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Association between vision and hearing impairment and successful aging over five years

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ABSTRACT

Objective: We aimed to prospectively examine the relationship between vision and hearing loss and successful aging in a cohort of older adults.
Study design: We analyzed 5-year data (1997-9 to 2002-4) from 1,085 adults aged 55+ years, who were free of cancer, coronary artery disease and stroke at baseline and who had complete data on sensory loss.
Main outcome measures: Visual impairment was defined as visual acuity <20/40 (better eye), and hearing impairment as average pure-tone air conduction threshold >25 dBHL (500-4000 Hz, better ear). Successful aging was defined as the absence of: disability, depressive symptoms, cognitive impairment, respiratory symptoms and chronic diseases (cancer, coronary artery disease and stroke) at 5-year follow-up.
Results: At 5-year follow-up, 243 (22.4%) participants had died and 248 (22.9%) had aged successfully. After multivariable adjustment, participants who had either best-corrected visual impairment or bilateral hearing impairment, versus those who did not have sensory impairment at baseline, had 37% reduced odds of successful aging after 5 years: OR 0.63 (95% CI 0.43-0.94). Concurrent vision and hearing loss at baseline was not associated with 5-year aging status. Participants with moderate and severe hearing handicap at baseline had 50% and 61% reduced odds of aging successfully after 5 years, respectively.
Conclusion: The presence of a single sensory impairment in older adults was associated with reduced odds of being disease-free and fully functional or having aged successfully, 5 years later. Objectively measured hearing loss and self-perceived hearing handicap, rather than vision loss, was more likely to negatively influence 5-year aging status.

1. Introduction

Concurrent vision and hearing impairment (termed dual sensory impairment, DSI) is strongly age-related; among population-based studies of samples aged ≥50 years which have applied objective measures of sensory function, the prevalence of DSI has been reported to affect between 4.6% – 9.7% of older people [1–3]. Vision loss has a negative impact on functional independence, mental health quality of life and cognition, and increases mortality risk [4–7]. Age-related hearing loss is more frequent and is associated with a greater risk of depression, impairs quality of life and the ability to conduct activities of daily living [8–10]. Furthermore, previous literature shows that the presence of more than one sensory impairment increases morbidity relative to single sensory impairments, including greater risk of comorbidities, activity limitations, hospitalization, and mortality as well as poorer self-rated health [4,11–14].

There has been considerable research on disability outcomes at older ages, but there is a dearth of cohort studies focussed on successful aging combining favourable functioning outcomes with optimal mental health and the absence of chronic disease and disability [15]. Rowe and Kahn first classified successful aging as absence of disease, good social engagement, lack of physical disability and good mental health [16]. Subsequently, it has been suggested that a multi-domain approach of successful aging rather than investigating risk factors for single health outcomes including, chronic diseases or disability could be more informative [15].

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To our best knowledge, there are no population-based studies that have prospectively assessed whether presence of single or dual sensory impairment (vision and hearing loss) independently predicts the likelihood of successful aging, as determined through a multi-domain approach. Therefore, in this cohort of adults aged 55 years and over we aimed to establish whether objectively measured vision and/or hearing loss is associated with a comprehensive definition of successful aging that included being: free of disability and chronic disease (coronary artery disease, stroke, diabetes, cancer), having good mental health and functional independence, and having good physical, respiratory and cognitive function, over a 5-year follow-up. Second, we examined the independent association between self-reported hearing-related measures (hearing handicap and hearing aid use) and aging status over the 5 years. We chose to explore this association as assistive technologies such as hearing aids can optimise auditory function, which in turn can improve the quality of life, mental wellbeing, social relations, and functional status of hearing impaired individuals [17–19], and the association between hearing aid use and aging successfully has not been investigated.

2. Methods

2.1. Study population

The Blue Mountains Eye Study (BMES) is a population-based cohort study of common eye diseases and other health outcomes in a suburban Australian population located west of Sydney. Baseline examinations of 3654 residents aged >49 years were conducted during 1992-4 (BMES-1, 82.4% participation rate). Surviving baseline participants were invited to attend examinations after 5- (1997-9, BMES-2), 10- (2002-4, BMES-3), and 15 years (2007-9, BMES-4) at which 2334 (75.1% of survivors), 1952 participants (75.6% of survivors) and 1149 (55.4% of survivors) were re-examined, respectively, with complete data. For the current study, we used data from BMES 2-3 (1997-9 to 2002-4) i.e. 5 years. This is because data on hearing loss was not collected at BMES-1 and we had incomplete data on some of the chronic diseases e.g. diabetes at BMES-4 and therefore, aging status could not be accurately determined. The University of Sydney and the Western Sydney Area Human Ethics Committees approved the study, and written, informed consent was obtained from all participants at each examination.

2.2. Assessment of sensory impairment

Pure-tone audiometry was performed by audiologists in sound-treated booths, using TDH-39 earphones and Madsen OB822 audiometers (Madsen Electronics, Denmark). Bilateral hearing impairment was determined as the pure-tone average of audiometric hearing thresholds at 500,1000, 2000, and 4000 Hz ($PTA_{0.5\text{-}4kHz}$) in the better ear, defining any hearing loss as $PTA_{0.5\text{-}4kHz}$ > 25 dB HL; mild hearing loss as $PTA_{0.5\text{-}4kHz}$ > 25-40 dB HL; and moderate to severe hearing loss as $PTA_{0.5\text{-}4kHz}$ >40 dB HL. An audiologist asked questions about history of any self-perceived hearing problem, and if a hearing aid had been provided. Specifically, participants were asked: ‘Do you or have you ever worn a hearing aid?’ (Yes/No/Don’t know). The Hearing Handicap Inventory for the Elderly - Shortened version (HHIE-S), developed by Ventry and Weinstein [20], was also administered. The HHIE-S includes 10 questions and a response of ‘yes’ is given 4 points; ‘sometimes’ is given 2 points, and ‘no’ is given 0 points. Scores ≥8 were taken to indicate the presence of self-reported hearing handicap.

Monocular distance visual acuity was measured using Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR (logarithm of the minimum angle of resolution) charts. Charts were retroilluminated with automatic calibration to 85 cd/m2 (Vectorvision CSV-100TM; Vectorvision Inc, Dayton, Ohio). Number of ETDRS letters read was determined using forced-choice procedures with habitual correction (presenting visual acuity, i.e. acuity with the patient’s usual distance spectacle or contact lens correction, if worn) and after subjective refraction (best-corrected visual acuity, i.e. protocol refraction to determine the patient’s subjective refraction and using that prescription in a trial lens frame to read the chart). For each eye, visual acuity was recorded as the number of ETDRS letters read correctly on the ETDRS LogMAR chart. For the present study, any visual impairment was defined as best corrected visual acuity of the better eye less than 39 ETDRS letters score.

2.3. Assessment of study outcomes (aging status and mortality)

The normal aging group in the context of this study included all participants who were alive at the end of the 5-year follow-up, but who were not classified as aging successfully (see definition below) [15]. Among surviving participants aged 60+ years, we used a definition similar to that used by *Sabia et al.* [15], which defined successful aging as satisfying all of the following criteria: 1) Absence of disease i.e. no history of cancer, coronary artery disease, stroke, angina, acute myocardial infarction, or diabetes; and good cognitive, physical, respiratory and cardiovascular functioning; 2) Good mental health i.e. absence of depressive symptoms; and 3) Lack of physical disability i.e. absence of disability in walking, able to perform activities of daily living, and did not receive formal and informal support. Specifically, participants were asked whether they had ever been diagnosed by a physician with cancer, angina, acute myocardial infarction, stroke or all coronary artery disease (all available information about coronary artery diseases) at each examination. Diabetes was defined either by history of diagnosis or from fasting blood glucose ≥7.0 mmol/L. Cardiovascular function was assessed using systolic and diastolic blood pressure (BP). BP was recorded from the right arm with a mercury sphygmomanometer using a cuff size appropriate for the participant’s arm circumference, after they had been comfortably seated for at least 10 min. Hypertension was defined as systolic blood pressure >140 mmHg or diastolic blood pressure >90 mmHg or on taking anti-hypertensive medications. Respiratory function was determined by either the trained examiner observing continual shortness of breath or coughing in the participant, or if the participant reported any heart or lung symptoms at the 10-year follow-up.

Disability in walking at baseline was based on the trained examiner’s observation of the participant having walking difficulties or used walking aids or a wheelchair. Additionally, at the 10-year follow-up (we did not have this measure at baseline) we also assessed perceived difficulties in basic and instrumental activities of daily living using the Older American Resources and Services (OARS) ADL scale [21]. Participants reporting that they needed help with any of the activities or were completely unable to perform any of the activities were considered to have a disability. Functional independence was determined from self-report after 10 years. Dependence on community support services was defined as self-reported regular use of meals on wheels, homecare or community nursing. Reliance on informal support was defined as receiving assistance from someone other than a spouse (family member/friend) for cleaning or shopping. In addition, participants’ ability to go out alone was also assessed. Participants who did not report dependence on formal and informal support and were able to go out alone were defined as having functional independence.

Cognitive decline was assessed using the mini mental state examination (MMSE) questionnaire and was only available at follow-up [22]. The MMSE has test components covering concentration, language and memory. MMSE scores range from 0 to 30; scores ≥24 were considered as being in good cognitive function. We assessed mental health using the Mental Health Index (MHI) component of the 36-Item Short-Form Survey (SF-36), which has previously been validated as a screening instrument to detect depressive symptoms among elderly persons [23,24]. A score of <59 on the MHI is indicative of having depressive symptoms [24]. Also, we administered the 10-item version of the Centre for Epidemiologic Studies Depression Scale (CES-D-10) at follow-up only. The CES-D-10 measures depressive feelings and behaviors experienced in the past week [25]. A cut-off score of ≥10 out of a total possible score of 30 was used to define participants with significant depressive symptoms [25]. Participants who did not have depressive symptoms according to the MHI or CESD-10 at follow-up were considered in good mental health.

To identify and confirm persons who died after BMES-2, demographic information including surname, first and second names, gender and date of birth of the participants were cross-matched with Australian National Death Index (NDI) data. The census cut-off point for deaths was end of December 2004 (i.e. a 5-year period from BMES-1 or the baseline examination).

2.4. Statistical Analysis

SAS 9.4 software (SAS Institute, Cary, NC, USA) was used for statistical analyses. Study factor was presence/ absence of sensory loss and three categories of study outcome were defined: successful aging (key study outcome), death during follow-up and normal aging (reference group). Baseline characteristics of study participants who were followed over 5 years were compared using χ^2-tests and general linear model. Multivariable logistic regression analyses for the outcome of aging status (successful aging, died and our reference group which was normal aging) used the generalized logit link and adjusted for: age, sex, marital status, living status and smoking. Participants self-reported history of smoking as never, past, or current smoking. Current smokers included those who had stopped smoking within the past year. Participants also reported who they lived with (alone or with e.g. partner, child, friend) and current marital status (married, widowed, divorced, or never married). In preliminary analysis, we had looked at whether other demographic variables such as education and occupation/ employment influenced aging status. We found that these factors were not significant covariates in the final multivariate model and did not independently influence aging status 5 years later. Therefore, these demographic factors were not adjusted for in multivariable analysis. When examining the association between baseline sensory loss and hearing-related measures with the 3 categories of outcomes (normal aging, successful aging and death) 5 years later, we used polytomous logistic regression with a generalized logit link.

3. Results

Of the 2334 participants aged 55 years and over examined at baseline (BMES-2), 773 were excluded as they had cancer, coronary artery disease and/ or stroke at the baseline examination. A further 476 were excluded as they did not have information on sensory loss and had insufficient information to characterize their aging status 5 years later (at BMES-3), leaving 1085 participants for longitudinal analyses. Of these 1085 participants, 243 (22.4%) had died, 594 (54.7%) aged normally (reference group); and 248 (22.9%) were successful agers, at 5-year follow-up. At baseline, those who aged successfully compared to non-participants (those who were excluded from further longitudinal analyses because they had cancer, coronary artery disease and stroke at baseline or who were excluded from analyses as they had incomplete sensory loss data or did not have sufficient information to characterise aging status) or those who aged normally or had died were more likely to be younger and married, and less likely to live alone, smoke and have sensory loss (Table 1). Persons who aged normally were less likely to be male compared to non-participants, and those who died or aged successfully.

Participants who had either best-corrected vision loss or uncorrected bilateral hearing loss (>25 dB HL) versus those who had no sensory loss at baseline, had 37% reduced odds of successful aging 5 years later in age-sex adjusted and multivariate adjusted analysis (Tables 2 and 3). No significant associations were observed between the presence of presenting visual impairment and/or uncorrected hearing impairment at baseline and 5-year aging status, after multivariable-adjustment (Tables 2 and 3).

After multivariable-adjustment, participants who had no best-corrected vision loss but had mild (>25-40 dB HL) hearing loss at baseline had 38% reduced odds of aging successfully 5 years later: OR 0.62 (95% CI 0.40-0.96). A marginally significant association ($p = 0.07$) was observed between moderate to severe hearing loss (>40 dB HL) at baseline and successful aging at 5-year follow-up: multivariable-adjusted OR 0.56 (95% CI 0.30-1.04). We further investigated other hearing-related measures and aging status (Table 4). Participants with

Table 2
Age-sex adjusted associations between objectively measured sensory impairment with aging status among Blue Mountains Eye Study participants from 1997-9 to 2002-4 (n = 1085)

Aging Status	Age-sex adjusted, odds ratio (95% confidence intervals)					
	Best corrected VI and/or bilateral HI			Presenting VI and/or bilateral HI		
	None (n = 631)	Single (n = 372)	Dual (n = 78)	None (n = 631)	Single (n = 372)	Dual (n = 78)
Normal aging (n = 243)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Successful aging (n = 248)	1.0 (ref)	**0.59 (0.41-0.85)**	0.81 (0.34-1.90)	1.0 (ref)	0.86 (0.61-1.20)	0.66 (0.34-1.27)
Died (n = 594)	1.0 (ref)	1.29 (0.89-1.87)	1.80 (0.97-3.35)	1.0 (ref)	1.34 (0.91-1.97)	**1.77 (1.07-2.93)**

HI - Hearing Impairment; VI – Visual Impairment. Bold values denote significant estimates ($p < 0.05$).

Table 1
Comparison of baseline characteristics of Blue Mountains Eye Study participants

Characteristics	Normal aging (n = 594)	Successful aging (n = 248)	Died (n = 243)	Excluded[a] (n = 773)	Missing data[b] (n = 476)	P-value[c]
Age, *yrs*	67.3 (7.7)	65.1 (6.4)	75.6 (9.1)	71.4 (8.2)	68.9 (9.1)	<0.0001
Male sex	223 (37.5)	107 (43.2)	119 (49.0)	365 (47.2)	177 (37.2)	0.0001
Married	376 (75.2)	178 (82.0)	133 (77.8)	481 (79.2)	265 (73.8)	0.10
Lives alone	146 (24.6)	51 (20.6)	79 (32.5)	213 (27.6)	166 (35.1)	<0.0001
Current smoking	57 (9.6)	10 (4.0)	33 (13.6)	63 (8.2)	44 (9.3)	0.01
Sensory Loss						
Any hearing loss (>25 dB HL)	199 (33.6)	55 (22.2)	144 (59.8)	298 (46.1)	82 (32.2)	<0.0001
Best-corrected vision loss	59 (9.9)	15 (6.1)	56 (23.1)	101 (15.5)	28 (11.1)	<0.0001
Hearing and vision loss	27 (4.6)	8 (3.2)	43 (17.8)	66 (10.2)	15 (6.0)	<0.0001

Data are presented as mean (SE) or n (%).
[a] Participants who were excluded from further longitudinal analyses because they had cancer, coronary artery disease and stroke at baseline.
[b] Participants who were excluded from analyses as they had incomplete sensory loss data or did not have sufficient information to characterise aging status 5 years later.
[c] Unadjusted p-values from test for heterogeneity across the five sub-groups.

Table 3
Multivariate-adjusted associations between objectively measured sensory impairment with aging status among Blue Mountains Eye Study participants from 1997-9 to 2002-4 (n = 1085)

Aging Status	Multivariable adjusted, [a] odds ratio (95% confidence intervals)					
	Best corrected VI and/or bilateral HI			Presenting VI and/or bilateral HI		
	None (n = 550)	Single (n = 382)	Dual (n = 147)	None (n = 550)	Single (n = 382)	Dual (n = 147)
Normal aging (n = 243)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Successful aging (n = 248)	1.0 (ref)	**0.63 (0.43-0.94)**	0.99 (0.41-2.39)	1.0 (ref)	0.85 (0.59-1.22)	0.75 (0.39-1.48)
Died (n = 594)	1.0 (ref)	1.18 (0.78-1.80)	0.78 (0.34-1.75)	1.0 (ref)	1.30 (0.84-1.99)	1.16 (0.63-2.12)

HI - Hearing Impairment; VI – Visual Impairment. Bold values denote significant estimates ($p < 0.05$).
[a] Further adjusted for marital status, living status, and smoking.

Table 4
Associations between hearing handicap inventory (HHIE-S) scores and hearing aid use with aging status among Blue Mountains Eye Study participants from 1997-9 to 2002-4 (n = 1085)

Hearing-related measures	Aging Status, OR (95% CI) [a]		
	Normal aging	Successful aging	Died
Severity of hearing handicap			
No handicap (HHIE < 8), n=986	1.0 (reference)	1.0 (reference)	1.0 (reference)
Moderate handicap (HHIE 8-24), n=541	1.0 (reference)	**0.50 (0.34-0.72)**	0.86 (0.63-1.17)
Severe handicap (HHIE ≥ 26), n=132	1.0 (reference)	**0.39 (0.18-0.83)**	0.82 (0.48-1.38)
Hearing aid use			
No, n = 1475	1.0 (reference)	1.0 (reference)	1.0 (reference)
Yes, n=249	1.0 (reference)	0.67 (0.37-1.21)	0.81 (0.55-1.20)

OR – odds ratio; CI – confidence interval. Bold values denote significant estimates ($p < 0.05$).
[a] Adjusted for age, sex, marital status, living status, and smoking.

self-reported moderate and severe hearing handicap at baseline, had 50% and 61% reduced odds of aging successfully 5 years later, respectively. Self-reported hearing aid use did not independently influence aging status at 5-year follow-up (Table 4).

4. Discussion

Sensory difficulties are frequently experienced by the older sub-population, however, they are often overlooked or dismissed as a normal part of aging. We provide novel epidemiological data showing that the presence of a single sensory loss, appears to influence an older adults' ability to reach old age disease-free and fully functional. Specifically, we show that older adults who had either best-corrected vision loss or any uncorrected bilateral hearing loss (>25 dB HL) versus those who had no sensory loss at baseline, had 37% reduced odds of successful aging 5 years later. Participants who did not have best-corrected vision loss but had mild (>25-40 dB HL) hearing loss at baseline had 38% reduced odds of aging successfully 5 years later. Increasing severity of self-perceived hearing handicap at baseline was associated reduced odds of aging successfully after 5 years. Concurrent vision and hearing loss, however, did not independently influence aging status.

Objectively measured uncorrected hearing loss rather than vision loss, was more likely to negatively influence the 5-year aging status of our study participants. This observation could be explained by the existing research evidence showing that the resulting communication problems associated with age-related hearing loss can lead to reduced quality of life, depressive symptoms, cognitive decline, functional disability and reduced life expectancy [8–10]. However, in our cohort we only observed a significant association with mild hearing loss and not moderate to severe hearing loss. Hearing thresholds do not necessarily reflect the degree of disability experienced by persons with hearing impairment, which could explain the lack of an association with successful aging. Alternatively, those with severe hearing impairment are more likely to use a hearing aid over a 5-year period as previously shown in the BMES [26], and this could have masked the temporal association between objectively measured hearing loss and aging status.

Self-perceived hearing handicap is likely to be the result of interactions between the magnitude of hearing loss and cognitive ability [27], which declines with age [28]. In our study, we observed a gradient effect from the severity of hearing handicap on aging status. It is unclear as to how the presence of self-perceived hearing handicap independently influences aging status. There is a possibility that chronic stress (e.g. self-perceptions of social isolation and an inactive social life directly due to a hearing loss), could be severe enough to stimulate autonomic, neuro-endocrine and immunological responses leading to chronic diseases [29], frailty, and/or adversely impacting on the interaction of multiple physiological systems needed to minimise the disablement process. Alternatively, people with self-perceived hearing handicap could be less effective at accessing and using healthcare services that might improve or protect their physical health [29,30] or prevent frailty, and this in turn could place them at increased risk of not reaching old age disease-free and fully functional. Finally, it could be that severe hearing handicap leads to decreased participation in everyday activities, and this in turn could accelerate the disablement process, and increase risk of cognitive decline and other chronic diseases. We caution, however, that ours could be a chance finding and that other longitudinal studies are needed to further assess the association between self-perceived hearing handicap and aging status in the longer-term.

In our cohort, we did not find that the presence of more than one sensory impairment increased morbidity relative to single sensory impairments. Specifically, we did not observe a potential interactive effect of vision and hearing loss on aging status, that is, the negative effects of vision loss were not multiplied by the effects from hearing loss and vice versa. The lack of a relationship between concurrent vision and hearing loss and successful aging is likely to be due to reduced statistical power, that is, a very small proportion (~1-4%) in the BMES had best-corrected visual impairment and either mild or severe hearing loss. Hence, there might have been inadequate study power to detect any modest associations with 5-year aging status. Moreover, given that significant associations were observed with the presence of either best corrected vision loss or uncorrected hearing loss, it is difficult to establish the specific contributions of vision or hearing to functioning and aging status.

Age-related hearing loss is often progressive and gradual in its onset in most people, the key clinical challenge is that it is often diagnosed and managed several years after onset and typically after having led to multiple negative impacts [31–33]. Brief questions such as "Do you feel you have a hearing loss?" could help to effectively identify hearing loss in older adults [30]. Although, it is unclear whether early correction of hearing loss can lead to appreciable improvements in the multi-dimensionally successful aging parameters. In our study, we did not find that hearing aid use at baseline influenced aging status 5 years later. Further large cohort studies with a longer follow-up are needed to establish whether early intervention strategies addressing hearing impairment and handicap, increases the likelihood of successful aging as determined through a multi-domain approach.

This study has several strengths, including its prospective design; representative cohort; a comprehensive definition of successful aging and use of objective, standardized audiometric and vision testing.

However, it is also important to discuss some of the study limitations. First, we cannot exclude the possibility of residual confounding from unaccounted factors which might have influenced the observed associations. Second, some of the aging parameters were self-report and not objectively measured (e.g. respiratory function), hence, it could be subject to potential measurement errors. Third, our definition of successful aging is not comprehensive as it did not include variables such as good social engagement, which are thought to be integral to successful aging [15]. Finally, several of the baseline characteristics (e.g. age, sex and smoking status) differed between participants and non-participants. Hence, we cannot disregard the possibility of selection bias influencing observed associations.

In summary, our study moves the research forward by providing novel empirical evidence of an independent and significant association between the presence of objectively measured uncorrected hearing loss and reduced odds of successful aging. Moreover, increasing severity of self-reported hearing handicap was associated with reduced likelihood of maintaining good functional status combined with the absence of chronic diseases and disability, over 5 years. These findings suggest that interventions specifically targeting hearing loss and hearing handicap in older adults, could help to promote successful aging and less illness and disablement in the longer-term.

Contributors

Bamini Gopinath conceived, designed and performed the experiments, analyzed and interpreted the data, and drafted the paper.

Gerald Liew analyzed and interpreted the data.

George Burlutsky analyzed and interpreted the data.

Catherine M McMahon analyzed and interpreted the data.

Paul Mitchell conceived, designed and performed the experiments, and analyzed and interpreted the data.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical approval

The study was approved by the Human Research Ethics Committee of the University of Sydney and was conducted adhering to the tenets of the Declaration of Helsinki. Signed informed consent was obtained from all participants at each examination.

Ethical statement

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Provenance and peer review

This article was not commissioned and was externally peer reviewed.

Research data (data sharing and collaboration)

There are no linked research data sets for this paper. Data will be made available on request.

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