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The Discrepancy between Social Isolation and Loneliness as a Clinically Meaningful Metric: Findings from the Irish and English Longitudinal Studies of Ageing (TILDA & ELSA)

Running head: Social Asymmetry and Cognitive Function

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Key points:

- Social isolation and loneliness both relate to cognitive function in later life.
- Little focus has been given to the discrepancy between social isolation and loneliness.
- The discrepancy between the two may reflect propensity to loneliness.
- This discrepancy appears to also be related to cognitive decline in older adults.

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Abstract

Objective: Scant evidence is available on the discordance between loneliness and social isolation among older adults. We aimed to investigate this discordance and any health implications that it may have. **Method**: Using nationally representative datasets from ageing cohorts in Ireland (TILDA) and England (ELSA), we created a metric of discordance between loneliness and social isolation, to which we refer as *Social Asymmetry*. This metric was the categorised difference between standardised scores on a scale of loneliness and a scale of social isolation, giving categories of: Concordantly Lonely & Isolated, Discordant: Robust to Loneliness, or Discordant: Susceptible to Loneliness. We used regression and multilevel modelling to identify potential relationships between *Social Asymmetry* and cognitive outcomes. **Results**: *Social Asymmetry* predicted cognitive outcomes cross-sectionally and at a two-year follow-up, such that Discordant: Robust to Loneliness individuals were superior performers, but we failed to find evidence for *Social Asymmetry* as a predictor of cognitive trajectory over time. **Conclusions:** We present a new metric and preliminary evidence of a relationship with clinical outcomes. Further research validating this metric in different populations, and evaluating its relationship with other outcomes, is warranted.

Introduction

Social isolation affects a significant minority of the ageing population, with prevalence ranging from 6-7% reported in Ireland (Barrett et al., 2011) to 20% in the UK (Barnes et al., 2012). Social isolation is an objectively measurable phenomenon, predictive of declines in health and cognition (Green et al., 2008, Bassuk et al., 1999, Béland et al., 2005, DiNapoli et al., 2014). Loneliness, a related concept, refers to a subjective insufficiency of social connection, and can occur in the presence or absence of social isolation (Peplau and Perlman, 1982). There is typically only a modest correlation between measures of loneliness and social isolation (Cornwell and Waite, 2009a, Coyle and Dugan, 2012, de Jong-Gierveld and Havens, 2004), although both relate to cognitive outcomes (Bassuk et al., 1999, DiNapoli et al., 2014, Gow et al., 2013, Shankar et al., 2013).

Other research suggests that loneliness and social isolation differentially relate to health outcomes such as subjective wellbeing, dementia, and mortality (Shankar et al., 2015, Steptoe et al., 2013, Holwerda et al., 2014).

Assuming that loneliness and social isolation are independent constructs, it is possible that the discrepancy between the two describes an individual's susceptibility or robustness to loneliness, relative to their isolation status. Loneliness has been described as being a discrepancy between desired and actual social contact (Peplau and Perlman, 1982). Individuals differ in the extent to which they experience loneliness (Hector-Taylor and Adams, 1996). Individual differences in propensity for loneliness may be explained by relating it to susceptibility to social isolation; individuals with a low propensity for loneliness may thrive in socially isolated conditions, while those with a high propensity for loneliness may require more social connectedness. This phenomenon could be measured using the discrepancy between

an individual's social isolation and their loneliness levels. To the best of our knowledge, the discrepancy between loneliness and social isolation and their impact on health outcomes has not yet been systematically investigated. We wanted to explore this discrepancy and whether it predicted clinically meaningful outcomes, such as cognitive decline, which has previously been shown to relate to both loneliness and social isolation (Cacioppo and Hawkley, 2009, Ertel et al., 2008).

Hypotheses

Hypothesis 1: The discordance between social isolation and loneliness is associated with cognition cross-sectionally, after controlling for covariates.

Hypothesis 2: The discordance between social isolation and loneliness is predictive of cognition over time, after controlling for covariates and cognition at baseline.

Methods

Design

The Irish Longitudinal Study on Ageing (TILDA) and the English Longitudinal Study on Ageing (ELSA) studies are representative, prospective, longitudinal cohort studies of ageing in populations in the Republic of Ireland and in England. TILDA assesses social, economic, and health circumstances among 8175 community-dwelling adults aged over 50 (Kenny et al., 2010). ELSA commenced with 11,391 individuals aged over 50 in 2002, and participants are followed up every 2 years.

All participants in both cohorts gave informed consent to participate. Each study was approved by the appropriate ethics committee (Taylor et al., 2007, Kenny et al., 2010).

Participants

TILDA

Participants in the current study were 4892 independently living, community dwelling older adults involved in Wave 1 of the TILDA dataset, who gave their interviews directly, and aged over 60 (age range of 60-80, mean age of 69.59, with standard deviation of 6.55), 46% of whom were male. Data collection took place between 2009 and 2010.

ELSA

Participants from ELSA who were analysed in the current study were those who in Wave 3 were aged over 60, community-dwelling, and had given an interview directly. This gave a sample size of 5604 individuals (age range 60 to 99, mean age 71.55, standard deviation of 8.45), of whom 44.5% were male. For the purposes of the longitudinal analyses, individuals from waves 4, 5, and 6 were included only if they had been involved in Wave 3, so that no new individuals from refreshment cohorts were included (no refreshment cohorts were recruited for TILDA). Data collection for waves 3 to 6 took place between 2006 and 2012. Attrition rates are complex in the ELSA cohort because of the use of refreshment cohorts (Steptoe et al., 2012), but of the 8811 participants engaged in Wave 3, 7595 engaged in Wave 4, and 7178 in Wave 5, and 6547 in wave 6 (Banks et al., 2014).

Measures

We explored *Social Asymmetry* in two different cohorts, cross-sectionally in TILDA, and then both cross-sectionally and longitudinally in ELSA. As the studies are harmonised, we could operationalise *Social Asymmetry* in similar ways for each cohort. Every attempt was made to use the same or similar covariates in the separate ELSA and TILDA analyses (see Table 1).

TILDA

Demographic information used in the current analysis included: age, sex, and education (levels were 'No qualification', 'Intermediate qualification', and 'Degree qualification or higher', following the same classification method used by (Llewellyn et al., 2008)). Cognitive outcomes of interest were:

- *Immediate Recall*: Participants were read a list of 10 words and their task was to recall aloud as many words as they could.
- *Delayed Recall*: Participants were later asked to recall as many of the original 10 words as they could, with distractor tasks in the interim.
- *MMSE scores*: The Mini Mental State Examination is a global test of cognition and a screen for dementia (Folstein et al., 1975). Scores range from 0-30, with those of below 24 indicating cognitive impairment in an Irish population (Cullen et al., 2005).

Covariates included measures of mood:

- Scores on the Centre for Epidemiological Studies Depression (CESD) scale of depressive symptomatology (Radloff, 1977). Scores range from 0-60 on the 20-item version of the scale used here, with a score of 16 or above indicating case level depressive symptomatology.
- Scores on the Hospital Anxiety & Depression Scale (HADS) Anxiety subscale (Zigmond and Snaith, 1983). Scores range from 0-21, with scores of 7 or above indicating case level anxiety.

Creation of the Social Asymmetry Metric

Taking our lead from cognition researchers who espoused the term *Cognitive Asymmetry* to describe differences between premorbid and current cognitive functioning (Benke, 2011, Bondi et al., 2008, Jacobson et al., 2009), we refer to our

discrepancy metric as *Social Asymmetry*. In order to evaluate its clinical relevance, we investigated potential relationships between *Social Asymmetry* and a domain known to relate to both social isolation and loneliness: cognitive function. While creating a categorical variable of a continuous variable in this way can reduce statistical power, it is a useful way to identify individuals who may be at risk of undesirable outcomes; in our case, cognitive decline.

Social Asymmetry is the difference between scores on a scale of loneliness (the modified UCLA scale (Russell, 1996, Russell et al., 1980)), and a scale of social connectedness (the Berkman-Syme Index; BSNI (Berkman and Syme, 1979). The BSNI categorises individuals as being isolated or integrated, so we interpreted scores inversely as a measure of social isolation. Scores on each scale were standardised, and loneliness scores were subtracted from social isolation scores. Scores were then categorized as falling *within* or *in excess* of ±1 standard deviation of the mean (0). Individuals whose scores fell within ±1 standard deviation were categorised as being *Concordant Lonely & Isolated* – that is, they were as lonely as expected from their social isolation status. Those whose scores fell one standard deviation above the mean were categorised as *Discordant Susceptible* – that is, for their social isolation status, they were lonelier than expected. Participants whose scores fell one standard deviation below the mean were categorised as *Discordant Robust* – given their social isolation status, they were less lonely than expected.

We divided the *Concordant Lonely & Isolated* group into two groups, since this group contains individuals who score high on both measures, and those who score low on both measures. Since these groups have different cognitive profiles (Cacioppo et al., 2000), it was deemed necessary to separate the group into two subgroups. The

group was divided along a median split of scores on the modified UCLA scale, giving a *Concordant High Lonely* group and a *Concordant Low Lonely* group.

ELSA

The BSNI was not used in ELSA, but sufficient information was available to recreate it (one substitution was made, replacing the original item 'attending religious services at least once per month' with 'belongingness to a religious organisation'). The other notable substitution made was to use scores on the General Health Questionnaire (GHQ-12) 12-item scale (Goldberg and Williams, 1988) in place of the HADS Anxiety scale (Zigmond and Snaith, 1983) used in TILDA. Scores on the GHQ 12 range from 0-36, with higher scores indicating more distress. The inclusion of the GHQ-12 at wave 3 of ELSA drove the decision to use data from this wave forwards.

Counts for individuals belonging to each *Social Asymmetry* category are described in Figure 1, for each cohort.

Figure 1 about here.

Data Analysis

All data analyses were performed in R software. For both datasets, missing data were imputed using the 'multiple imputation with chained equations' method, with the 'mice' package in R (Buuren and Groothuis-Oudshoorn, 2011). We used predictive mean matching for the imputation of interval data, and polytomous regression for imputing categorical data. Five datasets were imputed for each cohort (TILDA and ELSA) and data were pooled for analysis within each cohort. Predictors were specified to be included in the imputation using the 'quickpred' function. Multiple regression models were performed on pooled data to examine cross-sectional

relationships in TILDA[1]. For the follow-up analyses, weights were applied to ensure that results accounted for attrition between waves.

For each model, *Social Asymmetry*, along with covariates, was entered: for TILDA, outcomes were MMSE scores, immediate and delayed word recall scores. For the ELSA dataset, cross-sectional models were performed with Immediate Recall, Delayed Recall, and Animal Naming as outcomes, while longitudinal models were also derived, controlling for baseline cognition scores. Finally, growth curve modelling (using the 'nlme' R package, (Pinheiro et al., 2015) was used on imputed multilevel data to assess whether *Social Asymmetry* at wave 3 predicted trajectories of cognition across waves 4, 5, and 6.

Results

TILDA

3098 participants were aged over 60 and had sufficient information (i.e. scores on both the BSNI and on the modified UCLA loneliness scale) to calculate a *Social Asymmetry* score. Characteristics of the TILDA sample described in this analysis are given alongside those of their ELSA counterparts in Table 1.

Regressions were first performed with the three cross-sectional cognitive measures as outcomes, and Bonferroni corrections for multiple comparisons setting alpha at 0.016 ($\alpha = 0.05/3$). Model 1 was performed with Immediate Recall as the outcome and included covariates age, sex, education, anxiety and depressive symptomatology; Model 2 added *Social Asymmetry* as a dummy coded variable, with

[1] Cross-sectional weights were created for the TILDA dataset to account for individuals who did not participate in subsections of the assessment. The purpose of these weights was to attempt to make results based on those participants who did participate in all assessments representative of all participants. However, we did not use these weights in the current analysis, since because we used only a subsection of participants (those over the age of 60) we were not aiming to make our results representative.

Group 1 (*Discordant Susceptible*) as the referent. Participants in Group 2 (*Concordant High Lonely*) had higher scores for Immediate Recall ($\beta = 0.36$; $p<0.01$) than those in Group 1 (*Discordant Susceptible*), Group 3 (*Concordant Low Lonely*) had higher scores ($\beta = 0.32$; $p<0.05$) than Group 1, and those in Group 4 (*Discordant Robust*) had higher scores ($\beta = 0.69$; $p<0.001$) than Group 1, although with corrections for multiple comparisons, only *Concordant High Lonely* and *Discordant Robust* individuals outperformed those in the *Discordant Susceptible* group (see Table 2, and the Supplementary Appendix).

Table 1 about here

Next, a model was conducted with Delayed Recall as the outcome. Those in Group 2 (*Concordant High Lonely*) had higher scores than those in Group 1 (*Discordant Susceptible*; $\beta = 0.31$; $p<0.001$); Group 3 (*Concordant Low Lonely*) also had higher scores than those in Group 1 ($\beta = 0.27$; $p<0.05$), and Group 4 (*Discordant Robust*) had higher scores ($\beta = 0.81$; $p<0.001$) than Group 1; with multiple comparison corrections, only those in Groups 2 and 4 outperformed those in Group 1 (see Table 2). Last, a model was conducted with MMSE scores as the outcome, and this model showed that participants in Group 2 (*Concordant High Lonely*) had higher scores than those in Group 1 ($\beta = 0.59$; $p<0.01$); that Group 3 (*Concordant Low Lonely;* $\beta = 0.49$; $p<0.05$) and Group 4 (*Discordant Robust;* $\beta= 1.21$; $p<0.001$) had higher scores of MMSE (than Group 1, although with corrections for multiple comparisons only participants in Groups 2 and 4 outperformed those in Group 1 (see Table 2).

ELSA

Of 5604 participants, 4516 had sufficient information from which to derive the *Social Asymmetry* variable. For the eight models created, Bonferroni corrections set

alpha at 0.006 ($\alpha = 0.05/8$). The first linear regressions used cross-sectional data from wave 3, with cognitive outcomes (Immediate Recall, Delayed Recall, and Animal Naming), and with *Social Asymmetry* and covariates (age, sex, psychological distress, depressive symptomatology, and education) entered in blocks to the model. Participants in the *Concordant High Lonely* group outperformed those in the *Discordant Susceptible* group on Immediate Recall ($\beta = 0.16$; $p<0.05$), where individuals in the *Concordant Low Lonely* ($\beta = 0.49$; $p<0.001$) and in the *Discordant Robust* ($\beta = 0.44$; $p<0.001$) groups also outperformed the *Discordant Susceptible* group (see Table 3). With corrections for multiple comparisons, only the latter two findings remained significant. For Delayed Recall as an outcome, participants in the *Concordant Low Lonely* ($\beta = 0.45$; $p<0.001$) and in the *Discordant Robust* ($\beta = 0.45$; $p<0.001$) groups outperformed those in the *Discordant Susceptible* group (see Table 3). For Animal Naming as an outcome, participants in the *Concordant Low Lonely* ($\beta = 0.84$; $p<0.01$) and in the *Discordant Robust* ($\beta = 0.88$; $p<0.05$) groups outperformed those in the *Discordant Susceptible* group, but neither remained significant after correcting for multiple comparisons (see Table 3).

Table 2 about here

Analyses were repeated with cognitive outcomes at wave 4 as the dependent variables, controlling for "baseline" (wave 3) cognitive variables, and with an inverse probability weight applied to account for inter-wave attrition. These models showed that for Immediate Recall, participants in the *Concordant High Lonely* ($\beta = 0.18$; $p<0.05$), *Concordant Low Lonely* ($\beta = 0.28$; $p<0.001$), and *Discordant Robust* ($\beta = 0.41$; $p<0.001$) groups all outperformed individuals in the Discordant Susceptible group (see Table 4), although associations were significant only for individuals in the latter two groups following corrections for multiple comparisons. For Delayed Recall,

participants in the *Concordant High Lonely* (β = 0.18; p<0.05), the *Concordant Low Lonely* (β = 0.28; p<0.001) and the *Discordant Robust* (β = 0.41; p<0.001) groups outperformed those in the *Discordant Susceptible* group although only the latter two associations remained significant after corrections for multiple comparisons (see Table 4). For Animal Naming, no significant differences were found between *Social Asymmetry* groups.

Table 4 about here

For the growth curve analysis we included covariates from wave 3 as above and investigated the impact of *Social Asymmetry* on the trajectories of Immediate and Delayed Recall. Data were imputed again using the 'mice' package with single level methods used for baseline data (predictive mean matching and polytomous regression), and multilevel methods ('2l.norm') used for the multilevel outcomes. A maximum of ten iterations was specified and predictors were specified separately for each imputed variable. For Immediate Recall a significant linear trend (β = -0.11; p<0.001) but no interactions between Time and Social Asymmetry were found, indicating that Social Asymmetry did not impact on the trajectories of Immediate Recall (see Table 5). For Delayed Recall, a significant linear trend (β = -0.19; p<0.001), curvilinear trend (β= -0.26; p<0.05) and again no interactions between Time and Social Asymmetry were observed, indicating that Social Asymmetry does not impact the trajectories of Delayed Recall (see Figure 2; Table 5).

Figure 2 about here

Table 5 about here

Discussion

We investigated *Social Asymmetry* and its association with cognitive functioning. We found significant cross-sectional associations across two datasets,

thus supporting Hypothesis 1, that the discrepancy between social isolation and loneliness is associated with cognition cross-sectionally. Individuals in the *Discordant Robust* group outperformed those in the *Discordant Susceptible* group across all cognitive outcomes, with individuals in the concordant groups showing intermediate performance. Within the concordant groups, the *Concordant Low Lonely* individuals outperformed those in the *Concordant High Lonely* groups. We partially supported Hypothesis 2: that *Social Asymmetry* would predict cognitive functioning at follow-up, since associations similar to those in the cross-sectional analyses were found with the follow-up analysis, but there was little evidence that *Social Asymmetry* is associated with trajectories of cognitive function over a longer time period. Finally, we found similar rates of *Social Asymmetry* across TILDA and ELSA, as well as similar patterns of associations with cognitive outcomes.

Results are based on analysis of two existing datasets with power and representativeness, but some compromises were made with available measures. For instance, a global measure of cognition (MMSE) was available in TILDA but not in ELSA, and a measure of psychological distress was substituted for a measure of anxiety symptomatology.

Our findings suggest that the difference between social isolation and loneliness is meaningful. De Jong-Gierveld and Dykstra suggest that loneliness is related to isolation in different ways, depending on the broader context and expectations of social connectedness (de Jong-Gierveld and Dykstra, 1993, Van Tilburg et al., 1998). According to their theory of mental incongruity, culture shapes expectations of the extent of social engagement. Loneliness then arises from the difference between actual and expected states of isolation (Van Tilburg et al., 1998). While this theory may explain why previous findings are disparate in their

conclusions about loneliness and social isolation (de Jong-Gierveld and Havens, 2004), and how they relate differently to outcomes, (Cornwell and Waite, 2009a, Holwerda et al., 2012, Segrin and Domschke, 2011, Shankar et al., 2013, Cornwell and Waite, 2009d), we did not here find a cross-cultural difference in the discordance between loneliness and social isolation since *Social Asymmetry* distributions were similar across the two studies, although fewer individuals fell into the Discordant Robust category in ELSA than in TILDA. England and Ireland are neighbours with overlapping history. As such it would be wise to explore whether cultural contexts affect the discrepancy between loneliness and social isolation in more diverse populations.

We have introduced a novel social functioning concept into an already crowded and ill-defined research area; one that, as Cohen has stressed, appears to confuse many separate concepts related to social functioning (Cohen, 1988). Holt-Lunstad states that there is problematic variation in the manner in which social factors are defined (Holt-Lunstad et al., 2010). Furthermore, there is disagreement on the extent to which social isolation and loneliness overlap conceptually, with some characterizing loneliness as perceived social isolation (Cacioppo and Hawkley, 2009, Hawthorne, 2008). Others have differentiated further, describing loneliness as a trait (Boomsma et al., 2005) or psychological process (Duck et al., 1994, Ernst and Cacioppo, 1998), and social isolation as an environmental consideration. The situation is further confused by an alleged failure of those conducting research in the field to adequately measure the two constructs, with social isolation measures overlapping with loneliness (Coyle and Dugan, 2012). Social isolation and loneliness are infrequently examined together, precluding commentary on their relative contributions towards health outcomes (Cornwell and Waite, 2009a). With this lack of

consensus in mind, the current analysis may lead to further elucidation of the distinguishable effects of loneliness and social isolation on cognition and other health-related outcomes. In future research we aim to further explore the psychometric properties of the Social Asymmetry categorisation and examine its utility in identifying individuals at risk of functional decline based on the difference between their social isolation and loneliness levels.

Growth curve modelling of the ELSA dataset allowed us to investigate whether our *Social Asymmetry* metric would be predictive of cognition trajectories. This is an important consideration, since social isolation is not typically stable over the life course (Wenger and Burholt, 2004). Our analyses did not consider changes in loneliness or social isolation over time, but there are clearly opportunities to examine the impact of *Social Asymmetry* in further analyses that account for changes in both dependent and independent variables, using a joint modelling approach.

Evaluating the predictive power of *Social Asymmetry* in other cultures could inform us as to whether its effects are culturally dependent. It could be helpful to examine whether *Social Asymmetry* has associations with risk in other domains such as mortality, overall health, and psychological wellbeing. In terms of clinical significance, it could be informative to know whether an individual is lonely relative to their social isolation, rather than evaluating loneliness alone, in order to best identify individuals at risk of cognitive decline, and potentially other undesirable health outcomes. Finally, examining *Social Asymmetry* in relation to other traits could shed light on its origin – for instance, it may be more likely to occur in those who have higher trait loneliness, or neuroticism.

Our findings highlight an important aspect of social functioning in the older population, and suggest that the discrepancy between objective isolation and felt

loneliness may be associated with undesirable health outcomes such as cognitive dysfunction. From a public health perspective it is important that we can identify those whose social connectedness is at variance with their felt loneliness, and who may have the most to gain from interventions aimed at improving cognitive function at older ages. It is possible from our current findings that interventions will be of the highest impact in cognitive functioning for older adults who are lonely relative to their levels of social isolation.

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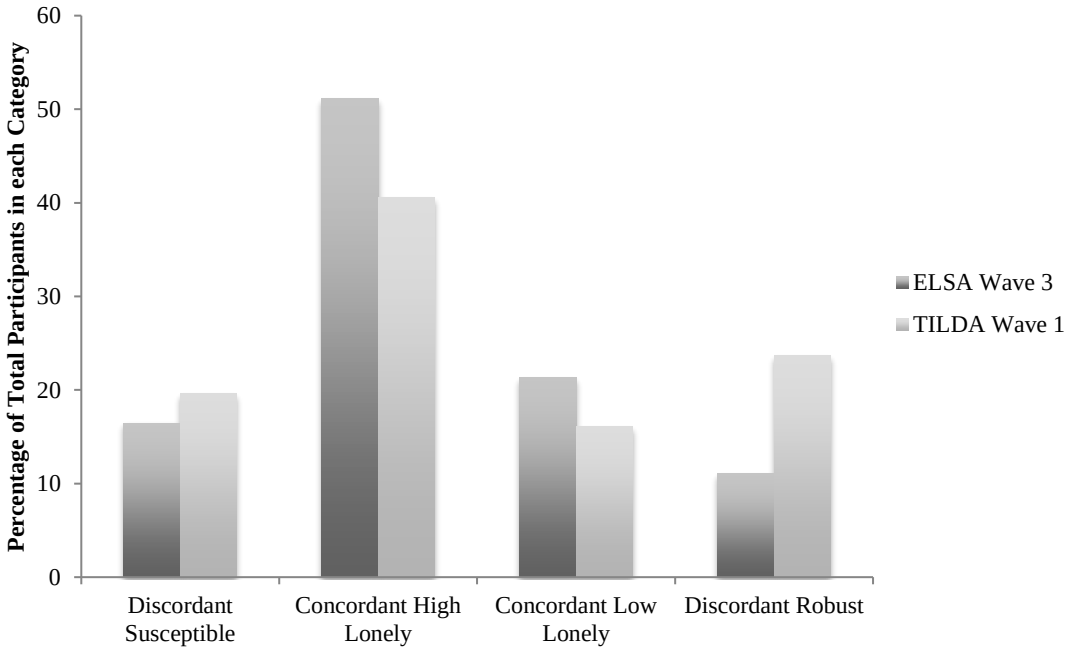

Figure 1. Percentage of total participants in each of the four *Social Asymmetry* categories for the ELSA wave 3 and the TILDA wave 1 cohorts.

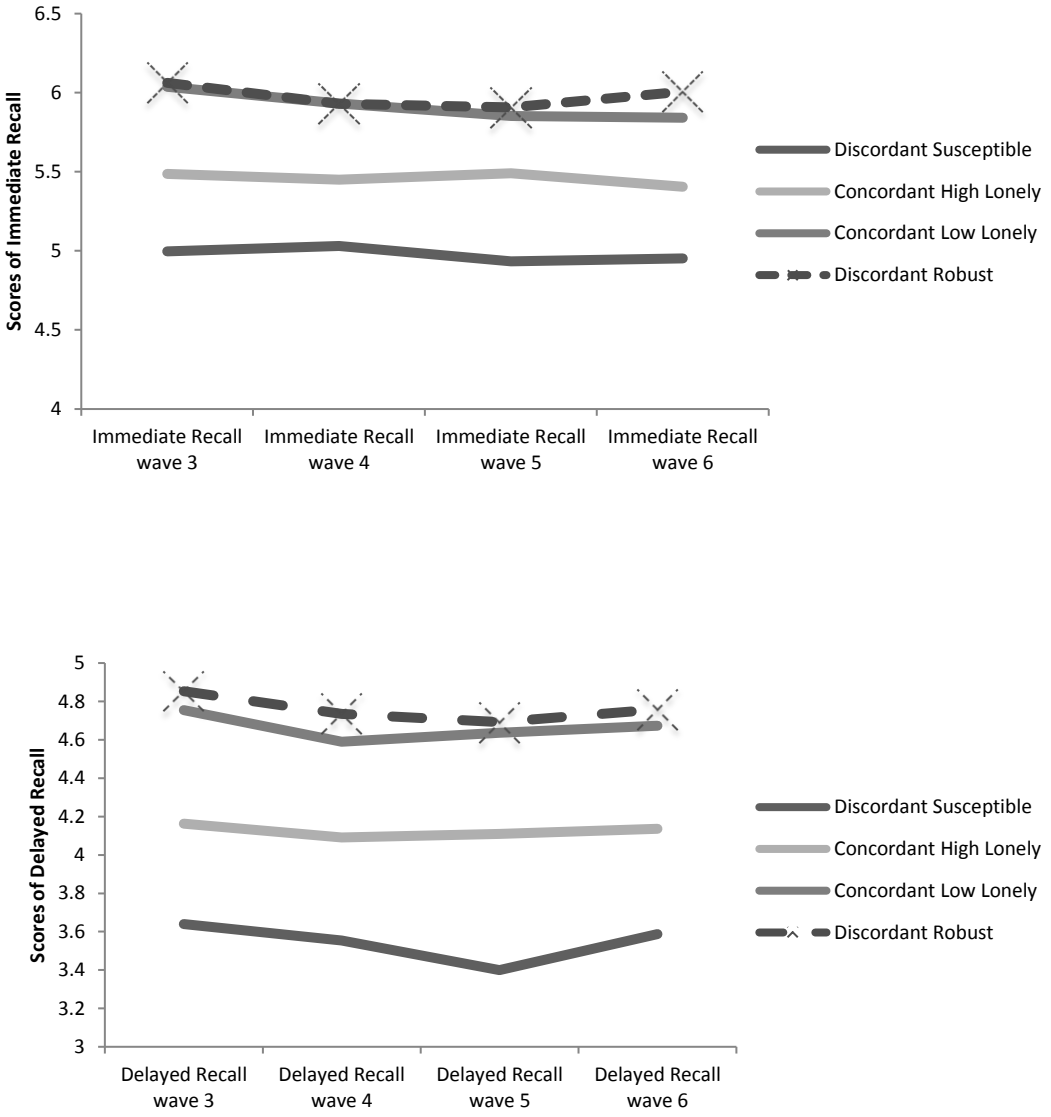

Figure 2. Changes in (a) Immediate Recall and (b) Delayed Recall over 4 waves, within each *Social Asymmetry* category. Linear trends were observed for both, with a curvilinear trend in Delayed Recall scores, likely due to the pronounced shift in scores between waves 5 and 6 in the Discordant Robust and Susceptible groups.

Table 1. Comparison of available measures from TILDA and ELSA datasets, along with means and standard deviations (SD) (or frequencies as percentages where appropriate) of each at baseline (wave 1 of TILDA, and wave 3 of ELSA).

TILDA	**Frequencies/ Mean (SD)**	**ELSA**	**Frequencies/ Mean (SD)**
Age	69.6 (6.6)	Age	71.6 (8.5)
Sex	46% male	Sex	44.5% male
Level of Education Attained		*Level of Education Attained*	
A: No qualification		A: No qualification	
Intermediate qualification	40%	Intermediate	36.8%
Degree or Higher	47.8%	qualification	47.1%
	12.2%	Degree or Higher	16.1%
Immediate Word List Recall	5.3 (1.8)	Immediate Word List Recall	5.4 (1.8)
Delayed Word List Recall	5.4 (2.4)	Delayed Word List Recall	4.05 (2.2)
MMSE	27.9 (2.4)	Animal Naming	18.98 (6.5)
CESD Depressive Symptomatology (20-item)	5.5 (6.6)	CESD Depressive Symptomatology (8 item)	1.53 (1.9)
HADS Anxiety Symptomatology	4.9 (3.5)	GHQ-12 Psychological Distress	10.18 (4.41)
Social Network Index	2.9(0.9)	Social Network Index	2.56 (0.83)
Modified UCLA	1.9 (2.1)	Modified UCLA	2.33 (2.27)

Loneliness Scale	Loneliness scale

Table 2. Pooled linear regression models based on imputed datasets, with Immediate Recall, Delayed Recall, and MMSE scores as outcomes, with predictors entered in blocks, all from Wave 1 TILDA). Final Models only are presented here (initial Model 1 results are presented in the Appendix). For Education, the referent group is '*No qualification'*. For Social Asymmetry (SA), the referent group is '*Discordant Susceptible'*.

	Estimate	*Standard Error*	*t (df)*
Outcome 1:Immediate Recall			
Model 2: Covariates & Social Asymmetry			
(Intercept)	9.51	0.28	34.03 (377)***
Age	-0.07	0.003	-20.9 (2669)***
Sex	0.28	0.05	6.05 (4391)***
Education (Intermediate Qualifications)	0.68	0.05	13.55 (2695)***
Education (Degree or higher)	1.24	0.08	16.36 (2129)***
Anxiety	0.01	0.01	1.75 (66)
Depression	-0.02	0.004	-3.75 (159)***
SA Concordant High Lonely	0.36	0.08	4.32 (26)**
SA Concordant Low Lonely	0.32	0.11	2.91 (15)*
SA Discordant Robust	0.69	0.12	5.88 (11)***
Outcome 2: Delayed Recall			
Model 2: Covariates & Social Asymmetry			

(Intercept)	11.14	0.36	30.59 (2834)***
Age	-0.10	0.01	-20.88 (3555)***
Sex	0.50	0.06	8.03 (3225)***
Education (Intermediate Qualifications)	0.85	0.07	12.67 (3116)***
Education (Degree or higher)	1.59	0.10	15.71 (3802)***
Anxiety	0.02	0.01	1.74 (1682)
Depression	-0.03	0.01	-5.91 (573)***
SA Concordant HL	0.31	0.09	3.39 (515)***
SA Concordant LL	0.27	0.11	2.51 (1294)*
SA Discordant Robust	0.81	0.13	6.29 (27.15)***
Outcome 3: MMSE			
Model 3: Covariates & Social Asymmetry			
(Intercept)	32.94	0.67	49.06 (8)***
Age	-0.09	0.01	-10.39 (8)***
Sex	0.14	0.10	1.41 (12)
Education (Intermediate Qualifications)	1.03	0.08	12.82 (75)***
Education (Degree or higher)	1.66	0.12	14.19 (142)***
Anxiety	0.01	0.01	0.52 (37)
Depression	-0.02	0.01	-1.98 (16)
SA Concordant HL	0.59	0.16	3.69 (8)**
SA Concordant LL	0.49	0.19	2.62 (10)*

SA Discordant Robust	1.21	0.14	8.39 (19)***

* = significant at p<0.05, ** = significant at p<0.01; *** = significant at p<0.001.

Table 3. Pooled linear regression models based on imputed datasets, with Immediate Recall, Delayed Recall, and Animal Naming scores as outcomes, with predictors entered in blocks, all from Wave 3 ELSA Final blocks only are presented here (initial Model 1 results are presented in the Appendix). For Education, the referent group is 'No qualification'. For Social Asymmetry (SA), the referent group is 'Discordant Susceptible'.

Outcome 1: Immediate Recall			
	Estimate	*Standard error*	*t (df)*
Model 2: Covariates & Social Asymmetry			
(Intercept)	8.87	0.24	37.07 (393)***
Age	-0.06	0.00	-25.77 (3939)***
Sex	0.52	0.04	11.7 (3343)***
Education: Intermediate Qualifications	0.74	0.05	14.87 (1080)***
Education: Degree or Higher	1.24	0.07	17.08 (422)***
GHQ	-0.01	0.01	-1.29 (15)
Depression	-0.03	0.02	-1.99 (33)*
SA Concordant High Lonely	0.16	0.07	2.45 (301)*
SA Concordant Low Lonely	0.49	0.08	5.90 (282)***
SA Discordant Robust	0.44	0.10	4.19 (129)***

Outcome 2: Delayed Recall			
Model 2: Covariates & Social Asymmetry			
(Intercept)	8.71	0.27	31.91 (1080)***
Age	-0.08	0.00	-28.24 (3762)***
Sex	0.63	0.05	12.1 (4945)***
Education: Intermediate Qualifications	0.85	0.06	14.27 (502)***
Education: Degree or Higher	1.48	0.08	17.97 (2035)***
GHQ	-0.01	0.01	-1.97 (76)
Depression	-0.03	0.02	-1.65 (372)
SA Concordant High Lonely	0.13	0.07	1.78 (640)
SA Concordant Low Lonely	0.45	0.10	4.26 (64)***
SA Discordant Robust	0.45	0.12	3.76 (188)***
Outcome 3: Animal Naming			
Model 2: Covariates & Social Asymmetry			
(Intercept)	32.58	0.85	38.27 (1501)***
Age	-0.21	0.01	-21.87 (4426)***

Sex	0.12	0.16	0.76 (5283)
Education: Intermediate Qualifications	2.42	0.18	13.21 (1141)***
Education: Degree or Higher	4.38	0.25	16.99 (2119)***
GHQ	-0.06	0.03	-2.06 (15)
Depression	-0.11	0.06	-1.65 (34)
SA Concordant High Lonely	0.34	0.24	1.44 (917)
SA Concordant Low Lonely	0.84	0.29	2.85 (1708)**
SA Discordant Robust	0.88	0.36	2.39 (281)*

Table 4. Pooled linear regression models based on imputed datasets, with Immediate Recall, Delayed Recall, and Animal Naming scores at wave 4 of ELSA as outcomes, with predictors entered in blocks from Wave 3 ELSA. Final Models only are presented here (initial Model 1 results in Appendix). For Education, the referent group is 'No qualification'. For Social Asymmetry (SA), the referent group is 'Discordant Susceptible'.

Outcome 1: Immediate Recall			
Model 2: Covariates & Social Asymmetry	*Estimate*	*Standard error*	*t (df)*
(Intercept)	4.77	0.28	16.69 (1956)***
Age	-0.05	0.00	-16.03 (4209)***
Sex	0.3	0.05	5.85 (4275)***
Baseline IR	0.48	0.01	36.43 (4092)***
Education: Intermediate Qualifications	0.39	0.06	6.68 (314)***
Education: Degree or Higher	0.62	0.09	6.64 (92)***
GHQ	-0.01	0.01	-0.83 (55)
Depression	-0.02	0.02	-1.22 (116)
SA Concordant High Lonely	0.18	0.08	2.16 (81)*
SA Concordant Low Lonely	0.28	0.09	2.9 (182)***
SA Discordant Robust	0.41	0.13	3.03 (31)***
Outcome 2: Delayed Recall			
Model 2: Covariates & Social Asymmetry			
(Intercept)	4.77	0.28	16.69 (1956)***
Age	-0.05	0.00	-16.03 (4209)***
Sex	0.3	0.05	5.85 (4275)***

Baseline DR	0.48	0.01	36.43(4092)***
Education: Intermediate Qualifications	0.39	0.06	6.68 (314)***
Education: Degree or Higher	0.62	0.09	6.64 (92)***
GHQ	-0.01	0.01	-0.82 (55)
Depression	-0.02	0.02	-1.22 (116)
SA Concordant High Lonely	0.18	0.08	2.16 (81)*
SA Concordant Low Lonely	0.28	0.09	2.9 (182)***
SA Discordant Robust	0.41	0.13	3.03 (31)***
Outcome 3: Animal Naming			
Model 2: Covariates & Social Asymmetry			
(Intercept)	16.12	0.91	17.56 (2918)***
Age	-0.12	0.01	-12.95 (3372)***
Sex	-0.06	0.16	-0.41 (3462)
Baseline AN	0.59	0.01	44.04 (3363)***
Education: Intermediate Qualifications	1.12	0.18	5.97 (180)***
Education: Degree or Higher	1.72	0.27	6.28 (385)***
GHQ	0.00	0.02	0.06 (3211)
Depression	-0.16	0.05	-2.94 (34)
SA Concordant High Lonely	-0.14	0.23	-0.60 (1039)
SA Concordant Low Lonely	0.42	0.30	1.39 (178)
SA Discordant Robust	0.00	0.35	0.01 (498)

Table 5. Pooled multilevel models with (a) Immediate Recall and (b) Delayed Recall across waves 3, 4, 5, and 6, as a multilevel outcome, and with Time, Social Asymmetry, age, sex, education level, depression and psychological distress as single-level covariates (full models in Appendix).

Outcome 1: Immediate Recall	*Estimate*	*Standard error*	*t (df)*
Model 5: Time, Social Asymmetry Categories, Interactions, and Covariates.			
Intercept	9.89	0.19	49.54 (9136)***
Time	-0.11	0.015	-6.76 (431)***
SA Categories 2	0.26	0.07	3.35 (349)***
SA Categories 3	0.10	0.11	0.88 (43)
SA Categories 4	-0.09	0.09	-1.03 (251)
Sex	0.48	0.04	12.65 (9367)***
Education 2	0.62	0.04	14.7 (9431)***
Education 3	1.07	0.05	18.36 (8936)***
CESD	-0.04	0.01	-3.48 (8574)***
GHQ	-0.01	0.01	-31.01 (9214)***
Age	-0.07	0.002	-31.01 (9435)***
Time*SA2	-0.02	0.03	-0.77 (224)

Time*SA3	0.05	0.04	1.38 (261)
Time*SA4	-0.01	0.03	-0.42 (665)
Outcome 2: Delayed Recall	*Estimate*	*Standard error*	*t (df)*
Model 5: Time, Social Asymmetry Categories, Interactions, and Covariates.			
Intercept	9.95	0.26	38.4 (8522)***
Time	-0.29	0.08	-3.45 (2082)***
Time Squared	0.03	0.02	2.01 (1446)*
SA Categories 2	0.24	0.16	1.46 (2461)
SA Categories 3	0.38	0.22	1.72 (1020)
SA Categories 4	0.21	0.19	1.11 (534)
Sex	0.57	0.04	12.03 (9387)***
Education 2	0.74	0.05	13.9 (9334)***
Education 3	1.29	0.07	17.83 (8943)***
CESD	-0.04	0.02	-2.82 (6310)**
GHQ	-0.01	0.01	-2.56 (6392)*
Age	-0.09	0.002	-31.44 (9183)***
Time*SA2	-0.05	0.15	-0.32 (4799)
Time*SA3	-0.11	0.21	-0.53 (268)
Time*SA4	-0.32	0.17	-1.81 (602)
TimeSq*SA2	0.01	0.03	0.40 (3024)

TimeSq*SA3	0.03	0.04	0.67 (251)
TimeSq*SA4	0.05	0.04	1.61 (438)