Title: Loneliness interacts with family relationship in relation to cognitive function in Chinese older adults

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Abstracts

Objectives: Loneliness and social network have been extensively studied in relation to cognitive impairments, but how they interact with each other in relation to cognition is still unclear. This study aimed at exploring the interaction of loneliness and various types of social networks in relation to cognition in older adults.

Design: a cross-sectional study

Setting: face-to-face interview.

Participants: 497 older adults with normal global cognition were interviewed.

Measurements: Loneliness was assessed with Chinese 6-item De Jong Gierverg's Loneliness Scale. Confiding network was defined as people who could share inner feelings with, whereas non-confiding network was computed by subtracting the confiding network from the total network size. Cognitive performance was expressed as a global composite z-score of Cantonese version of mini mental state examination (CMMSE), Categorical verbal fluency test (CVFT) and delayed recall. Linear regression was used to test the main effects of loneliness and the size of various networks, and their interaction on cognitive performance with the adjustment of sociodemographic, physical and psychological confounders.

Results: Significant interaction was found between loneliness and non-confiding network on cognitive performance (B=.002, β=.092, t=2.099, p=.036). Further analysis showed a significant interaction between loneliness and the number of family members in non-confiding network on cognition (B=.021, β=.119, t=2.775, p=.006).

Conclusions: Results suggested that non-confiding relationship with family members might put lonely older adults at risk of cognitive impairment. Our study might have implications on designing psychosocial intervention for those who are vulnerable to loneliness as an early prevention of neurocognitive impairments.

Keywords: Loneliness, social network, close tie, family estrangement, confidante relationships, cognitive impairment, dementia, older adults.

Introduction

Loneliness has been defined as "unpleasant experience that occurs when a person's network of social relations is deficient in some important way, either quantitatively or qualitatively" (Perlman and Peplau, 1981). The phenomenon is common in old age and also on the rise (Luo and Waite, 2014). In Western countries, 20% to 40% of older adults reported feeling lonely (Savikko et al., 2005). In China, the prevalence of loneliness has increased from 16% to 30% from 1992 to 2000, due to the increasing "empty-nested" phenomenon (Yang and Victor, 2008). Loneliness was reported to be associated with negative cognitive outcomes in older adults. Lonely individuals were found to be 2.1 folds more likely to develop an Alzheimer's disease-like dementia syndrome than were those who were less lonely (Wilson et al., 2007). Longitudinal studies showed that loneliness was predictive of subsequent cognitive decline in older people with no cognitive impairment even 10 years later (Tilvis et al., 2004, Shankar et al., 2013, Zhong et al., 2017). These studies suggested that loneliness is not only an emotional response, but might also be a mediating factor of neurodegenerative disease.

When studying loneliness, it is important to take social network into account. However, earlier studies focused on distinct aspects of social network. There was no agreement on how social network should be investigated. While much of the researches focused on the association between social network size and cognitive decline, some interested in the beneficial effect of staying socially active in late life on preserving cognitive function (Crooks et al., 2008, Pillai and Verghese, 2009, Bennett et al., 2006).

Recent studies yet investigated the protective effect of confiding relationship on cognitive preservation in old age (Bickel and Cooper, 1994, Yoshitake et al., 1995, Håkansson et al., 2009, Yeh and Liu, 2003). Due to heterogeneity in study design and measures, these results were mixed and difficult to compare.

Although loneliness and social network are differentially associated with cognitive impairment, it is not clear whether their effects are independent or whether loneliness and social network mediate one another to impair cognition. Very few studies examined loneliness and social network simultaneously in relation to cognition in old age. Among those that have, only one study examined the interaction effect of loneliness and social network size on cognition (Tilvis et al., 2004, McHugh et al., 2016, Steptoe et al., 2013). Even less that examined interaction between loneliness and the size of various social network types on cognition.

The objective of the present study was to examine the interaction effect of loneliness and the size of various social network types in relation to cognitive performance among cognitively healthy Chinese older adults. More specifically, we hope to identify which type of network that might truly interact with loneliness in relation to cognitive impairment. Through inspecting loneliness and personal network in older adults, our study could help to extend previous works to make advice on incorporating psychosocial components to existing cognitive interventions.

Methods

Design & Participants

This cross-sectional study was conducted between 2012 and 2013 in Hong Kong. Participants were community dwelling older adults aged 60 years or older with a clinical dementia rating (CDR) of 0 (Morris, 1997). All participants were explained the purpose of the study and consents were obtained before interviews.

Measurements

Loneliness was assessed by means of the Chinese 6-item De Jong Gierverg's Loneliness Scale. It is a reliable and valid measurement for overall, emotional, and social loneliness that can be used in a broad age range from 18 to 99 years. The overall loneliness score ranges from 0 to 12, where 0 means no loneliness and 12 indicates severe loneliness (Leung et al., 2008).

Social network size was defined as the total number of people in their network whom the participants has talked to or visited previously. Social network was further categorized into two types, confiding network and non-confiding network. Confiding network was defined as the total number of people who could share inner feelings with; whereas non-confiding network was computed by subtracting people who could share inner feelings from the total network size. Within each network type, it is further divided into close ties (family member) and non-close ties (friend). Close ties may comprise of parents, spouse,

children, and siblings; whereas non-close ties may include extended relatives, friends, neighbors, and any contacts through previous workplace or participating elderly centers.

Outcome variables

Cognitive performance was assessed with the Cantonese version of mini mental state examination (CMMSE) (Chiu et al., 1994); Categorical verbal fluency test (CVFT) (Chiu et al., 1997); and ten-minutes delayed recall.

CMMSE is a 30-points scale that examined global cognitive functioning by evaluating performance in different cognitive components, including orientation to time, orientation to place, registration, attention and calculation, delayed recall, language, ability to follow commands, and visuo-spatial perception (Chiu et al., 1994).

Categorical verbal fluency test (CVFT) is test of semantic fluency and executive function. Participants were asked to generate as many exemplars as possible for each of the three semantic categories, namely animals, fruits, and vegetables, in 60 seconds. Their responses were recorded and scoring was based on the total number of words that the participant was able to produce across all three categories (Chiu et al., 1997).

Word list learning and ten-minutes delayed recall is a test for episodic memory using the first part of the ADAS-Cog word list. It contains ten words that have no semantic association presented over 3 acquisition trials. Then, without additional presentation, participants were required to free recall the ten words after 10-minute delayed interval.

Potential Confounders

Diagnosis of depression was based on the use of the Tenth Revision of the International Classification of Diseases of the World Health Organization (ICD-10) diagnostic criteria generated by the Revised Clinical Interview Schedule (CIS-R). It consists of 14 sections of psychological symptoms. Symptom scores are calculated for each section. A total score is generated by summation of the section scores. It generated diagnosis of common mental disorders, including depressive disorder; generalized anxiety disorders; mixed anxiety and depressive disorder; other anxiety disorders; and comorbid mood disorders; according to the ICD-10 (Lewis et al., 1992).

Physical health status was assessed by means of chronic illness rating scale (CIRS). Medical diseases are categorized according to major bodily systems: (1) cardiovascular; (2) respiratory; (3) gastrointestinal; (4) genitourinary; (5) musculo-skeletal-integumentary; (6) neuropsychiatric illness; (7) general. The burden of illness for each system is rated along a dimension from 0 (No impairment to organs/system) to 4 (Extremely severe impairment). Higher total CIRS score represents increasing severity of impairment and urgency of

medical intervention. The total score is the sum of all bodily system scores ranging from 0 to 52 (Parmelee et al., 1995).

Neuroticism was assessed with a 10-item neurotic subscale extracted from the 50-item set of International Personality Item Pool representation of the Goldberg (1992) markers for the big-five factor structure. Respondent is asked to rate their answer on a 5-point scale ranging from 1 (very inaccurate) to 5 (very accurate as a description of you). The total score ranges from 10 to 50, with higher scores indicating higher tendency towards neuroticism (R. Goldberg, 1992, Goldberg et al., 2006).

Socio-demographics including age, years of education, gender (male/ female), family history of dementia (yes/ no), marital status (married/ not married), and living arrangement (living alone/ living with family) were adjusted during analysis.

Statistical Analysis

Cognitive performance was determined with a global composite z-score that derived from CMMSE, delayed recall and CVFT. For each cognitive test, a raw score was standardized into z-score by using the mean and standard deviation of an age and education matched norms (Lam et al., 2008). A global composite z-score was the sum of the three individual z-scores. Higher score represents better cognitive performance. The three cognitive tests were chosen as a composite measure on cognitive performance, because

each representing a specific cognitive domain that shown to have high sensitivity to the trajectory of decline and predictability of dementia progress in a local population based longitudinal observational study (Wong et al., 2013)

Bivariate correlation was used to check the relationship between sociodemographic variables with loneliness, and with social networks. To investigate the interaction effect on cognitive function, loneliness and several types of network size were mean centered. Interaction terms were computed using the products of the centered loneliness score and the respective types of centered social network size. The interaction of loneliness and social network size on cognitive performance was examined based on linear regression analysis. Similar analysis was repeated for confiding and non-confiding networks. Socio-demographic characteristics, physical burdens, mental health and depression were adjusted as potential confounders in all models. All statistical analyses were conducted using IBM SPSS Statistics 22. The significant level was set to p<0.05.

Results

Sample Characteristics

A sample of 497 older adults with a CDR rating of 0 was interviewed. The mean age was 68.7 (SD = 6.35) years, and 54.7% (N=268) of the sample were female. The mean years of education was 10.01 (SD = 4.68) years. Socio-demographic, clinical, social and psychological characteristics among the four groups are reported in Table 1.

Interaction with Social Network Type

Three models were tested with linear regression for significant interaction between loneliness and social network size on cognitive functioning. The first one tested for significant interaction between loneliness and the total network size on cognitive performance. The second and the third one tested for interaction with confiding and non-confiding networks size respectively. All three models were controlled socio-demographics, mental, physical illness and other psychological variables.

Linear regression showed that there was significant interaction between loneliness and non-confiding networks size (B=.002, β=.092, t=2.099, p=.036). However, no significant interaction effect with total network size (B=.002, β=.083, t=1.870, p=.062) and confiding network size network (B=-.001, β=-.010, t=-.165, p=.869) on cognitive functioning. Interaction effect of loneliness and types of social network on cognitive performance was shown in Table 2.

Further investigation was done on the type of relationship within non-confiding network. Linear regression analysis showed that there was significant interaction loneliness and the number of family members in the non-confiding networks (B=.021, β=.119, t=2.775, p=.006), while no significant effect was found for number of friends in the non-confiding networks (B=.002, β=.078, t=1.790, p=.074). Interaction between loneliness and

types of non-confiding networks on cognitive performance was shown in Table 3. To better illustrate the interaction effect, Figure 1 plotted the cognitive composite score as a function of groups formed by using median splits of number of family members in the non-confiding network (6 members) for participants with different levels of loneliness: low level of loneliness (25th percentile: a score of 3 or below), medium level (50th percentile: score ranging from 4 to 8) and high level (75th percentile: a score of 9 or above). The change in cognitive function across non-confiding family network size was more pronounced for older adults with low to medium level of loneliness. Older adults with highest level of loneliness had the poorest cognitive score regardless of the non-confiding family network size.

Discussion

This study explored the interaction effect between loneliness and social network in relation to cognitive functioning in cognitively healthy older adults. Our findings showed a significant interaction between loneliness and non-confiding network in relation to cognitive function, after controlling socio-demographic characteristics, mental distress, physical burdens, psychological factors, and depression. More specifically, our findings showed a significant interaction effect between loneliness and the number of family members in the non-confiding network in relation to cognitive function.

Consistent with previous studies, our findings suggested that high level of loneliness might be a risk factor of having low cognitive functioning on one hand and small social network on the other hand. However, there was no interaction between loneliness

and the total network size on cognition. It might be that the total network size is a broad inclusion of everyone in the social circle. It provided little information on the quality of relationships. A small network size did not necessarily worse than a large one. Thus, it is not specific enough to reflect interaction with loneliness in affecting cognitive functioning in older adults. Evidence from a recent longitudinal study in Netherland also found that loneliness rather than social isolation predicted heightened risk of AD (Holwerda et al., 2014). Therefore, small social network alone could not fully explain why lonely older adults were associated with higher risk of having low cognitive functioning. This interpretation seemed to make sense, because there were individuals who lived a solitary life but not feeling lonely, and conversely, there were individuals who lived a rich social life and still feeling lonely. It was suspected that loneliness might derive from social features other than the size of social network. Indeed, previous works examining the relation between social network and dementia found that number of close social tie, social supports or frequency of contacts was associated with the incident rate (Bassuk et al., 1999, Fratiglioni et al., 2000, Saczynski et al., 2006, Seeman et al., 2001). Together with our results, these studies suggested that loneliness might be linked to other features of social networks, such as close ties, that contributed to heightened risk of having low cognitive functioning in non-demented older adults.

Unlike previous studies emphasized on increasing social network size as a protective factor for cognitive performance in older adults, our findings demonstrated the importance of inspecting the type of social network that might matter to the social life and cognitive health in older adults. It suggested that simply expanding an individual's social

network might not be an effective method in maintaining cognitive health in old age. Instead, our results on interaction between loneliness and the non-confiding network size have prompted us to speculate the importance of looking at any estranged relationship in one's social network. Yet, it could be precarious to equate non-confiding network with estrangement in this study, as many reasons could contribute to a non-confiding relationships. Besides, we did not directly measure estranged relationships in this study. While our results only served to provide a legitimate basis for hypothesis generation, it remains interesting to explore if the unsatisfactory subjective feeling of loneliness would come from some unresolved conflicts or alienation in family relationships, such as extramarital affairs, or intergenerational communication breakdown. As this would help to understand how an older adults perceive and prioritize their relationships. Therefore, our findings suggest a logical conceptual model on how family relationship interacts with loneliness in relation to cognitive function in older adults for future testing.

Several strengths were noted in this study. First, the use of global cognitive standardized score has captured the performance of episodic memory, which often found to be impaired in older adults with cognitive impairment of Alzheimer's type. Second, our analysis had controlled for a number of factors including depression. Our results has enabled a strong association to be made between loneliness and social network with low cognitive functioning in non-demented older people. Third, social network represents a broad spectrum of social relationships that are differed in degree of intimacy. Our investigation on the size of various social network types has allowed us to inspect both quantitative and qualitative features of social network simultaneously. At the same time,

we could inspect relationships that might affect one's subjective feeling towards their network.

However, interpretations of the findings must be cautious and were subjected to two limitations of the study design. Cross-sectional data does not allow causal inference to be made on the hypothesized interaction effect. It is yet to be elucidated whether loneliness and network size are causes or consequences of cognitive impairment. As loneliness was also commonly reported in cognitively impaired older adults (Yu et al., 2016), it was possible that loneliness and small social network might be the signs of cognitive decline or precipitating factors of underlying neurodegenerative process. A recent novel study found that higher cortical amyloid burden was associated with loneliness in normal healthy older adults, suggesting that loneliness might be an early sign of neurodegenerative disorders and should receive clinical attention (Donovan et al., 2016). Second, it is difficult to assess the strength of the association based on the small beta coefficient on the interaction, as it might reflect that both predictors have a lot in common in explaining an individual's relationship. Therefore, the main effects of each independent variable could be useful to interpret whether network size or loneliness is more important for cognitive function. Third, we did not measure other features of social networks, such as frequency of contacts and social supports. These features should be examined simultaneously in future studies. Last but not the least, our study was conducted in a Chinese population that has a long tradition in emphasizing integrity of family union. It was possible that the results were reflecting cultural values treasuring by the Chinese community. Future studies might consider repeat the study to see if result is reproducible in Western countries.

Based on this preliminary result, we have identified the potential effect of family relationship on loneliness in relation to cognitive function in older adults. Although there is no direct evidence from our study on the effect of family estrangement on the cost of mental health services, accumulating evidences already reported a range of negative health outcomes of loneliness in old age. Therefore, it is worth to examine how loneliness and family relationship interact together to affect the cost on mental health services in the long run. Since loneliness might be due to lack of emotional supports from a trustable figure who could talk to or share with, simply suggesting the adoption of an active social life is not enough in reducing loneliness. Instead, activities should focus on how to identify the root of loneliness and address the barriers to promote family ties or social integration. In the future, it might be worth to examine why there are older adults with small social network but not feeling lonely. There might be some characteristics in these people that are protective against cognitive impairment.

Conclusion

This exploratory study has identified the potential effect of family relationship on loneliness in relation to cognitive function in a community sample of non-demented Chinese older adults. To assert the speculation, more works, both cross-sectional and longitudinal studies, would be needed to rigorously examine how loneliness and family relationship interact together in relation to cognitive functioning. Longitudinal studies would be able to track how cognitive functioning changes in response to the interaction

between persistent loneliness and weak bonding with significant people over time. At the same time, it might be useful to look for activities that might strengthen family relationship in lonely older adults, so to reduce possible risk of cognitive impairments.

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Conflict of interest declaration:

None.

Description of authors' roles:

AWT Fung contributed in the process of data collection, statistical analysis and manuscript writing. LCW Lam supervised the data collection and offered advices throughout study conceptualization to manuscript writing. ATC Lee provided advices on study design and manuscript writing. ST Cheng gave advices on statistical analysis and manuscript writing.

Acknowledgement:

References

BASSUK, S. S., GLASS, T. A. & BERKMAN, L. F. 1999. Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Ann Intern Med,* 131**,** 165-73.

BENNETT, D. A., SCHNEIDER, J. A., TANG, Y., ARNOLD, S. E. & WILSON, R. S. 2006. The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: a longitudinal cohort study. *Lancet Neurol,* 5**,** 406-12.

BICKEL, H. & COOPER, B. 1994. Incidence and relative risk of dementia in an urban elderly population: findings of a prospective field study. *Psychol Med,* 24**,** 179-92.

CHIU, H., LEE, H., CHUNG, W. & KWONG, P. 1994. RELIABILIY AND VAUDITY OF THE CANTONESE VERSION OF MINI-MENTAL STATE EXAMINATION - A PRELIMINARY STUDY. *J.H.K.C. Psych.,* 4**,** 25-28.

CHIU, H. F., CHAN, C. K., LAM, L. C., NG, K. O., LI, S. W., WONG, M. & CHAN, W. F. 1997. The modified Fuld Verbal Fluency Test: a validation study in Hong Kong. *J Gerontol B Psychol Sci Soc Sci,* 52**,** P247-50.

CROOKS, V. C., LUBBEN, J., PETITTI, D. B., LITTLE, D. & CHIU, V. 2008. Social Network, Cognitive Function, and Dementia Incidence Among Elderly Women. *American Journal of Public Health,* 98**,** 1221-1227.

DONOVAN, N. J., OKEREKE, O. I., VANNINI, P., AMARIGLIO, R. E., RENTZ, D. M., MARSHALL, G. A., JOHNSON, K. A. & SPERLING, R. A. 2016.

Association of Higher Cortical Amyloid Burden With Loneliness in Cognitively Normal Older Adults. *JAMA Psychiatry,* 73**,** 1230-1237.

FRATIGLIONI, L., WANG, H. X., ERICSSON, K., MAYTAN, M. & WINBLAD, B. 2000. Influence of social network on occurrence of dementia: a community-based longitudinal study. *Lancet,* 355**,** 1315-9.

GOLDBERG, L. R., JOHNSON, J. A., EBER, H. W., HOGAN, R., ASHTON, M. C., CLONINGER, C. R. & GOUGH, H. G. 2006. The international personality item pool and the future of public-domain personality measures. *Journal of Research in Personality,* 40**,** 84-96.

HÅKANSSON, K., ROVIO, S., HELKALA, E.-L., VILSKA, A.-R., WINBLAD, B., SOININEN, H., NISSINEN, A., MOHAMMED, A. H. & KIVIPELTO, M. 2009. Association between mid-life marital status and cognitive function in later life: population based cohort study. *BMJ,* 339.

HOLWERDA, T. J., DEEG, D. J., BEEKMAN, A. T., VAN TILBURG, T. G., STEK, M. L., JONKER, C. & SCHOEVERS, R. A. 2014. Feelings of loneliness, but not social isolation, predict dementia onset: results from the Amsterdam Study of the Elderly (AMSTEL). *J Neurol Neurosurg Psychiatry,* 85**,** 135-42.

LAM, L. C., TAM, C. W., LUI, V. W., CHAN, W. C., CHAN, S. S., WONG, S., WONG, A., THAM, M. K., HO, K. S., CHAN, W. M. & CHIU, H. F. 2008. Prevalence of very mild and mild dementia in community-dwelling older Chinese people in Hong Kong. *Int Psychogeriatr,* 20**,** 135-48.

LEUNG, G. T., DE JONG GIERVELD, J. & LAM, L. C. 2008. Validation of the Chinese translation of the 6-item De Jong Gierveld Loneliness Scale in elderly Chinese. *Int Psychogeriatr,* 20**,** 1262-72.

LEWIS, G., PELOSI, A. J., ARAYA, R. & DUNN, G. 1992. Measuring psychiatric disorder in the community: a standardized assessment for use by lay interviewers. *Psychol Med,* 22**,** 465-86.

LUO, Y. & WAITE, L. J. 2014. Loneliness and Mortality Among Older Adults in China. *The Journals of Gerontology: Series B,* 69**,** 633-645.

MCHUGH, J. E., KENNY, R. A., LAWLOR, B. A., STEPTOE, A. & KEE, F. 2016. The discrepancy between social isolation and loneliness as a clinically meaningful metric: findings from the Irish and English longitudinal studies of ageing (TILDA and ELSA). *International Journal of Geriatric Psychiatry,* 32**,** 664-674.

MORRIS, J. C. 1997. Clinical dementia rating: a reliable and valid diagnostic and staging measure for dementia of the Alzheimer type. *Int Psychogeriatr,* 9 Suppl 1**,** 173-6; discussion 177-8.

PARMELEE, P. A., THURAS, P. D., KATZ, I. R. & LAWTON, M. P. 1995. Validation of the Cumulative Illness Rating Scale in a geriatric residential population. *J Am Geriatr Soc,* 43**,** 130-7.

PERLMAN, D. & PEPLAU, L. 1981. Toward a social psychology of loneliness. *In:* GILMOUR, R. & DUCK, S. (eds.) *Personal relationships 3: personal relationships in disorder.* London: Academic Press.

PILLAI, J. A. & VERGHESE, J. 2009. Social networks and their role in preventing dementia. *Indian journal of psychiatry,* 51**,** 22-28.

R. GOLDBERG, L. 1992. *The Development of Markers For the Big Five Factor Structure*.

SACZYNSKI, J. S., PFEIFER, L. A., MASAKI, K., KORF, E. S., LAURIN, D., WHITE, L. & LAUNER, L. J. 2006. The effect of social engagement on incident dementia: the Honolulu-Asia Aging Study. *Am J Epidemiol,* 163**,** 433-40.

SAVIKKO, N., ROUTASALO, P., TILVIS, R. S., STRANDBERG, T. E. & PITKALA, K. H. 2005. Predictors and subjective causes of loneliness in an aged population. *Arch Gerontol Geriatr,* 41**,** 223-33.

SEEMAN, T. E., LUSIGNOLO, T. M., ALBERT, M. & BERKMAN, L. 2001. Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. *Health Psychol,* 20**,** 243-55.

SHANKAR, A., HAMER, M., MCMUNN, A. & STEPTOE, A. 2013. Social isolation and loneliness: relationships with cognitive function during 4 years of follow-up in the English Longitudinal Study of Ageing. *Psychosom Med,* 75**,** 161-70.

STEPTOE, A., SHANKAR, A., DEMAKAKOS, P. & WARDLE, J. 2013. Social isolation, loneliness, and all-cause mortality in older men and women. *Proc Natl Acad Sci U S A,* 110**,** 5797-801.

TILVIS, R. S., KAHONEN-VARE, M. H., JOLKKONEN, J., VALVANNE, J., PITKALA, K. H. & STRANDBERG, T. E. 2004. Predictors of cognitive decline and mortality of aged people over a 10-year period. *J Gerontol A Biol Sci Med Sci,* 59**,** 268-74.

WILSON, R. S., KRUEGER, K. R., ARNOLD, S. E., SCHNEIDER, J. A., KELLY, J. F., BARNES, L. L., TANG, Y. & BENNETT, D. A. 2007. Loneliness and risk of Alzheimer disease. *Arch Gen Psychiatry,* 64**,** 234-40.

YANG, K. & VICTOR, C. R. 2008. The prevalence of and risk factors for loneliness among older people in China. *Ageing and Society,* 28**,** 305-327.

YEH, S.-C. J. & LIU, Y.-Y. 2003. Influence of social support on cognitive function in the elderly. *BMC Health Services Research,* 3**,** 9-9.

YOSHITAKE, T., KIYOHARA, Y., KATO, I., OHMURA, T., IWAMOTO, H., NAKAYAMA, K., OHMORI, S., NOMIYAMA, K., KAWANO, H., UEDA, K. & ET AL. 1995. Incidence and risk factors of vascular dementia and Alzheimer's disease in a defined elderly Japanese population: the Hisayama Study. *Neurology,* 45**,** 1161-8.

YU, J., LAM, C. L. & LEE, T. M. 2016. Perceived loneliness among older adults with mild cognitive impairment. *Int Psychogeriatr,* 28**,** 1681-5.

ZHONG, B. L., CHEN, S. L., TU, X. & CONWELL, Y. 2017. Loneliness and Cognitive Function in Older Adults: Findings From the Chinese Longitudinal Healthy Longevity Survey. *J Gerontol B Psychol Sci Soc Sci,* 72**,** 120-128.

Tables

Table 1. Sociodemographic and clinical features of cognitively normal older adults (N=497)

	Mean	SD
Sociodemographics		
Age	68.7	6.3
Female, %	54.9	-
Education years	10.0	4.7
Married, %	68.0	-
Living alone, %	20.5	-
Physical health		
CIRS	4.3	2.5
Family history of mental illness, %	12.7	-
Family history of dementia, %	15.8	-
Mental health		
CISR	3.6	5.9
Cognitive performance		
Composite z score	2.2	1.9
CMMSE	0.7	0.7
Categorical verbal fluency test	1.1	1.1
Delayed recall	0.4	0.8
Social variables		
Total network size	41.6	33.6
Confiding network size	5.2	6.7
Non-confiding network size	36.4	31.5
Psychological variables		
Loneliness	3.4	2.9
Neuroticism	24.4	6.7
Satisfactory with life scale	24.4	6.4

CIRS = chronic illness rating scale; CISR = revised clinical interview schedule; CMMSE = Cantonese version of mini mental state examination

Table 2. Interaction of loneliness and various types of network size on cognitive performance in non-demented older adults.

	Model 1				Model 2				Model 3			
	B (SE)	β	t	p-value	B (SE)	β	t	p-value	B (SE)	β	t	p-value
Loneliness	-.105 (.034)	-.165	-3.102	.002	-.120 (.036)	-.188	-3.362	.001	-.109 (.034)	-.171	-3.233	.001
Total network	.007 (.002)	.126	2.819	.005	-	-	-	-	-	-	-	-
Total network x Loneliness	.002 (.001)	.083	1.870	.062	-	-	-	-	-	-	-	-
CF	-	-	-	-	.015 (.018)	.054	.850	.396	-	-	-	-
CF x Loneliness	-	-	-	-	-.001 (.006)	-.010	-.165	.869	-	-	-	-
NCF	-	-	-	-	-	-	-	-	.007 (.003)	.117	2.649	.008
NCF x Loneliness	-	-	-	-	-	-	-	-	.002 (.001)	.092	2.099	.036

Model 1 tested for significant interaction of loneliness and total social network on cognitive performance
Model 2 tested for significant interaction of loneliness and confiding network on cognitive performance
Model 3 tested for significant interaction of loneliness and non-confiding network on cognitive performance
All models adjusted for education year, marital status, living alone, physical burdens, mental health, neuroticism and depression
CF: confiding network
NCF: Non-confiding network

Table 3. Interaction of loneliness and various types of non-confiding network size on cognitive performance in non-demented older adults.

	Model 1				Model 2			
	B (SE)	β	t	p-value	B (SE)	β	t	p-value
Loneliness	-.127 (.033)	-.199	-3.840	<.001	-.111 (.034)	-.174	-3.301	.001
NCFfam	.-036 (.022)	-.071	-1.660	0.98	-	-	-	-
NCFfam x Loneliness	.021 (.008)	.119	2.775	.006	-	-	-	-
NCFfrd	-	-	-	-	.007 (.003)	.126	2.837	.005
NCFfrd x Loneliness	-	-	-	-	.002 (.001)	.078	1.790	.074

Model 1 tested for significant interaction of loneliness and non-confiding family network (NCFfam) on cognitive performance
Model 2 tested for significant interaction of loneliness and non-confiding friends network (NCFfrd) on cognitive performance
All models adjusted for education year, marital status, living alone, physical burdens, mental health, neuroticism and depression

Figure 1. A plot of the cognitive composite score as a function of groups formed by median split of number of family members in the non-confiding network (6 members) for participants with different levels of loneliness
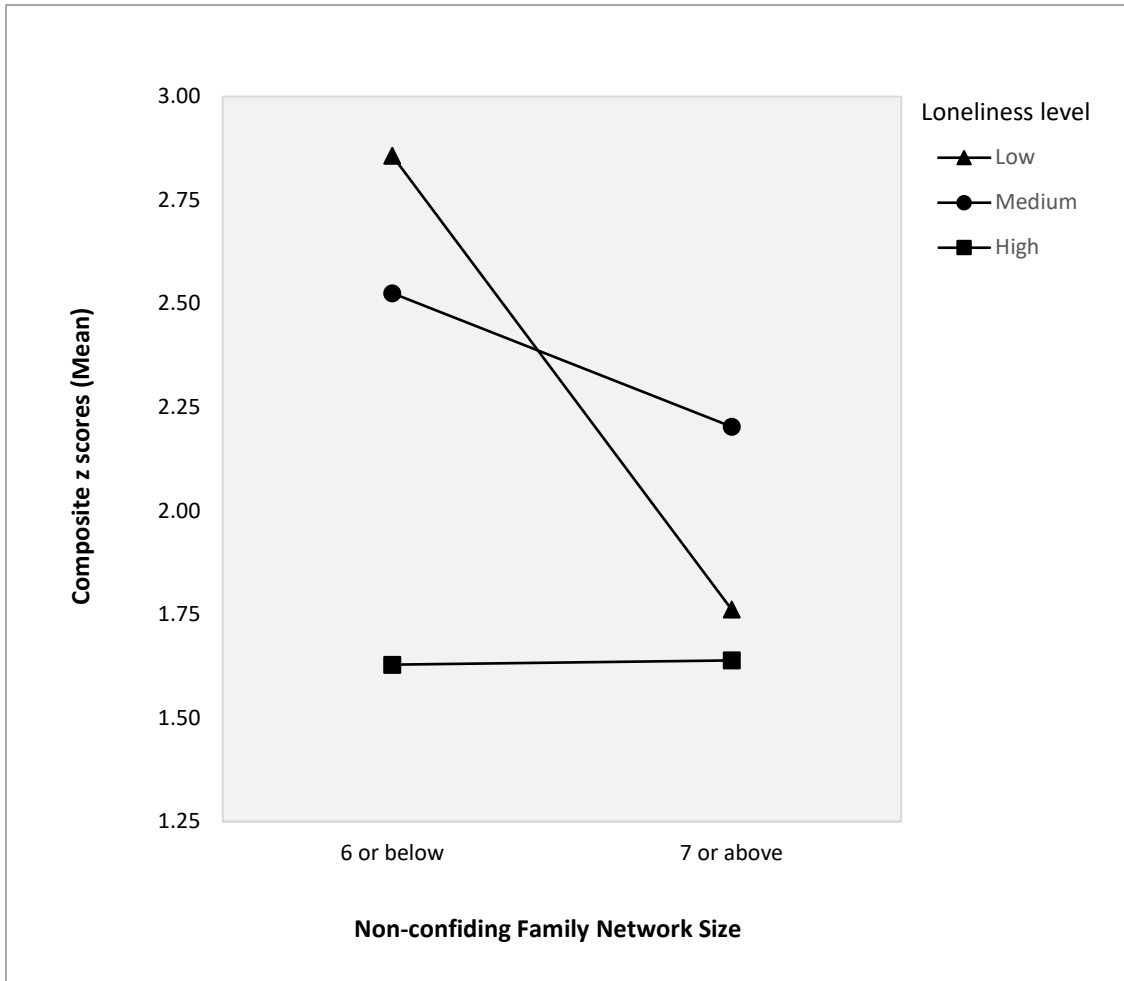
Low level of loneliness: 25th percentile (a loneliness score of 3 or below)
Medium level: 50th percentile with a score ranging from 4 to 8
High level (75th percentile: a score of 9 or above)