Loneliness and objective social isolation are differentially associated with anomalous perceptions in community-dwelling older adults

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Introduction: Anomalous perceptions are characterised by the subjective experience of a range of distorted and/or hallucinatory percepts. Whilst considerable attention has been paid to the neurocognitive processes contributing to anomalous perceptions amongst older adults, less is known about the social factors (e.g., social isolation, loneliness). Furthermore, it is unknown whether loneliness and social isolation are associated with different types of anomalous perceptions, including anomalous body-centred self-experiences and anomalous external experiences. **Methods:** This study examined the cross-sectional relationships between loneliness, objective social isolation, and anomalous perceptions in a sample of community-dwelling older adults (N = 242, M_{age} = 71.87 ± 7.73, range = 52-91, 67.8% female) using structural equation modelling. **Results:** Higher levels of loneliness were associated with more anomalous body-centred self-experiences and anomalous external experiences. Those reporting more loneliness also reported higher levels of anxiety and depression; however, the relationship between loneliness and anomalous perceptions was not mediated by these factors. Social disconnection from a religious group was associated with more anomalous external experiences and being married/living with a partner was associated with more anomalous body-centred self-experiences. **Conclusions:** These findings suggest that loneliness and social isolation have differential associations with anomalous perceptions in older adults and provide additional evidence that attending to loneliness in older adults is important.

Keywords: ageing; older adults; anomalous perceptual experiences; loneliness; objective social isolation

Anomalous perceptions refer to a broad range of perceptual distortions (e.g., changes in perceived size) and/or hallucinatory experiences (e.g., "hearing" voices that other people cannot) in any sensory modality (Bell et al., 2006). Although hallucinations represent one example of the general category, most research has focused on hallucinations specifically, rather than seeking to understand the phenomenology and potential mechanisms of anomalous perceptions more broadly. Additionally, while hallucinations are relatively common in the general population (Badcock et al., 2017), most studies have investigated anomalous and hallucinatory experiences in younger populations or in older adults with clinical disorders (e.g., Parkinson's disease). Thus, knowledge of the mechanisms underlying anomalous perceptions in community-dwelling older adults (without psychotic disorders/dementia) remains limited.

While some anomalous perceptions appear of little clinical importance, some cause the individual and/or their family considerable distress. Indeed, amongst older adults, anomalous perceptions, including hallucinations, are associated with increased risk of cognitive decline (Gasca-Salas et al., 2016), residential care placement (Scarmeas et al., 2005) and caregiver stress (Chiu et al., 2017). In the context of global population ageing, these findings highlight the need to investigate the potential correlates of anomalous perceptions in older adults. Perceptual anomalies may even offer insights into the development of mental health problems in older adults, and improved assessment and intervention strategies.

Using the Cardiff Anomalous Perceptions Scale (CAPS; Bell et al., 2006), Kelsall-Foreman et al. (2020) showed that anomalous perceptions in community-dwelling older and younger adults comprise two factors: anomalous body-centred self-experiences (alterations in body, touch, smell, and taste perception; Factor 1), and

anomalous external experiences (auditory, visual, and sensed presence hallucinations; Factor 2). These factors describe experiences with potentially different causes and consequences. Whilst the neurocognitive processes related to anomalous perceptual experiences amongst older adults have been studied, less is known about social factors that may be associated with anomalous perceptions, such as social isolation and loneliness.

Objective social isolation and loneliness are related, but separable constructs (Menec et al., 2019). Social isolation is a quantitative measure of the paucity of an individual's social network and contact with others, often indexed by marital status, social network size, and frequency of contacts (Badcock et al., 2022). In contrast, loneliness occurs when an individual perceives their social relationships to be fewer in quality and quantity than desired (Hawkley, 2018). Individuals may be objectively socially isolated but not lonely, whereas others may have many social connections but feel lonely (Coyle & Dugan, 2012). Consequently, examining both social isolation and loneliness is recommended to characterise an individual's overall social context (Newall & Menec, 2019), and because these experiences may be related.

Examining both allows researchers to investigate their unique and combined ability to predict anomalous perceptions, independently of potential confounding factors. In particular, age and sex have been linked to variations in the experience of anomalous perceptions (Östling et al., 2013; Scott et al., 2008), loneliness (van den Broek, 2017), and social isolation (Vandervoort, 2000), though not consistently. Furthermore, increased levels of depression and anxiety are common consequences of both (Beutel et al., 2017; Santini et al., 2020), whilst cognitive models outline a direct role of emotion in the onset of hallucinations (Paulik et al., 2006). It is important,

therefore, to consider affective states as potential mediators between an individual's social context and their experience of anomalous perceptions.

A much-cited account of the induction of hallucinations is the social deafferentation (SDA) hypothesis (Hoffman, 2007, 2008), which states that "high levels of social withdrawal/isolation in vulnerable individuals prompt social cognitive programs to produce spurious social meaning in the form of complex, emotionally compelling hallucinations and delusions representing other persons or agents" (Hoffman, 2007, p. 1066). The SDA hypothesis was proposed to explain hallucinations in schizophrenia; however, it has not been explored much in non-clinical, older adult samples, nor does it distinguish between the roles of social isolation and loneliness. One study (El Haj et al. 2016), found that social isolation significantly predicted hallucinations in both older adults with Alzheimer's disease and age-matched healthy controls, despite controlling for loneliness. This suggests that objective (rather than subjective) social isolation is associated with the production of anomalous perceptions, though whether this includes one or both factors of anomalous perceptions identified by Kelsall-Foreman et al. (2020) was not explored.

Given the social nature of the hallucinatory experiences described in the SDA hypothesis, it may be that social isolation is associated with anomalous perceptions involving other people or agents (termed anomalous external perceptions [Factor 2]; Kelsall-Foreman et al., 2020), whilst a relationship with anomalous body-centred self-experiences (Factor 1; Kelsall-Foreman et al., 2020) is less clear. On the other hand, in an extension of the SDA hypothesis in a sample of individuals with schizophrenia and matched controls, Michael and Park (2016) found high levels of loneliness were associated with increased risk of experiencing spurious anomalous bodily experiences,

leaving open the possibility that loneliness is also associated with anomalous body-centred self-experiences (Kelsall-Foreman et al.'s [2020] Factor 1).

This study examined cross-sectional relationships between loneliness, objective social isolation, and anomalous perceptions in community-dwelling older adults, hypothesising that (H1) higher levels of loneliness would relate to higher scores on a latent variable measuring anomalous body-centred self-experiences (Michael & Park, 2016), and (H2) higher levels of objective social isolation would relate to higher scores on a latent variable measuring anomalous external experiences (Hoffman, 2007, 2008), after adjusting for age and sex. Novel to this study, we also conducted exploratory analyses examining the relationships between loneliness and anomalous external experiences, and between social isolation and anomalous body-centred self-experiences. A secondary aim considered whether anxiety and depression mediated any relationships found.

Method

Participants

Participants were recruited through the Healthy Ageing Research Program (HARP) which is a longitudinal study of community-dwelling adults aged 50+ years that aims to investigate age-related changes in neuropsychological functioning and behaviour. Participants within the longitudinal study were initially recruited through several different avenues, including local bulletin boards and newspapers, community presentations, online via social media, and through personal connections. Given the focus on examining anomalous perceptions in older adults without psychotic disorders or dementia, participants with evidence of cognitive impairment (<18 on the telephone adapted version of the Montreal Cognitive Assessment [T-MoCA; Pendlebury et al.,

2013, *n*=15] or <24 on the Folstein Mini-Mental State Examination [MMSE; Folstein et al., 1975; O'Bryant et al., 2008, *n*=2]), history of neurological (e.g., stroke, Parkinson's disease, *n*=20) and/or psychiatric conditions associated with anomalous and hallucinatory experiences (e.g., schizophrenia, post-traumatic stress disorder, *n*=13) were excluded. Those who declined cognitive screening (*n*=18) or provided no data for key measures (*n*=6) were excluded, leaving 242 participants (range 52-91 years). Approval was provided by the Human Research Ethics Committee, University of Western Australia (RA/4/1/5361).

Materials

The **UCLA Loneliness Scale-3 (UCLA-LS3; Russell, 1996)** contains 20-items assessing feelings of loneliness, each rated from 1 ("*never*") to 4 ("*always*"). Responses are summed (range 20-80), with higher scores indicating greater loneliness. The UCLA-LS3 has excellent internal consistency (Cronbach's α=.89-.94) and validity (Russell, 1996).

Objective social isolation was measured using the **Brief Social Activity Index (BSAI; Hawkley et al., 2005)**, which summarises an individual's social contacts across a range of social domains, with good construct validity in older adults (Hawkley et al., 2005). The 4 BSAI items examine: (1) whether the individual is married/living with a partner ("yes"=1, "no =0), (2) number of friends/relatives spoken to every 2 weeks (≥2=1, ≤2=0), (3) membership of a religious group/church ("yes"=1, "no"=0), and (4) membership in social/sporting/neighbourhood groups (≥2=1, ≤2=0). Responses are summed (range 0-4), with lower scores indicating greater social isolation. In this sample, the BSAI total score had poor internal consistency (McDonald's Omega total [ωt]=.38). Consequently, each BSAI item was modelled simultaneously.

The **CAPS (Bell et al., 2006)** has 32 items assessing the tendency to experience perceptual anomalies across five sensory modalities, tapping changes in sensory intensity/distortion of perceptual input, and hallucinatory experiences. Participants answer with "yes" or "no". The total CAPS score is the number of items endorsed "yes" (range 0-32)[1], with higher scores indicating more anomalous perceptions. The CAPS total score has good internal consistency (Cronbach's α=.87; Bell et al., 2006) and convergent validity (Jaén-Moreno et al., 2014). The current study utilised the two-factor (23-item) form of the CAPS identified by Kelsall-Foreman et al. (2020). The first factor is labelled "*anomalous body-centred self-experiences*" and encompasses items related to alterations in body, touch, smell, and taste perception (CAPS items 8, 9, 14, 17, 18, 20, 21, 25, 29, and 30). One example item from this factor is CAPS Q8 which asks "*Do you ever detect smells which don't seem to come from your surroundings?*". The second factor is labelled "*anomalous external experiences*" and encompasses items related to auditory, visual, and sensed presence hallucinations (CAPS items 1, 2, 3, 4, 5, 6, 7, 15, 22, 23, 27, 31, and 32). One example item from this factor is CAPS Q2 which asks "*Do you ever sense the presence of another being, despite being unable to see any evidence?*".

The **T-MoCA (Pendlebury et al., 2013)** is a brief (10-15mins), valid, and reliable measure of cognitive status. Scores range from 0 to 22, where a cut-off of <18 indicates mild cognitive impairment (Pendlebury et al., 2013).

The **Folstein MMSE (Folstein et al., 1975)** is a brief (5-10mins), well-established instrument assessing overall cognitive status (Folstein et al., 1975). Scores

[1] For each item endorsed "yes", participants also rate the level of associated distress, intrusiveness, and frequency on a 5-point scale. Here, factor analysis is of the "yes/no" responses to all CAPS items; therefore, these subscales were not analysed further.

range from 0 to 30, with a recommended cut-off score to detect cognitive impairment of <24 (O'Bryant et al., 2008).

The **Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001)** contains 9 items examining depressive symptoms over the last 2 weeks, with good validity in older adults (Costa et al., 2016). Higher scores indicate greater levels of depressive symptoms (range 0-27).

The **Generalized Anxiety Disorder Scale-7 (GAD-7; Spitzer et al., 2006)** has 7 items examining generalized anxiety symptom severity over the last 2 weeks, valid in clinical and research settings (Spitzer et al., 2006). Higher scores indicate greater levels of anxiety symptoms (range 0-21).

Procedure

Participants completed the questionnaires online or by post and were informed that return of completed questionnaires indicated consent to participate. The questionnaires took approximately one hour. Within 4-6 weeks of questionnaire completion, participants completed the T-MoCA or MMSE with a trained assessor.

Data Analysis

Descriptive analyses were conducted in SPSS (IBM Corp, released 2017) and JASP (JASP Team, 2019). The GAD-7 and PHQ-9 each had one missing value (0.059% and 0.046% missing values, respectively), so Little's MCAR was not calculated for these data. Little's (1988) MCAR test was used to examine missing values for the UCLA-LS3 (0.124% missing values), BSAI (2.789%), and CAPS (0.181%). Data from the UCLA-LS3 and BSAI were missing completely at random (MCAR; Little's MCAR $p = .540$ and $p = .866$, respectively). Given the very small proportions of missing values in all measures (<5%), expectation maximisation (25 iterations) was used to replace values in

the BSAI, GAD-7, UCLA-LS3, and PHQ-9. The CAPS was not MCAR ($p < .001$), though imputation would not have been appropriate because of the categorical nature of the data. Because factor analysis using maximum likelihood can handle cases with missing values (0.181% for CAPS), all cases were included in the analyses. The internal consistency of the UCLA-LS3, BSAI, CAPS, PHQ-9, and GAD-7 were calculated using ωt, with values >.70 considered adequate (Nunnally, 1978).

First, we used Mplus version 8.0 (Muthén & Muthén, 1998-2017) to test whether the original 2-factor CAPS model identified by Kelsall-Foreman et al. (2020) gave good fit to the current data. Next, structural equation modelling was conducted to test associations between loneliness, social isolation, anomalous body-centred self-experiences (Factor 1), and anomalous external experiences (Factor 2). Lastly, depression and anxiety were examined as mediators in the relationships between loneliness, social isolation, and perceptual anomalies. Drawing on prior evidence, sex and age were included as covariates in all models.

A robust weighted least-squares mean and variance estimator was used given the categorical nature of CAPS data (Muthén & Muthén, 1998-2017). Fit statistics were: chi-square (χ^2), standardized root mean square residual (SRMR; Jöreskog & Sörbom, 1998), comparative fit index (CFI; Bentler, 1990), Tucker-Lewis index (TLI; Tucker & Lewis, 1973), and root mean square error of approximation (RMSEA; Steiger, 1990). Recommended cut-offs for reasonable model fit to the data were: SRMR .06-.08, CFI .90-.95, TLI .90-.95, and RMSEA .05-.08 (Byrne, 2001; Hu & Bentler, 1999; Tabachnick & Fidell, 2001), and for good model fit were: SRMR<.06, CFI≥.95, TLI≥.95, and RMSEA<.05 (Hu & Bentler, 1999; Tabachnick & Fidell, 2001; Yu, 2002).

Results

Descriptive Statistics

Table 1 reports sample demographics. Table 2 reports means, *SD*s, ranges, and ωt for the UCLA-LS3, CAPS Factor 1 and 2, PHQ-9 and GAD-7: 58.7% of participants reported at least one anomalous perceptual experience (see Table 3)[2], 16.1% reported a PHQ-9 score above the recommended cut-off of 5 (Pellas & Damberg, 2021), while 10.7% of participants reported a GAD-7 score above the recommended cut-off of 5 (Wild et al., 2014)[3].

Table 4 provides fit statistics for all models. Of the 242 participants, CAPS data from 194 (80%) were also used in Kelsall-Foreman et al. (2020). Model fit was adequate to good; in particular, the RMSEA revealed good fit. However, CAPS Item 21 had a negative residual variance. The residual variance of a categorical item is not a model parameter and thus cannot be fixed to zero (Muthén, 2013), so this item was removed from subsequent analyses.

In Model 1 (Figure 1), higher levels of loneliness were associated with higher levels of anomalous body-centred self-experiences[4] and higher levels of anomalous external experiences. When examining social isolation, being married/living with a partner was associated with higher levels of anomalous body-centred self-experiences and being a member of a religious group was associated with lower levels of anomalous external experiences. Lower levels of loneliness were associated with being married or

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[2] Table S1 shows frequency counts for each individual CAPS item.

[3] Tables S2 and S3 show frequency counts for the GAD-7 and PHQ-9 total scores, respectively.

[4] Standardised loadings for each model are reported in the associated figure and unstandardised loadings are reported in Table S4.

living with a partner, and with seeing a greater number of friends/relatives every 2 weeks. Seeing a greater number of friends/relatives every 2 weeks was associated with membership in more social/sporting/neighbourhood groups.

Males were more likely to be older. Older and female participants were less likely to be married/living with a partner, and older participants were more likely to see more friends/relative every 2 weeks and less likely to have membership in social/sporting/neighbourhood groups.

Anxiety and depression were significantly associated (r=.64, p<.001), as was loneliness with both anxiety (r=.34, p<.001) and depression (r=.49, p<.001). However, only the social isolation item assessing the number of friends/relatives spoken to every 2 weeks was significantly related to depression (r=-.19, p<.001), but not to CAPS Factor 1 or 2, meaning it was not appropriate to test for mediation using the social isolation items. Consequently, the mediation analyses focused on the mediating effect of depression and anxiety between loneliness and anomalous perceptions.

Higher levels of loneliness were associated with higher levels of anomalous body-centred self-experiences and higher levels of anomalous external experiences (Figure 2). Higher levels of loneliness were also related to higher levels of anxiety and depression. However, anxiety and depression were not associated with anomalous experiences of any kind, meaning there was no mediating effect between loneliness and anomalous perceptual experiences, via anxiety or depression.

Discussion

This study examined the cross-sectional relationships between objective social isolation, loneliness, and anomalous perceptions in community-dwelling older adults, after adjusting for age and sex, and considered whether anxiety and depression mediated any relationships found.

As hypothesised (H1), those who reported higher levels of loneliness reported more anomalous body-centred self-experiences. This finding builds on previous evidence by Michael and Park (2016), who found that high levels of loneliness were associated with increased risk of spurious anomalous bodily experiences. In addition, our exploratory analyses showed that higher levels of loneliness are also related to more anomalous external experiences. There are several potential explanations for these findings. Loneliness may influence each dimension of perceptual anomalies via separate etiological pathways, though a more parsimonious interpretation is that loneliness may exert its effects on anomalous perceptions via a common mechanism: albeit, the nature of this mechanism is unclear, warranting investigation. Together, these findings demonstrate that loneliness is associated with an increase in a broad range of anomalous perceptions, though given the cross-sectional nature of the current study, the direction of these relationships remains unclear. For example, research shows that anomalous perceptions such as hallucinations can lead to loneliness (e.g., Michalska Da Rocha et al., 2018), which leaves open the possibility that anomalous perceptions may have indeed prompted increased levels of loneliness within the current study. Given the potential for reciprocal relationships between anomalous perceptual experiences and loneliness, future longitudinal studies will be important in determining causality.

These findings have important theoretical implications for the SDA hypothesis (Hoffman, 2007, 2008). First, this hypothesis proposes that social isolation is a direct, biologically-based precursor of hallucinations derived from a socially-wired brain that reorganises in the absence of social stimulation, in turn prompting anomalous perceptions. This hypothesis draws on prior sensory deafferentation literature (e.g., Menon et al., 2003) which posits that limited sensory input results in a compensatory increase in neural activation, but does not explicitly address the distinction between the

role of objective and subjective social isolation (loneliness) in these experiences. Building on the SDA hypothesis, the current findings indicate that loneliness may also be related to the experience of anomalous perceptions, though, as noted above, the direction of this relationship is unclear given the cross-sectional nature of this study. Second, the SDA hypothesis assumes that "high levels" of social isolation are required to prompt hallucinatory experiences. The mean UCLA-LS3 score in this sample (36.72) was comparable to—or slightly lower than—previous data from healthy older adults (40.08; Anderson, 2010); only .03% of our participants would be classified as having "very high" levels of loneliness, with 18.6% having "moderately high" levels of loneliness[5]. This implies that anomalous perceptions are particularly sensitive to feelings of loneliness (or vice versa), in that even relatively modest elevations of loneliness are related to the experience of anomalous perceptions, at least in older adults within the general population. This is consistent with a large body of literature that recognises loneliness as a major social stressor which can affect a broad range of emotional and cognitive outcomes (Lim et al., 2020). Lastly, though originally proposed to account for the induction of complex auditory hallucinations in schizophrenia, the current findings show that the SDA hypothesis may also be useful in explaining the onset of a broader suite of perceptual anomalies in community-dwelling older adults. This observation is important in view of recent evidence that multimodal hallucinations are a potential risk factor for the development of clinically relevant symptoms (Laloyaux et al., 2019).

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[5] There are no specific guidelines for defining who is (or is not) lonely on the UCLA-LS3. However, unpublished recommendations (sent as a personal communication) from Russell (2017) suggest that criterion scores 2 SDs above the mean be employed to define "very high" levels of loneliness, and >1 SD above the mean be used to define "moderately high" loneliness.

Consistent with Beutel et al. (2017), those reporting more loneliness also reported more anxiety and depression. However, the relationship between loneliness and anomalous perceptual experiences was not mediated by anxiety or depression. One possible explanation is that, overall, participants reported few symptoms of anxiety and depression: the recommended cut-off to detect significant anxiety and depression in older adults using the GAD-7 and PHQ-9 is 5 (Pellas & Damberg, 2021; Wild et al., 2014), yet the mean PHQ-9 and GAD-7 scores were 2.34 and 1.62, respectively, with few of the current sample scoring higher. Future studies could examine whether higher levels of anxiety and depression are indeed associated with anomalous perceptual experiences. Given that depression is evidenced as being related to both loneliness and anomalous perceptual experiences such as hallucinations (Hsueh et al., 2019; Östling et al., 2013; Paulik et al., 2006), it is also plausible that depression may be a confounding variable in the relationship between loneliness and anomalous perceptions. Potential confounders not measured in the current study, such as poor sleep (e.g., Hom et al., 2020) or impaired cognitive function (e.g., Cacioppo et al., 2014)—both of which occur in normal ageing—may also explain why anxiety and depression did not mediate the relationship between loneliness and perceptual anomalies. As such, it is important that future research investigates other social, cognitive, and biological mechanisms linking loneliness and anomalous perceptions, and considers mediating factors other than mood. The neural basis of loneliness has also been investigated, with evidence pointing to a range of structural and functional changes in cortical circuits linked to social cognition, such as the left posterior superior temporal sulcus (Nakagawa et al., 2015). Of note, a diverse array of cognitive and neural mechanisms has been implicated in the experience of hallucinations and other anomalous perceptions in clinical and non-clinical populations (Zmigrod et al., 2016).

A more variable pattern of relationships was observed between social isolation and anomalous perceptions. Preliminary analyses of the BSAI revealed poor internal consistency. Accordingly, the four items were entered as simultaneous predictors. Importantly, H2 was only partially supported since an increase in objective social isolation for only 1 of 4 items was associated with an increase in anomalous perceptions (as hypothesised). Specifically, social disconnection from a religious group was associated with more anomalous external experiences. Exploratory analyses of the relationship between social isolation and anomalous body-centred self-experiences revealed that being married/living with a partner—rather than an absence of intimate relationships—was associated with more anomalous body-centred self-experiences. Furthermore, no significant associations were found between the number of friends/relatives spoken to every 2 weeks or membership in social/sporting/neighbourhood groups and either type of anomalous perceptions. It is unclear why these differential patterns emerged, as El Haj et al. (2016) found that social isolation significantly predicted anomalous and hallucinatory experiences in older adults (both with and without Alzheimer's), even when controlling for loneliness. However, El Haj et al. (2016) examined visual and auditory hallucinations, rather than the broad range of anomalous perceptions assessed here.

One potential explanation is that the nature of an individual's social connection is important when examining risk for anomalous perceptions. That is, "strong" (i.e., BSAI Q1) and "weak" (i.e., BSAI Q3) social ties may differentially impact the experience of anomalous perceptions (Brooks, 2019). Indeed, previous research shows that social network size decreases with age (Cornwell et al., 2008), along with an increase in "strong" ties (e.g., spouses/partners, children) and a decrease in "weak" ties (e.g., acquaintances, fellow club members; Moore et al., 2016), which may serve as a

protective mechanism with age. Another explanation is that, although being married/living with a partner is typically used as a proxy for increased social contact, it is possible that undetected social stress/negativity (Badcock et al., 2022), potentially related to illness and/or changes in role and functioning in married older adults, is associated with increased anomalous perceptions. For instance, being a spousal caregiver may limit or reduce social connection outside of the nuclear family (Li et al., 2021; Vasileiou et al., 2017), thus increasing anomalous perceptual experiences. Consequently, a more nuanced approach, such as investigating how the nature or quality of someone's relationship may influence their social functioning, may be required to unravel the relationship between social isolation and anomalous perceptions.

These findings must be considered with some caveats. First, the social isolation measure was problematic. While previous research has often used a range of social isolation metrics (such as the four used here), we found the measure was psychometrically weak. Other measures of social isolation (e.g., the Lubben [1988] Social Network Scale) may be more robust; however, given the current findings, measures assessing both "strong" and "weak" social ties may be appropriate in future studies. Secondly, as noted above, the cross-sectional nature of this study means that we cannot assume causality. Indeed, experiences such as hallucinations can lead to loneliness, suggesting that reciprocal effects are likely (Michalska Da Rocha et al., 2018). Longitudinal studies examining social isolation, loneliness, and later anomalous perceptual experiences are required to help unravel causality. Nevertheless, the findings are still informative for clinical practice. For example, they highlight that attending to loneliness in older adults should be a public health priority (Perissinotto et al., 2019), particularly given our ageing population, since loneliness is related not only to increased levels of anxiety and depression, but also to higher rates of anomalous and hallucinatory

experiences. Thirdly, the current sample had relatively low diversity (most participants were female, Anglo-Australian, considered relatively well socially connected, with low levels of anxiety and depression); consequently, the generalisability of the findings cannot be assured. As also noted above, it is possible that variables such as depression, sleep, and cognition may be confounders in the relationship between loneliness and anomalous perceptions. Consequently, future research should seek to examine the relationships between loneliness, social isolation, and anomalous perceptions, alongside other potential confounds. Finally, the current analysis focussed on how loneliness and social isolation are related to the absence/presence of anomalous perceptions, regardless of individual variation in the frequency, intrusiveness, and distress associated with these experiences. Our results, suggest that these social factors (especially loneliness) may play a significant role in prompting the onset of anomalous perceptions, and are thus worthy of attention. That said, it will be important to explore if, and how, loneliness and social isolation are (or are not) associated with ratings on other phenomenological characteristics of anomalous perceptions using the CAPS subscales.

In summary, regardless of whether participants were socially isolated, those reporting higher levels of loneliness also reported more anomalous body-centred self-experiences and anomalous external experiences. Though some (but not all) components of social isolation (i.e., marital/living status and religious group involvement) were associated with perceptual anomalies, further research is recommended to investigate the relationship between the nature of someone's social context (e.g., "strong" and "weak" social ties) and anomalous perceptions. Nevertheless, that this is likely a high-functioning, non-clinical sample with relatively low levels of anxiety, depression, loneliness, and social isolation, makes the reported findings of significant relationships even more striking. Together, these findings have important

implications for theoretical models of perceptual anomalies, and for the treatment of loneliness as a precursor to these experiences. In particular, the current findings suggest that greater priority must be given to understanding the consequences of social risk factors for older adults, and that improved training for clinicians about loneliness and its effects in older adults is key. Lastly, these findings further highlight the importance of examining both objective social isolation and loneliness to provide a more complete picture of people's overall social context.

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Data Availability Statement

The deidentified data that support the findings of this study are openly available in OSF at https://doi.org/10.17605/OSF.IO/WC92Y

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Table 1. Demographic characteristics of the sample (*N*=242).

Characteristic	*n* (%)	*M* (*SD*)	Range
Age (years)		71.87 (7.73)	52-91
Sex			
Females	164 (67.8)		
Males	78 (32.2)		
Years of education[a]		13.15 (2.73)	7-19
Ethnicity[b]			
Caucasian	228 (94.2)		
Asian	9 (3.7)		
Other	3 (1.2)		
T-MoCA		19.64 (1.34)	18-22
MMSE		28.14 (1.49)	24-30

Note. [a]Two participants did not report years of education; [b]Two participants did not report ethnicity.

Table 2. Characteristics of the UCLA-LS3, BSAI, CAPS, PHQ-9, and GAD-7 (*N*=242).

	M	*SD*	Range	ωt
UCLA-LS3	36.72	9.95	20-67	.93
CAPS Factor 1	.93	1.43	0-7	.68
CAPS Factor 2	.95	1.55	0-8	.65
PHQ-9	2.34	2.89	0-18	.78
GAD-7	1.62	3.02	0-21	.90
BSAI Q2	18.14	18.1	2-200	
BSAI Q4	2.44	1.97	0-14	
	n (% yes)			
BSAI Q1[1]	143 (59.1)		0-1	
BSAI Q3[1]	66 (27.3)		0-1	

Note. CAPS Factor 1 (anomalous body-centred self-experiences) comprises items 8, 9, 14, 17, 18, 20, 25, 29, and 30, and CAPS Factor 2 (anomalous external experiences) comprises items 1, 2, 3, 4, 5, 6, 7, 15, 22, 23, 27, 31, and 32. [1]Internal consistency of the BSAI index was poor, so each of the four items comprising this measure were entered as simultaneous predictors. Therefore, ωt for each individual BSAI item is not reported.

Table 3. Frequency counts for total number of CAPS items endorsed (*N* = 242).

Number of CAPS items endorsed	*n*	%
0	100	41.3
1	45	18.6
2	29	12.0
3	22	9.1
4	16	6.6
5	5	2.1
6	7	2.9
7	5	2.1
8	6	2.5
9	2	0.8
10	1	0.4
11	3	1.2
12	1	0.4
Total	242	100

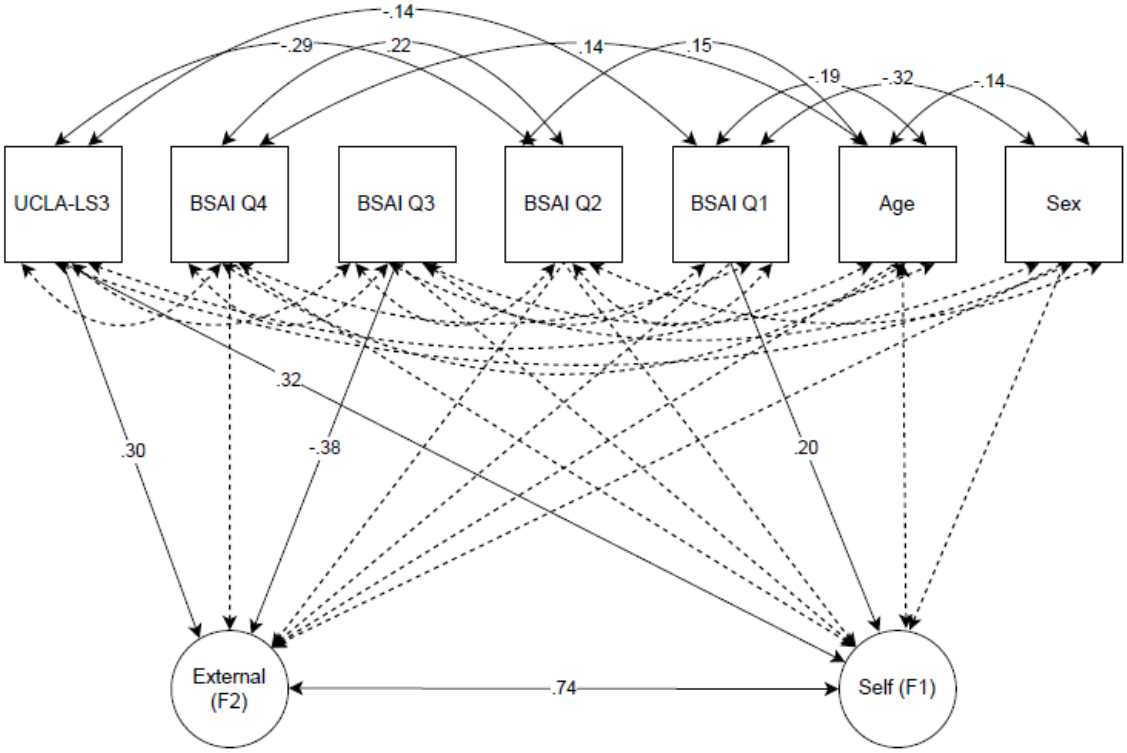
Note. CAPS = Cardiff Anomalous Perceptions Scale. The maximum number of CAPS items endorsed within the current sample was 12; therefore, the frequency counts for scores between 13 and 22 (i.e., the highest possible number of CAPS items that could be endorsed) are not reported.

Table 4. Structural equation models of standardised path coefficients between CAPS factors, loneliness (UCLA-LS3), objective social isolation (BSAI), anxiety (GAD-7), and depression (PHQ-9), covarying for age and sex, with fit statistics (*N*=242).

Model	*df*	χ^2	*p*	SRMR	CFI	TLI	RMSEA (90% CI)
1. CAPS 2-factor model	208	250.649	.0230	.160	.913	.903	.029 (.012-.041)
2. Loneliness and objective social isolation predicting CAPS factors, covarying for age and sex	348	411.326	.0109	.147	.898	.881	.027 (.014-.037)
3. Loneliness predicting CAPS factors, with anxiety and depression as mediators, covarying for age and sex	308	346.313	.0655	.147	.936	.927	.023 (.000-.034)

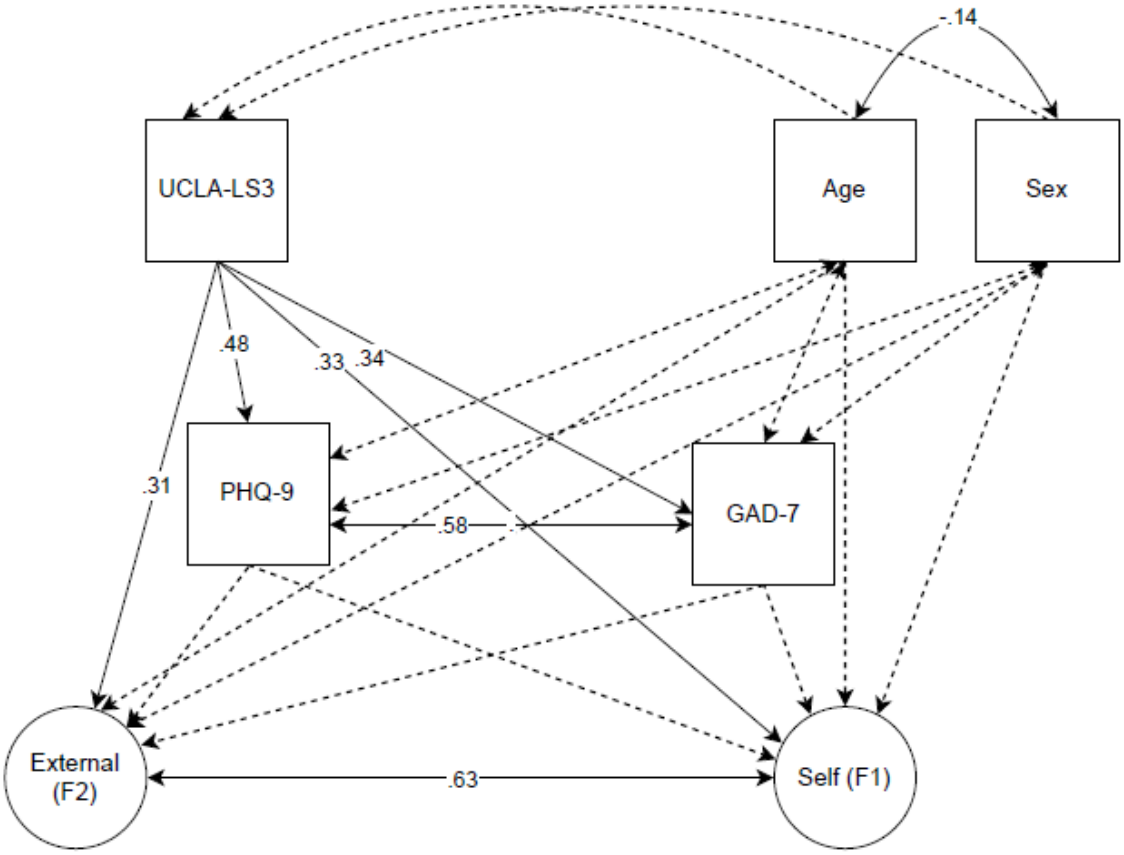
Note. CI = confidence interval.

Figure 1. Structural equation model examining direct relationships between loneliness (UCLA-LS3), objective social isolation (BSAI items 1-4), anomalous body-centred self-experiences (Self [F1]) and anomalous external experiences (External [F2]), covarying for age and sex.



Note. Dotted lines indicate non-significant pathways, and solid lines indicate significant pathways. Squares = observed variables, circles = latent variables.

Figure 2. Structural equation model examining direct and indirect relationships between loneliness (UCLA-LS3), anxiety (GAD-7), depression (PHQ-9), anomalous body-centred self-experiences (Self [F1]), and anomalous external experiences (External [F2]), covarying for age and sex.



Note. Dotted lines indicate non-significant pathways, and solid lines indicate significant pathways. Squares = observed variables, circles = latent variables.

Supplementary Materials

Table S1

Frequency counts (highest to lowest) for CAPS items (N = 242).

CAPS Item: Do you ever…	*n*		%	
	Yes	No	Yes	No
Q29: Notice smells or odours that people next to you seem unaware of?[a]	46	195	19.0	80.6
Q20: Find that your skin is more sensitive to touch, heat or cold than usual?	42	200	17.4	82.6
Q5: Experience unusual burning sensations or other strange feelings in or on your body?	38	204	15.7	84.3
Q18: Smell everyday odours and think that they are unusually strong?	31	211	12.8	87.2
Q1: Notice that sounds are much louder than they normally would be?	28	214	11.6	88.4
Q6: Hear noises or sounds when there is nothing about to explain them?	26	216	10.7	89.3
Q9: Have the sensation that your body, or a part of it, is changing or has changed shape?[a]	26	215	10.7	88.8
Q27: Find that your experience of time changes dramatically?[a]	24	217	9.9	89.7
Q30: Notice that food or drink seems to have an unusual taste?[a]	23	218	9.5	90.1
Q14: Experience unexplained tastes in your mouth?	21	221	8.7	91.3
Q8: Detect smells which don't seem to come from your surroundings?	20	222	8.3	91.7
Q3: Hear your own thoughts repeated or echoed?	18	224	7.4	92.6
Q23: Have days where lights or colours seem brighter or more intense than usual?	18	224	7.4	92.6
Q4: See shapes, lights or colours even though there is nothing really there?	16	226	6.6	93.4
Q2: Sense the presence of another being, despite being unable to see any evidence?	15	227	6.2	93.8
Q22: Look in the mirror and think that your face seems different from usual?	12	230	5.0	95.0
Q32: Hear sounds or music that people near you don't hear?[a]	12	229	5.0	94.6
Q7: Hear your own thoughts spoken aloud in your head, so that someone near might be able to hear them?[a]	9	232	3.7	95.9
Q25: Find that common smells sometimes seem unusually different?[a]	9	232	3.7	95.9
Q31: See things that other people cannot?[b]	9	231	3.7	95.5
Q17: Have difficulty distinguishing one sensation from another?	7	235	2.9	97.1
Q15: Find that sensations happen all at once and flood you with information?	6	236	2.5	97.5

**Note*. CAPS = Cardiff Anomalous Perceptions Scale. [a]These items each have one missing value, so the total sum of responses is less than the total *N* of 242. [b]This item has two missing values, so the total sum of responses is less than the total *N* of 242. CAPS Factor 1 (anomalous body-centred self-experiences) comprises items 8, 9, 14, 17, 18, 20, 25, 29, and 30, and CAPS Factor 2 (anomalous external experiences) comprises items 1, 2, 3, 4, 5, 6, 7, 15, 22, 23, 27, 31, and 32.

Table S2

Frequency counts for GAD-7 total score (N = 242).

GAD-7 total score	*n*	%
0	133	55.0
1	33	13.6
2	22	9.1
3	17	7.0
4	11	4.5
5	8	3.3
6	5	2.1
7	4	1.7
8	1	0.4
9	2	0.8
10	-	-
11	1	0.4
12	-	-
13	-	-
14	-	-
15	1	0.4
16	2	0.8
17	1	0.4
18	-	-
19	-	-
20	-	-
21	1	0.4
Total	242	100

**Note.* GAD-7 = Generalized Anxiety Disorder Scale-7.

Table S3

Frequency counts for PHQ-9 total score (N = 242).

PHQ-9 total score	*n*	%
0	80	33.1
1	40	16.5
2	34	14.0
3	31	12.8
4	18	7.4
5	14	5.8
6	7	2.9
7	4	1.7
8	4	1.7
9	1	0.4
10	3	1.2
11	1	0.4
12	2	0.8
13	1	0.4
14	-	-
15	-	-
16	1	0.4
17	-	-
18	1	0.4
Total	242	100

**Note.* PHQ-9 = Patient Health Questionnaire-9. The maximum PHQ-9 total score reported in the current sample was 18; therefore, the frequency counts for total scores between 19 to 27 are not reported.

Table S4

Unstandardised effects and standard errors of structural equation models between CAPS factors, loneliness, objective social isolation, anxiety, and depression, covarying for age and sex.

Model	Predictor	Mediator/s	Covariates	DV	Path	Unstandardised estimate	S.E
Loneliness (UCLA-LS3) and objective social isolation (BSAI) items predicting CAPS factors, covarying for age and sex							
Basic model							
	UCLA-LS3	-	Age, sex	F1		0.036	0.010
	BSAI_Q1	-	Age, sex	F1		0.444	0.209
	BSAI_Q2	-	Age, sex	F1		-0.007	0.007
	BSAI_Q3	-	Age, sex	F1		0.095	0.210
	BSAI_Q4	-	Age, sex	F1		0.080	0.055
	Age	-	-	F1		0.004	0.014
	Sex	-	-	F1		-0.153	0.202
	UCLA-LS3	-	Age, sex	F2		0.034	0.011
	BSAI_Q1	-	Age, sex	F2		-0.203	0.214
	BSAI_Q2	-	Age, sex	F2		0.003	0.004
	BSAI_Q3	-	Age, sex	F2		-0.978	0.145
	BSAI_Q4	-	Age, sex	F2		0.068	0.053
	Age	-	-	F2		-0.006	0.013
	Sex	-	-	F2		-0.205	0.231
Loneliness (UCLA-LS3) predicting CAPS factors, with anxiety (GAD-7) and depression (PHQ-9) as mediators, covarying for age and sex							
Mediator model: Anxiety and depression							
	UCLA-LS3	-	Age, sex	GAD-7	*a*	0.104	0.009
	UCLA-LS3	-	Age, sex	PHQ-9	*a*	0.141	0.011
	GAD-7	-	Age, sex	F1	*b*	0.005	0.043
	GAD-7	-	Age, sex	F2	*b*	0.038	0.035
	PHQ-9	-	Age, sex	F1	*b*	-0.025	0.042
	PHQ-9	-	Age, sex	F2	*b*	-0.029	0.040
	UCLA-LS3	GAD-7, PHQ-9	Age, sex	F1	*c*	0.032	0.009
	UCLA-LS3	GAD-7, PHQ-9	Age, sex	F2	*c*	0.032	0.009

UCLA-LS3	-	Age, sex	F1	*c'*	0.036	0.010
UCLA-LS3	-	Age, sex	F2	*c'*	0.032	0.010
UCLA-LS3	GAD-7	Age, sex	F1	*ab*	0.000	0.004
UCLA-LS3	GAD-7	Age, sex	F2	*ab*	0.004	0.004
UCLA-LS3	PHQ-9	Age, sex	F1	*ab*	-0.004	0.006
UCLA-LS3	PHQ-9	Age, sex	F2	*ab*	-0.004	0.006
Age	-	-	F1		-0.002	0.012
Sex	-	-	F1		-0.245	0.191
Age	-	-	F2		-0.005	0.012
Sex	-	-	F2		-0.083	0.200

Note. S.E = standard error; UCLA-LS3 = UCLA Loneliness Scale-3; BSAI = Brief Social Activity Index; GAD-7 = Generalized Anxiety Disorder Scale-7; PHQ-9 = Patient Health Questionnaire-9; F1 = Factor 1 (anomalous body-centred self-experiences); F2 = Factor 2 (anomalous external experiences).