Trends in Cognitive Sciences

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Review

Neurocomputational mechanisms of maladaptive behaviors in loneliness

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'Loneliness' refers to the perceived social isolation triggered by unsatisfying relationships. Most research and interventions have framed it as an individual problem rather than a broader social issue rooted in the (infra)structures of our societies. Here, we synthesize the neurocomputational evidence on the cognitive processes underpinning loneliness and the psychological and behavioral effects of the social environment and, in particular, community identification on feelings of loneliness. We propose that community-based interventions might effectively tackle loneliness by creating the preconditions that can prevent the emergence and reinforcement of the cognitive biases that foster maladaptive behavioral and reasoning patterns in lonely individuals. Finally, we discuss how future work can better design and tailor social interventions to reduce loneliness and improve mental health in general.

Highlights

Loneliness is associated with cognitive biases that might reinforce maladaptive behaviors leading to increasing feelings of loneliness and poor mental health.

These cognitive biases might impair lonely individuals' ability to reconnect because of inaccurate and overly negative social inferences about their social partners.

Stronger functional coupling between the orbitofrontal cortex and default mode network brain regions helps counteract the formation of overly negative impressions of others.

Community-based approaches create a safe environment that fosters more positive inferences and adaptive social behaviors for more stable long-term social bonds.

Loneliness from a multidimensional perspective

'Loneliness' (subjective feeling of being isolated) refers to the distressing feeling that one's social relationships are deficient in quantity and quality [1,2]. Loneliness is linked to negative health outcomes [3], and already a decade ago, 7% of the European population reported high levels of loneliness [4]. However, this figure has worsened after the COVID-19 pandemic, especially in urban areas [5]. The healthcare cost of treating poor mental health and mental disorders associated with loneliness is estimated to be £6000 per person over 10 years[i]. Moreover, loneliness has been recognized as a transdiagnostic experience common to the most frequent psychiatric disorders [6], representing a pivotal public health problem in many countries [7]. A number of existing interventions, mostly tackling social isolation (objective state of being alone), have been developed to facilitate opportunities for social interactions [8]. Nevertheless, they have been only moderately effective to reduce loneliness, and lonely individuals do not report feeling better when with others than when alone [9]. Thus, loneliness has been steadily increasing [10], highlighting its difference from social isolation [11–13].

A common approach toward loneliness is to treat it as a problem at the individual level [14]. Hence, it has been suggested that tackling specific individual cognitive biases leading to maladaptive cognitive and behavioral patterns might be the most promising approach to reduce feelings of loneliness and their negative effects on mental health [15]. This individual-focused perspective, though, has been recognized as limited, and recent proposals have urged multidimensional approaches, including social and societal factors [14,16].

We suggest that neither individual-focused approaches nor approaches targeting the isolating social structures alone are sufficient. We contend that it is necessary to look at the interplay between the individual and society using a more holistic approach that tries to identify both the neurocognitive mechanisms that contribute to loneliness at the individual level and the environmental and societal factors that determine the conditions that favor the emergence of those neurocognitive mechanisms.

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Here, we provide a concise synthesis and balanced, interdisciplinary overview of the neurocomputational as well as health and social psychological work on loneliness. We present evidence at three different levels of analysis (Figure 1): (i) individual level, where we synthesize studies on the relationships of loneliness with mental health, cognition and neurocomputational processes; (ii) interpersonal level, where we discuss evidence on the positive effects interactions with others and the environment can have on the individual; and, finally, (iii) societal level, where we show how community identity and group membership create the preconditions for healthy dynamics within societies. On the basis of preliminary evidence pointing to the effectiveness of community-based interventions that foster a sense of belonging [8,17,18], we propose a novel research agenda for future work to investigate how community-based approaches could reduce loneliness.

Loneliness in the individual

A wide range of research has focused on the impact of loneliness on individual mental health, cognition, and neural processing. In the next sections, we analyze this body of work to highlight the mechanisms that promote loneliness at the individual level.

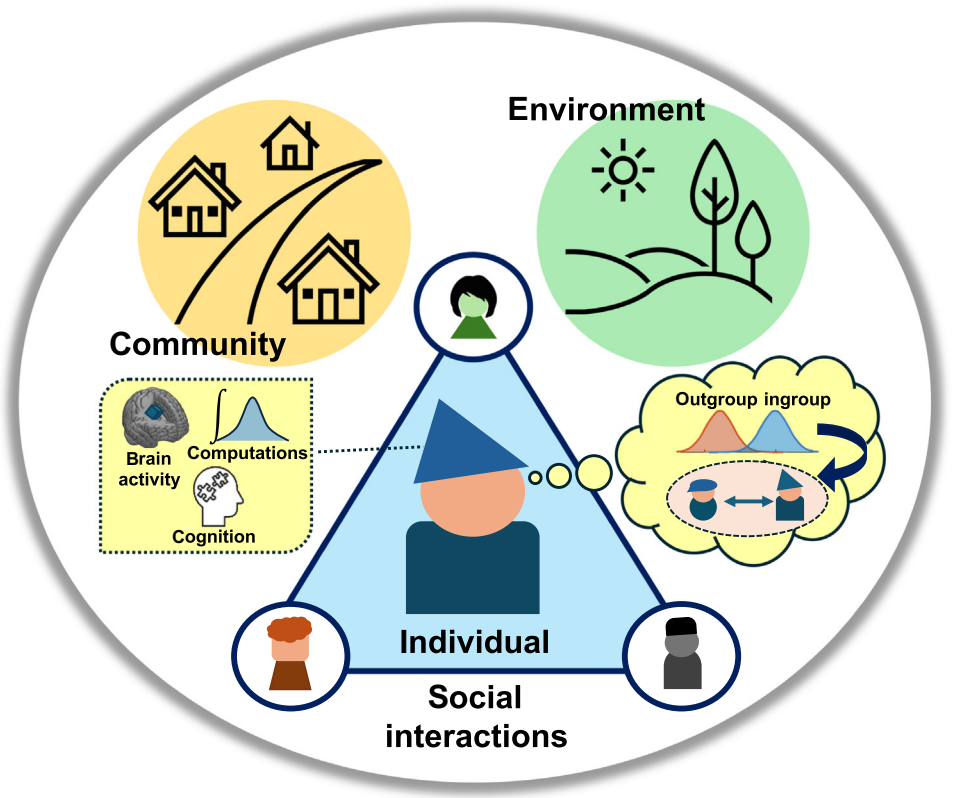

Figure 1. Multilevel dimensions of the effects of loneliness. Tackling loneliness requires studies at different levels of analysis: *individual level*, demonstrating the impact of loneliness on an individual's cognition, neural mechanisms and computational processes; *interpersonal level*, investigating the effects of an individual's interactions with other social partners and the surrounding environment; and finally, *societal level*, understanding the neurocognitive mechanisms triggered by community identity and group membership at the individual and interpersonal levels and the broader dynamics that supporting communities promote within societies.

Glossary

Community Sheds: Community Sheds (see Box 2 in the main text) are shared spaces where people can gather to socialize, work on projects, share skills, and collaborate. They offer a safe, welcoming environment for various social activities that promote regular encounters with others, group identification, and purpose of life.

Default mode network (DMN): the DMN is a network of functionally interconnected brain regions activated by processes broadly associated with mentalizing, such as self-reflection, autobiographical memory, and mental state representations. It includes areas such as the **temporoparietal junction**, medial prefrontal cortex, posterior cingulate cortex, and precuneus and has recently been associated with loneliness.

Ingroup favoritism: the tendency for people to prefer and give favorable treatment to members of their own group over those in an outgroup. It is tied to a basic human drive for belonging and identity and is manifested in different social behaviors (e.g., trust, generosity) and social expectations (e.g., their trustworthiness, kindness).

Investment game: a two-player, sequential decision-making paradigm where the investor receives an initial endowment they can share with the trustee. The amount shared by the investor (a measure of trust) is multiplied (generally tripled) and passed on to the trustee, who decides how much to return to the investor (a measure of reciprocity).

Mentalizing: the term 'mentalizing' – also labeled 'theory of mind' – denotes the ability to understand and interpret other people's behaviors in terms of their mental states (e.g., beliefs, desires, and intentions). It is a key skill for empathy, communication, and social behaviors.

Orbitofrontal cortex (OFC): a brain region crucial to decision-making, learning, and social behavior. It evaluates action outcomes by integrating different types of information and is involved in adjusting behaviors on the basis of changes in the environment and others' behaviors. It mediates the relationship between loneliness and a negativity bias in lonelier individuals.

Temporoparietal junction (TPJ): the TPJ is a brain region involved in social cognition, especially in processes such as perspective-taking, empathy, and

mentalizing. It is essential for social inferences and distinguishing between one's own and others' mental states. Its functional connectivity with the OFC correlates with more positive impressions of others in lonelier individuals.

Loneliness and mental health

Many studies have demonstrated that loneliness is associated with several mental health problems. Previous work has focused predominantly on the relationships between loneliness and depression [19], providing strong evidence on the longitudinal and bidirectional association of loneliness with depression onset [19,20]. However, there is now compelling evidence that loneliness is further associated with social anxiety, characterized by the fear of being negatively evaluated or judged by others in social interactions [19]. A longitudinal study tracking the development of loneliness and its relationship with anxiety over 6 months found that loneliness positively predicts future social anxiety and that social anxiety is a predictor of future loneliness [21]. Social anxiety is further associated with a number of dysfunctional processes and behaviors that impair an individual's ability to connect with others, such as selective attention, threat anticipation and excessive worrying [22–24].

Research has also found that loneliness is highly prevalent in schizophrenia spectrum disorders and has pointed to important clinical implications for psychotic experiences and paranoid delusions [25,26]. In support of a causal link, suspiciousness toward others (i.e., paranoid thoughts) has been found to worsen in experimental manipulations of social exclusion [27], and preliminary questionnaire-based evidence has also shown that reducing loneliness leads to a decrease of paranoid symptoms [28]. Furthermore, experience sampling research has found that feelings of loneliness predict more paranoid ideation over time, whereas the reverse is not the case. Interestingly, feelings of exclusion were related to decreasing trust in others, illustrating their impact on social behaviors [29,30]. This is in line with previous evidence showing that individuals affected by psychosis have higher levels of social distrust [31,32] and are less likely to cooperate with others [33], especially if they report higher levels of loneliness [34]. Importantly, loneliness and paranoia strongly correlate with each other cross-sectionally and over time not only in patients but also in healthy individuals [34]. Increased negative affect has been proposed as a mechanism leading to poor mental well-being in lonely, healthy individuals [29,35]. One of the key questions is why loneliness is so closely related to poor mental health. Some evidence that could explain this link comes from research into cognitive biases.

Loneliness and cognitive biases

Lonely individuals manifest a range of behavioral and reasoning patterns similar to many clinical symptoms, and extant evidence suggests that cognitive biases characterizing loneliness play a pivotal role in bridging between loneliness and clinical disorders [15]. This is because these cognitive biases have been associated with maladaptive reasoning and behavioral patterns that might worsen loneliness and potentially contribute to the development of mental health issues.

For instance, loneliness has been associated with memory and attentional biases [36,37] underlying hypervigilance for social threats [38]. Lonely individuals are more aware of and more sensitive to negative evaluations from others, remember more negative feedback, and judge others more negatively [39–41]. Experimental work shows that lonely individuals fixate earlier on threatening social stimuli and manifest difficulties in disengaging from socially threatening stimuli [26,37,42]. Such cognitive patterns affect not only the perception of present and the memory of past events but also expectations about the future [43]. This contributes to the formation of overly negative social expectations in lonely individuals, fostering distrust and social withdrawal that impair their ability to socially connect [15,44].

Similarly, biased learning has been suggested to contribute to more negative expectations of others and distrust among lonelier individuals. Specifically, in a learning task where participants learn about the honesty of their partner, lonelier individuals place greater emphasis on others'

dishonesty and expect more untrustworthy behaviors in a subsequent trust-based interaction [40,41]. Computationally, these behavioral patterns stem from a stronger integration of evidence about others' dishonesty, leading to the formation of more negative impressions of social partners [41].

Importantly, computational mechanisms other than biased integration processes could explain this negativity bias in impression formation among lonelier individuals. Previous computational studies have mostly inferred participants' beliefs by reverse-engineering their behavior, assuming that observed behaviors are strictly informative of an individual's expectations (i.e., if I don't trust you, it's because I don't think you are trustworthy). However, individuals might also form accurate expectations of others but display behaviors inconsistent with those expectations. Previous evidence indicates that expectations of others' trustworthiness and trusting behaviors might strongly diverge, especially in lonely individuals. For example, even though they rate strangers less favorably than acquaintances, lonely individuals show more positive attitudes toward strangers [45]. In the **investment game** (see Glossary), lonely individuals exhibit trusting behaviors that more strongly diverge from their expectations of others' trustworthiness [46].

To address this discrepancy between individual expectations and behaviors, recent computational work using the **investment game** has tested whether negative expectations and distrust among lonelier individuals were due to biased integration processes or other evaluative mechanisms [34]. Results show that a biased learning model was only second-best. The winning model was one with a weighting parameter that underweights prior expectations of partner reciprocity in favor of the potential negative consequences of a betrayal of trust (Box 1). This weighting parameter formalizes an individual's willingness to trust their partners above and beyond their expectations of partner reciprocity, capturing potential idiosyncrasies between individual expectations and behaviors. Thus, lonelier individuals manifested more distrustful behavior

Box 1. Willingness to trust in lonely individuals

Different traditions define 'trust' as the willingness to accept vulnerability to others on the basis of expectations of their behavior and intentions. Accordingly, a recently proposed, psychologically informed, computational model (i.e., the vulnerability model [128]) formalizes trust as a subject-specific weighting parameter (τ) that weights the degree to which an individual relies on their expectations of others' behavior against the negative consequences associated with a betrayal of trust. In the **investment game**, this trade-off is between the potential loss from sharing an amount [$s_t(i_t) = e_t i_t$, where e_t is the investor's initial endowment] and the expected reciprocity of the trustee (r_t) as the back-transfer from their endowment [the tripled amount received: $\eta_t(i_t) = 3s_t(i_t)$]. Psychologically, the amount shared constitutes a loss (negative utility), whereas the potential back-transfers represent a gain (positive utility). Thus, applying the vulnerability model to the **investment game**, the investor chooses an investment i_t as a proportion of their initial endowment e_t based on their expectations of the trustee's reciprocity ($\mathbb{E}[r_t|i_t, \mathcal{D}_{t-1}]$ or the proportion the trustee is likely to choose from $\eta_t(i_t)$) and their willingness to rely on these expectations (τ). This captures idiosyncrasies in trust whereby individuals differ in how strongly they weight past partner reciprocity when trusting. The investor's expectation $\mathbb{E}[r_t|i_t, \mathcal{D}_{t-1}]$ can be understood as the expected value of the conditional distribution $P_t(r_t|i_t, \mathcal{D}_{t-1})$ over the trustee's possible, finite proportions r_t they can choose from for their back-transfers, contingent on the investment i_t the investor will choose during the current interaction t and the history of the social interaction with the trustee until now ($\mathcal{D}_{t-1}$). The vulnerability model formalizes this with the following utility function:

$$u_t(i_t, \mathcal{D}_{t-1}) = e_t - (1-\tau)\, s_t(i_t) + \tau\, \eta_t(i_t)\, \mathbb{E}[r_t|i_t, \mathcal{D}_{t-1}],$$

where $\tau \in [0, 1]$ reflects the investor's willingness to rely on their expectations of the trustee's reciprocity (i.e., their willingness to trust) against the consequences of a betrayal of trust [128]. These expectations are updated trial by trial based on the observed back-transfers.

Recent work [34] found that the vulnerability model better explains trust behavior among lonely individuals than a biased learning model, which ranked second-best. This work shows that lonely individuals do not integrate evidence in a biased way, but instead exhibit a lower willingness to trust (i.e., lower τ values). Lower τ reflects a tendency to underweight the predictive prior expectation $\mathbb{E}[r_t|i_t, \mathcal{D}_{t-1}]$ in favor of the potential loss from sharing [$s_t(i_t)$], suggesting that lonelier individuals are less inclined to rely on their own beliefs about how others are likely to behave in the future.

because they were less willing to rely on their expectations of partner reciprocity rather than because of biased learning processes.

Another potential mechanism underlying maladaptive behaviors and reasoning in lonely individuals relates to biased inferences about others' intentions and behaviors (**mentalizing**) [47,48]. Negative social expectations and behaviors might hinge on lonely individuals' tendency to predict unkind, unsupportive, and untrustworthy behaviors from others in future interactions. This might generate paranoid-like thinking patterns with excessive attributions of harm intent [49] that fuel distrust and social withdrawal [50,51]. Previous work indicates that lonelier individuals have even more negative expectations of others and manifest higher levels of distrust during the unfolding of a social interaction if they also report high levels of paranoid thoughts [27,34]. Such distrustful suspiciousness might be a core mechanism underlying higher risk of conspiracy theorizing among lonely individuals [52].

Loneliness and neural mechanisms

Defensive behaviors in response to abuses of trust represent an adaptive, protective mechanism to safeguard an individual in vulnerable circumstances. However, these behaviors might turn maladaptive in safe and trustworthy interactions when, for instance, individuals end up distrusting a benevolent partner [29]. Cognitive biases might facilitate these maladaptive behavioral patterns, with deleterious consequences for social functioning. However, how these cognitive biases translate into maladaptive behaviors is still not well understood [53]. Understanding the neurocognitive mechanisms of loneliness can help provide a mechanistic explanation of how cognitive biases foster deleterious behavioral and thinking patterns in lonely individuals, which might in turn be useful to identify lonely states and their different stages in individuals (Figure 2).

Lonely individuals have been shown to more strongly recruit brain regions associated with an attentional brain network and manifest stronger activations in response to unpleasant social pictures, likely resulting in an attentional bias toward more negative events [54,55]. Dopaminergic brain regions associated with reward processing (e.g., ventral striatum) are less engaged by pleasant social pictures in lonelier individuals, indicating differing neural processing of positive social information [54,56]. Similarly, processing of naturalistic social scenes evokes higher neural similarity between two nonlonely individuals than in dyads where one or both individuals are lonely [57]. Crucially, lonelier individuals manifest more distinct neural representations of self and others in the medial prefrontal cortex during evaluations of one's own and others' personality traits, which has been interpreted as evidencing stronger idiosyncratic processing of the social world [58].

Biased information integration and inference processes might be traced back to reduced engagement of brain regions responsible for social learning and belief formation. For example, stronger integration of negative information about others' traits in a social learning task has been linked to reduced activity in the **orbitofrontal cortex** (**OFC**), particularly when processing positive feedback about others' behaviors [41]. Importantly, reduced **OFC** activations in response to positive social cues have further been associated with more negative impressions of others' trustworthiness [41]. Moreover, evidence on stronger functional connectivity within the **default mode network** but overall less whole-brain network segregation (a central neural marker in schizophrenia) among lonely individuals indicates differences in information integration and representation of social events and others [59–61].

Importantly, greater discrepancy between social expectations and behaviors in lonely individuals might be associated with a higher frequency of experiencing expectation violations, which could trigger various retaliative and punishing behaviors. For example, lonely individuals' distrust during

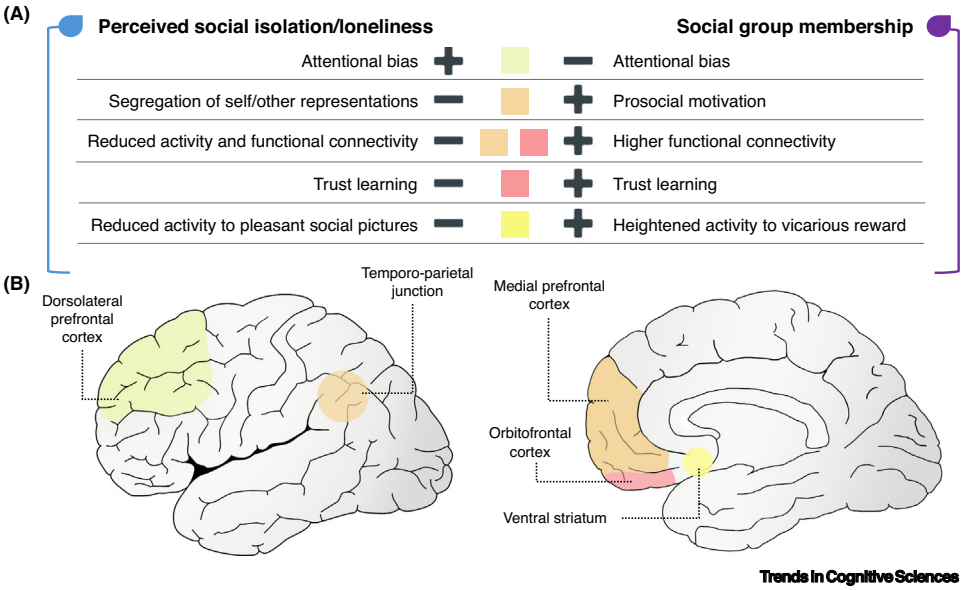

Figure 2. Overview of the neurocognitive underpinnings of loneliness. This figure schematically shows the different cognitive processes and biases linked to loneliness and group membership. (A) Loneliness and group membership have been observed to have opposite effects on many cognitive functions (e.g., self/other representations, trust), biases (e.g., attention), behaviors (e.g., prosociality), and brain processing (e.g., brain activity and functional connectivity). In particular, the positive effects of group membership across these dimensions suggest that group membership (likely via community identity) might effectively counteract the negative impact of loneliness on individual well-being. (B) Key brain regions linked to differential neural processing in loneliness and group membership studies. The temporoparietal junction, because of its role in mentalizing, and the orbitofrontal cortex, as an information integration and learning hub, are particularly important to social information and inference processes during social interactions for the establishment of successful social relationships in lonely individuals.

the **investment game** might signal irritation or disappointment with their partner's reciprocity [62,63], which in turn might facilitate attributions of malicious intent [64] even when interacting with overall benevolent and reciprocating partners [34]. Neural evidence shows that during encoding of others' behavior, stronger functional connectivity between the **OFC** and the **temporoparietal junction** (central to **mentalizing**) correlates with more positive impressions of others, suggesting a potential neural mechanisms counteracting malicious intent attribution [41].

Overall, these studies indicate that complex neurocognitive dynamics involving attention, memory, learning, and inference processes play a central role in lonely individuals' maladaptive social behaviors and their difficulties in connecting with others.

Loneliness in the group

Although the above-mentioned cognitive biases and their neurocomputational mechanisms could contribute significantly to the development and maintenance of maladaptive social behaviors in lonely individuals, the responses of their social partners (interpersonal level) and the structure of their social environments (societal level) are likely to play an equally significant role in how lonely they feel. It is thus imperative to shift our focus beyond individual cognitive processes and attend to the broader social context.

Social environments that reinforce positive interactions might help mitigate the negative interpretations and defensive behaviors exhibited by lonely individuals. Conversely, environments characterized by exclusion and indifference toward those who are lonely may exacerbate lonely individuals' biases and reinforce behaviors that increase feelings of loneliness (e.g., social

withdrawal). This highlights the importance of creating social environments that actively promote positive social exchanges. Thereby, we can address not only the biased neurocognitive mechanisms underpinning loneliness but also the social structures that help us tackle its disruptive feelings. In the next sections, we review the social and health psychological literature on how group-based approaches may help tackle loneliness more effectively through the lens of its neurocomputational underpinnings.

Loneliness and the social environment

Recent loneliness research has increasingly shifted its attention from the individual to environmental and societal factors [65,66]. Previous work has associated mental health in general, and loneliness in particular, with objective characteristics of neighborhoods[ii], such as fewer resources and opportunities, stress-inducing factors (e.g., poverty, crime, heavy traffic), and socioeconomic variables [67,68]. Loneliness is geographically patterned, with overcrowded urban areas reporting the highest levels of loneliness [69,70], and unemployment, low income levels, and socially disadvantaged neighborhoods have been associated with higher levels of loneliness [67,68]. Preliminary work shows that neighborhood attachment and social cohesion are associated with higher frequency of public space use and life satisfaction, as well as lower loneliness [71].

Conversely, objective measures of green space availability and use have been associated with better perceived mental health, reduced mental distress [72,73], and lower levels of depression and anxiety [74,75]. Longitudinal work suggests that exposure to green spaces during childhood, especially for individuals with high levels of social deprivation, is associated with better mental health outcomes at age 70, particularly protecting against anxiety [76]. Finally, a study combining experience-sampling methods with neuroimaging techniques has shown that exposure to green spaces is associated with better momentary psychological well-being and reduced prefrontal activity during negative emotion processing [77]. These results suggest that intervening to modify features of the built environment could reduce loneliness in different ways and possibly improve overall mental health as a result [78].

Yet, the relationship of those objective environmental and societal features with loneliness is not consistent [74,75,79]. Some disadvantaged neighborhoods in fact offer better resources than advantaged ones (e.g., more local communal space and better social support networks) [80], and people do not always exploit the available environmental resources [81]. Moreover, the same environment differently influences the mental health of individuals from different social groups [79]. Because these features and subjective experiences of them often diverge [82], intervening to change those objective features might not always be effective in reducing loneliness. On the contrary, characteristics of a person's social network and social support (e.g., perceived meaningfulness of one's social network) are central to the emergence of loneliness and the development of associated clinical disorders [83,84]. This calls for psychological investigations into how individuals experience and behave within their (social) environments and, relatedly, how these dynamics impact loneliness.

Drawing on the social identity literature [85–87], health and social psychologists have indicated that community identity plays a pivotal role in shaping the experience and perception of environments, as well as in modifying the influence of objective environmental features on loneliness [66,88]. Community identity is a person's sense of self stemming from their membership in their local community (e.g., neighborhood) [89,90]. Past research found that strong community identity is associated with a range of positive physical [91] and mental [92] health outcomes. Community identity can alleviate depression [88] both directly and indirectly via increased self-

esteem [93]. More relatedly, a lower sense of belonging correlates with higher levels of loneliness [94], and community identity has been associated directly with reduced loneliness [66,95].

Loneliness and community identity

Correspondingly, interventions aimed at fostering a sense of belonging and community identity have shown promising positive impacts on loneliness and mental health [18,96,97]. Nevertheless, the mechanisms by which community-based interventions might be effective are unknown. Below, we explore the hypothesis that the experience of shared group membership, social support, and group identity fostered by community-based approaches might help individuals counteract the neurocognitive biases associated with loneliness.

The key principle of the community-based approach is to offer a community space in which individuals can, for instance, mingle, work, and develop skills together [96,98]. Psychologically, they establish a positive community identity that promotes social support between community members. Community-based approaches often target a certain group of individuals to create group cohesion and to facilitate awareness among participating members that they are similar to one another. Such awareness has been found to increase positive community identification [92].

Shared group membership fosters positive expectations about group members' behaviors, and previous studies have consistently found that individuals tend to expect group members to be more cooperative [99,100] and trustworthy [101] than strangers. Previous empirical research suggests that individuals' higher levels of cooperation with ingroup members is due to the positive assumption that ingroup members are trustworthy [102]. The importance of a strong ingroup feeling for social affiliation and trust also yields support from large-scale and cross-cultural experimental research on trust and trustworthiness perceptions in the **investment game** across 17 different countries [101].

In line with this, previous work has consistently demonstrated that individuals trust and cooperate substantially more with ingroup members than with strangers or outgroup members [103]. Such **ingroup favoritism** has positively been associated with the strength of an individual's group identification [104]. Importantly, **ingroup favoritism** has been shown to result from increased ingroup cooperation rather than outgroup derogation, suggesting that **ingroup favoritism** has a direct, positive effect on social behaviors toward ingroup members [103,105]. Together, this evidence suggests that identification with a group can enhance positive expectations about others, potentially helping lonely individuals form less negative impressions of others and equilibrizing the associated biases that reinforce them. Community-based approaches designed to cultivate community identity may hence help lonely individuals nurture a more positive outlook on their social partners and promote more adaptive social behaviors [106]. Consequently, they may support individuals to build trust and form long-term, supportive, meaningful bonds that could be effective in reducing their feelings of loneliness.

The specific programs offered in community-based approaches provide the opportunity for individuals with similar interests to self-select and opt into activities where they will interact with similarly minded peers. These offer valuable shared experiences that might increase bonding and social integration, buffering against psychological stress [107] and promoting well-being [108]. In particular, social bonding has a strong rewarding effect and is key to social buffering [109]. Social buffering relates to animals' ability to better recover from aversive experiences when in groups and plays an important role in increasing social affiliation, reducing stress levels and improving well-being [109]. Isolated and lonely individuals show high levels of stress responses [110], and social isolation has strong negative effects on both physical and mental well-being [111].

Experimental work has shown that social identity buffers against stressful experiences by attenuating stress-induced cortisol levels [112,113]. Furthermore, dopaminergic brain regions have been associated with an individual's strength of community identity [114], social approval [115], social inclusion [116], and **ingroup favoritism** in prosocial motivation [117]. Specifically, social buffering may reduce lonely individuals' heightened stress levels and mitigate their feelings of loneliness via oxytocinergic modulations of dopamine transmission associated with attenuated stress [110].

In addition, community-based approaches may enhance resilience against negatively biased inference processes among lonely individuals by providing repeated exposure to positive social impressions. For instance, behaviors by ingroup members are perceived more favorably, with their prosocial actions seen as more altruistically motivated than identical behaviors by outgroup members [118,119]. Such benevolent attitudes toward ingroup members may emerge over time through the reframing of their behavior in line with initially positive expectations [120]. These attitudes can foster attributions of benign intent, encouraging affiliative behavior and counteracting suspiciousness and paranoid-like thinking in lonely individuals [93]. Thus, by promoting positively-biased expectations through **ingroup favoritism**, community identity may facilitate more favorable social impressions and social interactions, increasing the likelihood of rewarding social experiences. Thereby, community identity may initiate a virtuous cycle of expectations, attitudes, behaviors and feedback that counteracts the vicious spiral of negative biases and maladaptive behavioral responses in loneliness [38].

Importantly, though, community-based interventions can also reinforce lonely individuals' maladaptive cognitive biases or paranoid thinking if the psychological safety of individuals is not ensured [51,121]. Because of heightened sensitivity to social threats, social exchanges for individuals experiencing loneliness and persecutory ideation may be fraught with ambiguity, misunderstanding, or even social rejection and exclusion. To mitigate these risks, community-based interventions around the world, such as **Community Sheds**, establish clear ground rules and explicitly promote a culture of inclusion and equality[iii]. In addition, some community-based interventions implement a 'buddy system' in which experienced members help newcomers by providing orientation and social support, thereby facilitating smoother engagement and safer social interactions. Thus, clearly shared ground rules and concrete systems that help implement them in practice enable community-based interventions to work effectively. This is particularly important, given the complexity of human social dynamics and the potential for (unintended) adverse effects on vulnerable individuals.

In sum, this evidence tentatively suggests that community-based approaches might be particularly effective in reducing loneliness if the psychological safety of individuals is ensured by fostering social group membership, regular encounters with others, and meaningful and purposeful relationships.

Concluding remarks

Loneliness has been declared a pressing public health issue by the World Health Organization[iv] and international governments[v]. Here, we highlighted the need to consider both the neurocognitive processes at the individual level and the social structures and dynamics at the interpersonal and societal levels to properly tackle the current loneliness epidemic. Consequently, we concluded that the available evidence tentatively indicates community-based approaches as promising interventions for the successful reduction of individual feelings of loneliness.

Future work needs to address a few gaps we identify in the extant literature (see Outstanding questions). First, the nascent computational literature on social behavioral neuroscience still heavily relies on models developed in other disciplines for far less complex (nonsocial)

Outstanding questions

Can improved computational models capture the complexity of social cognition and help disentangle inference from learning biases in lonely individuals?

How does the sense of belonging induced by community identity counteract neurocognitive biases in lonely individuals?

Can community identity effectively reduce loneliness across different cultural contexts?

Can community-based approaches tackle the neurocognitive biases triggered by loneliness and reduce feelings of loneliness?

To what extent can tackling loneliness help address other mental disorders?

environments. These models make simplifying assumptions about the structure of social interactions, which are often violated. As recently suggested, future computational work needs to adopt frameworks that better embed the existing social knowledge into computational models [122]. The ability of models to satisfactorily reveal the computational failures of biased reasoning in loneliness (as well as clinical disorders) can at best be only as good as their ability to adequately capture the complex dynamics of social reasoning in general.

Second, social and health psychological studies have so far provided some preliminary evidence on the impact of community-based approaches to loneliness, but future empirical investigations are still needed to properly evaluate their effectiveness and understand how they actually work. Some countries have already successfully implemented some community-based approaches (e.g., Community Sheds [123]; Box 2) and integrated them into their general practitioner systems [8]. The existing sites and interventions can be an ideal testbed for computationally informed, empirical tests on how community-based interventions successfully buffer against the contributing factors of loneliness. As opposed to in-lab studies, they provide real-life settings where researchers could further deepen our understanding of the usefulness of physical (i.e., in-person) social interactions in building trust and creating social connections. Previous research has already demonstrated that face-to-face interactions are uniquely effective in strengthening social bonds [124] and building interpersonal trust [125].

Finally, we note that community-based approaches have been implemented mostly in rich Western countries. As such, the existing findings on their effectiveness may not be generalizable to different cultural contexts. For instance, previous studies have suggested that community identity differs between Western and East Asian cultures. Although individuals in Western cultures tend to perceive a community as a homogeneous entity consisting of similar, interchangeable individuals, East Asian individuals tend to perceive it as a network of unique individuals [126]. Consequently, among East Asians, it is not perceived similarity among group members but knowledge about how group members are interconnected that predicts strong identification [127]. These findings suggest that community identity might have different buffering effects in individuals with different cultural backgrounds. As a consequence, its positive effects on loneliness might greatly vary across cultures.

However, in the various disciplines we have reviewed, there already exist multiple tools to address these gaps, and an interdisciplinary effort could help bridge the current knowledge and

Box 2. Community Sheds

Community Sheds are a type of community approach that originated in Australia in the 1990s to maintain and improve older men's mental health [123]. Community Sheds are often referred to as Men's Shed but are not exclusive for men [98]. In Community Sheds, participants engage in various activities, including woodworking and metalworking (e.g., crafting furniture and fixing local infrastructure). Previous work has consistently reported the positive impact of participation in Sheds on mental and physical health [96,97]. Recognizing their effectiveness, some countries have integrated Community Sheds into their general practitioner system and formally serve as a secondary intervention to loneliness [8].

Specific programs in Sheds typically offer the opportunity for individuals with similar interests to self-select and opt into activities, sometimes with collective goals. These experiences offer valuable shared experiences that increase sense of belonging and social integration, offering an environment where individuals can expect and indeed experience cooperative social interactions. Sheds go beyond merely offering opportunities for social interactions by providing *a place* for continuous safe and positive social engagements.

Successful Sheds typically involve participant-driven management and organization [17] that establish rules and norms in the Sheds shaped by their members. This provides meaningful purpose within a group and induces a strong sense of belonging to a community that effectively provides a social environment where people can have positive and meaningful interactions with others. This may ultimately help lonely individuals avoid engaging in protective behaviors that reinforce cognitive biases fostering social withdrawal.

methodological deficits in each of those disciplines to readily tackle the many remaining questions. These methods and practices will enable deeper insights into the mechanisms underpinning the emergence and worsening not only of loneliness but of many other mental disorders as well, significantly contributing to the development of theory-informed, empirical investigations and interventions to improve mental health in the general and clinical populations. With this review, we hope to initiate a multidisciplinary discourse that could bridge computational social neuroscience and social and health psychology. Such discourse can spark new research avenues that might, in the near future, bring significant progress in current attempts to address loneliness.

Author contributions

G.B.: Conceptualization; methodology; visualization; project administration; writing – original draft; writing – review and editing. H.I.: Conceptualization; writing – original draft; writing – review and editing. A.-K.F.: Writing – review and editing. A.I: Conceptualization; writing – review and editing.

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Declaration of Interests

The authors declare no competing interests.

Resources

[i]www.lse.ac.uk/business/consulting/reports/making-the-economic-case-for-investing-in-actions-to-prevent-and-or-tackle-loneliness.aspx (accessed June 12, 2023)

[ii]www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/compendium/nationalmeasurementofloneliness/2018/recommendednationalindicatorsofloneliness (accessed May 6, 2024)

[iii]https://menssheds.ie/wp-content/uploads/2021/08/MENS-SHED-TOOLKIT-FOR-UK-AND-IRELAND.pdf

[iv]https://www.who.int/news/item/15-11-2023-who-launches-commission-to-foster-social-connection (accessed April 5, 2025)

[v]www.gov.uk/government/publications/tackling-loneliness-evidence-review/tackling-loneliness-evidence-review-full-report (accessed August 8, 2023)

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