

The Relationship between Executive Functions and Interoceptive Awareness in the Elderly with Perceived Feelings of Loneliness

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Abstract

Objectives: Older adults are more vulnerable to perceived feelings of loneliness which may lead to depression, cognitive decline, and an overall decrease in their quality of life. In the present study, the main objective was to compare executive functions and interoceptive awareness between the elderly with and without perceived feelings of loneliness. **Methods:** In the study, we recruited a sample of 100 study subjects (50 individuals with perceived feelings of loneliness and 50 healthy controls). UCLA 3-Item Loneliness Scale was used as a screening tool for loneliness. Multidimensional Assessment of Interoceptive Awareness, Stroop Test, N Back Test (verbal and visual), and Wisconsin Card Sorting Test were used as measures of interoceptive awareness and executive functioning, respectively. **Results:** Significant difference was found between both the groups in working memory ($p < 0.05$) and set shifting ability ($p < 0.01$). In interoceptive awareness, significant difference was found between both the groups in the domains of significantly high on not distracting ($t = 5.723, p < 0.01$), significantly less on not worrying ($t = 2.028, p < 0.05$), significantly less on body listening ($t = 2.302, p < 0.05$), and significantly less on trusting ($t = 4.630, p < 0.01$). **Conclusion:** To understand the possible neuropsychological mechanism of loneliness may help conceptualize a better intervention plan for those with perceived feelings of loneliness to prevent progression to severe psychological problems and cognitive decline.

Key words: older adults, UCLA 3-Item Loneliness Scale, Multidimensional Assessment of Interoceptive Awareness, Wisconsin Card-sorting Test
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Introduction

Loneliness is a subjective emotional state. Feelings of loneliness may be present in any age group. But it is more prevalent for adolescents and the elderly [1]. The prevalence of loneliness is found to be higher among those older adults who are male, lives alone, has no spouse, and has poor emotional support [2]. These feelings can trigger a depressive syndrome. The elderly with depressive features are also at a considerable risk for suicidal behaviors [3]. It often manifests in the elderly and often goes unnoticed [4]. Loneliness is one of the most frequent complaints among the elderly.

Cognitive functioning declines with age, and it is important to differentiate between normal age-related cognitive changes

and symptoms of any degenerative disease [5]. Preliminary research evidence indicated that loneliness in the elderly is associated with cognitive decline which may progress to dementia including Alzheimer's disease [6]. In a study with the largest sample size ($N = 13,176$), a negative association between loneliness and executive function (EF) has been found [7]. Thus, recent evidence indicated that loneliness in the elderly is associated with poorer cognitive function.

Maturation dualism indicates that the weakening of mind-body connections with age can influence emotional experiences. The internal surface of the body is referred to

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as interoception [8]. Interoceptive awareness is a relatively new concept which is defined as the interpretation of bodily sensations at the conscious level.

Understanding of internal bodily states and their representations and also being aware of these bodily sensations are related to emotional experiences and cognitive functions [9]. Interoception involves multiple components such as different markers at neurophysiological, neuroanatomical, hemodynamic, cognitive, and behavioral levels [10].

Executive functioning such as set shifting ability is an important concept in interoceptive awareness because those with good interoceptive ability can focus on all the internal bodily sensations, and this requires the constant shifting and manipulation of information between external and internal cues to interpret social situations. Thus, cognitive functioning is an important mechanism in interoceptive processing [11]. The loss of ability to detect internal states can make older people rely more on their environmental cues.

Thus, the clinical implication of interoceptive awareness is that understanding internal bodily states may help better understand emotional states. Thus, any disruption of internal states or the ability to understand these internal states may have an effect on emotional control [10]. Difficulties in anticipating interoceptive states and their changes can be linked to different disorders, especially mood and anxiety disorders [12].

Thus, to understand whether there is any underlying dysregulation of interoception which may be related to loneliness in the aging population is important. In addition, since perception of a social situation as well as internal bodily states requires cognitive functioning, understanding EFs in relation to interoception is an important area of research. In the present study, the objective was to compare EFs and interoceptive awareness between the elderly with perceived feelings of loneliness and control group. Additional objective was to understand whether EFs and interoceptive awareness can predict feelings of loneliness in older adults.

Methods

Study participants

This was a cross-sectional study conducted on older people within the age range of 60–75 years. The study included two groups of participants. Group I comprised 50 older adults with perceived feelings of loneliness, and Group II comprised 50 older adults without feelings of loneliness. To be included in the study, the participants were required to be aged 60–75 years with at least 10 years of education and residing in Kolkata. Those with neurological or psychological disorders, geriatric depression, cognitive impairment, and physical disability were excluded from the study. Furthermore, older adults who were currently working or institutionalized were also excluded from the study.

A pool of 187 individuals was drawn using purposive sampling method, and they were assessed using the screening tools. Those who met the inclusion criteria were included in

the study. Based on their scores on UCLA 3-Item Loneliness Scale, they were divided into Group I (with loneliness, $n = 50$) and Group II (without loneliness, $n = 50$) (Figure 1). The institutional ethics committee approved the study (Ref No. = DRC-AIBHAS/ETHICS/A95210919001, and date of approval = May 21, 2021), with the requirement to obtain written consent from all study participants.

Assessment instruments

UCLA 3-Item Loneliness Scale

The short version of the UCLA Loneliness Scale (3 items) was developed for large multilevel study of social isolation and health in the aging process [13]. This scale was used to screen the elderly with loneliness. The alpha coefficient of reliability is 0.72. The scale is a screening tool for loneliness which measures three aspects of loneliness: social connectedness, relational connectedness, and self-perceived isolation. Those who scored within 3–5 are grouped as “not lonely” and those who scored within 6–9 are grouped as “lonely.”

General Health Questionnaire–28

General Health Questionnaire (GHQ) is a screening test that can be self-administered. GHQ is aimed at assessing short-term changes in mental health. It was designed as a state measure [14]. Its sensitivity was found to be 0.80 and specificity 0.88. Scoring was done using GHQ method (0-0-1-1).

Mini-Mental State Examination

The Mini-Mental State Examination is administered to screen for cognitive impairment and to estimate the severity of cognitive impairment among the elderly. It includes various tests such as orientation, attention, memory, language, and visual-spatial skills. It was shown to have good test-retest reliability (0.80–0.95). A score of 24 or above (out of 30) indicates a normal cognition.

Geriatric Depression Scale-15

The short form of Geriatric Depression Scale (GDS) comprising 15 items (GDS-15) is administered to screen elderly with depression. The alpha coefficient of the 15-item Short Form was only 0.82, indicating moderate internal

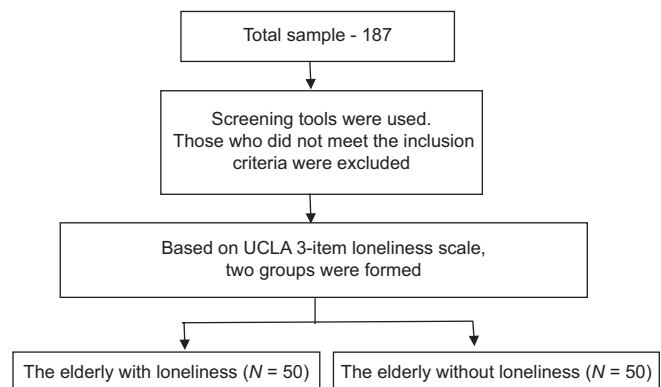


Figure 1. Study design in diagrammatic presentation.

consistency. Each answer is scored 1 based on the scoring norms. A total of 5 or more suggests depression.

Multidimensional assessment of interoceptive awareness

The scale is applicable to people above 18 years of age and is used to assess interoceptive awareness [15]. The Multidimensional Assessment of Interoceptive Awareness (MAIA)-2 consists of 37 items and 8 domains. The domains are noticing, not distracting, not worrying, attention regulation, emotional awareness, self-regulation, as well as body listening and trusting. Internal-consistency reliabilities of MAIA ranged from 0.66 to 0.82. It is a five-point scale. The total score is obtained for each domain, and then, their average is calculated to obtain the final score for each domain.

Stroop Test

The Stroop Test – National Institute of Mental Health and Neurosciences (NIMHANS, India) version is used to assess response inhibition and attentional control. The reading time subtracted from the naming time was used to get the Stroop effect score. The reading time was used to assess attentional control.

N-Back Test

The 1-back and 2-back versions of the verbal and visual N back test were used to assess working memory (WM). The test was taken from the NIMHANS Neuropsychological Battery for adults. The number of correct responses formed the score in each test. The higher the score, better the performance.

Wisconsin Card-sorting Test

Set shifting ability is tested using the Wisconsin Card-sorting Test. This test is to examine various facets of cognition such as concept formation and the ability to shift cognitive strategies in response to changing environments. The administration and scoring of the test were based on the NIMHANS Neuropsychological Battery for adults.

Statistical analysis

Continuous variables were evaluated in the form of mean and standard deviation (SD), and ordinal and nominal variables were evaluated in the form of frequencies with percentages. Student's *t*-test was used to compare both the groups in EFs and interoceptive awareness. Regression analysis was done to understand the significant predictors of loneliness.

Statistical analysis was carried out using the International Business Machine Statistical Package for the Social Science version 20 for Windows (IBM SPSS, Inc., Armonk, New York, USA). The differences between groups were considered significant if *p*-values were smaller than 0.05.

Results

Table 1 compares the sociodemographic variables of the groups with perceived feelings of loneliness (Group A) and without perceived feelings of loneliness (Group B). The mean age of the older adults with perceived feelings of loneliness was higher than that of the control group. The number of males

with perceived feelings of loneliness was higher than females. Furthermore, those staying alone and the number of widow/widower were higher in the group with feelings of loneliness compared to healthy controls (Table 1).

Table 2 shows the comparisons of the clinical variables of the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B). The clinical details of both groups were presented in mean \pm SD.

Table 3 compares the variables of executive functioning for the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B). As shown in executive functioning domains, significant differences were found in set shifting ability on the measures of total errors ($t = 5.709$, $p < 0.01$), perseverative response ($t = 6.735$, $p < 0.01$), nonperseverative errors ($t = 4.815$, $p < 0.01$), and conceptual responses ($t = 5.594$, $p < 0.01$) on

Table 1. Comparisons of the sociodemographic variables of the groups with perceived feelings of loneliness (Group A) and without perceived feelings of loneliness (Group B)

Variables	Group A, <i>n</i> (%)	Group B, <i>n</i> (%)
Age (years), mean \pm SD	66.30 \pm 4.13	64.14 \pm 4.08
Education (years), mean \pm SD	12.14 \pm 2.22	12.36 \pm 2.00
Gender		
Male	35 (70)	29 (58)
Female	15 (30)	21 (42)
Religion		
Hindu	49 (98)	47 (94)
Islam	1 (2)	1 (2)
Christian	0	2 (4)
Marital status		
Married	35 (70)	45 (90)
Widow/widower	16 (30)	5 (10)
Family type		
Joint	2 (4)	0
Nuclear	48 (96)	50 (100)
Staying with family or alone		
With family	43 (86)	47 (94)
Alone	7 (14)	3 (6)
Occupation		
Retired	39 (78)	35 (70)
Housewife	11 (22)	15 (30)
Socioeconomic status		
Upper middle	2 (4)	0
Middle	48 (96)	50 (100)
Physical illness		
Arthritis	7 (14)	5 (10)
Asthma	2 (4)	0
Cardiac problem	11 (22)	4 (8)
COPD	1 (2)	0
Diabetes	15 (30)	32 (64)
Hypertension	12 (24)	9 (18)
Stroke	2 (4)	0

COPD, chronic obstructive pulmonary disease; SD, standard deviation

Table 2. Comparisons of the clinical variables of the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B)

Clinical details	Mean \pm SD	
	Group A	Group B
UCLA 3-Item Loneliness Scale	7.50 \pm 1.18	3.93 \pm 0.76
General Health Questionnaire	0.78 \pm 0.67	0.15 \pm 0.97
Mini-Mental State Examination	25.17 \pm 0.70	26.23 \pm 0.50
Geriatric Depression Scale	3.49 \pm 0.50	2.88 \pm 0.88

SD, standard deviation

Table 3. Comparison of the variables of executive functioning for the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B)

Test measures	Group A	Group B	<i>t</i>
Working memory			
N back 1 verbal hits	7.86 \pm 1.86	8.46 \pm 0.90	-2.047*
N back 1 verbal error	1.22 \pm 1.83	0.60 \pm 1.01	2.095*
N back 2 verbal hits	5.40 \pm 1.79	6.60 \pm 1.20	4.119***
N back 2 verbal error	3.86 \pm 1.95	2.72 \pm 1.92	2.933**
N back 1 visual hits	7.66 \pm 2.51	8.66 \pm 1.39	-2.461*
N back 1 visual miss	0.82 \pm 1.81	0.34 \pm 1.39	1.483
N back 2 visual hits	2.62 \pm 1.66	3.90 \pm 1.01	4.642***
N back 2 visual miss	3.42 \pm 1.53	2.14 \pm 1.01	4.914***
Attentional control			
Stroop reading time	79.94 \pm 26.86	68.86 \pm 17.09	2.460*
Stroop color naming time	221.86 \pm 53.99	209.78 \pm 59.94	1.059
Response inhibition			
Stroop effect	136.16 \pm 54.26	138.92 \pm 54.27	-0.254
Set shifting			
Total correct	66.10 \pm 16.10	70.26 \pm 11.55	-1.484
Total error	42.28 \pm 29.14	16.06 \pm 14.31	5.709***
Perseverative response	13.41 \pm 10.94	28.45 \pm 11.38	-6.735***
Perseverative error	6.30 \pm 6.97	6.44 \pm 4.30	0.123
Nonperseverative error	29.35 \pm 22.48	11.37 \pm 13.83	4.815***
Conceptual response	54.64 \pm 26.33	79.02 \pm 16.00	5.594***
Failure to maintain set	0.76 \pm 1.53	0.58 \pm 1.07	0.681

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, using Student's *t*-test for group comparison

WCST. Total error (42.28 \pm 29.14 vs. 16.06 \pm 14.31) and nonperseverative errors (29.35 \pm 22.48 vs. 11.37 \pm 13.83) were significantly higher in the group with loneliness ($p < 0.001$). The conceptual level response and categories completed were significantly lower in the elderly with loneliness ($p < 0.001$). Furthermore, significant difference has been found in Stroop reading time ($t = 2.460$, $p < 0.05$) and on attentional control where group with loneliness scored higher than control group. Significant difference has also been found in WM for both verbal and visual WM on N back 1 and 2 ($p < 0.05$) except on

visual N back 1 misses. Group with loneliness has higher errors or misses on N Back Test compared to control group (Table 3).

Table 4 compares the domains of interoceptive awareness for the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B). Interoceptive awareness scale had eight subscales totally. Significant differences were found on four domains that is on not distracting ($t = 5.723$, $p < 0.001$), not worrying ($t = 2.028$, $p < 0.05$), body listening ($t = 2.302$, $p < 0.05$), and trusting ($t = 4.630$, $p < 0.001$). Group with loneliness was significantly scored higher on not distracting domain and significantly lower on the other three domains compared to control group. On the domain of noticing, loneliness group was scored higher than control group. But on domains of attention regulation, emotional awareness, and self-regulation, group with loneliness were scored lower than control group (Table 4).

Table 5 compares the possible neuropsychological predictors of loneliness using linear regression model. We found that the hits on visual N back 2 test which is a measure of visual WM (VWM) was a significant possible neuropsychological predictor of loneliness ($p < 0.05$) in the present study.

Discussion

In this present study, we compared the perceived feelings of loneliness of the elderly with those of with control group in assessed executive functioning and interoceptive awareness in an attempt to understand the possible neuropsychological predictor of loneliness in elderly people. Socioeconomic challenges such as high poverty, high dependency ratio, and unplanned urbanization increase the likelihood of loneliness among the Indian population. In addition, cultural factors such as marital status, family structure, and religious practices have an impact on loneliness [16]. But not all the elderly experience loneliness. Thus, the current study focused on understanding the possible underlying mechanism of loneliness in the elderly through taking into account of executive functioning and interoceptive awareness.

The study results showed that those with perceived feelings of loneliness scored significantly lower on measures of executive functioning (Table 3) and domains of interoceptive awareness (Table 4) compared to control group. As shown in Table 5, VWM was found to be a possible neuropsychological predictor of loneliness ($p < 0.05$). Thus, there was a significant difference between both the groups in terms of executive functioning and interoceptive awareness. Therefore, the current study results showed that the processing of information among those with loneliness was different from that of the control group, and they also have poorer interoceptive awareness.

In the present study, significant difference between both the groups were found in WM ($p < 0.05$) and set shifting ability ($p < 0.01$) domains of executive functioning (Table 3). EFs such as WM, focusing, shifting, problem solving and inhibition plays an important role in forming a successful social interaction which often requires active understanding of another person's beliefs, expectations, emotions, and also to focus, solve problems and inhibit inappropriate behaviors [17].

Those with perceived feelings of loneliness tend to focus only on those negative cues that indicate social rejection, and they develop a negative expectation about the way they are perceived by others [18]. Thus, loneliness can lead to a cycle of negative interactions where lonely people stick to their beliefs that social life is unrewarding and negative [18, 19]. Thus, it can be said that those with loneliness have difficulty in perceiving and shifting between different social situations and tends to focus only on the negative aspects of social situations.

WM is recruited in social interaction when people draw inferences about others' emotional reactions. During social interaction, a constant manipulation of information is important, and also, a constant shifting between one's own emotions and the other person's emotional cues, facial cues, and gestures is required [6]. In the current study (Table 5), those with loneliness were found significantly to have impaired WM ($p < 0.05$).

In the current study (Table 5), VWM was also found to be a significant possible neuropsychological predictor of loneliness ($p < 0.05$). In social interactions, faces and facial expressions and socio-affective stimuli are processed and maintained in VWM. Different socially relevant information is likely to interact with the facial memory representations [20]. Facial expressions can also provide information on other's affective states and on the environment [21]. People with loneliness tend to perceive angry faces more readily than happy faces [22]. Thus, they generally perceive more of social threats and negative emotions. Existing evidence has shown that impairments in WM and inhibition processes

reduce with normal aging and these factors are associated with self-monitoring and self-regulation of emotions, impulsivity control, and anticipation of behavioral consequences [23]. Thus, through this self-monitoring mechanism, WM contribute to the development of perceived loneliness [24]. Thus, deficit in VWM may lead to problems in social interaction and relations. In the present study, the scores on VWM were also found to be lower for the loneliness group compared to healthy controls.

In the present study (Table 4), those with loneliness scored significantly higher on not distracting (3.36 ± 1.17 vs. 2.05 ± 1.12 , $p < 0.001$) and significantly lower on not worrying (2.04 ± 1.02 vs. 2.43 ± 0.88 , $p < 0.05$) domains. Relating this finding with the enhanced emotional discernment hypothesis, it can be said that because they have poorer interoceptive awareness compared to healthy controls and they focus more on their negative sensations, they tend to experience more negative emotions which may increase their feelings of loneliness.

Because it is known that with aging the mind body connection weakens (maturational dualism) and this influences emotional experiences, they have to rely more on their external environment for information about internal states [25]. Thus, in the present study (Table 4), those with loneliness scored significantly less on body listening (1.99 ± 1.08 vs. 2.45 ± 0.90 , $p < 0.05$) and significantly less on trusting (3.77 ± 0.62 vs. 4.30 ± 0.50 , $p < 0.01$). However, from the social needs model of loneliness, it is also known that they focus on only negative cues that signal rejection and also have a negative expectation about the way they are perceived by others [26]. Thus, while taking information from external environment about internal bodily states, they are focusing on negative cues and thus perceiving negative bodily sensations, leading to more negative emotional experiences.

Thus, the overall findings on interoceptive awareness and executive function indicate that those with feelings of loneliness may have impaired ability to shift themselves away from negative social cues and they also have difficulty in manipulating information during social interactions, leading to increased feelings of loneliness. They may also include information from external environment to understand their internal states and use both these information for interpreting emotional experiences. Thus, the process and the link between these two variables in loneliness can be explained by a hypothetical model (Figure 2).

Further, from the neurobiological perspective, it has been proposed that insular cortex (IC) is the main cortical

Table 4. Comparisons of the domains of interoceptive awareness for the elderly with perceived feelings of loneliness (Group A) and the elderly without perceived feelings of loneliness (Group B)

Domains	Group A	Group B	<i>t</i>
Noticing	3.98 ± 0.73	3.94 ± 0.55	0.347
Not distracting	3.36 ± 1.17	2.05 ± 1.12	5.723***
Not worrying	2.04 ± 1.02	2.43 ± 0.88	-2.028*
Attention regulation	2.59 ± 1.08	2.99 ± 0.92	-1.973
Emotional awareness	3.36 ± 0.85	3.48 ± 0.64	-0.838
Self-regulation	2.65 ± 0.97	3.02 ± 0.92	1.924
Body listening	1.99 ± 1.08	2.45 ± 0.90	2.302*
Trusting	3.77 ± 0.62	4.30 ± 0.50	4.630**

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, using Student's *t*-test for group comparison

Table 5. Comparison of the possible neuropsychological predictors of loneliness

Model 1	Unstandardized coefficients		Standard coefficients	R^2	<i>t</i>	ANOVA
	<i>B</i>	SE	Beta			
Constant						
Visual working memory	6.740	0.303	0.281	0.079	2.030*	4.120*
N back 2 hits	0.198	0.098				

* $p < 0.05$, using regression analysis.

ANOVA, analysis of variance; SE, standard error

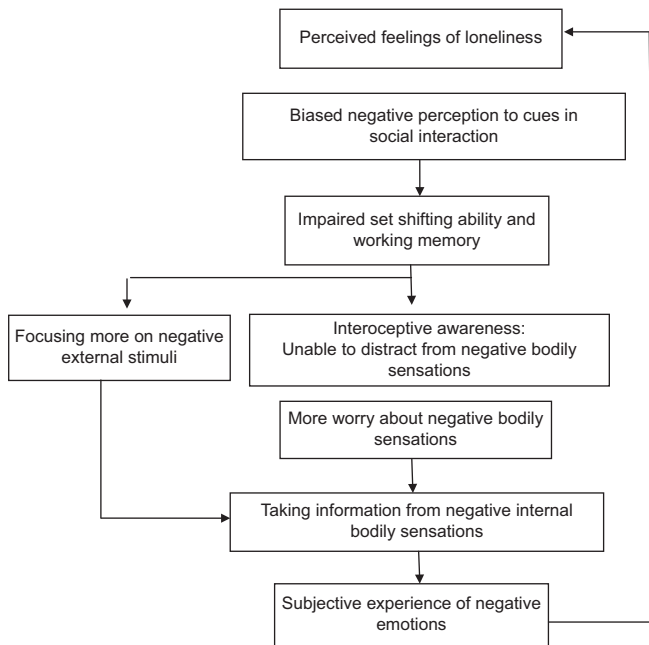


Figure 2. Diagrammatic demonstration of the connection between interoceptive awareness and executive functioning in perceived feelings of loneliness.

area responsible for interoceptive awareness. The ICs are bidirectionally connected to the cingulate, prefrontal, parietal, and medial temporal cortices and subcortically to basal ganglia [27]. The anterior IC is strongly connected with the anterior cingulate cortex which is involved in the functioning of cognitive flexibility. Cognitive flexibility also involves the dorsolateral prefrontal cortex (PFC), basal ganglia, and posterior parietal cortex [28]. In an fMRI study, it was found that there was an activation of visual cortex which is involved in the functioning of working memory in the lonely people when they were exposed to unpleasant pictures [29].

Thus, those with loneliness may be unable to manipulate information during social interaction which is a function of working memory (PFC and visual cortex) and may have difficulty in flexibly shifting between positive and negative cues of a social situation which is a function of cognitive flexibility.

Study limitations

Over-interpretation of the results must be avoided because this study has two major limitations:

- The sample for this study was drawn using purposive sampling technique and a cross-sectional study design was used. Therefore, the generalizability of the study results can be compromised.
- A better neuropsychological measure of response inhibition in context of social interactions could have yielded better results.

Summary

It is observed from the current study results that those with perceived feelings of loneliness have impaired set shifting

ability and WM which impairs their information processing and manipulation in social situations and this finding is strengthened by their lowered interoceptive awareness. Thus, the implication of the present study is that the current findings can help understand the possible neuropsychological mechanism, leading to loneliness which calls for effective intervention strategy for this subclinical group. Every individual experiences feelings of loneliness in their life. Some people are able to cope with it effectively, but some people cannot. The difference thus may lie in the underlying processing of information. Thus, the intervention strategy for feelings of loneliness in older adults may include both counseling and cognitive exercise to enhance their information processing ability in social situations.

Future studies should focus on using interoceptive awareness and its rôle in theory of mind in the elderly with perceived feelings of loneliness. Studies can also focus on understanding the neuropsychological correlates of the progression from loneliness to depression to mild cognitive impairment.

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Conflicts of Interest

The authors declare that there are no conflicts of interest in writing this paper.

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