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Building safer public spaces: Exploring gender difference in the perception of safety in public space through urban design interventions

Pablo Navarrete-Hernandez [a,b,*], Arielle Vetro [c], Paz Concha [d,e]

[a] Institute of Housing (INVI), University of Chile, Santiago, Chile
[b] Department of Architecture and Urban Planning (DAStU), Politecnico di Milano, Milan, Italy
[c] Department of Social Policy, London School of Economics and Political Science, London, United Kingdom
[d] Institute of Urban and Territorial Studies (IEUT), Pontificia Universidad Católica de Chile, Santiago, Chile
[e] Centre for Social Conflict and Cohesion Studies (COES), Santiago, Chile

HIGHLIGHTS

- We examine the impact of three urban design interventions on people's perception of safety in the public space.
- Photo simulation is used in a randomised control trial setting.
- Safety-enhancing design interventions have a significant impact on enhancing perceived safety.
- Removing solid walls leads to significant improvements of perceptions of safety for women.
- Eliminating graffiti from streetscapes has a weak significant impact on perceived safety only for women.

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ABSTRACT

Concern around personal safety is a significant factor in constraining women's access to and use of public space. One strategy presented to address this involves altering the design of built environments. However, tension and controversy surround these arguments in the literature on safety perception in public space. This study seeks to explore whether the presence of three design interventions commonly cited in the literature act to enhance or reduce perceptions of safety in public space, focusing on women's experiences in particular. Three design interventions are examined: public toilets, solid walls, and graffiti removal. To test these interventions, an image-based randomised control trial with 104 participants was conducted in 2018 in London (UK). A series of control and treatment images simulating each design intervention was viewed and ranked by participants according to perceived safety. The findings of this study suggest that: the presence of public toilets does not affect perceived safety; eliminating graffiti has a weak significant impact on perceived safety; and removing solid walls leads to significant improvements of perceptions of safety, with the effect being stronger for women. These results suggest that to maximise investment effectiveness, urban design and planning policies that aim to increase perceptions of safety should be evidence-based, and need to integrate a gendered perspective. The presented technique could support urban design processes by examining the safety-enhancement impact of proposed public space interventions prior to their being rolled out.

1. Introduction

The ability to safely utilise the urban public realm has profound implications for people's wellbeing. A wealth of research (Anderson, Ruggeri, Steemers, & Huppert, 2017; Cattell, Dines, Gesler, & Curtis, 2008; Giddings, Charlton, & Horne, 2011) illustrates the benefits of public space utilisation including strengthened social inclusion, reinforced feelings of belonging and improved mental health. Studies also suggest that intensive use of public space can stimulate the local economy by boosting tourism and recreational activities and thereby increasing property values (CABE, 2004). Despite interest over recent decades in rejuvenating public spaces to stimulate their use – notably in

* Corresponding author.
E-mail address: pablo.navarrete@uchile.cl (P. Navarrete-Hernandez).

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Europe, the US and Latin America – concerns around inaccessibility and the exclusion of particular groups, among them women, from these spaces remain largely unaddressed (Cattell et al., 2008; Soraganvi, 2017).

According to Ratnayake (2013), concern for personal safety not only has a detrimental psychological effect but also limits a person's freedom and choice to move in a public space, thus reducing its use. Women as a group feature prominently in the literature on this subject, as it is argued that they face especially acute safety concerns when accessing public spaces and considering travel patterns. A large body of literature documents gendered differences in uses of and travel patterns in the public realm. Blöbaum and Hunecke (2005) argue that women's concerns of personal safety can result in their exclusion from outdoor sport and leisure activities, contributing to decreased use and a more muted city life. The perceived safety of a place may result in women altering or altogether cutting out travel to places perceived as dangerous (Koskela, 1997; Gargiulo et al., 2020). Concern for personal safety thus has often been found to preclude women from full and meaningful inclusion in public spaces, thus limiting opportunities to effectively reap the benefits to one's wellbeing that come from accessing the public realm (Blöbaum & Hunecke, 2005; Thynell, 2016; Valentine, 1990).

One promoted strategy to tackle issues of perceived safety in public space is the design and planning of the urban environment (Blöbaum & Hunecke, 2005; Dymén & Ceccato, 2012; Harvey, Aultman-Hall, Hurley, & Troy, 2015; Gargiulo et al., 2020; Jorgensen, Ellis, & Ruddell, 2002). Valentine (1990) argues that, particularly for women, "public environment can have an influence on…perception of safety and hence on their willingness to use spaces and places" (p.301), and so careful design and planning of public spaces should foster their use. A great deal of research details the consideration of perceived safety when designing and planning public spaces. Harvey et al. (2015) for instance, show how street skeleton – greenery, alignments and continuity of buildings and building street ratios – all impact perceived safety in public space, while Soraganvi (2017) argues that women are particularly deterred by poorly designed urban public spaces such as those with poor lighting, empty lots, lack of public toilets or inadequate signage.

While scholars argue for the importance of considering women's perceived safety when designing a space (Jiang, Mak, Larsen, & Zhong, 2017), these concerns are often neglected in practice (Burgess, 2008; Greed, 2005; Parker, 2016). This is due in part to a lack of practical evaluation tools and causal empirical evidence on their effectiveness in helping urban planners and designers to operate. For example, a recent Systematic Reviews and Meta-Analyses shows that while a range of built environment interventions have been hypothesised to increase safety perceptions, few empirical studies have shown their effectiveness, resulting in low-quality evidence owing to "possible confounders [involved in] complex social interventions such as these" (Lorenc et al., 2013), p.2. There is little evidence that widely used investment strategies such as improving street lighting or installing closed-circuit television (CCTV) have a significant impact on increased perception of safety.

In light of this evidence, we aim to assess the link between gender and perception of safety in public spaces while addressing some confounding factors seen in correlational studies[1]. By doing this, we provide a research strategy to test ex-ante the effectiveness of design interventions to enhance perceived safety using photo-simulations. To do this, we designed an image-based, randomised control trial (RCT) technique implemented through a purpose-built platform. We collected data from 104 participants in London (UK) in 2018 that stated their perceived safety of a series of control and treatment images representing three urban planning interventions in a public space: building public toilets, removing solid walls and removing graffiti. Through this experiment, we generated reliable estimates of whether these urban interventions have an impact on perceived safety in public space and whether there are differences between women and men.

The contribution of our paper is threefold. Firstly, we test the effectiveness of three widely promoted public space interventions on perceived safety on a sample of participants in London, providing evidence to promote designs that enhance safety perception in public space. Secondly, we present an explicitly gender-focused piece of work that adds evidence to the existing urban research on the relation of women's safety perception to the built environment. Finally, by conducting this study, we present a RCT methodology based on photo-simulated scenarios that urban researchers and practitioners could use as a low-cost technique for testing the impact of urban interventions on the perceived safety of a public space before they are ruled out.

In the next section, we present an overview of the relevant literature on public space and gendered perceptions of safety, detailing the three design interventions assessed in the study. This is followed by a methodology section covering the main considerations for the image-based RCT. We then present our findings with a focus on the gender difference in safety perception. Finally, we conclude with a discussion of the generalisability, limitations, and policy implications of this study.

2. Literature review

2.1. Public space: Gender inequality by planning and design

There is increasing evidence that access to and participation in public space[2] can offer a range of social, emotional, and psychological benefits (Anderson et al., 2017; Cattell et al., 2008; Garcia-Ramon, Ortiz, & Prats, 2004; Giddings et al., 2011; Mehta, 2014). Authors underline that the use of public space helps to build a sense of community by facilitating encounters and shared interactions, and promotes mental and physical health (Anderson et al., 2017; Cattell et al., 2008, Francis, Wood, Knuiman, & Giles-Corti, 2012; Gargiulo et al., 2020; Luymes & Tamminga, 1995). Studies have also linked the active use of and participation in public spaces with lower levels of exclusion and isolation. Sauter and Huettenmoser have even proposed that "public space is one of the crucial elements in any society for the social, cultural, economic and political inclusion of its members" (2008, p.68).

Nevertheless, the benefits of using the public realm are not equally shared among members of society, as certain social groups have difficulty accessing or are explicitly excluded from public space due to their gender, age, ethnicity, abilities, economic backgrounds or citizenship status (Cattell et al., 2008; Garcia-Ramon et al., 2004; Jabareen, Eizenberg, & Hirsh, 2019; Williams, Logan, Zuo, Liberman, & Guikema, 2020). On the one hand, socioeconomic inequalities are built into spaces through design and planning. Low-quality public spaces tend to agglomerate in low-income areas, while socioeconomic spatial sorting means that vulnerable groups, such as female-headed households, are often found to "bear the brunt of poor environments" (Cavanagh, 1998, p.172; Williams et al., 2020). Since studies show that the quality of public space is related to the intensity of its use, vulnerable groups are disproportionately impacted by poor quality public space due to limited choices in where they live and work, and how they travel. (Garcia-Ramon et al., 2004; Jorgensen et al., 2002). On the other hand, exclusion from the public realm might also result from the lack of diversity consideration in urban planning. Theoretical and empirical studies show that poor urban design and planning of public spaces can serve as a powerful form of exclusion, deterring people from not only accessing public spaces but from navigating them with dignity and without fear (Chiodi, 2016; Gargiulo et al., 2020; Luymes & Tamminga, 1995;

[1] For example, unobservable variables such as an individual's personality traits might influence their perception of safety in a public space. In contrast, an Image-Based RCT technique balances observable and unobservable covariables of individuals rating control and treatment images, making groups comparable.

[2] Used interchangeably with "public realm" in this paper.

Whitzman, 2013).

A vast body of literature recognises that design and planning do not take into account women's uses of and experiences in public space, even though they differ considerably from those of men (Burgess, 2008; Greed, 2005). These differences can be illustrated, for instance, by comparing distinct mobility patterns in cities by gender. Feminist scholars argue that broader structural factors can disproportionately affect women's movement patterns and experiences in cities around the world (Hanson, 2010; Beebeejaun, 2017; Chant, 2013). Women, for instance, are disproportionately responsible for caring and domestic duties and are overrepresented in part-time work. This results in women having more complex daily movement patterns and ultimately spending more time in public space than men (Levy, 2013; Garcia-Ramon et al., 2004; Whitzman, 2013). Generally, these considerations are not taken into account in urban planning, which instead bases its modelling methods on the male breadwinner's daily trajectory of "home–work–home". Current transport planning models thus find a failure to reflect "trip-chaining" travel patterns more common amongst women, such as "home–childcare–grocer–home–work–childcare–home" (Burgess, 2008; Greed & Johnson, 2014). Authors also argue that, due to having less access to private cars, women are more likely to walk or take public transport than men (Greed & Johnson, 2014; Whitzman, 2013). As a consequence, women may be exposed to encounters with strangers and therefore be significantly more concerned about safety when travelling (Thynell, 2016).

These analyses underline how planning and design reinforce gender inequalities. Investigating women's movements in and access to public space through the context of broader power structures highlights the need to consider and advance methods for the inclusion of women in the design and urban planning of public space (Cavanagh, 1998; Listerborn, 2016)[3].

2.2. Women's perception of safety in public space

A key factor credited in shaping women's movement in public spaces is fear of violence. Cavanagh (1998), p.169 argues that concern over personal safety profoundly shapes women's lives and will "largely determine when and where women will go". However, concerns of safety cannot be fully tackled simply by addressing crime – there is now robust evidence showing a lack of relationship between crime rates and perceived safety (Romer, Jamieson, & Aday 2003). A neighbourhood, for instance, can experience a reduction of crime over time while the perceived safety of its community remains unchanged. Notions of women's safety thus move beyond merely the "absence of violence" to meaningfully integrating women's perceived freedom and confidence in moving through and accessing public space without fear (Shaw, Andrew, & Whitzman, 2013).

Studies have shown that women feel less safe than men in public space, displaying a range of hypotheses for this. The vulnerability hypothesis argues that perceived safety is the product of an individual's conception of their own vulnerability to victimisation (Baur, 2007). Compared to men, women's physical and social vulnerability results in a greater perception of risk in the built environment (Skogan & Maxfield, 1981). Indeed, studies show that women's susceptibility to "harassment and (sexual) violence, including staring, groping, remarks and stalking as well as assault" (Whitzman, 2013), p.39 contribute to feeling less safe in public than men, regardless of reported crime rates (Pain, 1997; Warr, 1984). Conversely, the emotional gender-stereotypes hypothesis postulates that while women are encouraged to express their emotions, men are expected to repress these feelings, including fear (Sutton & Farrall, 2005). Men are taught to play a protective role and to believe that physical strength can prevent them from becoming victims of crime. This can lead to a tendency to minimise their fear and the risk of victimisation in a public space (Tulloch, 2000).

Existing correlational evidence explores the differing perspectives of men and women on the implementation of safety interventions in public space. For example, Yavuz and Welch (2010) indicate that the presence of cameras in public transit stations increases the perceived safety for both genders, with an impact notably higher in men. A UK study shows that while men can feel unsafe in the presence of groups of men, women can feel unsafe in the presence of a single man, with the reasons being gendered concerns of violence and sexual assault, respectively (Crime Concern, 2004). Research has also shown that women are more likely than men to avoid walking in dark public spaces, and to feel less safe in degraded or isolated spaces or from signs of uncivil behaviour such as vandalism or graffiti (Crime Concern, 2004; Yavuz & Welch, 2010; Gargiulo et al., 2020) and prefer to drive or take a taxi rather than walk (Atkins, 1989). This evidence suggests that policymakers should seriously consider a gendered perspective when planning public spaces if seeking to maximise perceived safety (Blöbaum & Hunecke, 2005; Pain, 1997; Valentine, 1990).

Despite the valuable work of the researchers noted above, such feminist perspectives remain peripheral to mainstream urban research and planning (Parker, 2016) while evidence remains correlational. As such, our study seeks to strengthen this body of work by offering causal evidence in support of the gendered nature of perceived safety in public space and practical methods to introduce a gendered lens in urban research and planning policy.

2.3. Focusing on interventions in the built environment

Several theories describe the potential mechanisms through which the built environment could impact perceived safety, leading to various urban design and planning strategies to address concerns of safety. Here we assess the impact of three theory-driven interventions commonly debated in the literature (Austin & Sanders, 2007; Beebeejaun, 2017; Greed, 2016; Chiodi, 2016; Jacobs, 1961): (1) the provision of public toilets based on feminist theories of women's restricted mobility, (2) the elimination of solid walls grounded in the "eyes on the street" theory of passive control, and (3) the removal of graffiti founded on the "broken windows" theory of stopping signs of disorder from spreading. [4]There are, however, many tensions and gaps in the literature surrounding these interventions, allowing for a valuable study to assess their impact on perceived safety.

2.3.1. Public toilets

Accessible and adequate public toilet provision in public space has been underlined as a key gendered issue affecting women's mobility and safety (Beebeejaun, 2017; Greed, 2016).

Inadequate toilet provision can serve to restrict the mobility of women in the public realm, as they tend to require access to toilets more often than men. Studies show that women generally urinate more frequently and may require increased toilet use for reasons related to menstruation, pregnancy or menopause (Greed, 2016), in addition to their prevalence as carers for vulnerable groups such as the elderly,

[3] It is also important to include an intersectional perspective as, for instance, women who are older, disabled or using a pram might have very different experiences navigating the same spaces as younger, able-bodied women without children (Whitzman, 2013; Gargiulo et al. 2020).

[4] While there are many other theories- and practice-driven interventions that could be tested, we have selected these interventions for three reasons. First, these interventions correspond to potentially competing, theory-driven strategies to transform the built environment in order to enhance safety perceptions. Second, there are divided opinions about their impact in the literature (graffiti, public toilets, and solid walls), so testing their effectiveness contributes with empirical evidence to the ongoing academic and practitioner debates. Finally, all of the three selected interventions are commonly present in London, and therefore they look like reasonable photo-simulated scenarios to participants.

children and people with disabilities (Afacan & Gurel, 2015). Research also shows that women are more frequent public transport users, often accompanying children or elderly family members (*ibid.*). As a result, a lack of provision in quantity and quality of toilets may restrict choices of routes and destinations for women.

Increased attention is being drawn to the link between public toilet provision and women's safety. In 2011, United Nations Women (UN-Women) argued that women's safety is compromised when female public toilets are situated in covert, poorly lit areas, and when men's public toilets open directly onto sidewalks (UN-Women, 2011). This report states that "better situated and maintained public toilets can go a long way in preventing sexual harassment of women" (p.7). It can thus be argued that adequate toilet provision and design help to increase women's perceived safety and, therefore, their participation in the public realm (Afacan & Gurel, 2015).

We seek to gain greater insight into how public toilets impact perceived safety, particularly for women.

2.3.2. Solid walls

A common strategy to promote safety is to establish an urban environment that ensures greater visibility of the public space, or allows for more "eyes on the street" (Chiodi, 2016). The frequently cited "eyes on the street" theory originates from sociologist and urban planner Jane Jacobs who suggests that more people, or "eyes," serve as a form of informal surveillance. By extension, it is argued that this increases the likelihood of witnesses and bystander intervention, thereby reducing crime and increasing perception of safety (Chiodi, 2016; Jacobs, 1961; Sweet & Ortiz Escalante, 2010; Scott et al., 2008). Interventions to promote more "eyes on the street" have included the strategic placement of windows and entrances, the redesign of green spaces and the removal of solid walls or similarly large obstructions to public space visibility (Chiodi, 2016; Cozens, Love, & Nasar, 2015). UN-Women (2011) also cited improved visibility, informal surveillance and "eyes on the street" as essential strategies to establish safer cities for women.

Despite its popularity, Jacobs' theory and similar approaches have received criticism, mainly due to a lack of causal evidence on the reduction of crime rates or improved safety perception through purposeful design (Anderson et al., 2013). Notwithstanding these critiques, correlational research and safety audits have demonstrated that people, particularly women, tend to feel less safe in closed-off, isolated areas, and often feel safer in well-maintained spaces that have more people, higher levels of activity and non-enclosed vegetation settings and are in streets lined with houses, shops, restaurants and windows (Cattell et al., 2008; Gargiulo et al., 2020; Harvey et al., 2015; Jorgensen et al., 2002; Mehta, 2014; Sandberg & Rönnblom, 2015).

We seek to add to causal evidence in determining whether or not improved visibility on the streets does indeed influence perceptions of safety in urban public space.

2.3.3. Graffiti

A number of studies have argued that graffiti can lower perceived safety by increasing fear of crime (Austin & Sanders, 2007; Mehta, 2014; Rader et al., 2012). These arguments draw from Wilson and Kelling's "broken windows" theory, which posits that vandalised, neglected and poorly maintained areas provide clues to criminal activity in the area and show that residents care little about the social or physical condition of their neighbourhood (Wilson & Kelling, 1982). Graffiti, in this context, is argued to indicate neighbourhood incivilities and a neglected urban environment, enhancing public fear and, therefore, concerns of safety (Adu-Mireku, 2002). Similarly, some gender-sensitive urban planning research has suggested that removing graffiti will specifically improve women's perceptions of safety (UN-Women, 2011; Valentine, 1990). "Tough on graffiti" policy approaches have thus been popular amongst many local governments, particularly in the UK (Vanderveen & van Eijk, 2016), pp.109.

Nevertheless, researchers have questioned this approach and its theoretical underpinnings, finding more nuance in the public's view of graffiti. Research has illustrated how people's perceptions of graffiti can differ vastly. It may be deemed as offensive or fear-inducing, welcomed as a form of art or condemned as a crime (Shobe & Banis, 2014). Indeed, graffiti consists of a variety of forms, ranging from smaller tags to large-scale street art, and these different forms may be regarded and valued differently (Austin & Sanders, 2007; Vanderveen & van Eijk, 2016).

We explore whether removing graffiti, specifically tags, from the urban landscape could be considered a useful strategy to help promote perceived safety, particularly among women.

2.4. Photosimulation and perceptions of safety in the built environment

Photo simulations, a technique that involves manipulating photographs to recreate changes to the built environment, has been widely used to understand people's preferences in urban planning and environmental psychology research (Jorgensen et al., 2002; Kuo, Bacaicoa, & Sullivan, 1998; Rodiek & Fried, 2005). It has been often used to study the impact of landscape changes, for example, the effect of river restoration on the satisfaction of individuals' needs (Junker & Buchecker, 2008), the influence of architectural design on adult's satisfaction with care home facilities (Cerina, Fornara, & Manca, 2017), or the effect of including car parks and natural elements over residents' preferences of commercial strip developments (Sullivan & Lovell, 2006).

A specific body of research uses photo-simulations to study the impact of built environment transformations on perceived safety. A number of studies focus on the effect of different types of green infrastructure on perceptions of safety, finding positive effects (Jiang et al., 2017, Kuo et al., 1998, Navarrete-Hernandez & Laffan 2019). A few studies have specifically utilized photo-simulation to assess urban environment transformations' impact on gendered perceptions of safety. One of these exceptions is Jiang et al. (2017) whose study simulates improvement of alleyways, showing that assigning both urban functions (e.g. cafes or bike parking) and vegetation contributes to closing the safety perception gap between men and women. Jorgensen et al. (2013) use the presence or absence of people in photos of public parks to show that perceptions of safety increase at a higher rate for men than women. This body of literature demonstrates that photo simulation can be used to understand people's preferences for urban environments and, particularly, perceptions of safety. In this study, we use photo simulation to inform the design of public spaces that enhance perceptions of safety, notably for further inclusion of women in public space.

3. Empirical strategy

3.1. Study design

To test the impact of these design interventions on perceived safety, we conducted an experiment to compare participants' perceptions of different urban spaces using computerised photo-simulations. We used an online platform, Urban Experiment (www.urban-experiment.com), to collect a data sample of 104 individuals walking in open streets in the London School of Economics (LSE) campus in 2018. Participants were presented with a series of six randomly assigned public space images, either control or treatment (with or without the incorporation of a safety-enhancing urban design or planning intervention, respectively), then rated them according to how safe they would feel walking alone in the presented public space. As with any RCT, this means that our results have strong internal validity, however, they should not be extrapolated to the larger population of London residents.[5]

[5] As we collected data from passers-by and volunteers near LSE, the sample of participants contains observable and unobservable characteristics that differ from the general London population. Therefore, the conclusion of this study applies to the sample and cannot be extrapolated to other populations directly.

Fig. 1. Photographic Simulations.

The images were modified to represent three types of urban space interventions: 1) the introduction of public toilets; 2) the elimination of continuous solid walls from a street, and 3) the removal of graffiti. To obtain comparable pairs of images, we modified the control and treatment images to maintain consistency of all relevant features (cars, people and weather, among others) excluding the intervention being tested. We then obtained six pairs of images equal in all components, save for the treatment (Fig. 1).

3.2. Sampling method

We installed a stand outside the LSE Library over the weekday period of July 16–20, 2018. We approached potential participants and asked them to participate in a six-minute experiment. We did not offer monetary compensation or rewards. Volunteers completed a registration questionnaire requiring their socioeconomic information, read an experiment protocol and signed an informed consent form. Participants

Table 1
Descriptive statistics.

Variables	Mean	S.D.	Min.	Max.
Gender (Female)	0.5	0.502	0	1
Birth Year	1993	5.111	1960	2000
Educational Level (University Degree or Above)	0.8	0.403	0	1
Disability (Yes)	0.04	0.195	0	1
Student Status (No)	0.19	0.396	0	1

were instructed to imagine themselves walking in the location shown in each image and to state their perception of safety on a scale from 1 (not at all safe) to 10 (very safe). Each participant saw a series of six randomly allocated full-screen images.

We selected this in-field experimental approach for two reasons. Firstly, conducting the study not in a laboratory but instead in a more natural setting can help to relax participants, potentially encouraging them to respond more authentically (Cheung et al., 2017) yet retain "the key experimental feature [of]…random assignment important for inferences of causality" (Pager, 2007), pp.109. Secondly, approaching participants 'in-the-field' is a strategy commonly used in urban planning and design and thus replicable in this setting (Navarrete-Hernandez & Laffan, 2019).

To ensure that covariates were balanced among control and treatment groups, we used an automated, dual-randomisation process. Firstly, we randomised the order of each pair of images presented. This allows controlling for any possible spillover effect that might affect participants' responses from one image to the next. Secondly, for every pair of images, we randomly assigned whether a control or treatment image would be seen. This allowed for the balanced assignment of covariates between the control and treatment groups. We conducted balance tests for each type of intervention to determine whether systematic differences were observed by gender, age, ethnicity, disability, employment status, educational level and order of image appearance. Across twenty-one conducted tests, none were significant at the 5% level, indicating a successful randomisation (output tables available on request).

3.3. Data set

To perform our analysis, we use three sources of data: 1) background characteristics; 2) measures relating to the experimental conditions; and 3) participants' perceptions of safety. The socio-demographic data collected from participants' questionnaires provided information on gender identity, year of birth, ethnicity, student status and educational level. Descriptive statistics of participants are presented in Table 1. The second source of data collected was the experiment conditions of each image, including treatment status, order of appearance and the date of the test. The participants' declared perception of safety from 1 to 10 for each image is the dependent variable in the study.

3.4. Empirical strategy

The purpose of this experiment is to test whether three selected interventions affect people's perceptions of safety, and how this varies with gender. To analyse this, we use random intercept models with fixed effects at the image level. We include the random intercept to account for the presumption that each participant might have a unique predisposition to feel safe. We include an image's fixed effects to control for each image's average safety rating. The models take the following form:

$$Perception_{ij} = \beta_1 Treatment_i + \beta_2 Image_i + U_j + E_{ij} \quad (1)$$

where $Perception_{ij}$ is the declared perception of safety of participant j for image i. Treatment is a dummy variable equal to one if the *i*th image contains a public space intervention (treatment) and 0 otherwise (control). β_1, the Average Treatment Effect, is the central coefficient of interest which captures the impact of the interventions on participants' reported safety. $Image_i$ is an image fixed effect for the *i*th image. U_j is the random intercept associated with the *j*th individual. E_{ij} is the error term.

We analyse the impact of design and planning interventions in the following ways. Firstly, we run EQ.1 at an aggregate level to estimate the overall impact of selected interventions on participants' perceived safety. Following that, we run EQ.1 on the three subsamples to test the impact of each intervention type. Finally, we run EQ.1 in gendered subsamples to explore the impact of interventions by gender.

3.5. Robustness checks

We examine the robustness of results by running EQ.1 with and without control variables (EQ.2). Control variables include a respondent's socio-demographic characteristics (gender, age, educational

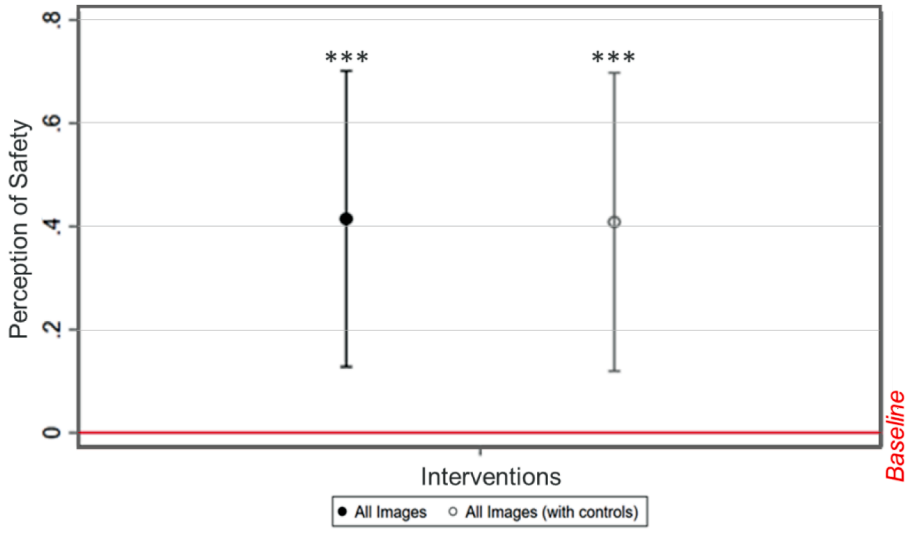

Fig. 2. Impact of Safety Enhancement Interventions (All Interventions) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared with images with no interventions. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

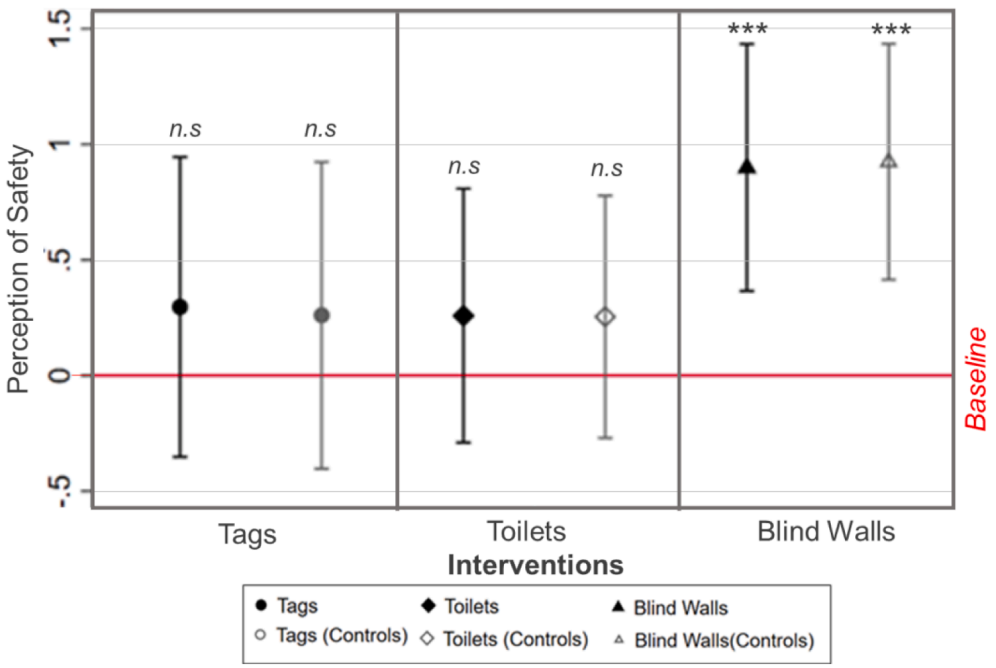

Fig. 3. Impact of Safety Enhancement Intervention (By intervention type) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared with images with no interventions. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

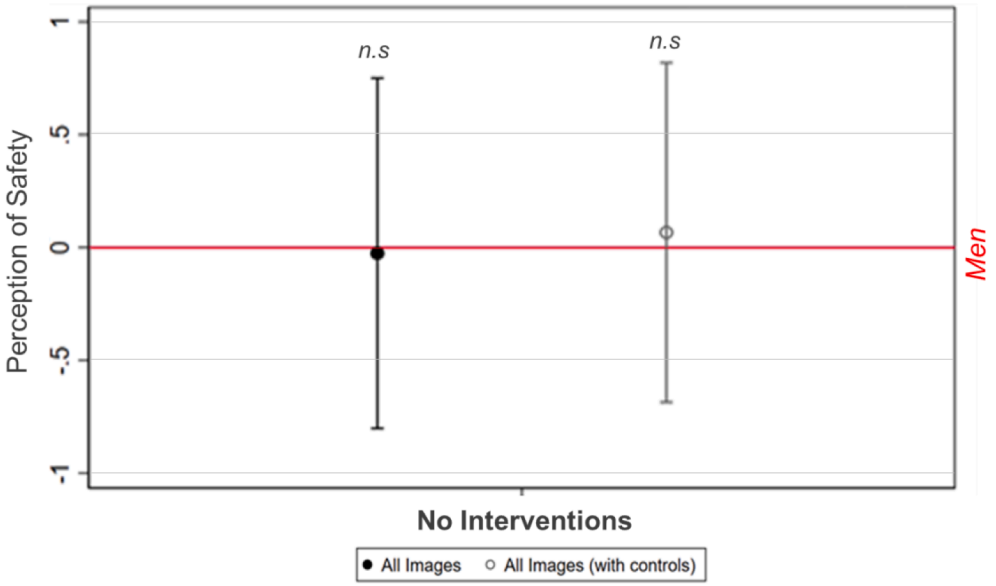

Fig. 4. Gendered Perception of Safety Without Interventions Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared to men's safety perception score. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

level, disability and employment status) as well as two study conditions: the time and day of the response. The model takes the following form:

$$Perception_{ij} = \beta_1 Treatment_i + \beta_2 Image_i + \beta_3 X_{ij} + U_j + E_{ij} \quad (2)$$

The model takes the same form as EQ.1 with the exception of X_{ij} - which contains the demographic variables for participant j and study condition measures for image i.

4. Results

4.1. General findings for all participants

In this section, we study perceived safety by all genders in public space. We perform two analyses with the aim of understanding: 1) whether interventions have their desired impact on perceived safety; and 2) which, if any, of the three explored interventions are most effective.

4.1.1. Are safety enhancement interventions effective?

As Fig. 2 shows, on the whole, the incorporation of these

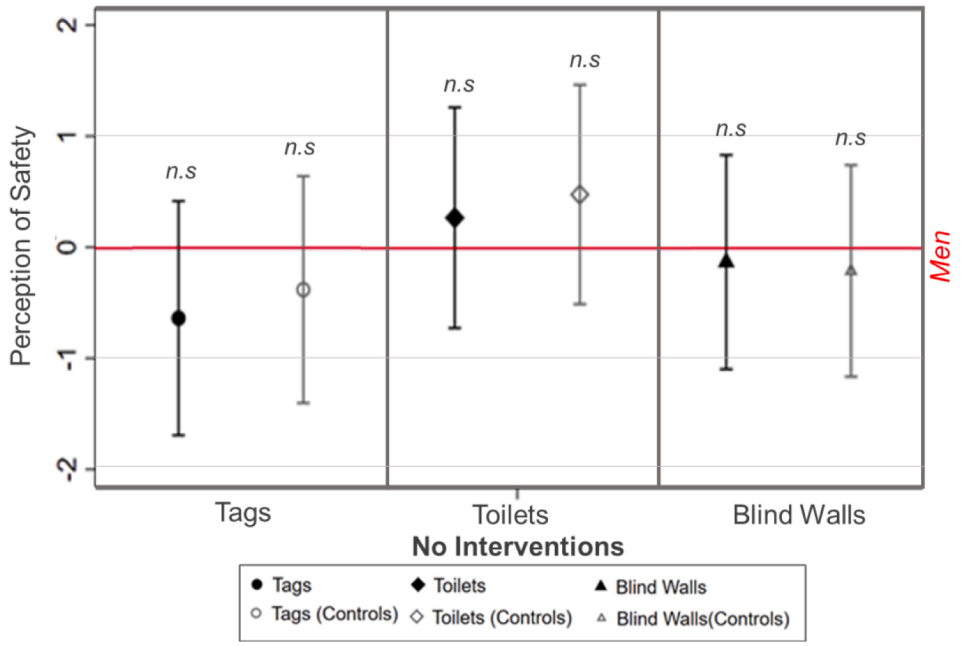

Fig. 5. Gendered Perception of Safety Without Interventions (by Interventions Types) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared to men's safety perception score. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

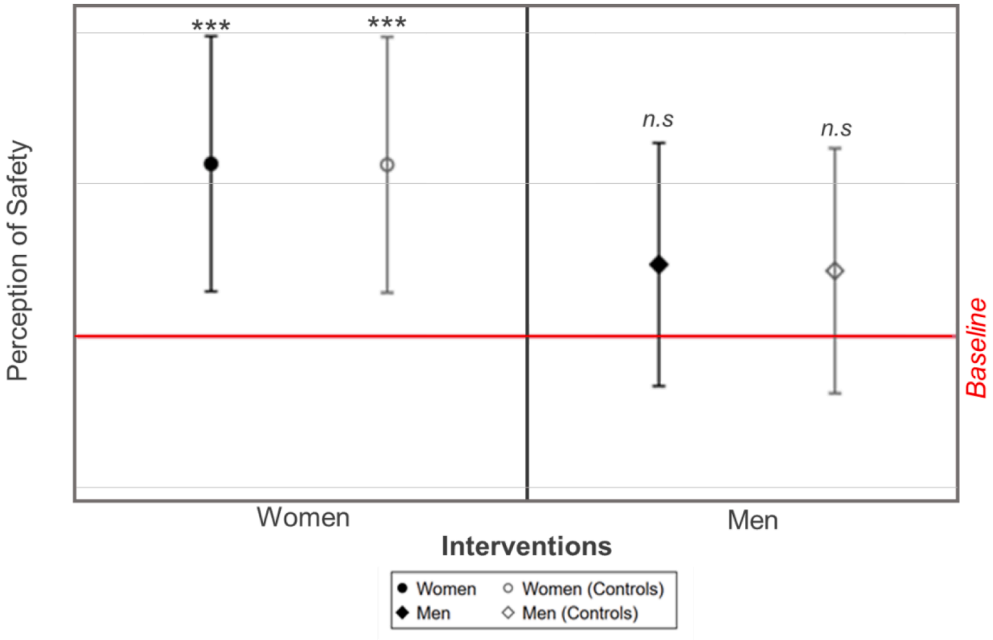

Fig. 6. Impact of Safety Enhancement Interventions by Gender (All Interventions) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared with images with no interventions. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

interventions significantly enhances participants' perceptions of safety. As shown in column 1 of Table 2.A (see Appendix), using the full pooled sample, design interventions significantly increase perceived safety in public space (estimate = 0.415, S.D. = 0.146, p = 0.005), while column 2 shows that the consideration of socioeconomic and experimental condition controls has no substantial impact on the estimates.

4.1.2. *Which safety enhancement interventions are effective?*

Fig. 3 illustrates the change in the participants' safety perceptions following each of the three types of interventions. As Table 2.B (columns 1 and 3) indicates, we find a positive, though statistically insignificant, increase in perceived safety for removing tags (estimate = 0.297, S.D. = 0.331, p = 0.370) and building public toilets (estimate = 0.258, S.D. = 0.280, p = 0.357). As column 5 in Table 2.B shows, the removal of solid walls is the only intervention that has a statistically significant impact on

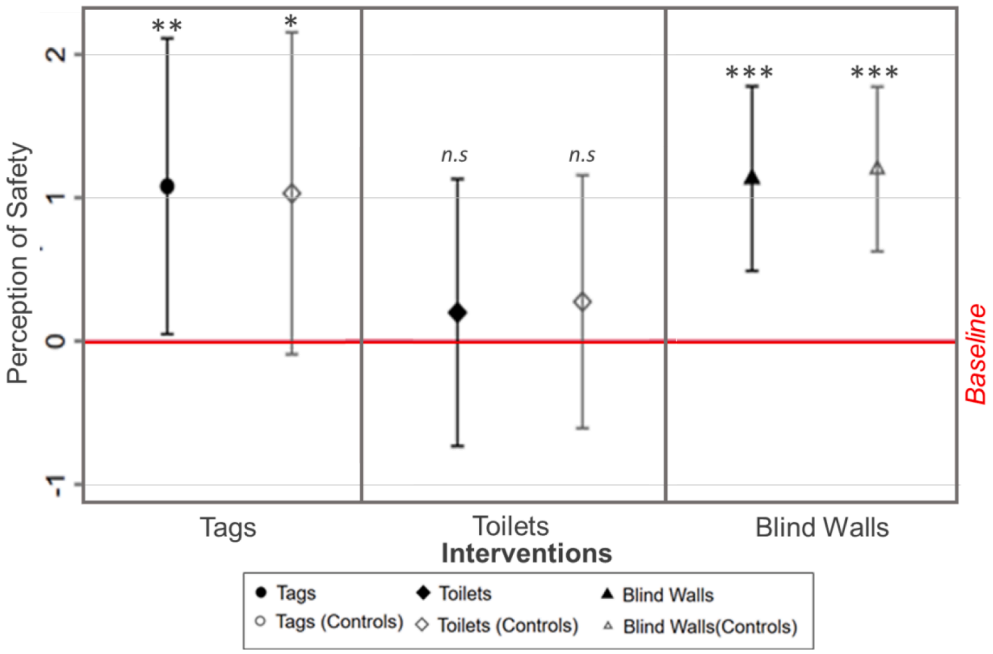

Fig. 7. Impact of Safety Enhancement Interventions for Women (by Intervention Type) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared with images with no interventions. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

enhancing perceived safety (estimate = 0.900, S.D. = 0.273, p = 0.001). As shown in columns 2, 4 and 6 in Table 2.B, these results remain stable with the addition of controls.

4.2. General findings by gender

The following subsection explores how findings varied depending on a participant's gender identity. To assess this, we break the interventions down by gender and intervention type. We perform three different data analyses to determine: 1) whether overall perceived safety in a public space varies by gender; 2) whether the impact of interventions varies by gender; and 3) the most effective interventions for each gender.

4.2.1. Gendered perception of safety

We first run an exploratory analysis to test the hypothesis that public space is perceived differently by women and men. For this, we analyse participants' perceived safety level for images containing a typical London street landscape, i.e. without any toilets, graffiti or significant solid walls.[6] Fig. 4 displays the differences between women and men (baseline) on their public space safety perception, pooling all without intervention images. The results suggest that on average, women and men feel equally safe viewing the control images that represent a typical London street landscape. As column 1 in Table 2.C (see Appendix) shows, perceived safety of female participants is marginally less than that of male participants, with the difference being statistically insignificant (estimate = -0.638, S.D. = 0.362, p < 0.860). As column 2 in Table 2.C shows, this result is robust with the addition of eight controls.

These results are consistent throughout the analysis of control images for each type of intervention. As Fig. 5 indicates, we do not find significant gendered differences in perceived safety of non-intervened street images for any of the tested typologies (absence of tags, absence of public toilets, and absence of solid walls). As columns 2, 4, and 6 in Table 2.D indicate, these results are robust with the addition of control covariates.

[6] We run the regression using safety perception ratings for images 1. B, 2.B, 3. A, 4.A, 5.B, and 6.B in Fig. 1.

4.3. Intervention type findings by gender

4.3.1. Does the effectiveness of safety enhancement interventions differ by gender?

Fig. 6 indicates that the tested urban planning interventions have a significant positive impact on perceived safety for women (estimate = 0.572, S.D. = 0.215, p < 0.008) whereas the increase for men is smaller and not statistically significant (estimate = 0.238, S.D. = 0.205, p < 0.247). The estimated impacts on perceived safety remain stable with the incorporation of controls; see Table 2.E in the Appendix for more details.

4.3.2. Which safety enhancement interventions are effective?

Fig. 7 shows the impact of the three studied street interventions on women's perception of safety in public space. As Table 2.F indicates (column 1), there is a strong increase in female participants' perceived safety by removing solid walls facing streets (estimate = 1.136, S.D. = 0.329, p < 0.001). As columns 3 and 5 in the same table show, the removal of street tags has a significant positive impact on female participants' perceived safety (estimate = 1.084, S.D. = 0.207, p = 0.039), while the addition of public toilets to public space has a positive, yet not significant, impact (estimate = 0.201, S.D. = 0.207, p = 0.672). As columns 2, 4 and 6 in Table 2.F indicate, with the addition of controls, the results for the addition of toilets and removal of solid walls remain stable, while the results for the removal of street tags become weakly significant (p = 0.071).

Fig. 8 illustrates the differences in male participants' reported perceptions of safety before and after the incorporation of the three interventions. As Table 2.G (columns 1, 3 and 5) indicates, the removal of street tags has a negative impact, (estimate = -0.458, S.D. = 0.358, p = 0.241) while the addition of public toilets (estimate = 0.348, S.D. = 0.304, p = 0.251) and removal of solid walls (estimate = 0.652, S.D. = 0.420, p = 0.120) have a positive impact on perceived safety. However, none of the changes are statistically significant. As shown in columns 2, 4, and 6 of Tablet 2.G, the estimated impact on perceived safety remains stable with the addition of controls.

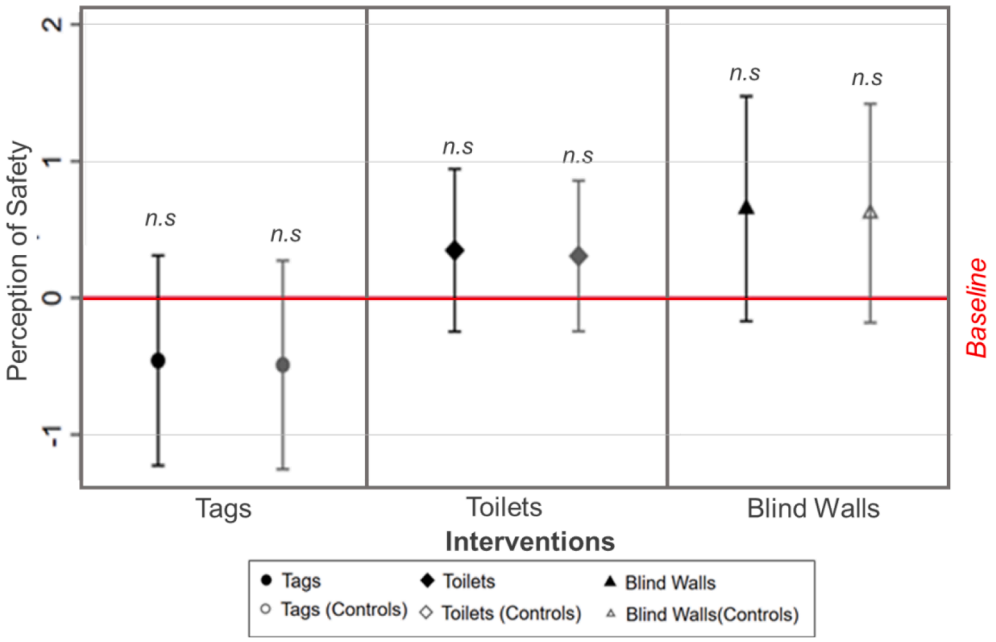

Fig. 8. Impact of Safety Enhancement Interventions for Men (by Intervention Type) Note: Regression results are plotted with and without controls. Each point represents the average treatment effect compared with images with no interventions. Capped spikes represent 95% confidence intervals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, n.s no significant.

5. Discussion

The central objective of this study is to provide a research tool to test ex-ante the effectiveness of design interventions to enhance perceived safety using photo-simulations. In doing so, this work adds to causal evidence on the relationship between three urban interventions and gendered safety perceptions. This image-based technique has enabled us to produce a priori evidence of the expected impacts of proposed design and planning interventions.

Overall, the findings of this study suggest that certain design interventions can have a significant impact on enhancing perceived safety, and also highlight the differences of these impacts by gender. When considering the entire sample, urban interventions have a positive and statistically significant impact on perceived safety in the public space. Separating the results by intervention type, we find that although each intervention have a positive estimate, we only find a significant impact for the removal of solid walls This finding supports the component of Jacob's "eyes on the street" theory that people feel less safe in areas containing potentially isolating structures, such as solid walls and visibility-reducing barriers (Sandberg & Rönnblom, 2015). Conversely, people feel safer in spaces containing rows of housing that line streets with windows (Chiodi, 2016).

When assessing the treatment by gender, we can observe gendered differences in these impacts. Typical streets without interventions showed no difference in perceived safety by gender. When analysing all interventions by gender, we found that perceptions of safety only increase significantly for women. This suggests that, although there may not be a systematic difference in perceived safety by gender in a typical public space, women are more sensitive to improvements in public space. Overall, these findings support feminist theories of the gendered nature of safety perception in public space, and that a gendered approach to urban design and planning is needed to close this gap (Burgess, 2008; Soraganvi, 2017; Valentine, 1990).

In further analysis, we assess perceived safety by type of intervention and gender combined. We found that removing solid walls significantly increases perceived safety for women only, while eliminating graffiti is shown to have a similar positive effect, although weakly significant. For men, interventions have no significant impact on perceived safety. This finding supports claims that more isolated streets – with fewer opportunities for surveillance and bystander intervention – make women feel more unsafe than men in the same location; a gendered interpretation of the "eyes on the street" theory. When considering the removal of graffiti, the results should be taken with caution. While our study suggests that the presence of graffiti has a negative impact on perceived safety for women, research does also indicate that tags, as used in this study, are often reported to be the least popular type of graffiti (Shobe & Banis, 2014). Therefore, other graffiti typologies, such as murals, may not be wholly perceived as a negative feature of public space (Vanderveen and van Eijk, 2015).

Our research did not find evidence that the addition of public toilets increases perceptions of safety. As such, we cannot conclusively solve the ongoing debate over whether the addition of public toilets improves perceived safety, thereby facilitating women's increased movement in public space (Afacan & Gurel, 2015).

This study is not without its limitations. The current findings correspond to a convenience sample of passers-by in a street within a London university campus. Subsequently, this study incorporates a large proportion of students and young adults, and was carried out in an affluent area of London, in Summer. As such, results cannot be extrapolated to other population groups or other seasons of the year. Similarly, the category of "women" is not invariable but nuanced and complex, given the multifaceted identities of women (Crenshaw, 1989). While there is no a priori reason to believe the recorded effects would show opposite outcomes or disappear in other samples, they may vary when considering an intersectional perspective, including factors such as ethnicity (Dymén & Ceccato, 2012; Sandberg & Rönnblom, 2015). In future, we plan to collect a larger sample with a diversity of ethnicities, allowing us to identify any effects that these variables may have on our findings.

A further consideration is the exposure of participants solely to photo-visual landscapes. Research shows that the interaction of visual and audial stimuli can enhance people's perceived emotions (Annerstedt et al., 2013). Furthermore, photo stimuli provide a non-immersive environment compared to video and virtual reality technologies. Environmental factors such as temperature, observers' point of view, or the scent of a place all impact people's experience of public space, and therefore can interact with visual factors to either enhance or diminish

Table 2
Impact of Safety Perception Enhancement Interventions.

A. All Genders

	All Interventions	
VARIABLES	(1)	(2)
Treatment	0.415***	0.409***
	(0.146)	(0.148)
Controls	No	Yes
Constant	6.551***	8.407***
	(0.260)	(0.750)
Observations	831	831
Number of groups	104	104

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B. All Genders (By intervention type)

	Tags		Toilets		Solid Walls	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.297	0.260	0.258	0.254	0.900***	0.925***
	(0.331)	(0.339)	(0.280)	(0.268)	(0.273)	(0.261)
Controls	No	Yes	No	Yes	No	Yes
Constant	6.607***	8.111***	6.446***	7.937***	5.970***	8.427***
	(0.293)	(0.894)	(0.308)	(1.056)	(0.265)	(0.897)
Observations	208	208	311	311	312	312
Number of groups	104	104	104	104	104	104

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

C. Men and women (typical street)

	Baseline	
VARIABLES	(1)	(2)
Women	-0.0256	0.0665
	(0.396)	(0.384)
Controls	No	Yes
Constant	6.582***	7.872***
	(0.404)	(1.126)
Observations	412	412
Number of groups	103	103

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D. Men and women by intervention type (typical street)

	Tags		Toilets		Solid Walls	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Women	-0.604	-0.377	0.0937	0.484	-0.338	-0.205
	(0.547)	(0.521)	(0.512)	(0.504)	(0.495)	(0.487)
Controls	No	Yes	No	Yes	No	Yes
Constant	7.323***	7.721***	5.411***	6.592***	7.558***	9.251***
	(0.814)	(1.644)	(0.677)	(1.431)	(0.791)	(1.481)
Observations	98	98	170	170	144	144
Number of groups	67	67	95	95	88	88

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

E. Men and women (Treatment effect)

	Women		Men	
VARIABLES	(1)	(2)	(3)	(4)
Treatment	0.572***	0.568***	0.238	0.217
	(0.216)	(0.216)	(0.205)	(0.207)
Controls	No	Yes	No	Yes
Constant	6.398***	8.043***	6.789***	8.968***
	(0.407)	(1.462)	(0.319)	(0.821)
Observations	407	407	416	416
N. of groups	51	51	52	52

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

F. Women's perceived safety (by intervention type)

	Tags		Toilets		Solid Walls	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	1.084**	1.034*	0.201	0.277	1.136***	1.202***
	(0.526)	(0.573)	(0.476)	(0.451)	(0.329)	(0.293)
Controls	No	Yes	No	Yes	No	Yes
Constant	6.157***	6.545***	6.404***	7.062***	5.726***	8.813***
	(0.477)	(1.785)	(0.495)	(1.766)	(0.402)	(1.858)
Observations	102	102	152	152	153	153
N. of groups	51	51	51	51	51	51

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

G. Male perceived safety (By type of intervention)

	Tags		Toilets		Solid Walls	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.458	-0.489	0.348	0.307	0.652	0.619
	(0.390)	(0.387)	(0.304)	(0.281)	(0.420)	(0.408)
Controls	No	Yes	No	Yes	No	Yes
Constant	7.124***	9.191***	6.512***	8.772***	6.251***	8.357***
	(0.310)	(1.038)	(0.374)	(1.188)	(0.348)	(0.870)
Observations	104	104	156	156	156	156
N. of groups	52	52	52	52	52	52

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

these results. However, we selected an image-based method for three reasons. First, this method is affordable, thus it can be implemented by urban designers and planners in developed and developing countries alike. Second, it provides insights into the impact the built environment has on one of the most important senses used to navigate urban space: the visual sense. Finally, photo-simulations' ratings produce a conservative, lower-bound estimate of the impact of visual changes of an urban landscape, rendering it a reliable tool for decision making. This is because if we find significant results with low visual stimuli, we expect to obtain larger estimates through more immersive methods or in reality. Furthermore, research shows that perceived safety does not differ significantly between static images and more immersive media representation (Rossetti & Hurtubia, 2020).

A final restriction of the study is the limited number of images. Although in this experiment we measure the impact of urban interventions on people's perceptions of safety while holding constant other image elements (e.g. people, cars, vegetation and lighting), we cannot test the contextual impact of where an intervention is placed. Further studies should, therefore, test an intervention in different urban contexts to understand the robustness of results across city contexts.

The methodological approach presented in this study has the potential to feed a gendered perspective into everyday urban design and planning in public spaces. An image-based RCT could be incorporated, for example, into urban regeneration strategies that test – through participatory processes – the impact of different design prototypes and separate results by gender in order to ensure that women's perceptions

of safety are considered. Moreover, by associating geotagged coordinates with the images, this technique could be used as a planning tool to identify the location of urban spaces that women perceive as unsafe, and then to rapidly prototype and test interventions at minimal cost. Conducting this type of experiment, along with follow up interviews, could provide researchers with insights into what works to increase women's perceptions of safety, and also why this is the case and what are the mechanisms at play. Finally, running this type of image-based RCT using a more representative sample could increase the external validity of this type of study.

6. Conclusion

This study explores whether urban design and planning interventions in public space have an impact on perceived safety and whether the results vary by gender. By doing so, we contribute – with causal evidence – to the existing literature on gendered theories of the urban public realm, while also offering a practical methodological tool to incorporate a gender-attentive approach in everyday urban policy and research. This tool allows researchers and practitioners to identify effective design and planning interventions to enhance perceived safety amongst women.

Despite limitations, the study provides further evidence that strengthens existing theories of gendered differences in public space. While feminist or gender-focused approaches to urban design and planning practice remain at the margins (Parker, 2017; Burgess, 2008), this study's findings provide clear evidence to support the efforts to adopt a gender-sensitive approach to create safe and inclusive built environments. Although our study provides insights into the gendered perceptions of safety in public space, our sample was primarily young, non-disabled, highly educated students. Further studies casting a broader sample can investigate if perceptions of safety differ not only for women of different ethnicities but also for older women, carers, and women with disabilities. Applying the presented research tool with an intersectional approach can then help to design built environments that better serve all women considering their differing identities.

When planning and designing the urban environment, consideration of the needs of women alone will not solve the deep-rooted issues of gender inequality and violence against women in public space (Burgess, 2008; Listerborn, 2003; Sandberg & Rönnblom, 2015). However, it is a necessary step for the inclusion of women on equal grounds in the public realm (Beebeejaun, 2017). As feminist scholars have argued, thoughtful gender-attentive planning can play an essential role in helping to design a built environment where women feel the freedom and confidence to move through and access public space without fear (Levy, 2013). In this way, they may better experience the advantages and rewards associated with their inclusion and participation in urban life.

CRediT authorship contribution statement

Pablo Navarrete-Hernandez: Visualization, Methodology, Validation, Software, Data curation, Writing - original draft, Writing - review & editing. **Arielle Vetro:** Conceptualization, Investigation, Data curation, Writing - original draft, Writing - review & editing. **Paz Concha:** Conceptualization, Writing - original draft, Writing - review & editing.

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

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