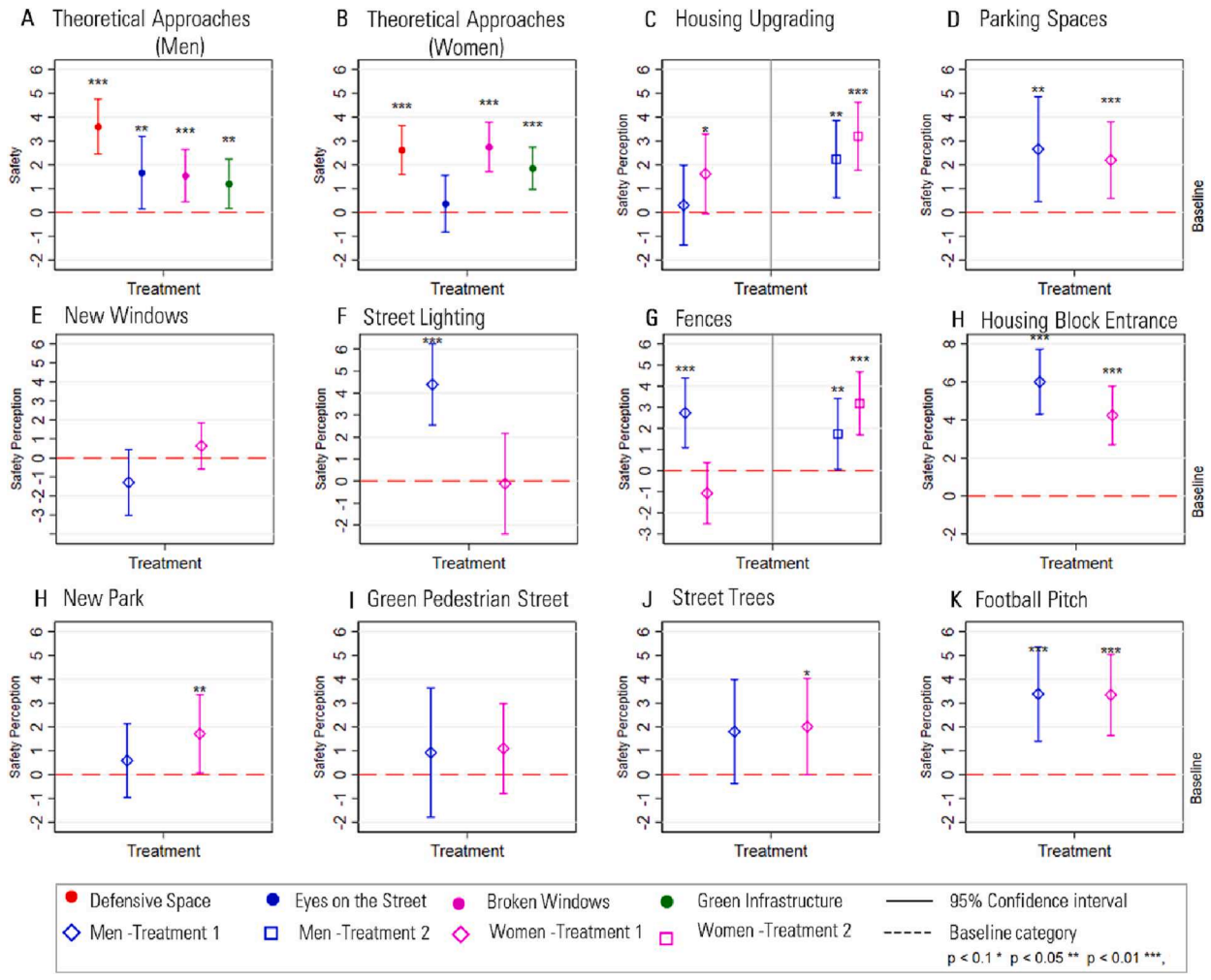



**Fig. 4.** Impact of PRUMB interventions on perceptions of safety (by gender) Note: Regression results are plotted with controls. Each point represents the average treatment effect compared with images with no interventions.

in the plan with the locations from our mapping images database. For each location, we add to the baseline mapping image score the corresponding safety perception estimates for interventions with significant outcomes, as calculated above. When none of the interventions proposed at a given location were found to have significant outcomes, we add a zero effect (maintaining the average baseline value of this location). When more than one proposed intervention had a significant outcome, we add only the effect of the most effective intervention. This method sets what we consider a lower-bound or conservative scenario of increased perceived safety. Indeed, we could reasonably expect that, when the PRUMB implements two or more effective interventions at the same location (e.g. improving housing entrances and renovating a housing block), this would yield at least the effect of the most effective intervention.

Fig. 5, Panel A.1 presents the estimated changes. As column 1 in Table A.5 (in Appendix) indicates, overall the PRUMB generates a significant improvement in safety perception in public spaces (estimate: 1.589, S.D.: 0.119, $p < 0.001$), representing an increase of 40.9% compared to the neighborhood baseline. Fig. 5, Panel B.1 displays these results for men, showing a significant increase of 39.2% (estimate-men: 1.648, S.D.: 0.201, $p < 0.001$) (see column 1 in Table A.6, in Appendix). Panel C.1 shows that this is also the case for women (see column 1 in Table A.7, in Appendix), but with a higher overall improvement of 43.9% (estimate-women: 1.594, S.D.: 0.148, $p < 0.001$).

The maps presented in Fig. 5, Panels A.2-C.2, show the distribution of these increases. To elaborate this, only the most favorable intervention for each location was added. We then interpolated from the new scores to create a visualization of the safety perception for the whole neighborhood after the regeneration plan.

Overall, the area is felt to be considerably safer across all public spaces, with slight differences between the north and the south. A notable difference appears, however, when visualizing these changes by gender. Following the intervention, men feel relatively safe, reaching a score of 5–6 across all neighborhood public spaces, with the safest scores in the southwest area. For women, while the regeneration plan does create a significant increase in perceived safety (from 3.62 to 5.22), large areas remain perceived as very unsafe, notably around the main streets, with the least safe areas around the center-north areas (scoring around 3 points). This gender difference is the result of two factors: first, women start from a lower baseline of perceived safety across the neighborhood, and second, several locations incorporate interventions that are only effective for men, leaving women's perceptions unchanged.

## 4. Discussion

In this study of an urban regeneration plan in a deprived urban area of Chile, our contributions are threefold. First, we have shown that this type of regeneration drawing from CPTED techniques is indeed an effective planning policy to decrease fear of crime in the public space. Second, we show that gender specificity considerations must be taken into account, providing new empirical evidence showing that

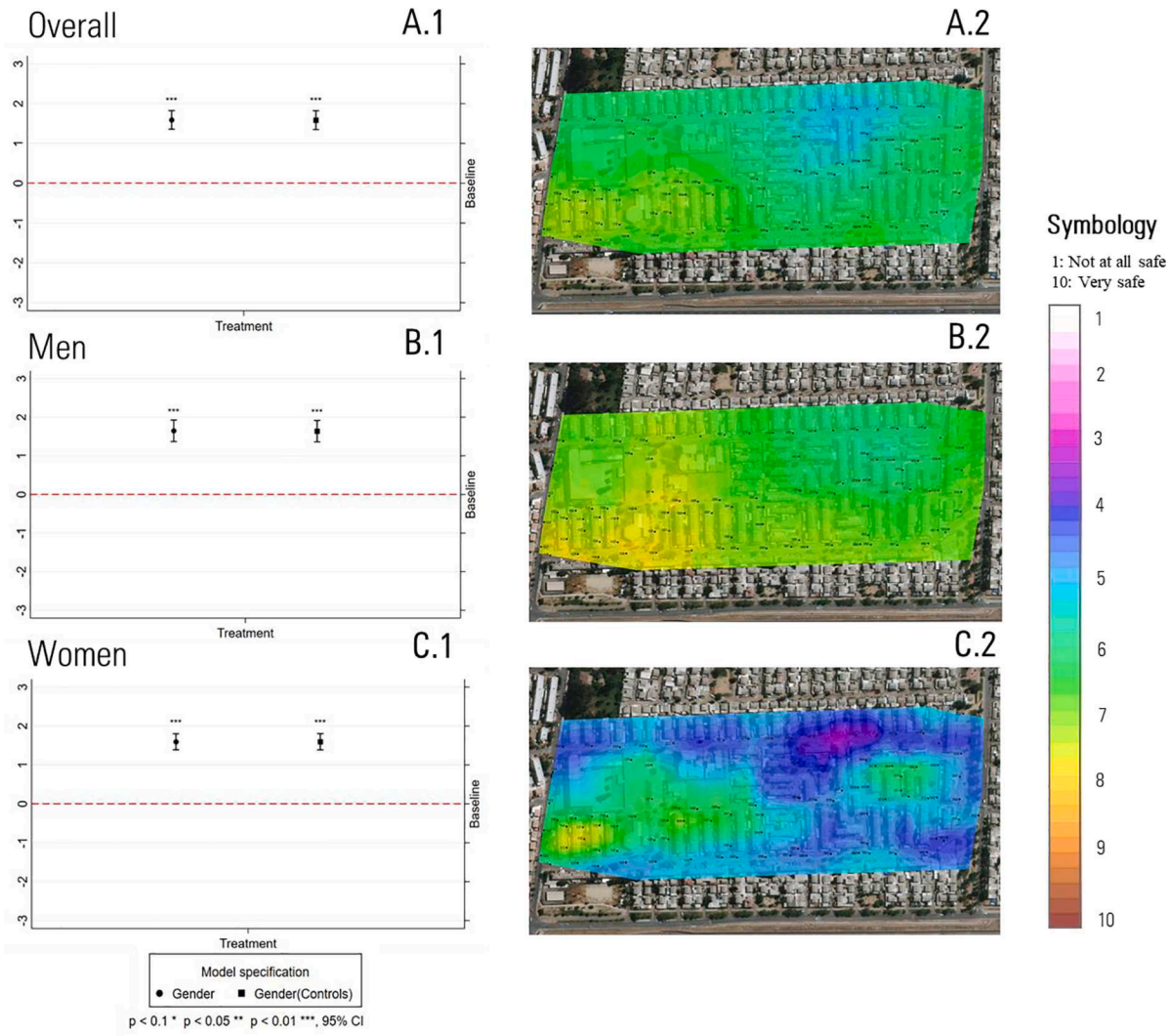



**Fig. 5.** Safety perception coefficient plots and heat maps after PRUMB interventions, for all participants and by gender. Note: Regression results are plotted with controls. Each point represents the average treatment effect compared with images with no interventions.

environmental design can play a particularly integral role for women's perceptions of safety in these areas. Finally, we have proposed and tested a flexible methodology that combines measurements of fear of crime with geotagged images and photo simulations, solving some of the problems that arise when using these methods independently. This method provides an affordable technique that could be used by urban researchers and policymakers beyond the case presented here to evaluate the impact of public space regeneration programs before they are rolled out.

### *4.1. The effectiveness of CPTED-based urban interventions on fear of crime*

Our starting point was to tap into the residents' knowledge by rating images of their own neighborhood's public spaces in its current state and in the proposed regenerated condition. Overall, residents perceived their neighborhood as highly unsafe, but there is significant spatial variation with some places concentrating high and low levels of fear of crime. Starting with a positive finding, one of the few public spaces where residents experience low fear of crime is the neighborhood's central park, along with street intersections, and the main avenue in the south of the neighborhood. This central park is a clean, well-maintained green public space where people have a wide field of vision, most likely enhancing perceived safety via the effects proposed by broken window and prospect–refuge theories. Furthermore, as seen in the results, the presence of green infrastructure itself can contribute to this positive assessment. However, as we move to the inner core of the neighborhood, fear of crime increases along narrow alleys, reaching a peak in communal spaces between building blocks. These spaces are characterized by being confined and degraded, with irregular extensions of houses and a lack of clarity in the definition of private and public space. This aligns with Appleton's (1975) proposals from prospect–refuge, defensive space and disorder theories (Wilson & Kelling, 1982) regarding the importance of wide views and well-kept spaces, and the need for well-maintained and more defined separation between public and private space (Boomsma & Steg, 2014; van Rijswijk & Haans, 2018). Overall, these findings suggest that CPTED theory aligns with the spatial concentration of fear of crime in public spaces, and these spaces can be mapped and identified.

Using this baseline, we explored the impacts of CPTED theory and specific interventions from the PRUMB on residents' fear of crime. We found that all the theoretical approaches tested can reduce fear of crime, with the highest impact produced by DS techniques, while EOS strategies have the lowest impact. It appears that GI approaches are also able to increase safety perceptions, however these are yet to be fully integrated into CPTED theory, and so much less is known about the theoretical bases behind this effect. However, this presents scope for further research and expansion of CPTED theories. Interestingly, regarding the

four interventions that yielded non-significant outcomes, each of these represents a different theoretical approach (one each from the DS, BW, EOS and GI categories), and so this reinforces our findings that one approach is not particularly deficient in its potential to minimize fear of crime. Furthermore, We found that relatively simple and low-cost interventions from across all theoretical approaches could yield dramatic changes, such as upgrading communal entranceways to housing blocks, or fencing off houses using greenery. Undertaking more major renovation of housing stock and facades has a similarly significant impact, although it demands large expenditure requirements. It is clear, however, that there is much more scope for public space interventions to draw from CPTED theory as an effective means of reducing fear of crime. Indeed, many principles from across CPTED theory are reflected in the PRUMB, and we can conclude from the study here that the plan is successful in producing a significant decrease in fear of crime for local residents.

### 4.2. The relevance of gender in the study

Our results also clearly highlight the issue of gender inequality in fear of crime, an imbalance in need of urgent attention from policymakers. In line with expectations from the literature (Valentine, 1990), we see that women feel less safe than men overall in their local neighborhood. Of note, we also find that women and men both experience fear of crime in the same areas of Marta Brunet, demonstrating the potential of this technique to pinpoint focus areas for urban transformation. However, when considering the most effective intervention types, we find that our results differ by gender: EOS strategies were not effective for increasing safety perceptions for women, while BW and to a lesser extent GI approaches were more effective for women. DS strategies, however, were the most impactful approach of all for both males and females. This suggests that the public spaces needing investment to increase feelings of safety are the same for men and women, but the types of investments needed differ. As women feel less safe, we argue that interventions that either work for both genders, or work for women only, should be prioritized. Regarding specific interventions, it appears that those establishing high-quality communal spaces suitable for family use – such as building a soccer pitch or upgrading communal block entrances to become places where children can play – are highly effective interventions that work for both males and females, and so present a preferable option to adopt. As Jiang et al. (2018) propose, these interventions might have achieved these impacts not only through the direct physical change incorporated in the images, but also by encouraging people to predict that a given space would see an increase in desirable routine activity. Overall, our findings evidence the work of several authors who state that urban planning strategies and design require an intersectional approach (Gargiulo et al., 2020; Whitzman et al., 2013), which is most often neglected in practice (Greed & Johnson, 2014; Parker, 2016).

### 4.3. A new methodology to tackle fear of crime

The methodology presented in this paper has the potential to feed into urban planning processes to make the most disadvantaged areas of cities feel safer. Our strategy provides a means by which governments can maximize value for money when developing regeneration plans, first by allowing them to channel public investment into the neighborhood spaces where it is most needed, and second by facilitating the selection of the most effective fear-reducing investments from a large array of potential candidates. The current technique could be combined with traditional participatory workshops to define the interventions to be tested, and therefore ensure that local community proposals are included in the planning process. While we tested our approach using an already established regeneration plan, future research could be incorporated into the planning process itself.

This technique could also be used by policymakers to incorporate further intersectional perspectives on fear of crime into urban planning strategies. We found that in deprived neighborhoods women might feel more fearful, and that effective fear-reduction interventions can have gender-specific effects. While traditional male-dominated urban planning might reinforce this gender gap, the approach here provides substantive information to favor interventions that work for women. This methodology also presents opportunities for future research using larger sample sizes to consider other intersectional factors, such as age and ethnicity, as relevant variables that might influence outcomes (Dymén & Ceccato, 2012; Sandberg & Rönnblom, 2015).

### 4.4. Limits and recommendations for future studies

This research, however, is not without limitations, and scope remains for improvements. This study collected responses from a convenience sample of passers-by from a stall in a park in Marta Brunet. This sample may represent people who use public spaces more frequently and live closer to the data collection space, and therefore cannot be assumed to be representative of the whole population of local residents. While there is no reason *a priori* to think that this would heavily impact our results, our technique could be improved by running the presented 5-minute test with a representative household sample, or even across housing units, carrying out the experiment door-to-door using a tablet.

This study uses a real-life case study to determine the impact of urban regeneration plans on perceptions of safety, and this means that the photo-simulations used are principally reality driven rather than theory driven. While this has the advantage of better reflecting what will actually be done (potentially through a combination of approaches) and increases the applicability of the methods to real-life scenarios with the target population, this come at the price of a less refined match between intervention and theory, compared to what could be achieved in a (non-real) study built from the ground up based on theory rather than actual proposed interventions.

Another important issue is that this methodology does not associate the impact of fear-reduction investments with their cost. The capacity of built environment interventions to reduce fear of crime lies alongside the public sector's responsibility for selecting value-for-money investments. We saw that, for example, transforming building entrances is a more effective intervention, and is likely less costly, than rebuilding housing blocks. Thus, from the perspective of fear of crime, it provides a better return on investment, and future studies could incorporate a more in-depth cost-benefit analysis in this way.

A final limitation of this study is that residents were only exposed to visual stimuli. Existing research shows that the combination of visual stimuli and soundscapes can enhance the impact of environments on emotions. Further research could include recordings of background noise to accompany images (Annerstedt et al., 2013; Jiang & Kang, 2016), although this might come at the cost of extending the data collection time and expense. That being said, image ratings arguably produce a lower-bound estimate – if we obtain significant results with simple visual stimuli, we could reasonably expect larger estimates when soundscapes are incorporated.

## 5. Conclusion

In this study, we have presented a technique that combines measurements of residents' fear of crime in response to images of public space and photo simulations of proposed interventions to inform urban regeneration plans of deprived neighborhoods. First, our statistical analysis of geotagged images allowed us to produce a high-resolution map of perceived safety in public spaces, and detect spatial clusters of concentrated fear of crime. Next, our analysis showed that regeneration of public spaces using CPTED significantly decreases residents' fear of crime, and allowed us to determine which specific interventions yielded the strongest outcomes, finding also that the effects were gender-specific. Then, by combining our map of perceived safety and our

estimates of effectiveness of interventions, we are able to produce lower-bound estimates of the expected impact of a proposed regeneration plan for a deprived, high crime urban neighborhood in Chile.

This study is particularly relevant for urban planning efforts in the Latin American region specifically, and in the Global South more generally, aiming to make deprived neighborhoods feel safe for all. An array of urban regeneration programs undertaken in the region – such as the Community Neighborhood Improvement Program in Mexico, the Favela Neighborhood Program in Brazil, and the Neighborhood Improvement Program in Uruguay – place fear of crime as a central concern. The methodology here, and its potential for participatory use in contexts of limited public resources, can help to increase the effectiveness of urban planning strategies by channeling resources to the most effective interventions and to the places most in need.

This approach can help us, along with more qualitative participatory approaches, to gain insight into how we can best define urban regeneration plans from the perspective of gender and, when using a larger sample, other socio-demographic groups. Given its relatively rapid and affordable implementation, this technique can feed into urban planning more generally as a valuable information source for practitioners, so that cities may become places where everyone can feel the freedom and confidence to move around and access public spaces without fear (Levy, 2013). In this way, we may all reap the rewards associated with a full inclusion and participation in urban life.

## 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.

## Data availability

The authors do not have permission to share data.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2023.104809.

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