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Robots are coming to town: A visual experiment on urban belonging and anxiety

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ABSTRACT

Robots are becoming increasingly common in urban social environments and this is likely to cause emotional reactions among people. Utilizing theoretical frameworks of social identity approach and integrated threat theory, we investigated a sense of belonging to and perceived anxiety toward an urban environment with robots. We conducted a visual survey experiment using a representative sample of Finnish adults ($N = 1226$). Results based on multilevel regression analysis showed that, compared to deserted settings or settings with humans, robots in urban spaces decreased a sense of belonging to and increased anxiety toward an urban environment. Participants who were living in less urban areas, older, or neurotic reported a lower sense of belonging. Women and people that were living in less urban areas, young, neurotic, or introverted reported higher perceived anxiety. The results suggest that new technologies like robots in urban spaces can bring forth also feelings of anxiety and disruption for the sense of belonging, at least for some people. Hence, introduction of these technologies should be considered carefully in urban planning. Our study contributes to the theoretical discussions on place identity and examining anxiety as a disruption of the identification process.

1. Introduction

We are currently witnessing a rapid transition toward using artificial intelligence (AI) in many occupational fields and life domains (Ayoko, 2021; Beam et al., 2023; Marikyan, Papagiannidis, & Alamanos, 2019). Robotization is part of this process (De Vries, Gentile, Miroudot, & Wacker, 2020; Lu et al., 2020; Rubio, Valero, & Llopis-Albert, 2019; Savela, Turja, & Oksanen, 2018; Taipale, De Luca, Sarrica, & Fortunati, 2015; Yam et al., 2022). Robots have been designed and introduced into households over recent years (Fortunati, 2018; Kalisz, Khelladi, Castellano, & Sorio, 2021) and proposed as a solution to avoid human contact during pandemics (Coombs, 2020; He, Zhang, & Li, 2021; Shen et al., 2020; Wang & Wang, 2021; Zemmar, Lozano, & Nelson, 2020). Public places are also being robotized, as private corporations have sought to attract customers by deploying robotic technology in customer service (Savela et al., 2018), and public agents have harbored innovation spaces for experimenting with future technology in such spaces (While, Marvin, & Kovacic, 2021).

Smart city development has become a central part of urban planning and there has been a growing interest toward usage of intelligent technologies like robots especially in smart city strategies across major cities (Angelidou, 2017; Yang, 2020). While more intelligent solutions exist that are currently deployed in urban cities (Martínez-Plumed, Gómez, & Hernández-Orallo, 2021), scholars of urban studies argue that smart city discussions have been steered by the needs of technology developers and have neglected the potential of failed technological transitions and the consequences in the social domain (Luque-Ayala & Marvin, 2015). Thus, researchers have called for more social scientific research on smart cities (Feher & Katona, 2021) and investigations on cities' advanced technology development from different perspectives for more nuanced understanding of utopian or dystopian scenarios (Ylipulli & Luusua, 2020). Although the notion of smart cities includes various type of advanced technology solutions aside from robots, discussions around smart cities show the pressure and motivation to design and implement AI and robotic technologies to unpredictable and public urban environments.

Urban architecture and infrastructure of today are designed for people, which is a challenge for the design of mobile robots operating in such environments (Alterovitz, Koenig, & Likhachev, 2016). In addition to technical challenges, implementing notable unfamiliar elements to people's daily work and living environments can alter their perceptions of those environments. Significant changes in familiar surroundings can be a potential source of anxiety and disruption to citizens' place

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attachment and sense of belonging (Phillips, Walford, Hockey, Foreman, & Lewis, 2013; Rishbeth & Powell, 2013). As it is the citizens who are most affected and can to some extent decide where to live or work, they will ultimately judge the value and usefulness of the new additions to the environments they inhabit daily. To understand the potential societal change that novel technologies such as robots may cause, it is critical to investigate citizens' perspectives on robotization of streets and other urban environments. Imagination is a useful tool for such investigations as examining people's expectations and reactions to possible or fictive future scenarios offers novel insights on robots' impact on the environments designed for people and their relations with people (Bina, Inch, & Pereira, 2020; Sumartojo et al., 2021).

In this study, we aim to fill the current gap in human–computer interaction research investigating citizens' reactions to urban spaces with robots. We utilized an experimental survey design with visual stimuli to investigate a sense of belonging to and anxiety toward urban environments. The theoretical framework of our research consists of theories on social identity approach (Postmes, Tanis, & De Wit, 2001; Schwarz & Watson, 2005; Tajfel & Turner, 1979; Turner, Hogg, Oakes, Reicher, & Wetherell, 1987; Wu & Lin, 2016), integrated threat theory (Stephan, Renfro, & Davis, 2008; Stephan & Stephan, 2013), place identity (Dixon et al., 2022; Peng, Strijker, & Wu, 2020; Proshansky, Fabian, & Kaminoff, 2014), psychological security in urban spaces (Wang, Long, Chen, & Li, 2019), and familiarity principle (Reis, Maniaci, Caprariello, Eastwick, & Finkel, 2011). This is the first study to investigate affective reactions to robots in an urban environment using experimental design with a representative population-wide survey.

1.1. A sense of belonging to and anxiety toward urban environments

Researchers have long investigated psychological and social factors in perceptions of built environments from viewpoints other than technology. Humans have a need to belong socially to each other (Baumeister & Leary, 1995; Deci & Ryan, 2008) and to the environments in which they live (Hauge, 2007; Twigger-Ross & Uzzell, 1996). In addition to the immediate neighborhood, the sense of belonging can extend to the city of residence (Liu, Zhang, & Wu, 2022). According to the view of relational ecologies of belonging, connections to places and cultural identities are interconnected and formed through relationships with other humans and other-than-human entities (Poe, LeCompte, McLain, & Hurley, 2014). Physical settings such as home, school, work, and neighborhood influence the formation of place-identity related to people's social roles (Proshansky, Fabian, & Kaminoff, 1983). Although a sense of place and belonging to neighborhood are connected to social factors, they can be nonreflexive and subconscious (Jørgensen, 2010). People living in urban societies have often become disconnected from places and local communities, but this has been argued to increase the value of place and a longing for community (Inalhan & Finch, 2004).

Researchers have studied the role of identity and emotional connection with the environment using multiple concepts, such as environmental identity (Clayton, 2012), sense of place (Pourbahador & Brinkhuijsen, 2023), human geography (Mallett, 2004), human–place bonding (Kyle, Graefe, Manning, & Bacon, 2004; Lewicka, 2008), place attachment, and its two components, place identity and dependence (Kyle et al., 2004; Lewicka, 2008). Place identity has proven to be a useful concept to highlight physical environment's significance in identity formation as one level of identity (Hauge, 2007). However, some have argued that social psychological theories, such as social identity theory and identity process theory, are more useful and empirically supported in explaining the connection of identity to place (Hauge, 2007). Hinds and Sparks (2008) utilized the theory of planned behavior and highlighted the utility of social psychological theories in examining emotional factors and attachment to urban space by showing that affective connection is associated with intentions to interact with the environment. Place attachment and identification are critical factors for prosperous cities as they have been linked to the commitment to remain in the environment (Tournois & Rollero, 2020).

Considering the role that emotions play in belonging to urban spaces, anxiety, fear, and other negative affects that urban surroundings cause could impact people's ability to relate to their environments and therefore disrupt their sense of belonging. Researchers have studied urban environments from the perspectives of well-being factors, such as psychological distress (Gong, Palmer, Gallacher, Marsden, & Fone, 2016), psychological security (Wang et al., 2019), perceived safety, and fear of crime (Loewen, Steel, & Suedfeld, 1993). In the criminology literature, fear has been the prominent conceptualization for the emotional response citizens might experience regarding the potential threat of victimization (Ditton & Farrall, 2017) although emotional states such as anxiety, worry, concern, anger, and irritation have also been targets of interest (Ditton, Bannister, Gilchrist, & Farrall, 1999; Hough, 2004). Context situatedness and the neighborhood effect demonstrate how the physical environment influences emotional states, such as fear of crime (Pain, 2000). Concerns about neighborhood disorder might lead to increased insecurity and anxiety levels, but the mere modern urban way of living and even positive change in it can also cause anxiety (Farrall, Jackson, & Gray, 2009).

Anxiety has also been addressed in the literature of urban environments and belonging. Research on place identity has suggested an anxiety and defense function where an individual can get anxious and alarmed of potential danger when the physical environment is too far from their place identity cognitions (Dixon et al., 2022; Peng et al., 2020; Proshansky et al., 2014).

According to anxiety research, a distinction should be made between situational anxiety and a personality trait. In contrast to individual differences in trait anxiety, which is the tendency to express anxiety across situations, state anxiety would demonstrate a more situational response to a new encounter, place, or otherwise potentially fear- or insecurity-producing situation (Chadee, Virgil, & Ditton, 2009).

1.2. Identification with and anxiety toward robotic technologies

In addition to places, people become attached to other nonhuman targets, such as pets (Tovares, 2010) and objects (Wheeler & Bechler, 2021), and can form a strong sense of belonging to or a shared identity with them. People have been argued to perceive human-like and social qualities in nonhuman entities, such as technology, and treat them like they would treat other humans (Reeves & Nass, 1996). A similar argumentation has been stated in the case with social robots that people perceive as social or moral agents (Banks, 2019). While some researchers have speculated that advanced social features could lead to stronger emotional bonds with social robots (Gonzalez-Jimenez, 2018), others have argued that humans could ultimately reject robots as trustworthy members of a social group (Groom & Nass, 2007). Nevertheless, perceiving robots as social actors leads to the reality that interacting with robots can cause equally positive or negative reactions and consequences as socializing with humans can (Nash, Lea, Davies, & Yogeeswaran, 2018).

Robots and AI agents are defined as entities that can sense their environment and perform tasks with some level of automation (ISO, 2021; ISO, 2022). The difference is that robots take actions in the physical world (ISO, 2022). A typical appearance for an industrial robot is a mechanical arm, which is also present in future trend imaginaries outside of manufacturing industry (IFR, 2022). Examples for urban settings include robotic lawnmowers, delivery robots, and robotic cars (Macrorie, Marvin, & While, 2021; Verne, 2020). However, due to the influence of science fiction it is not uncommon for people to imagine a humanoid robot when they think of robots (Kajita, Hirukawa, Harada, & Yokoi, 2014). Designing humanoid robots have also been seen as essential for future society (Saeedvand, Jafari, Aghdasi, & Baltes, 2019). The imagery of robots implemented in urban settings is likely to change over time as the technology develops and future will reveal how realistic science fiction and other futuristic images of robots in urban environments will eventually be.

To aid decision-making and designing both robotic technologies and urban areas, it is important to gain insight into potential reactions to and psychosocial consequences of different future scenarios upfront. In previous studies on human–robot interaction and social identification, researchers have examined, for instance, robot workforce influence on intergroup prejudice and anxiety (Jackson, Castelo, & Gray, 2020), the impact of anthropomorphism on ingroups and outgroups with robots (Fraune, 2020), identification with work teams shared with robots (Savela, Kaakinen, Ellonen, & Oksanen, 2021), and the impact of age identity on perceptions of AI (Edwards, Edwards, Stoll, Lin, & Massey, 2019). Although findings point toward preference for humans as ingroup members and social interaction partners, robots seem to somewhat fulfill social needs in the absence of human contact (Latikka et al., 2021; Lee, Jung, Kim, & Kim, 2006; Pirhonen, Tiilikainen, Pekkarinen, Lemivaara, & Melkas, 2020). Researchers have not previously examined identification with urban places inhabited by robots.

Human–robot interaction literature on social processes also includes studies on emotional reactions to robots. Previous findings include, for example, negative written reactions to working with robots (Savela, Oksanen, Pellert, & Garcia, 2021). Naneva, Sarda Gou, Webb, and Prescott (2020) found in their systematic review that people tend to feel slightly anxious toward robots. However, Naneva et al. (2020) speculated that the design of current social robots might appear less threatening, which could affect the reaction to some extent. Despite the human–robot interaction studies researchers have conducted in urban environments, such as museums and shopping malls (Savela et al., 2018), prior literature does not include studies on anxiety toward urban scenarios with robotic technologies utilizing representative population data.

1.3. Theoretical background and hypotheses development

The theoretical framework of our research consists of theories on social identity approach, integrated threat theory, familiarity principle, place identity, and psychological security in urban spaces. People have a desire to belong to their environments (Hauge, 2007; Twigger-Ross & Uzzell, 1996). In addition, as social identity approach and a strong body of social psychological research evidence demonstrate (Postmes et al., 2001; Schwarz & Watson, 2005; Tajfel & Turner, 1979; Turner et al., 1987; Wu & Lin, 2016), people have a need to relate to others and are more inclined to do so with similar others (Baumeister & Leary, 1995; Deci & Ryan, 2008; McPherson, Smith-Lovin, & Cook, 2001). Familiarity principle suggests that people are attracted to familiar things (Reis et al., 2011). Thus, we expected people to feel a stronger sense of belonging in urban environments that populate other people and therefore to have a decreased sense of belonging in environments populating robots.

H1: Having robots in an urban space decreases a sense of belonging.

Drawing on integrated threat theory, realistic or symbolic threats can increase negative emotions, such as anxiety (Stephan et al., 2008; Stephan & Stephan, 2013). Robots could pose a realistic or symbolic threat to urban residents increasing their discomfort and prejudice against urban spaces inhabiting robots (Vanman & Kappas, 2019). An anxiety and defense function of place identity has been suggested to alarm individuals of potential threat in the physical environment, causing anxiety and avoidance (Dixon et al., 2022; Peng et al., 2020; Proshansky et al., 2014). From the perspective of psychological security, if robots increase the perceived risk and uncertainty in the surrounding environment, they can evoke feelings of fear and anxiety (Wang et al., 2019). Familiarity principle suggests that people are prone to react negatively toward new and unfamiliar things (Reis et al., 2011). Therefore, we expected robots to evoke more anxiety than a deserted setting or people in an urban environment.

H2: Having robots in an urban space increases anxiety.

The hypotheses were pre-registered to Open Science Framework (Oksanen, Savela, Latikka, & Lahtinen, 2021). In addition to the main hypotheses, we designed our study to include control variables of image background, perceived level of a living area's urbanization, extraversion, neuroticism, and avoidance of social contact during the COVID-19 pandemic, in addition to gender and age.

2. Method

2.1. Participants and procedure

To conduct the experiment, we collected survey data in May–June 2021 designed to represent the Finnish population ($N = 1226$; 49.92 % male; $M_{age} = 48.43$; $SD = 17.33$; range = 18–80). The sample was collected as part of larger research project and the sample size was determined beforehand by the aim to collect as representative sample as possible that enables analysis of different sub-groups and enough statistical power. Based on power analysis this sample size can detect robust effect sizes with lower than 1 % false-positive rate. The research group designed the survey and collected data in collaboration with Norstat, utilizing Norstat's online research panel for recruiting participants. The response rate for the survey was 30.81 %. The sample size was not increased after any data analysis. Five respondents were excluded from the final sample based on quality checks including tests for straightlining. The data closely represented the 2020 official statistics of 18–80 aged Finnish population (Official Statistics of Finland, n.d.) based on age and gender distributions (49.90 % male, $M_{age} = 48.40$). The Ethics Committee of the Tampere Region stated that the study design does not include any ethical issues. We conducted the survey in Finnish, and participation was voluntary.

In our within-person survey experiment procedure, we showed participants three images (see, Appendix A), after which we asked them each time to rate first their perceived anxiety toward and then their sense of belonging to the urban environment in the image. We manipulated the main elements the three images showed (robots, humans, empty) while controlling for their background (concrete, glass, or red brick buildings). To consider the influence of the order of the stimuli, we primed each participant with three images with the following main elements in a random order: one empty, one with humans, and one with robots. To minimize the background's impact, the three images had three different backgrounds in the following order for all participants: concrete buildings, glass buildings, and red brick buildings. To avoid complicating the design further, we did not randomize the order of the three images presented to each participant based on background. Thus, only the three main elements were seen in a random order by the participants.

We randomly assigned the respondents to six groups, which dictated which three of the nine unique images we showed them (see Appendix B). Hence, they saw and reacted to one of the six possible 3-image series. We found no statistically significant differences between the six participant groups in terms of gender, age, extraversion, or neuroticism, which suggested a successful randomization of participants into experimental groups. Our study's visual imagery was chosen based on robotic technology definitions, examples, and future trends suggested in the literature (IFR, 2022; ISO, 2021; ISO, 2022; Kajita et al., 2014; Macrorie et al., 2021; Saeedvand et al., 2019; Verne, 2020).

2.2. Measures

This study's two dependent variables were a sense of belonging to and anxiety toward an urban environment. The experimental stimulus variable was the study's main independent variable, indicating whether the hypothetical urban environment scenario included robots or humans or was deserted. The control variables included visual background, perceived level of a living area's urbanization, extraversion, neuroticism, avoidance of social contact during the COVID-19 pandemic, gender, and age.

2.2.1. Urban belonging

To measure a sense of belonging to the urban environment shown in hypothetical visual scenarios, we utilized a 3-item measure. The items were adapted from a social and emotional loneliness scale for adults (DiTommaso, Brannen, & Best, 2004; DiTommaso & Spinner, 1993). Before rating three statements, the participants were asked to imagine that the image represents their living environment. The items were "I closely belong to this urban space," "This urban space is important to me," and "I am a part of an urban space where I am cared for." The respondents rated the statements on a scale from 1 (*totally disagree*) to 7 (*totally agree*). The scale ranged from 3 to 21, and its interitem reliability was good in all nine unique scenarios ($\omega = 0.88$–0.95; $M_{\omega} = 0.92$).

2.2.2. Anxiety

To measure perceived anxiety toward images of urban environments in the hypothetical scenarios, we utilized a short 6-item version (STAI-6) of the state subscale of the Spielberger State—Trait Anxiety Inventory (Marteau & Bekker, 1992). Before rating six statements about their current state, the participants were asked to imagine themselves to the urban environment of the image. The respondents rated on a scale from 1 (*does not describe my state at all right now*) to 7 (*completely describes my state right now*) the following adjectives: "calm," "tense," "upset," "relaxed," "content," and "worried." The scale ranged from 6 to 42, and its interitem reliability was good in all nine unique scenarios ($\omega = 0.84$–0.88; $M_{\omega} = 0.86$).

2.2.3. The experimental stimulus

To measure the main stimulus's effect, we used a variable indicating which of the three stimuli (robot, people, empty) we showed the participants before they rated their perceived anxiety and sense of belonging. To control for the possible effect of the order of the main stimulus, each participant saw one of each stimulus in a randomized order. In the models, we utilized the experimental stimulus variable as a categorical variable, using robot stimulus as a reference category.

2.2.4. Control measures

Visual Background. To control for the background's possible effect, we used a visual background variable that also indicated the order in which the three backgrounds were shown to the participants. For every participant, the first image had concrete buildings in the background, the second image had buildings with glass elements, and the third image showed buildings made from red bricks. In the models, we used the visual background variable as a categorical variable and concrete buildings as a reference category.

Perceived Urban Living Area. To control for how familiar the participants were with urban environments, we asked them to rate their living area's perceived urban quality with the question, "How urban of an environment do you live in?" Possible responses ranged from 1 (*not at all urban*) to 7 (*very urban*).

COVID-19 Social Avoidance. To account for the possible effect the COVID-19 pandemic has had on individuals' social behavior, we asked the participants to rate how much they have restricted their contact with other people during the crisis on a scale ranging from 1 (*not at all*) to 7 (*very much*).

Extraversion and Neuroticism. We measured extraversion and neuroticism with 3-item subscales from the 15-item big five personality inquiry (Hahn, Gottschling, & Spinath, 2012). Possible answers to the statements varied from 1 to 7, and the final range for the sum of the variables in each trait was 3–21. The scales' internal consistency was good for both extraversion ($\omega = 0.88$) and neuroticism ($\omega = 0.78$).

Gender and Age. We used "male" as a reference category for gender, and we used age as a continuous variable. Table 1 shows descriptive statistics of the study variables, and Appendix C contains Pearson correlation coefficients.

Table 1
Descriptive statistics of the study variables.

Measure	*n*	*M*	*SD*	Range	*n* of items	ω
Sense of Belonging	3678	9.59	4.92	3–21	3	0.92
Robots (main stimulus)	1226	8.75	4.77	3–21	3	0.92
Empty (control stimulus)	1226	9.62	4.84	3–21	3	0.92
People (control stimulus)	1226	10.42	5.01	3–21	3	0.92
Concrete (background)	1226	9.42	4.83	3–21	3	0.90
Glass (background)	1226	9.50	4.90	3–21	3	0.93
Red brick (background)	1226	9.86	5.02	3–21	3	0.94
Anxiety	3678	21.61	7.98	6–42	6	0.86
Robots (main stimulus)	1226	24.30	8.27	6–42	6	0.87
Empty (control stimulus)	1226	20.93	7.54	6–42	6	0.85
People (control stimulus)	1226	19.60	7.35	6–42	6	0.85
Concrete (background)	1226	22.64	8.10	6–42	6	0.86
Glass (background)	1226	21.95	7.82	6–42	6	0.86
Red brick (background)	1226	20.24	7.83	6–42	6	0.86
Perceived urban living area	1226	4.35	1.91	1–7	1	
Avoidance of social contact	1226	4.82	1.75	1–7	1	
Extraversion	1226	13.80	4.57	3–21	3	0.88
Neuroticism	1226	11.68	4.10	3–21	3	0.78
Age	1226	48.43	17.33	18–80	1	
Gender	1226				1	
Female	614 (50.08 %)					
Male	612 (49.92 %)					

Note. 1226 participants and 3678 observations for a sense of belonging and anxiety.

2.3. Analysis methods

We performed all statistical analyses with Stata 16 software and computed McDonald's omega (ω) coefficients with a Stata module (Shaw, 2020) to estimate scale reliability. Table 1 reports descriptive results for the study variables, including means (*M*), standard deviations (*SD*), range, frequencies (*n*), and proportions (%). In addition to descriptive statistics, we computed multilevel regression models using Stata's mixed command with robust estimation of variance and unstructured variance. For these main analysis models and effect sizes, in Table 2 and Table 3, we report unstandardized regression coefficients (*B*), their estimated robust standard errors (*SE B*), and statistical significance (*p* value). The main models included 1226 participants and 3678 observations. We report all data exclusions, manipulations, and measures utilized in this study.

3. Results

The descriptive results showed that participants expressed the lowest sense of belonging ($M = 8.75$) and highest anxiety ($M = 24.30$) when urban spaces included robots. Table 2 and Table 3 show the main results based on the multilevel regression models. We found that the sense of belonging was lower when the visual stimulus in the urban space included robots, in contrast to empty space ($B = 0.87, p < .001$) or space with other people ($B = 1.68$, $p < .001$). Similarly, robots increased anxiety, compared to empty space ($B = -3.31, p < .001$) or space with other people ($B = -4.70, p < .001$).

Table 2
Linear multilevel regression model predicting a sense of belonging in the experiment.

	B	Robust *SE*	95 % CI	*p*
Stimulus (ref. robot)				
Empty	0.87	0.10	[0.68, 1.06]	<0.001
People	1.68	0.11	[1.47, 1.88]	<0.001
Background image (ref. concrete)				
Glass	0.10	0.09	[−0.08, 0.28]	0.289
Red brick	0.44	0.11	[0.23, 0.65]	<0.001
Perceived urban living area	1.02	0.06	[0.90, 1.14]	<0.001
COVID-19 social avoidance	0.01	0.07	[−0.12, 0.15]	0.843
Extraversion	0.04	0.03	[−0.01, 0.09]	0.137
Neuroticism	−0.07	0.03	[−0.14, −0.01]	0.025
Gender (female)	−0.45	0.24	[−0.92, 0.01]	0.058
Age	−0.02	0.01	[−0.03, −0.01]	0.004

Note. 1226 participants and 3678 observations for a sense of belonging.

Table 3
Linear multilevel regression model predicting anxiety in the experiment.

	B	Robust *SE*	95 % CI	*p*
Stimulus (ref. robot)				
Empty	−3.31	0.22	[−3.74, −2.89]	<0.001
People	−4.70	0.22	[−5.14, −4.26]	<0.001
Background image (ref. concrete)				
Glass	−0.67	0.20	[−1.07, −0.27]	0.001
Red brick	−2.36	0.22	[−2.79, −1.93]	<0.001
Perceived urban living area	−0.75	0.09	[−0.93, −0.57]	<0.001
COVID-19 social avoidance	−0.01	0.11	[−0.22, 0.19]	0.889
Extraversion	−0.13	0.05	[−0.22, −0.04]	0.006
Neuroticism	0.35	0.05	[0.26, 0.45]	<0.001
Gender (female)	1.35	0.35	[0.67, 2.03]	<0.001
Age	−0.03	0.01	[−0.05, −0.01]	0.003

Note. 1226 participants and 3678 observations for anxiety.

Compared to concrete background images, a sense of belonging was slightly higher for the red brick background ($B = 0.44$, $p < .001$), and anxiety was higher for both glass ($B = -0.67$, $p = .001$) and the red brick background ($B = -2.36$, $p < .001$). From other control variables, higher perceived level of urbanization of a participant's living area had a positive connection to the sense of belonging ($B = 1.02$, $p < .001$) and a negative connection to anxiety ($B = -0.75$, $p < .001$). Neuroticism had a weak negative connection to the sense of belonging ($B = -0.07$, $p = .025$) and a slight positive connection to anxiety ($B = 0.35$, $p < .001$), and extraverted people reported slightly lower anxiety ($B = -0.13$, $p = .006$). Women reported higher anxiety ($B = 1.35$, $p < .001$) toward the presented urban scenarios. In addition, higher age had very weak negative connections to both the sense of belonging ($B = -0.02$, $p = .004$) and anxiety ($B = -0.03$, $p = .003$).

4. Discussion

In this experimental survey study, we investigated whether robots in urban environments decrease people's sense of belonging to the environment and increase their anxiety. Based on our results, people report more anxiety and a lower sense of belonging in the urban environment when it includes only robots than when it is empty or includes only people. These main results supported our hypotheses (H1−H2).

In addition to the main hypotheses, the results from the control factors revealed that urban environments with other people were perceived as least anxious and most relatable, compared to deserted urban environments and especially environments populated by robots. Among the Finnish respondents, backgrounds with concrete buildings evoked the most anxiety, compared to glass and especially red-brick backgrounds. The sense of belonging did not differ between concrete and glass building backgrounds, but Finnish citizens reported a stronger sense of belonging to urban environments that included buildings made of red bricks. Participants who were living in less urban areas, older, or neurotic reported a lower sense of belonging to the urban environments of the scenarios. Women, people that were living in less urban areas, young, neurotic, or introverted reported higher perceived anxiety toward the urban environments of the scenarios.

4.1. Theoretical and practical implications

The results contribute to the theoretical work on the connection between place and identity and to examining anxiety as a disruption of the identification process. Research on social identity approach (Postmes et al., 2001; Schwarz & Watson, 2005; Tajfel & Turner, 1979; Turner et al., 1987; Wu & Lin, 2016) demonstrates that people are more prone to interact with and relate to similar others (Baumeister & Leary, 1995; Deci & Ryan, 2008; McPherson et al., 2001). The familiarity principle, on the other hand, suggests that unfamiliarity might produce a negative response, such as anxiousness, and that people more easily feel affection and emotional connections with familiar targets (Reis et al., 2011). Our results support these arguments by showing that people prefer urban spaces that populate other humans the most and even deserted urban environments to the more unusual scenarios with robots.

Our results expand the empirical evidence of the connection of identity with place and nonhuman entities and suggest that seeing robotic technology and no humans in urban surroundings may disrupt the feelings of attachment and belonging that could otherwise emerge toward the introduced scenarios of urban spaces. In addition to the familiarity principle (Reis et al., 2011), this finding supports arguments based on integrated threat theory (Stephan et al., 2008; Stephan & Stephan, 2013), which propose that robots might present realistic and symbolic threats to humans and result in negativity and prejudice (Vanman & Kappas, 2019). Our findings also align with the idea of how a physical environment that is too far from one's place identity cognitions can pose a threat and cause anxiety and avoidance (Dixon et al., 2022; Peng et al., 2020; Proshansky et al., 2014).

Our study provides some implications for the discussion of urban planning in a prospect where robots become more common in urban settings. Although some studies argue that robots could fulfill social needs in the absence of human contact (Latikka et al., 2021; Lee et al., 2006; Pirhonen et al., 2020), our findings suggest that strong robotization of urban spaces can have negative consequences for citizens' psychological well-being and their ability to fulfill their social needs in urban environments. To ensure success in implementing robotic technology and securing citizens' well-being, designers and decision-makers should consider not introducing robotic technology to urban spaces too abruptly and making sure they are not too intrusive or dominating the landscape.

Increasing citizens' knowledge of robotic technologies has also been highlighted as critical in socio-technical transitions and attitudes toward robots (Pekkarinen et al., 2020). A sense of belonging is a vital factor for prosperous cities as affective connection and attachment have been linked to intentions to interact with and the commitment to remain in the environment (Hinds & Sparks, 2008; Tournois & Rollero, 2020). Previous studies from the work domain have reported that being the only human in a social environment with robots may have negative psychosocial consequences (Savela, Kaakinen, et al., 2021; Savela, Oksanen, et al., 2021). The present findings highlight how important the presence of other people is for decreasing anxiety and building a sense of belonging in urban places.

4.2. Strengths, limitations, and future research direction

A significant strength of our study was the fact that we utilized nationally representative large-scale survey data from a Finnish population and adapted validated measures to examine anxiety toward and a sense of belonging to urban environment. Our visual experiment enabled us to study possible future scenarios that could be hard to imagine without such stimuli. Using multilevel mixed regression models provided means for assessing both between- and within-person effects in a case where participants rated multiple scenarios.

However, our study has certain limitations that need to be acknowledged when drawing conclusions from the findings. As a visual experiment, the results reflect the robotic technology imagery present in this study. Future studies should examine whether the hypotheses hold true across visual stimuli about urban spaces with different types of robots or other technology. Future experiments could also integrate an image including both humans and robots to yield more nuanced results. The present study did not focus on and was not designed to measure how people's reactions toward urban environments differ based on different building elements. This aspect was used as a control factor for the background (red bricks, glass, concrete). Although our results from the Finnish population imply a preference for red brick in terms of our dependent variables (anxiety, a sense of belonging), it should be noted that cultural and geographical dependencies apply. Our study also focused on highly urban environment and futuristic imaginary. Our aim was to study people's reactions to possible but not necessarily realistic urban scenarios and, thus, they may prove to be unrealistic in the future. As all subjects of our study are Finnish citizens, future research could validate our results with nationally representative samples collected from other populations from various cultural backgrounds for the results to be considered generalizable to other populations.

5. Conclusions

New generation robots of different shapes and forms are increasingly entering not only homes and workplaces but also public places and urban environments. These robotic technologies are designed to aid people in various tasks and increase the efficiency of different operations. This technological transformation will lead to changes also in urban landscapes and alter the ways how the urban environments are perceived by people. Our visual experiment based on a possible world scenario suggests that people feel more anxious about an urban space with robots and that their sense of belonging to such an environment is weaker, compared to deserted urban environments or urban spaces shared with other people. In addition to our main findings, we found that in contrast to people living in urban areas, older and neurotic people seem to be less inclined to belong to urban environments while women and young, neurotic, and introverted people might be more anxious toward urban spaces in general. These observations will contribute to the scientific discussions and our understanding of people's perceptions in urban spaces. Overly robotized urban landscapes devoid of other humans may compromise human psychological well-being, which should be considered in urban planning and decision-making.

Author note

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The authors do not have a conflict of interest to declare.

The academic ethics committee of the Tampere region stated that the research project did not include any ethical problems. Participation in the study was voluntary, and participants were informed about their opportunity to withdrawn from the study. The data that support this study's findings are available from the corresponding author upon reasonable request. The hypotheses were pre-registered to Open Science Framework (Oksanen et al., 2021).

Author contributions (CRediT)

Nina Savela: Conceptualization, methodology, formal analysis, investigation, data curation, writing (e.g., original draft, review, and editing), visualization, and funding acquisition. Rita Latikka: Conceptualization, investigation, data curation, writing (e.g., original draft, review, editing), and funding acquisition. Jussi Lahtinen: Conceptualization, investigation, resources, visualization, and funding acquisition. Atte Oksanen: Conceptualization, methodology, investigation, data curation, writing (e.g., original draft, review, editing), supervision, project administration, and funding acquisition.

Data availability

Data will be made available on request.

Appendix A. Three example images of the visual stimuli shown to one group of participants (Group 2)

Appendix B. Order, background, main element, and image id of the visual stimuli by experimental group

Experimental group	Order of the image	Background	Main element	Image ID
Group 1 ($n = 209$)	1st	Concrete	People	1
	2nd	Glass	Robots	5
	3rd	Red brick	Empty	9
Group 2 ($n = 219$)	1st	Concrete	People	1
	2nd	Glass	Empty	6
	3rd	Red brick	Robots	8
Group 3 ($n = 201$)	1st	Concrete	Robots	2
	2nd	Glass	People	4
	3rd	Red brick	Empty	9
Group 4 ($n = 222$)	1st	Concrete	Robots	2
	2nd	Glass	Empty	6
	3rd	Red brick	People	7
Group 5 ($n = 185$)	1st	Concrete	Empty	3
	2nd	Glass	People	4
	3rd	Red brick	Robots	8
Group 6 ($n = 190$)	1st	Concrete	Empty	3
	2nd	Glass	Robots	5
	3rd	Red brick	People	7

Appendix C. Pearson correlation coefficients of the study variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Sense of Belonging (robot stimulus)	1.00																	
2. Sense of Belonging (empty stimulus)	**0.73**	1.00																
3. Sense of Belonging (people stimulus)	**0.70**	**0.79**	1.00															
4. Sense of Belonging (concrete background)	**0.84**	**0.80**	**0.80**	1.00														
5. Sense of Belonging (glass background)	**0.81**	**0.85**	**0.84**	**0.74**	1.00													

(*continued on next page*)

(*continued*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
6. Sense of Belonging (red brick background)	**0.76**	**0.85**	**0.84**	**0.68**	**0.74**	1.00												
7. Anxiety (robot stimulus)	**−0.54**	**−0.29**	**−0.26**	**−0.40**	**−0.36**	**−0.31**	1.00											
8. Anxiety (empty stimulus)	**−0.38**	**−0.53**	**−0.42**	**−0.41**	**−0.45**	**−0.45**	**0.51**	1.00										
9. Anxiety (people stimulus)	**−0.36**	**−0.43**	**−0.53**	**−0.40**	**−0.45**	**−0.46**	**0.46**	**0.67**	1.00									
10. Anxiety (concrete background)	**−0.40**	**−0.31**	**−0.29**	**−0.48**	**−0.27**	**−0.24**	**0.74**	**0.63**	**0.60**	1.00								
11. Anxiety (glass background)	**−0.45**	**−0.42**	**−0.42**	**−0.35**	**−0.56**	**−0.36**	**0.67**	**0.71**	**0.71**	**0.49**	1.00							
12. Anxiety (red brick background)	**−0.42**	**−0.47**	**−0.45**	**−0.34**	**−0.40**	**−0.60**	**0.54**	**0.76**	**0.74**	**0.44**	**0.55**	1.00						
13. Perceived urban living area	**0.37**	**0.41**	**0.41**	**0.43**	**0.39**	**0.36**	**−0.14**	**−0.20**	**−0.18**	**−0.15**	**−0.19**	**−0.17**	1.00					
14. COVID-19 social avoidance	0.00	0.00	0.02	0.00	−0.01	0.03	0.04	0.03	−0.01	0.04	0.03	0.00	0.04	1.00				
15. Extraversion	0.01	0.01	0.04	0.03	0.01	0.01	**−0.08**	**−0.11**	**−0.17**	**−0.12**	**−0.13**	**−0.10**	−0.04	0.04	1.00			
16. Neuroticism	**−0.10**	−0.04	−0.04	**−0.07**	−0.06	**−0.06**	**0.29**	**0.22**	**0.22**	**0.28**	**0.23**	**0.20**	0.01	**0.13**	**−0.30**	1.00		
17. Age	0.00	**−0.12**	**−0.09**	−0.05	**−0.10**	**−0.07**	**−0.23**	−0.03	**−0.09**	**−0.19**	**−0.09**	**−0.07**	−0.05	0.03	**0.17**	**−0.28**	1.00	
18. Gender	**−0.10**	−0.03	−0.02	−0.04	**−0.07**	−0.03	0.19	**0.10**	0.04	**0.16**	**0.13**	0.04	0.02	**0.16**	**0.15**	**0.23**	0.03	1.00

Note. p values < .05 are indicated with bold font.

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