



Crowding and aggression during the COVID-19 lockdown in the United Kingdom: The relationship between residential density, subjective crowding, privacy, and aggression

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ABSTRACT

Background: During national lockdowns in response to the COVID-19 pandemic, individuals were confined to their home environment for prolonged time with limited options to leave the dwelling. European comparative housing polls suggest social density in the home environment (square meters per person) are highest in the United Kingdom, making potentially detrimental costs to home dwellers during national lockdowns more likely. While research has extensively studied the relationship between social density and aggression across different settings, including housing, there has been limited exploration of the connection between subjective crowding and aggression, despite evidence suggesting its stronger influence. Moreover, previous studies have indicated that privacy might mediate the link between social density conditions and psychological experiences, necessitating further investigation.

Objective: This study examined the relationships between residential density, subjective crowding, and perceived privacy and its psychological costs, specifically focusing on aggression during the COVID-19 lockdown. Specifically, the study examined the sequential relationship of residential density on subjective crowding on self-reported aggression. Perceived privacy was hypothesized to mediate the relationship between residential density and subjective crowding.

Methods: An online cross-sectional survey was conducted with individuals ($n = 299$) using the crowd-sourcing platform Prolific during the COVID-19 lockdown in June 2020 in the United Kingdom.

Results: Path analysis with bootstrapping was used to examine the hypothesized relationships in three hierarchical models. The first model showed that self-reported aggression levels were higher for those experiencing greater levels of residential density. In the second model, residential density was found to be associated with subjective crowding, which in turn was associated with aggression. The association between subjective crowding and aggression (model two) was stronger than between residential density and aggression (model one). In the final model, perceived privacy was included as a mediator between residential density and subjective crowding, and this relationship was found to be statistically valid. This suggests that when there is a shortage of objective living space per person within a household, it can affect how residents perceive their ability to control privacy, resulting in feelings of crowding and subsequent aggression. Age, gender, and employment were controlled.

Conclusions: The empirical evidence for testing the sequential relationship between residential density, perceived privacy, subjective crowding, and aggression has so far been largely neglected in housing research. Recognizing the influence of privacy regulation on aggression is essential for guiding housing design and planning, shifting the focus away from overreliance on housing size specifications towards prioritizing the quality of floor plan design to better promote residents' well-being.

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1. Introduction

During national lockdowns in response to the COVID-19 pandemic, individuals were confined to their home environment for prolonged periods of time with limited options to leave their dwelling, although measures varied between countries (Hale et al., 2020). In the United Kingdom, a nationwide lockdown was introduced on March 23rd, 2020, with strict social distancing and isolation measures (Institute for Government, 2021). This included the closure of all non-essential businesses and the prohibition of gatherings involving more than two individuals. People were required to stay at home and could only leave for essential shopping, medical necessities, or if they were engaged in essential work that couldn't be conducted remotely. Outdoor physical activities (such as jogging or walking) were permitted no more than once per day (Institute for Government, 2021). As a result of these government directives, people's homes became the space where they worked, ate, engaged in physical activities, and maintained social connections (Amerio et al., 2020). Individuals' own residences involuntarily became the exclusive venues for all activities (Rogers & Power, 2020), leading to profound alterations in habits, routines, human relationships, and work patterns (Rogers & Power, 2020; D'Alessandro et al., 2020). Family units and shared households were compelled to maintain intensive, prolonged contact within their homes, while simultaneously, support networks through extended family or social connections remained inaccessible (Usher et al., 2020).

It is very likely that the lockdown measures imposed during the pandemic may have resulted in a reduced ability to regulate social interactions at home – to find a place to be alone or be with others when they wanted to. When individuals encounter a discrepancy between their preferred level of social contact and the actual levels they experience, while feeling powerless to manage these circumstances, they may experience subjective crowding and psychological distress (e.g., Baum & Paulus, 1987). This scenario is particularly significant in the United Kingdom, where the square meters of living space per person in homes is the smallest in the European Union (RIBA, 2011). As supported by a substantial body of research, residential density is associated with various adverse psychological outcomes, including distress and aggression (cf. Evans, 2003). The global increase in reports of domestic violence during the initial COVID-19 lockdown period (Usher et al., 2020), particularly in the United Kingdom where the national domestic violence hotline reported a 25% surge in calls since the lockdowns (Kelly & Morgan, 2020), underscores the need to investigate the impact of residential density on aggression. Interestingly, despite subjective assessments of social/residential density having been found to explain more variance in psychological outcomes, including aggression, than objective density measures (e.g., Welch & Booth, 1975), limited research has explored the relationship between subjective crowding and aggression, especially within the housing context. Consequently, there is a pressing need to explore the connections between (objective) residential density, subjective crowding, and their respective roles in aggression. Furthermore, previous studies have suggested that control over social interactions (privacy) might act as a potential mediator between social density conditions and psychological experiences (e.g., Cohen & Sherrod, 1978; Chan, 1999), warranting further examination of its role in the relationship between residential density and crowding experiences.

Therefore, our study aims to make two contributions to the existing literature:

1. Conduct an initial examination of the direct and indirect relationships between the residential density, subjective crowding, and perceived privacy.
2. Examine the effect of those variables on aggression in the residential context during the first COVID-19 lockdown period.

1.1. Residential density and aggression

Residential density, also referred to as objective home crowding (Fornara et al., 2022) is predominantly conceptualized as people-per-room ratio, commonly referred to as the American Crowding Index (ACI). The ACI has been positioned by health researchers as the most widely utilized measure for assessing residential density (Baker et al., 2013).¹ Social density (relative number of people per space) has been consistently found to be associated with psychological distress and related psychological outcomes during temporary social density exposure in laboratory studies (Baum & Paulus, 1987; Evans & Cohen, 2001; Paulus, 1988), as well as during chronic social density exposure in field studies, for example in prisons (McCain et al., 1976; Paulus, 1988; Wener, 2012; Wener & Keys, 1988), in colleges (Evans & Cohen, 2001; cf. Baum et al., 1981), in offices (Veitch, 2012; Weber et al., 2023) and residential housing (Amerio et al., 2020; Campagna, 2016; Evans et al., 1996, 2000, 2001; Fornara et al., 2022; Gómez-Jacinto & Hombrados-Mendieta, 2002; Gove et al., 1979; Wells & Harris, 2007). Evans (2003) argues for a “dose-response relationship” (p. 540), wherein psychological distress exhibits a progressive increase in correlation with the number of occupants per room.

Ample evidence is available for the association between social density and aggression. Aggression is defined as “individual differences in thoughts (e.g., hostility), emotions (e.g., anger), and behaviour (e.g., verbal and physical aggression) that are intended to harm another person” (Webster et al., 2015, p. 121). A proposed explanation for the association between social density and aggression in studies on animals (Freeman, 1971) and humans (e.g., Fuller et al., 1996; Lawrence & Andrews, 2004) is increase of arousal and stress. Others propose that the experienced stress is caused specifically by the lack of freedom of choice and reduced access to resources (e.g., Baum & Paulus, 1987; Altman, 1975). Resorting to aggression has been positioned as a means to alleviate social density/crowding constraints (Baum & Paulus, 1987). Residential density has been found to be associated with violent incidents, physical assaults, and verbal aggression in settings of confined housing such as prisons (Megargee, 1977; Nijman & Rector, 1999) and psychiatric inpatient units (Ng et al., 2001; Palmstierna et al., 1991; Virtanen et al., 2011). Likewise, within housing research, there is ample evidence suggesting connections between residential density and violence, anti-social behaviour among residents, and family conflict (Booth et al., 1976; Booth & Edwards, 1976; Gove et al., 1979; Welch & Booth, 1975; Regoeczi, 2008; Torres-Soto et al., 2023; Makinde et al., 2016; Gao et al., 2021; cf. Evans, Saegert, & Harris, 2001). The COVID-19 pandemic has been linked to a significant rise in intimate partner violence (McNeil et al., 2023), with residential density/“overcrowding” (p. 247) identified as a key risk factor contributing to this increase. Hence, for our first model, we propose:

H1. Individuals reporting higher levels of residential density during the COVID-19 pandemic will report higher levels of aggression.

1.2. Subjective crowding and aggression vs. residential density and aggression

Studies including residential density as well as subjective crowding indicate that subjective crowding may account for a greater portion of the variance in psychological outcomes (such as feelings of anger or stress) compared to residential density (e.g., Rodgers, 1982; Thornock et al., 2019; Torshizian & Grimes, 2021; Welch & Booth, 1975). Subjective crowding is a psychological state that arises when an individual perceives that there are more people in a given environment than they

¹ Other measures include, for example the floor area per person, people per bedroom or national standards, such as the Canadian National Occupancy Standard (cf. Torshizian & Grimes, 2021).

prefer (Stokols, 1972); a situation or place is perceived as crowded (Rapoport, 1975). In contrast to the multitude of studies that have demonstrated a connection between residential density and aggression, the body of evidence is surprisingly sparse when it comes to examining the link between subjective crowding and psychological outcomes (Thornock et al., 2019), including aggression. Prison research indicates that inmates who experienced subjective crowding reported more sick calls (Wener & Keys, 1988) and were more inclined to perceive behaviour as hostile and physically aggressive (Lawrence & Andrews, 2004). Other prison research discovered that subjective crowding was associated with psychological stress among inmates whereas social density of inmates was not associated (Baum & Koman, 1976; Schaeffer et al., 1988). Residential research on subjective crowding, thus far, has predominantly focused on residential satisfaction (Fornara et al., 2022; Rodgers, 1982; Thornock et al., 2019; Torshizian & Grimes, 2021). Some exceptions exist underscoring the relationship between perceived crowding and aggression (Lo & Li, 2023; Welch & Booth, 1975). Further, Welch & Booth's (1975) research, nearly fifty years ago, who undertook an investigation into the relationship between residential density and subjective crowding, with a specific focus on its influence on family aggression, physical punishment, and aggression beyond the household. Their findings revealed that, in contrast to residential density, which showed little relationship to aggression, subjective crowding had significant correlations to all three aggression-indicators. Considering that subjective crowding may account for a greater portion of the variance in psychological outcomes compared to residential density (e.g., Baum & Koman, 1976; Rodgers, 1982; Schaeffer et al., 1988; Thornock et al., 2019; Torshizian & Grimes, 2021; Welch & Booth, 1975), it becomes evident that there is a compelling need for further inquiry into the association between perceived residential crowding and aggression.

1.3. The relationship between objective and subjective crowding

Although it is evident that residential density increases the likelihood to experience subjective crowding (e.g., Knowles, 1983), evidence on the strength of the relationship is limited and characterized by mixed findings. Whereas some studies (Booth & Edwards, 1976; Edwards et al., 1994; Torshizian & Grimes, 2021) indicate only a modest relationship, others find stronger relationships in residential (e.g., Thornock et al., 2019) and prison settings (Wener & Keys, 1988). Edwards et al. (1994) examined whether modest relationships were purely an artifact of measurement. Using seven different indicators of residential density they concluded the relationship is not an artifact. Considering the consistent presence of effects, our study considers residential density as an antecedent to subjective crowding. Hence, for our second model, we propose:

H2. Individuals reporting higher levels of residential density will report higher levels of subjective crowding.

H3. Individuals reporting higher levels of subjective crowding will report higher levels of self-reported aggression.

1.4. Privacy as mediator between objective and subjective crowding

Overall, it appears that the relationship between objective and subjective crowding is underexplored. Moreover, relatively little is known as to *when* residential density may lead to experiences of subjective crowding, as this is not necessarily always the case (Edwards et al., 1994). For instance, some researchers stress that subjective crowding is dependent on individual differences, for instance in personal space preference (e.g., Lawrence & Andrews, 2004; Thornock et al., 2019). Others suggest it may vary with room configurations and atmospheric qualities (e.g., Fisher-Gewirtzman, 2017; Schiffenbauer et al., 1977). Yet others propose that the strength of the relationship depends on the degree of control people have over the environment (e.g., Edwards et al., 1994). Evans (2003), amongst others (e.g., Cohen & Sherrod, 1978)

positioned a lack of control – including uncontrollable social interactions (cf. Cohen & Sherrod, 1978) – as a key factor influencing the relationship between built environment features and negative psychological experiences in those environments. Cohen and Sherrod (1978) point out that “high density environments are often ... uncontrollable environments ... [However,] when density does not affect the perceived controllability ... there should be no negative effects of density ... Density is not necessarily stressful unless features of social or physical environment imply or foster a loss of perceived control” (p. 191–192). People's ability to control social interactions – or their perceived privacy-regulation control is central to understanding a social-environmental concept such as crowding (Altman, 1975; Weber et al., 2021). *Privacy*, as defined by Altman's (1975), entails the selective control of access to oneself or one's group—a process involving both input and output control, where individuals and groups aim to regulate social contact and the information they share. Altman's (1975) privacy regulation model specifies that unmet privacy needs can result in feelings of subjective crowding when opportunities for social interaction exceed demands (the reverse could result into feeling of loneliness). This suggested mediation effect of perceived privacy between residential density and perceived crowding finds some empirical support (Chan, 1999). Hence, for our third model, we propose:

H2: Individuals reporting higher levels of residential density will report higher levels of subjective crowding.

H3: Individuals reporting higher levels of subjective crowding will report higher levels of self-reported aggression.

H4. Perceived privacy will mediate the relationship between residential density and subjective crowding.

1.5. Control variables: gender, age, and employment

We incorporated gender, age, and employment as control variables, as research indicates their potential influence on subjective crowding experiences and aggression reactions. For instance, prior studies have suggested that men may exhibit lower tolerance for high levels of social density compared to women (e.g., Baum & Koman, 1976). Considering the inconclusive evidence regarding gender differences in aggressive reactions to social density (Regoeczi, 2008), we included this variable as a precautionary measure. Additionally, some research suggests that residential density may have had a lesser impact on the satisfaction of older adults during the pandemic (Fornara et al., 2022). Moreover, pandemic-related studies have identified unemployment as a risk factor for intimate partner violence (McNeil et al., 2023).

1.6. Hypotheses

This paper therefore aimed to conduct a preliminary investigation of the direct and indirect relationships between residential density, subjective crowding, and perceived privacy, and their effects on aggression in a residential housing context during the *COVID-19 lockdown period*. We propose the following hypotheses tested in three hierarchical path models:

H1 Individuals reporting higher levels of residential density during the COVID-19 pandemic will report higher levels of self-reported aggression.

H2 Individuals reporting higher levels of residential density will report higher levels of subjective crowding.

H3 Individuals reporting higher subjective crowding will report higher levels of self-reported aggression.

H4 Perceived privacy will mediate the relationship between residential density and subjective crowding.

2. Methods

2.1. Study design and procedure

An online cross-sectional survey was conducted using the 'Qualtrics' platform. The survey targeted an opportunistic sample of individuals recruited through 'Prolific,' a crowd-sourcing platform in the United Kingdom. To recruit participants, Prolific advertised the study by emailing a random subset of eligible participants within their pool. Registered users could also access the survey through a list of available studies for which they were eligible. It was positioned as a study that examines how people who live with others cope with being restricted to their homes during the pandemic. The survey was administered in English. The survey launched on June 23rd, 2020. This was at the end of the first lockdown period in the UK (the second commenced November 5th, 2020). The strongest restrictions had been in place since March 23rd, 2020 (Institute for Government, 2021). On May 10th, individuals unable to work remotely were permitted to resume on-site work. On June 1st, educational institutions resumed operations, followed by the reopening of all non-essential shops from June 15th. Inclusion criteria to partake in the study were that during the previous two weeks of the COVID-19 lockdown (e.g., the two weeks prior to survey completion) participants: (a) were aged 18 years or older, (b) were living with others and (c) had been living in the UK.

2.2. Ethics

Involvement in the study was voluntary, with participants granting their informed consent before participating. The survey was anonymous, adhering to the guidelines outlined in Swiss federal law on human research. Data were treated confidentially, analysed solely for scientific purposes, and shared exclusively with the research team. Both, data collection and usage, were compliant with the Swiss Federal Data Protection Act, and all data were securely stored on the university server. As per Prolific's ethical guidelines, participants received a payment of £10.27 per hour for completing the survey. To address the potential stress imposed by the COVID-19 lockdown, a post-survey page tailored to the UK audience was provided. This page included links to healthcare resources and online support platforms. Due to the absence of an institutional ethics review board at the host institution, this study, conducted through the first author's institute, did not undergo a formal ethical evaluation. However, as outlined, the study adhered to local laws and widely acknowledged institutional mandates and international declarations, such as the Declaration of Helsinki.

2.3. Sample

A total of 301 respondents participated, of which two cases were excluded in the first data cleaning step due to extensive missing data and due to incorrect data entry. This resulted in a sample of 299 respondents with no missing data. The sample size was deemed appropriate for the current study which was exploratory in nature. The gender distribution among participants was uneven; almost two times more females ($n = 205$) than males ($n = 93$) and other ($n = 1$) took part. Participants had a mean age of 31.81 years ($SD = 12.19$, range 18–83 years). Approximately a half of the sample ($n = 176$) reported to have care responsibilities (children, elderly or family members needing care); a fifth was home-schooling during the survey period ($n = 68$). Overall, 111 participants reported that between one to four children under the age of 15 years were present at home; and 54 reported one to five children over the age 15 years were present during the study period. Regarding employment, over half of the sample ($n = 162$) was employed, 32 were not employed, 50 were students, 7 retired, 16 unable to work, 13 were homemakers or volunteers, and 19 declared 'other'. Almost half ($n = 144$) were teleworking from home during the study period.

Regarding participants' home environment, majority lived in their

usual home ($n = 283$); 13 participants lived temporarily in someone else's home and three in other temporary accommodation. The median number of people present at home, including the participants, was three (range 1–8). The median number of total rooms participants had in their home/flat was six rooms (range 1–14) of which 3 were bedrooms (range 0–7). As such, the residential density/Average Crowding Index (ACI) score was low 0.64 ($SD = 0.35$, range 0.01–2.00). Additionally, the majority had an outdoor access, such as a private or shared garden ($n = 258$), a balcony ($n = 16$) or both ($n = 9$); only 16 participants had no outdoor access. On average, participants left their home between once a day and every other day ($M = 2.82$, $SD = 1.23$). Detailed participant demographics and home information are provided in Table 1.

2.4. Measures

Measures used in this study are described below.² Descriptive statistics and correlations are provided in Table 2.

2.4.1. Demographics

Data were collected on age, gender (female, male, other or prefer not to say), employment and teleworking, number of children aged under and over 15 years being present, caretaking (none, children, elderly or other) and home-schooling responsibilities during the study period (past two weeks). Information about participants' home environment was also collected, including own or temporary housing arrangements (usual home, temporarily in someone else's home or other temporary accommodation), total number of people in the accommodation, type of co-dwellers (e.g., children, partner/spouse, other family members, friends, acquaintances or lodgers), number of rooms,³ number of bedrooms, and available outdoor access (private garden, shared garden or balcony) during the study period (past two weeks). The answer option 'no outdoor access' was added subsequently to account for those participants who had no outdoor access. Gender was dummy coded with 'female' being the referent. Employment was recoded into three categories 'employed' (full time, part time, self-employed), 'unemployed' (looking or not looking for work), and 'other' (student, retired, homemaker, unable to work, unpaid work in or outside home, other) with 'unemployed' being the referent.

2.4.2. Residential density

Residential density was operationalized by calculating a person-per-room ratio (number of dwellers/persons divided by number of separate rooms), also known as American Crowding Index (ACI; WHO, 2018). The ACI is a calculation commonly used in the literature to determine the objective density in households (cf. Baker et al., 2013; cf. Fornara et al., 2022). Both questions for this calculation were part of the demographics section of the survey. According to ACI, scores >1 , (more than one person per room in a household) reflect residential density. Scores of 1.5 and larger reflect severe crowding (WHO, 2018).

2.4.3. Perceived privacy

Perceived privacy was measured using a simplified version of Marshall's (1972) assessment of 'environmental privacy composites' to achieve 'privacy within the home' (p. 98) and Pedersen's PQ scale (1979); both scales had been tested for overlaps (Pedersen, 1996). Five items were used or modified to reflect five dimensions of the PPS/PQ scales: Reserve, solitude, intimacy with friends, intimacy with family,

² The questionnaire included a set of other measures that are not the focus of the present report.

³ In accordance with the calculation of the ACI, the instructions specified that 'rooms must be separated by built-in walls that go from floor to ceiling or archways that extend out at least 6 inches' (including bedrooms, kitchens, living rooms, dining rooms, etc., and excluding bathrooms, porches, balconies, foyers, halls, or unfinished basements or attics).

Table 1
Demographic details of the sample.

Characteristic	Count	Percentage
Gender		
Male	93	31.1
Female	205	68.6
Other	1	0.3
Prefer to not say	0	0
No. of Children <15 years		
0	186	62.2
1	68	22.7
2	32	10.7
3	10	3.3
4	2	0.6
No. of Children >15 years		
0	245	81.9
1	40	13.3
2	9	3.0
3	3	2.0
4	2	0.7
Care responsibility		
None	176	58.9
Children	17	5.7
Elderly	94	31.3
Multiple	5	1.7
Other	7	2.3
Employment		
Employment full time (40 or more hours per week)	95	31.8
Employment part time (up to 39 h per week)	52	17.4
Self-employed	15	5.0
Unemployed and currently looking for work	24	8.0
Unemployed and not currently looking for work	8	2.7
Student	50	16.7
Retired	7	2.3
Homemaker	8	2.7
Unable to work	16	5.4
Doing unpaid work outside the home (e.g., volunteering)	0	0.0
Doing unpaid work at home (e.g., volunteering)	5	1.7
Other – furloughed from work	9	2.8
Other – maternity leave	4	1.3
Other – Self-isolating	1	0.3
Other	5	1.9
Telework from home		
Yes	114	38.1
No	185	61.9
Type of accommodation		
Usual home	283	94.6
Temporarily in someone else's home	13	4.3
In other temporary accommodation	3	1.0
No. of people present		
1	7	2.3
2	82	27.4
3	74	24.7
4	73	24.4
5	51	17.1
6	10	3.3
7	1	0.3
8	1	0.3
No. of rooms		
1	3	1.0
2	9	3.0
3	16	5.4
4	51	17.1
5	58	19.4
6	68	22.7
7	43	14.4
8	25	8.4
9	13	4.3
10–14	13	4.3
No. of bedrooms		
0	2	0.7
1	16	5.4
2	80	26.8
3	112	37.5
4	72	24.1
5	14	4.7

Table 1 (continued)

Characteristic	Count	Percentage
6	2	0.7
7	1	0.3
Outdoor access		
Private garden	231	77.3
Shared garden	27	9.0
Balcony	16	5.4
Multiple	9	3.0
No outdoor access	16	5.4

Note. *n* = 299.

and anonymity. Explicitly, the items were: (1-reserve/selective exposure) ‘the house/flat allows for noisy and quiet activities at the same time’; (2-solitude) ‘there are places I can be alone’; (3-intimacy with friends) ‘there are places I can interact with friends (also virtually)’; (4-intimacy with family) ‘there are places I can interact with my family’; (5-anonymity) ‘I have a place to do my things (work, leisure activities)’. Participants rated their agreement with the statements on a 5-point Likert scale ranging from (1) Strongly disagree to (5) Strongly agree. Internal consistency was acceptable ($\alpha = 0.75$). An overall privacy regulation possibility mean composite score across all dimensions was calculated. High scores reflect high levels of privacy regulation possibility.

2.4.4. Subjective crowding

Subjective crowding was measured using a single item based on Marshall (1972) and Bordas-Astudillo et al. (2003). The item ‘it feels crowded’ was rated on a five-point Likert scale ranging from (1) Strongly disagree to (5) Strongly agree and was part of various statements about the house/flat participants had stayed in during the past two weeks. High scores reflect high levels of subjective crowding.

2.4.5. Self-reported aggression

Self-reported aggression was assessed with the Brief Aggression Questionnaire (BAQ) by Webster et al. (2015) using 12 items on a five-point Likert scale ranging from (1) Very unlike me to (5) Very like me. The BAQ considers four dimensions of aggression assessed by three items each: physical aggression, (e.g., ‘given enough provocation, I might have hit another person’), verbal aggression (e.g., ‘when people annoy me, I may tell them what I think of them’), anger (e.g., ‘have trouble controlling my temper’), and hostility (e.g., ‘when people are especially nice, I wonder what they want’). An overall aggression mean composite score across all dimensions was calculated. The wording was amended to suit the study by using a reference frame of the last two weeks oppose to originally no reference frame. Internal consistency was adequate ($\alpha = 0.84$). High scores reflect high levels of aggression.

2.5. Data analysis

The statistical software package SPSS version 28 (IBM Corp, 2013), was used to compute descriptive statistics and correlation matrices. We used Pearson correlations where both variables were continuous and point-biserial correlations between a dichotomous and continuous variable (Table 2). SPSS AMOS version 28 (IBM Corp, 2013) was used to compute the path models and indirect effects for hypothesis testing. We used 5000 bootstrap estimates to generate 95% bias-corrected confidence intervals for the indirect effects observed. Age (continuous), gender (categorical), and employment (categorical) were entered as control variables; gender and employment were covaried. Bonferroni corrections to adjust p-values for multiple testing was not applied given latest recommendations (Armstrong, 2014; Nakagawa, 2004; Perneger, 1998). For hypothesis testing, we examined three hierarchical models. The first model (H1) assessed the direct relationship between residential density and aggression. The second model (H2, H3) explored the direct, sequential relationships among residential density, subjective crowding,

Table 2
Means, standard deviations, and correlations between the study variables.

Variable	M/%	SD	1	2	3	4	5	6	7
1 Age	31.81	12.19	–						
2 Male	31.1%	–	–0.07	–					
3 Employed	54.2%	–	0.26**	–0.09	–				
4 Residential density	0.64	0.29	–0.23**	0.04	–0.08	–			
5 Perceived privacy	4.01	0.78	0.06	–0.03	–0.09	–0.33**	–		
6 Subjective crowding	2.54	1.31	–0.10	0.01	0.07	0.29**	–0.51**	–	
7 Self-reported aggression	2.34	0.73	–0.27**	–0.01	0.22**	0.22**	–0.26**	0.31**	–

Note. $n = 299$. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (2-tailed). % represents the percentage of the value of “1” where dummy coding was used. Reference dummy variables Gender: Female; Employment: Unemployed.

and aggression. In the third model, an extension of the second model, we introduced privacy regulation possibility as a mediator between subjective crowding and aggression (H4).

3. Results

Three path models were tested to investigate H1-4; see Figs. 1–3 for significant relationships and Table 3 for regression parameters. Among the control variables (age, gender, and employment) across the three models, age exhibited a negative relationship with both subjective crowding and aggression. Age significantly predicted aggression suggesting that Aggression levels decreased with age. Age did not significantly predict subjective crowding. No gender differences were observed in subjective crowding and aggression. Employment status showed a significant difference; individuals who were employed and in the ‘Other’ category reported lower levels of aggression in comparison to unemployed individuals.

The first model tested whether residential density was positively associated with levels of aggression among residents. An acceptable fit was found with their robust estimators (Hu & Bentler, 1998) (RMSEA = 0.08; CFI = 0.93; TLI = 0.89; SRMR = 0.07), with chi-square ($\chi^2 = 38.39$, 13, $p = 0.000$) being significant. H1 was supported, as higher residential density ($B = 0.39$; $\beta = 0.15$; 95% CI 0.04 to 0.26) predicted higher levels of aggression.

The second model tested whether residential density was positively associated with subjective crowding (H2) and whether subjective crowding was positively associated with levels of aggression (H3). The model had an acceptable fit (RMSEA = 0.08; CFI = 0.93; TLI = 0.88; SRMR = 0.07), with chi-square ($\chi^2 = 45.74$, 16, $p = 0.000$) being significant. H2 was supported, as higher residential density ($B = 1.29$; $\beta = 0.28$; 95% CI 0.16 to 0.39) predicted higher levels of subjective crowding. H3 was also supported, as higher subjective crowding ($B = 0.16$; $\beta = 0.28$; 95% CI 0.17 to 0.39) predicted higher levels of aggression.

The third model tested whether residential density was positively associated with subjective crowding (H2), whether subjective crowding was positively associated with levels of aggression (H3) and whether privacy mediates the relationship between residential density and subjective crowding (H4). The model had overall the best goodness of fit

(RMSEA = 0.07; CFI = 0.94; TLI = 0.90; SRMR = 0.07), with chi-square ($\chi^2 = 54.58$, 22, $p = 0.000$) being significant. H2 path parameters remained as in model 2; therefore, H2 was supported. H3 was also supported. However, once the mediator was introduced, the direct effect of residential density on subjective crowding was reduced (c' path, $B = 0.57$; $\beta = 0.13$ 95% CI - 0.02 to 0.24). In line with H4, an indirect relationship was observed between residential density and subjective crowding with privacy being a significant mediator (ab path, $B = 0.70$; $\beta = 0.15$ 95% CI 0.10 to 0.22). Those experiencing residential density reported greater subjective crowding levels, as a result of having less privacy.

Post-hoc power analyses were conducted on R software (v.4.4.0, R Core Team, 2023) using the pwrss package (Bulus, 2023). The hypothesized paths within our models (Soper, 2023) yield excellent power with a specified $\alpha = 0.05$ (e.g., model three: H2, $R^2 = 0.08$, $1-\beta = 0.99$; H3, $R^2 = 0.11$, $1-\beta = 1.00$; H4, $R^2 = 0.27$, $1-\beta = 1.00$, model III, $1-\beta = 0.98$).

4. Discussion

This cross-sectional study aimed to explore the relationships between residential density, subjective crowding, perceived privacy, and self-reported aggression at home during the COVID-19 lockdown. As hypothesized, our findings indicate that there is a modest association between residential density at home and aggression, while the relationship between subjective crowding and aggression is stronger. Furthermore, our analysis revealed that residential density is a significant predictor of subjective crowding. Moreover, this relationship is mediated by perceived privacy. Having objectively less space per person available in UK households during the COVID-19 pandemic therefore appears to impact on residents perceived ability to regulate their privacy which subsequently results into feelings of crowding and aggression.

With regards to the distribution of our hypothesized aggression predictors within our sample, our results show that residential density was, on average, relatively low, as reflected by an Average Crowding Index (ACI) score of 0.64 ($SD = 0.35$, range 0.01–2.00), with only a few individuals reporting an ACI score > 1.00 . This score suggests that there were more rooms available than there were dwellers, indicating a lower level of residential density within the study population. Subjective crowding scores were similarly modest with no difference in age or

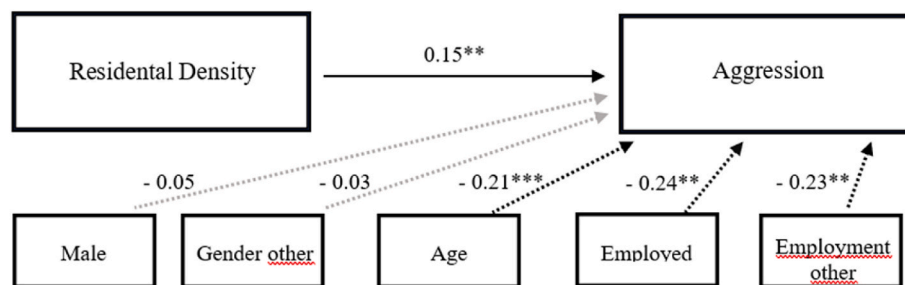


Fig. 1. Path analyses results for model 1. Note: Control variables are indicated by dashed lines. Insignificant relationships are indicated by grey lines. Standardized coefficients are reported. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $n = 299$.

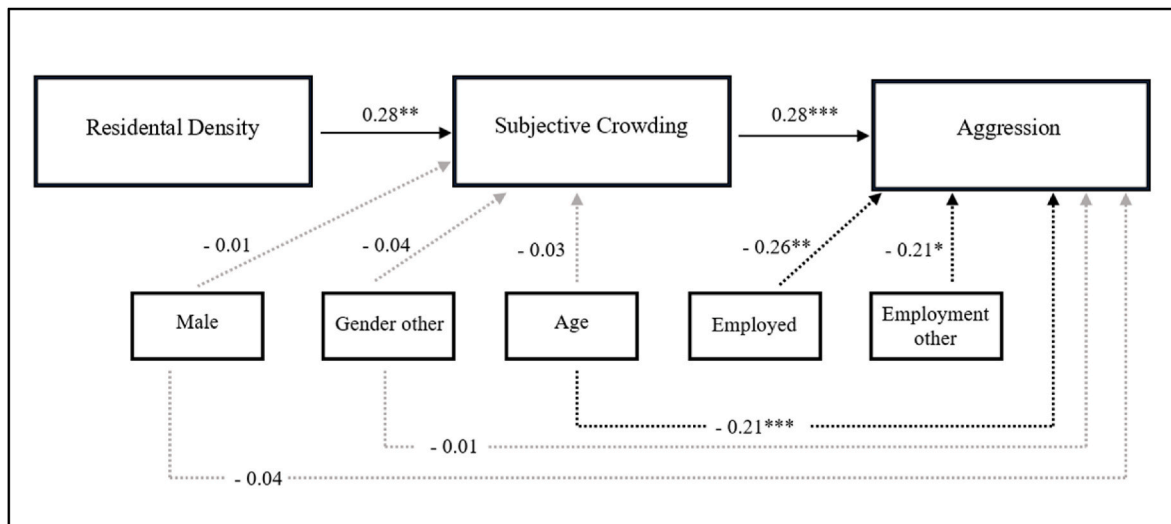


Fig. 2. Path analyses results for model 2. Note: Control variables are indicated by dashed lines. Insignificant relationships are indicated by grey lines. Standardized coefficients are reported. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $n = 299$.

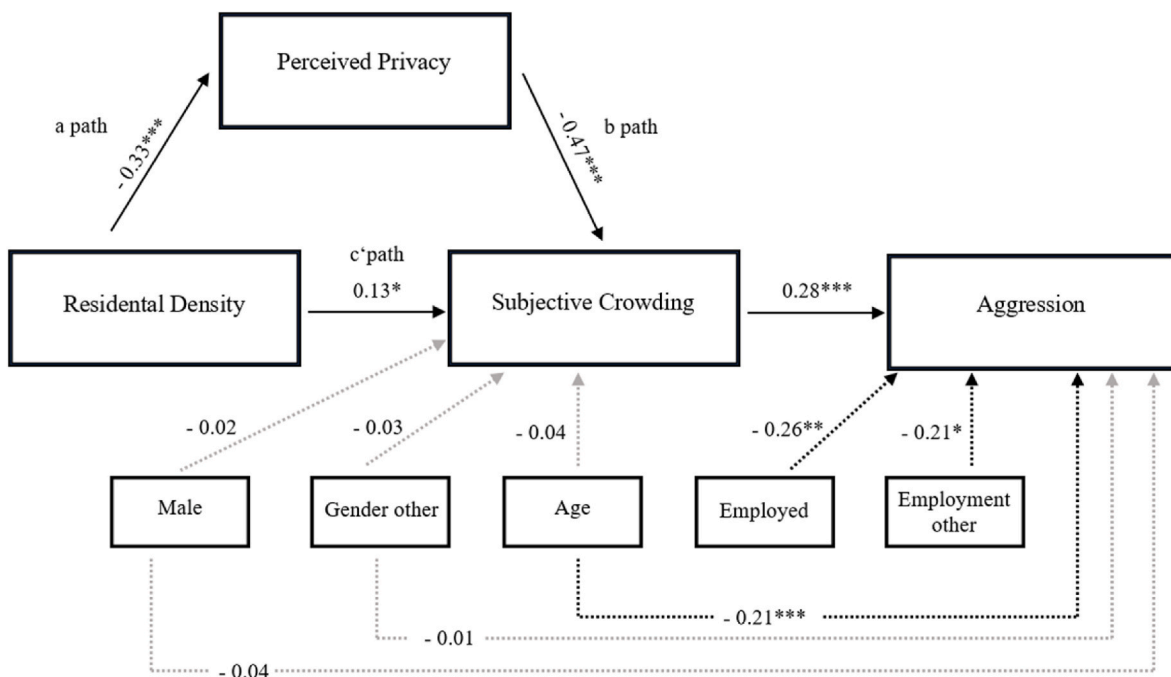


Fig. 3. Path analyses results for model 3. Note: Control variables are indicated by dashed lines. Insignificant relationships are indicated by grey lines. Standardized coefficients are reported. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $n = 299$.

gender. Also, aggression levels within our sample were low on average. Participants indicated that engaging in aggressive behaviour was relatively uncommon for them in the two weeks preceding their participation in the study. Further, individuals who were younger and currently not employed reported higher levels of aggression, aligning with previous research during the pandemic (McNeil et al., 2023). Nonetheless, our findings indicate positive associations between residential density and aggression, as well as subjective crowding and aggression, with the latter demonstrating a stronger relationship. An in-depth discussion of the observed associations is provided in the following sections.

4.1. Aggression predictors and reconsidering residential density parameters (ACI)

Residential density: Our finding of the moderate relationship between residential density and aggression adds to the extensive existing body of evidence and supports pandemic research identifying residential density as risk factor for domestic violence (McNeil et al., 2023). Research consistently demonstrates that in conditions characterized by high social density in confined environments, such as prisons or psychiatric institutions, but also in residential settings, the likelihood of violent incidents, anti-social behaviour, and conflicts increases (Megargee, 1977; Nijman & Rector, 1999; Ng et al., 2001; Palmstierna et al., 1991; Virtanen et al., 2011; Booth et al., 1976; Booth & Edwards, 1976; Gove et al., 1979; Welch & Booth, 1975; Regoeczi, 2008; Torres-Soto et al.,

Table 3
Direct effects and indirect effects in the three models.

	B	(B) SE	β	C.R. (t)	95% CI	p
Model 1						
Male - >	-0.07	0.09	-0.05	-0.83		0.438
Aggression						
Gender other - > Aggression	-0.42	0.68	-0.03	-0.62		0.538
Employed - > Aggression	-0.36	0.14	-0.24	-2.64		0.008**
Employment other - > Aggression	-0.35	0.14	-0.23	-2.53		0.011**
Age - > Aggression	-0.01	0.00	-0.21	-3.81		<0.001***
Residential density - > Aggression	0.37	0.14	0.15	2.79		0.005**
Model 2						
Male - > Subjective Crowding	-0.03	0.16	-0.01	-0.17		0.865
Gender other - > Subjective Crowding	-0.98	1.25	-0.04	-0.79		0.432
Male - > Aggression	-0.07	0.08	-0.04	-0.81		0.420
Gender other - > Aggression	-0.17	0.66	-0.01	-0.26		0.796
Age - > Subjective Crowding	-0.01	0.01	-0.03	-0.56		0.575
Age - > Aggression	-0.01	0.00	-0.21	-3.94		<0.001***
Employed - > Aggression	-0.38	0.13	-0.26	-2.92		0.003**
Employment other - > Aggression	-0.32	0.13	-0.21	-2.41		0.016*
Residential density - > Subjective crowding	1.29	0.25	0.28	5.09		<0.001***
Subjective Crowding - > Aggression	0.16	0.03	0.28	5.39		<0.001***
Model 3						
Male - > Subjective crowding	-0.05	0.14	-0.02	-0.37		0.713
Gender other - > Subjective crowding	-0.57	1.11	-0.03	-0.51		0.608
Age - > Subjective crowding	-0.01	0.01	-0.04	-0.90		0.419
Male - > Aggression	-0.07	0.08	-0.04	-0.81		0.420
Gender other - > Aggression	-0.17	0.66	-0.01	-0.26		0.796
Age - > Aggression	-0.01	0.00	-0.21	-3.94		<0.001***
Employed - > Aggression	-0.38	0.13	-0.26	-2.94		0.003**
Employment other - > Aggression	-0.32	0.13	-0.21	-2.41		0.016*
Residential density - > Subjective crowding (c' path)	0.57	0.24	0.12	2.241		0.016*
Residential density - > Perceived	-0.89	0.15	-0.33	-5.97		<0.001***

Table 3 (continued)

	B	(B) SE	β	C.R. (t)	95% CI	p
privacy (a path)						
Perceived	-0.80	0.09	-0.47	-9.10		<0.001***
privacy - > Subjective crowding (b path)						
Subjective crowding - > Aggression	0.16	0.03	0.28	5.38		<0.001***
<i>indirect effect</i>						
Residential density - > Perceived privacy - > Subjective crowding (ab path)	0.70	0.15	0.04		[0.44,1.05]	<0.001***

Note. $n = 299$. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (2-tailed). Reference dummy variables Gender: Female; Employment: Unemployed.

2023; Makinde et al., 2016; Gao et al., 2021; cf. Evans, Saegert, & Harris, 2001). Notably, early laboratory data, which initially indicated no relationship between social density and anti-social behaviour (cf. Megargee, 1977), were challenged by field studies focusing on chronic high-density environments. For example, Lepore et al.'s study (1991) emphasized the importance of the temporal aspect of density exposure. In their longitudinal study on residential environments, they discovered that while density showed no connection to psychological distress when residents initially moved in, it became linked to increased psychological distress six months later. Equally, Regoeczi (2002) introduced a nuanced perspective on the density-aggression relationship, suggesting a non-linear relationship, akin to a J-curve, between density and aggressive behaviour. He proposed that “the likelihood of aggression decreases at very low levels of persons per room, but once a threshold is met, there are exponential increases in withdrawn or aggressive behavior” (p. 525). While we did not observe a curvilinear relationship, our results reveal a relatively gradual slope ($\beta = 0.13$) with a low intercept (2.10). In relation to its moderate predictability, also in comparison to subjective crowding, our findings prompt inquiries into the usefulness of an over-reliance of residential density parameters when predicting environmental stress. However, it has to be pointed out that our sample did not depict a full range of residential crowding in comparable proportions (positively skewed distribution), which may limit the comprehensive exploration of the impact of residential density on aggression.

Subjective crowding: Our finding on the relationship between subjective crowding and aggression contributes to the limited existing research in this area (Thornock et al., 2019). Previous studies have primarily concentrated on prisons (e.g., Lawrence & Andrews, 2004), while residential research has predominantly centered on satisfaction outcomes (e.g., Fornara et al., 2022; Rodgers, 1982; Torshizian & Grimes, 2021). Our study adds to the limited exceptions in the studies conducted by) that also observed a link between subjective crowding and various indicators of aggression (Lo & Li, 2023; Welch & Booth, 1975).

Relationship between predictors and their relative strengths: Our findings show a modest relationship between residential density and subjective crowding of similar strength than majority of studies observing this relationship (Booth & Edwards, 1976; Edwards et al., 1994; Torshizian & Grimes, 2021). Further findings show a stronger relationship between subjective crowding and aggression than between residential density and aggression. This contributes to the limited existing research comparing these pathways, which has also suggested that subjective crowding has a stronger predictive role in aggression (Welch & Booth, 1975) and in other psychological outcomes (Baum & Koman, 1976;

Rodgers, 1982; Schaeffer et al., 1988; Thornock et al., 2019; Torshizian & Grimes, 2021). Considering the stronger influence of subjective crowding on psychological outcomes relative to residential density, and the wealth of research on objective density parameters, future studies should prioritize the exploration of the subjective crowding phenomenon, and its predictors.

4.2. When residential density results in feelings of crowdedness

Recognizing the potential significance of subjective crowding in relation to psychological outcomes, we investigated *when* residential density turns into subjective crowding. Our findings indicate that privacy acts as a mediator in this relationship. This implies that having objectively less space per person available in a household can influence residents' perceived ability to control their privacy, subsequently leading to feelings of crowding and aggression. This finding corresponds with theoretical works, such as Altman's (1975) privacy regulation framework, suggesting that not being able to reach a desired level of social interaction/privacy, will result in feelings of crowding. Further, these results add to the sparse empirical evidence on this relationship (Chan, 1999) as so far, studies have primarily pointed to personal space preference, spatial configuration, atmospheric qualities, or perceptions of control as determinants of subjective crowding (Baum & Koman, 1976; Rodgers, 1982; Schaeffer et al., 1988; Thornock et al., 2019; Torshizian & Grimes, 2021; Welch & Booth, 1975).

So far, most crowding research has traditionally considered privacy as an explanatory factor between built environment characteristics like residential density and psychological outcomes such as aggression (e.g., Cohen & Sherrod, 1978; Evans, 2003; Gove et al., 1979; Nijman & Rector, 1999; Thornock et al., 2019; Wells & Harris, 2007). For example, Nijman and Rector (1999) proposed that inadequate privacy might play a key role in explaining the link between social density in prison wards and aggression. Furthermore, in other prison studies, individual sensitivity to physical closeness or personal space was suggested to exacerbate the impact of social density on violence (Hildreth et al., 1971; Kinzel, 1970; Ng et al., 2001). In housing context, Gove et al. (1979) observed that residential density had no significant effect on disputes in the home, whereas lack of privacy was strongly related. Further, Gove et al. (1979) observed an indirect effect of lack of privacy on the relationship between residential density and mental health. In our study, however, we focused on privacy as an indirect factor influencing the relationship between built characteristics and crowding appraisal/perceptions, rather than investigating its role in the link between built characteristics and aggression. This approach contributes to the broader understanding of the subjective crowding phenomenon, which has received limited attention in previous research.

The findings of this study invite future studies to explore acceptable standards of spatial and social density with considerations given to its potentially negative/contradicting implications for residents' health and wellbeing outcomes as well as the wider environmental and societal concerns. For instance, lower social density and perceived evaluations of social isolation and loneliness could put vulnerable resident groups such as older adults, children and adolescents at a risk of developing depressive symptoms and social anxiety (Loades et al., 2020; Müller et al., 2021; Robb et al., 2020). Whereas residential schemes such as co-housing and shared living communities that have higher social density facilitate a more environmentally friendly lifestyle and lower carbon emissions (Clark, 2021; Daly, 2017) that are becoming increasingly pertinent to delivering sustainable housing in the UK.

4.3. Implications

Our investigation not only scientific but also practical purposes. Our examination of the interplay between objective factors (e.g., residential density) and subjective experiences (e.g., perceived crowding and privacy) allowed us to assess their relative importance and roles in shaping

residents' responses, offering valuable insights into the potential consequences of high residential density on individual well-being and, by extension, public health. In line with WHO (2018), our findings highlight that it is paramount for living spaces to offer privacy for individuals, both in quantitative and qualitative terms (Capolongo et al., 2020), particularly during the pandemic. Most notably, our results emphasize the influential role of individuals' perceptions of spatial conditions and their control over social interactions, outweighing the direct influence of physical space dimensions on aggression.

Addressing these concerns requires housing guidelines prioritizing flexible, quality spatial configurations, incorporating partitions for separation and depth (CABE, 2009; RIBA, 2011; Signorelli et al., 2016). Crucially, spatial configuration mitigates unwanted stimuli, ensuring privacy needs are met (Campagna, 2016; D'Alessandro et al., 2020; Evans et al., 1996). Whilst acknowledging the detrimental impact of severe overcrowding, design focus should shift from an overemphasis on room or square meter per person, particularly considering the trend towards larger flats in Europe, where development of residential space per capita has seen a notable increase (Eurostat, 2023). Pandemic research has shown that insufficient living spaces and privacy not only hinder remote work and schooling (e.g., Lindert, 2019; Weber et al., 2022) but also exacerbate health and restoration risks (Lindert, 2019; Mejía-Castillo et al., 2023; Weber et al., 2023). Future studies could specifically examine the importance of residential design qualities and features that support and enhance higher privacy regulation in residents living in small-sized and objectively crowded environments. For example, the influence of open private spaces (Azad et al., 2018) like balconies, gardens and courtyards, and flexible and adaptable features such as partition walls to create temporary private activity spaces (Soleimani & Gharehbaglou, 2021) on residents' subjective experiences and perceptions of crowding can be examined.

4.4. Limitations

The current investigation is constrained by several limitations. The first limitation concerns the study's representativeness which is compromised by the utilization of convenience sampling and potential biases arising from self-selection and participation. This potentially led to the inclusion of solely those participants capable of engaging in the study, disregarding individuals facing considerable difficulties during the lockdown period. Consequently, it remains plausible that the study fails to fully capture the extent of the adverse effects of residential density amid the lockdown circumstances. This limitation is emphasized by the limited number of cases with high residential density in our sample, preventing a comprehensive assessment of the full spectrum of aggression associations. Further, the sample is not representative for the population in the UK; neither is the sample representative across the country's housing, which in this study appears to exceed national standards (cf., RIBA, 2011). Furthermore, the study collection procedure, using a crowd-sourcing panel data, could have compromised data quality and increases self-selection bias (Lehdonvirta et al., 2021).

The second limitation concerns the lack of control variables, as we had overlooked to collect more individual, social, and cultural context data. Regarding data on individual differences, aggression proneness and coping style might influence how individuals perceive privacy and crowdedness and react to it (Baum et al., 1982). Further, in pandemic studies, socio economic status, which was not collected, appeared as a risk factor of intimate partner violence and aggression (McNeil et al., 2023). Moreover, emotional states might affect the privacy and crowding tolerance (Altman, 1975). Regarding the social context, the presence or absence of social support could impact how individuals perceive their crowded environments (Sinha & Nayyar, 2000) and how they cope with aggression (Scarpa & Haden, 2006). Similarly, the composition of the group in terms of familiarity and social dynamics could influence perceived crowding levels, privacy needs and aggression tendencies (Altman, 1975). Regarding context specifications, it is widely

believed that cultures vary in their tolerance for crowding and have varying norms and expectations regarding personal space, privacy, and social density (Altman, 1975), leading to potential differences in responses. However, as indicated by (Evans et al., 2000) whilst crowding perceptions may differ, similar negative psychological distress is caused by high-density housing.

The third limitation is the study's cross-sectional design, which examined variables at a single time point. This impedes causal inference and is susceptible to common method bias (Podsakoff et al., 2003). While cross-sectional samples are suitable for testing mediation (Hayes, 2018), they carry limitations—misrepresenting psychological processes and creating ambiguity on robust effect directions. Hence, longitudinal models are preferable (O'Laughlin et al., 2018). However, the urgent pandemic onset and swift lockdown implementations in early 2020 constrained our capacity to execute a more sophisticated study design. Caution is needed when interpreting causal inferences in this study. Validation through longitudinal approaches is warranted. Lastly, a conservative view on the use of a single item measure for crowding would suggest a potential risk to validity and reliability. However, the latest notions support the use of single-item measures when the phenomenon under investigation is narrow in scope (Allen et al., 2022), such as subjective crowding.

In addressing some of these limitations, future studies can adopt longitudinal study designs with socio-economic stratified representative sampling (cf. Evans et al., 2001). More studies exploring the predictors of subjective crowding in different demographic groups and socio-cultural contexts would contribute to an improved understanding of subjective crowding in residential environments and aid its application in housing design."

5. Conclusion

Our study contributes to a deeper understanding of the factors that influence aggressiveness in crowded settings by contextualizing it in the COVID-19 pandemic lockdown. In line with the literature, we found that not only residential density, but especially subjective crowding played a significant role in contributing to levels of aggression due to limited privacy regulation opportunities. Notably, our final model revealed that residential density serves as an antecedent to subjective crowding. Our study underscores the significance of considering crowding and privacy regulation or withdrawal opportunities within residential environments. These factors are indicative of an individual's propensity to develop and respond with aggression. These findings have residential design related implications for housing strategies, emphasizing the importance of designing with privacy regulation in mind, shifting away from over-reliance of space per person.

Data availability statement

The data for this study will not be made publicly available, as participants did not consent to this possibility at the time of recruitment. The datasets generated during and/or analysed during the study can be made available upon reasonable request.

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CRedit authorship contribution statement

Clara Weber: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Birgitta Gatersleben:** Writing – original draft, Writing – review & editing. **Sadhana Jagannath:** Data curation,

Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Barbara Fuchsli:** Writing – original draft, Writing – review & editing. **Zenith Nara Costa Delabrida:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

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