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Trinity College Dublin
The University of Dublin
School of Medicine,
Department of Gerontology

The Influence of Perceptions of Ageing on Frailty and Cognitive Function

PhD Thesis

Submission Date: January 2015

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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

The material of this thesis forms part of the data analysis from a prospective longitudinal study entitled "The Irish Longitudinal Study on Ageing" (TILDA). I certify that I conducted the work contained within this thesis including formulation of hypotheses, data analysis, interpretation and writing. The design and governance of the TILDA study is under the direction of Professor Rose Anne Kenny. Professor Rose Anne Kenny, Dr. George Savva and Dr. Bellinda King-Kallimanis provided guidance and direction for this thesis.

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Summary

The aim of this thesis is to investigate whether perceptions of ageing influence cognition and frailty in later life. Although much experimental work has shown that priming older adults with negative stereotypes about ageing causes immediate declines in cognitive and physical function, there is a paucity of research in this area in large-scale observational studies. Even fewer studies have had the capacity to assess the relationships longitudinally. This thesis thus uses data from waves one and two of the Irish Longitudinal Study on Ageing (TILDA) to investigate the relationship between perceptions of ageing, cognitive function and physical frailty in a population-representative sample of community-dwelling older adults.

A literature review on perceptions of ageing and health revealed some gaps in the literature, including limited knowledge about the role of negative perceptions of ageing on cognitive and physical health longitudinally. In addition, most studies have explored health outcomes and their relationship to perceptions of ageing in isolation from each other. If perceptions of ageing affect one aspect of health, they are likely to also impact upon other, related areas of health in later life. Two such related factors are frailty and cognition. Older adults who are frail have poorer cognitive function than their robust peers but it is not yet known why this is the case. A literature review in this thesis (Background 2) suggests that perceptions of ageing may play a role in the development of both frailty and cognitive decline. If this is the case, it may also mean that interventions to target them could focus on psychological solutions. In the absence of successful pharmacological treatments, and considering the already burdensome levels of polypharmacy in the older population, psychological or behavioural interventions could potentially prevent or delay some level of physical or cognitive decline [1]. All this depends, however, on whether there is any evidence to support the hypothesis that perceptions of ageing influence either cognitive decline, physical frailty, or both.

Paper 1 explores the association between frailty and cognitive function in the TILDA sample. Although the relationship to global cognitive function has been found in other studies, there has been little examination of individual cognitive domains. As TILDA has a large battery of cognitive tests, encompassing different domains of cognitive function, this paper was able to assess the relationship

between pre-frailty, frailty and six cognitive domains (global cognition, memory, attention, executive function, processing speed and self-rated memory). Pre-frailty and frailty were associated with poorer cognitive function in the domains of global cognition, memory, attention, executive function and processing speed.

Paper 2 explores the relationship between perceptions of ageing and walking speed - a key component of frailty. The measure used to assess perceptions - the Aging Perceptions Questionnaire (APQ) - allows for the analysis of five individual domains of perceptions of ageing – timeline (how much participants think about ageing), emotional representations (how depressed participants feel about ageing), positive control (how much in control participants feel over changes as they age), negative control and consequences (whether participants expect negative consequences with age) and positive consequences (whether participants expect positive consequences with age). Older adults who had negative perceptions of ageing – specifically in the negative control and consequences domain - at wave 1 had slower walking speed at wave 2 after controlling for baseline walking speed, baseline health and health changes over the same period.

Paper 3 assesses whether perceptions of ageing also influence cognitive function longitudinally. APQ at baseline was compared to all domains of cognitive function which had been measured at both wave 1 and wave 2 – immediate memory, delayed memory, executive function, prospective memory and self-rated decline in memory – at follow up. Participants with negative perceptions of ageing at wave 1 had poorer executive function and prospective memory at wave 2 after controlling for baseline cognition, baseline health and health changes in the same period. The same participants were more likely to report a decline in memory but there was no relationship to objective verbal memory.

Paper 4 returns to the original hypothesis, that perceptions of ageing may be one mechanism that explains the association between frailty and cognition. A hypothetical model outlined in the introductory chapter suggests that older adults who have negative perceptions of ageing may be more likely to attribute all mental or physical changes as being due to inevitable consequences of age and treat them as signs of decline. This attitude may lead them to feel that there is more effort involved in tasks which used to be easier – exercise, cognitively

demanding activities and social interaction involving new learning – causing a gradual decline in these activities. They may also be less likely to compensate for mistakes and to use coping strategies in the face of actual health changes, therefore putting themselves at risk of real cognitive and physical decline. Older adults with negative perceptions of ageing would therefore be at risk of developing both frailty and cognitive impairment through this cycle. Older adults with positive perceptions of ageing may still develop frailty or cognitive impairment through other pathways, but may be less likely to develop both simultaneously. Paper 4 provides some support for this theory as the relationship between frailty and cognition is attenuated in those with positive perceptions of ageing but remains strong in those with negative perceptions of ageing. A significant interaction effect suggests that perceptions of ageing may moderate the association between frailty and cognition.

The final paper, paper 5, assesses whether there is any relationship between perceptions of ageing and the types of social behaviours which protect older adults from physical and cognitive decline. Over 2 years, older adults with positive perceptions of ageing were more likely to remain involved in the community and cognitively stimulated, while adults with negative perceptions of ageing were less likely to remain engaged with social and active leisure pursuits.

In summary, this thesis suggests that negative perceptions of ageing are a risk factor for cognitive, physical and social decline in older adults. As perceptions of ageing are modifiable they may present a unique, targetable factor for novel interventions to limit the consequences, or delay the onset, of some elements of physical and cognitive decline in later life.

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Abbreviations

ACE-R= Addenbrookes Cognitive Examination – Revised

AD = Alzheimer's disease

ADL = Activities of Daily Living

APQ = Aging Perceptions Questionnaire

BMI = Body mass index

CAPI = Computer-assisted personal interview

CES-D = Centre for epidemiologic studies depression scale

CI = Confidence Interval

CIRS = Cumulative Illness Rating Scale

CRP = C-Reactive Protein

CRT = Choice Reaction Time Task

HADS-A = Hospital Anxiety and Depression Scale

HPA = Hypothalamic-Pituitary-Adrenal Axis

HR = Hazard Ratio

IADL = Instrumental Activities of Daily Living

IL-6 = Interleukin-6

IRR = Incident Risk Ratio

MCI = Mild cognitive impairment

MMSE =Mini-Mental State Examination

MOCA = The Montreal Cognitive Assessment

NA = Noradrenaline

OR = Odds Ratio

RCT = Randomised controlled trial

SART = Sustained Attention to Response Task

SCQ = Self-completion questionnaire

SD = Standard deviation

SE = Standard error

SIT = Social Identity Theory

SOC = Selection, Optimisation, Compensation Strategies

TILDA = The Irish Longitudinal Study on Ageing

TUG = Timed Up-and-Go Task

TNF = Tumor Necrosis Factor

TMT = Terror Management Theory

TIA = Transient Ischemia Attack

VaD = Vascular dementia

W1 = Wave 1

W2 = Wave 2

Background: Age Perceptions, Age Stereotypes and Their Impact upon Ageing Outcomes

"Age is just a number" is an oft-quoted adage to describe the variance in physical, cognitive and emotional outcomes as people age. Yet while individual self-perceptions of ageing may vary widely, societal perceptions of ageing are broadly consistent across historical, cultural and generational groupings and these connotations are, for the most part, negative. Some common age stereotypes include perceptions that older adults are weak, forgetful, helpless, rigid, stubborn and selfish, and there is widespread cross-cultural consensus about these and similar attributes [2-4]. These concepts of ageing are commonly understood "truths" about the ageing process and yet there is surprisingly little medical or psychological evidence to support them as being true to the actual experience of ageing [5]. How, so, do these come to be global representations of older adults? This review will attempt to answer this question by summarising the extant literature on ageing attitudes. We will explore this area by asking three main questions: Why are we ageist? What effects does ageism have on the health of older adults? How are these effects mediated?

1) Why are we ageist?

Societal Attitudes towards Ageing

Widespread knowledge of age stereotypes may be explained by their omnipresence in today's culture with, for example, 67% of age-specific birthday cards in retail outlets in the United States representing age in a negative manner, and 83 out of 84 age-related groups on Facebook devoted to promoting negative age stereotypes [6, 7]. Such is the cultural saturation of negative stereotypes that when children as young as 3 were asked to describe a drawing of an older man, they described him in terms of being "helpless, incapable of caring for himself and generally passive" and said that they would not like to become old themselves [8]. However, sensitive analyses in adults of all ages have revealed a more complex picture with young, middle aged and older adults expressing both positive and negative views of ageing. Hummert and colleagues asked 240 participants of all ages to assign traits to a typical elderly person and found a number of positive clusters were generated including those they defined

as: the golden ager, the perfect grandparent and the liberal matriarch or patriarch. There were also negative clusters including: John Wayne conservative, severely impaired, shrew/curmudgeon, despondent and recluse [9]. Boduroglu and colleagues, meanwhile, separated age traits into categories of valence and content and found cross-cultural agreement on the negative association of physical and mental traits in ageing but neutral, or in the case of Chinese adults, a slight positive bias towards social and emotional traits [10].

Thus many studies show broadly cross-cultural and cross-generational agreement about age-related traits. Nevertheless, one study noted that younger participants had a tendency to sort age-related traits into fewer descriptive groups than older adults [9]. They suggested that younger people have a more prescriptive view of typical ageing which develops into a more complex understanding with age. This hypothesis was explored by North and Fiske who suggested that there are both descriptive and prescriptive stereotypes about ageing. Descriptive stereotypes are beliefs held comparably across groups about what defines an older person. Prescriptive stereotypes, meanwhile, attempt to control or define how an older person *should* act. In a study of younger, middle aged and older adults North and Fiske asked participants to rate the warmth and competence of characters in vignettes, in which the character either adhered to or violated a prescriptive age-related behaviour (for example expressing preference for rap music over Frank Sinatra or opting to undergo an expensive medical procedure versus forgoing it). They found that young raters were strongly resentful of older adults who violated expected behaviours, while middle-aged and older raters were more forgiving [11]. This suggests that there is a difference in the way young, middle aged and older adults perceive ageing.

Young Adults

Although it may be explicable that as people get older themselves they have a more complex understanding of ageing, it does not explain why younger people display extreme negative and even emotional responses to older people. Previous work suggests that, not only are negative ageing stereotypes one of the most socially condoned forms of prejudice, but that young adults may be actively unwilling to inhibit them [12]. Part of the explanation for this behaviour may lie in social psychological research on Social Identity Theory (SIT) which, over the past half-century, has shown that human beings display a behavioural

and emotional bias for a group that they are part of even when that group has been formed at random and on the most superficial basis (e.g. Tajfel et al. [13]). There is, however, a large and obvious difference between age-related group membership and other categories: Age, unlike other primitive groups like sex and race, is not a stable entity. It is an inevitable fact that humans age and that young people will one day enter an older age-cohort themselves. We thus turn to two hypothetical explanations which may further the understanding of age-related in-group bias in younger adults.

Terror Management Theory

A recent review on ageism attempted to disentangle the reasoning behind ageism in younger adults. The authors proposed that Terror Management Theory (TMT) may provide one explanation. TMT suggests that humans create psychological anxiety buffers to protect both their worldview and self-esteem. Worldviews often include beliefs that allow people to maintain a sense of permanence, stability, immortality and meaning which protects them against anxieties related to death and dying [14]. These might include beliefs in an afterlife, in reincarnation and a belief that passing on one's genes allows one to live on through the next generation. It may also result in a mistaken sense of invincibility. In combination with this, high self-esteem allows individuals to comfort themselves that they are valuable and meaningful members of the world, rather than transient beings who will be forgotten when they pass away. TMT suggests that age-related cues cause mortality salience - it reminds people of the impermanence of life – and this creates a high level of anxiety. When younger people experience mortality salience they draw on their beliefs in invincibility and self-importance as psychological buffers to protect them from anxiety. The downstream effect of this, however, is that it often causes a wide psychological gap between younger and older adults, as younger adults tend to comfort themselves with the thoughts that they are very different from the older generation. This sense of otherness leads to an exaggerated preference for their in-group (other younger people), and a derogation of the out-group (older adults) which causes ageist attitudes [14].

Competition for Resources

An alternative theory proposes that there is a practical reasoning behind ageism such that inter-generational conflict is a result of competition for resources.

North and Fiske explored younger and older participants' reactions to vignettes of older people which described their behaviour in terms of 3 types of resources: succession, consumption and identity. Succession considered competition for employment, wealth and influence and included vignettes such as an older person who was wealthy but who would not share their money. Consumption concerned shared public resources such as the threats to American programmes like Medicare and Social Security due to the growing numbers of older adults in the population. Identity concerned creative resources and the desire to maintain generational boundaries to uphold the self-esteem of the younger generation. These included vignettes about older adults' opinions of modern music. Younger raters of these vignettes strongly resented what they saw as violations of age-related behaviours in older adults across all three categories [11]. For example, they expressed poor opinions of older adults who spent their money on themselves, who campaigned for programmes such as Social Security and who liked modern music. Older raters, however, were more forgiving of these 'digressions'. North and Fiske thus proposed that prescriptive stereotypes, or beliefs about how older adults *should* behave, along with perceived competition for resources, lie at the heart of ageism in younger adults.

Although North and Fiske described the effects of prescriptive stereotypes they did not make a distinction between prescriptive and proscriptive expectations. Prescriptive stereotypes are, as described, those which dictate how someone *should* behave. Proscriptive stereotypes, on the other hand, dictate how someone *should not* behave. Although these are opposites it is possible to conform to one and not the other. For example, in North and Fiske's study an older adult may dislike both Kanye West and Frank Sinatra's music. They would thus be conforming to a proscriptive stereotype (*should not* like modern music) but not to a prescriptive stereotype (*should* like Frank Sinatra). Younger raters disliked older adults who liked Kanye West because this did not conform to the stereotype. It is not clear, however, whether this stereotype is proscriptive or prescriptive and whether younger raters would have the same negative reaction to an older adult who disliked Frank Sinatra. Sociologists argue that social norms are either proscriptive or prescriptive in guiding behaviour. Prescriptive norms are based on positivity and reward (e.g. someone thanks you for holding the door open for them) while proscriptive norms are based on negativity and punishment (e.g. someone frowns at you for sneezing without covering your

mouth) [15, 16]. Additionally, prescriptive norms are more flexible - as behaviour is defined by degrees of conformity - while proscriptive norms describe inflexible behavioural rules based on duty [15, 16]. Someone who violates a proscriptive norm will therefore be treated as a greater deviant than someone who violates a prescriptive norm. If age-related stereotypes are proscriptive rather than prescriptive then this may explain the extremity of responses that North and Fiske observed – the stereotype states that older adults should *not* like Kanye West and therefore any deviation from this must be punished. If the stereotype was prescriptive we may have expected a smaller and less consistent result. Furthermore, North and Fiske found that younger raters' responses to middle aged adults who behaved in a manner contrary to stereotypes were also rated as less competent and warm by younger raters but the association was weaker than that for older adults and not consistent across all domains. It is possible that age-related stereotypes are prescriptive towards middle aged adults - who may be perceived as older but not necessarily old – and become increasingly proscriptive towards older adults. This would explain why there was some flexibility in the response towards middle aged adults who violated the stereotype but little to no flexibility for older adults.

Ageism and age-stereotypes in younger people may thus be explained either as a psychologically protective mechanism to reduce anxiety about mortality or as a practical competitiveness over limited global resources. These theories, however, do not explain why many older adults also display negative biases and behaviours towards their own age cohort.

Older Adults

Ageism in older adults was highlighted in a recent study which found that, even on implicit tests of attitudes, older adults showed a heightened preference for younger age groups over their own [17]. Furthermore, a 2005 survey of 1,656 participants aged 21-85 found that it was older adults who were most strongly opposed to programmes which would directly benefit older citizens and who were most supportive of youth targeted programmes instead [18]. The stronger their negative stereotypes about ageing, the stronger their opposition to increased funding of social security, meals on wheels or Medicare, even though these programmes could potentially benefit themselves [18]. Why would older adults seemingly favour the out-group over their own in-group?

As outlined above, Social Identity Theory illustrates that humans will develop an in-group bias for a group to which they are a part of. According to this theory, therefore, older adults should show preference for their own peers over the younger generation. However, an additional amendment to SIT proposes that in-group preference is moderated by the social status of each group [14]. In other words, when both groups are perceived to be equal then in-group/out-group biases will appear. When one group is perceived to have a lower social status than the other, however, members of that group will react in different ways. One strategy to deal with lower status can be to focus on positive aspects of the in-group so, in the case of ageing, older adults may focus on the positive aspects of being older such as having had more life experience. A second way of coping can be to consciously choose to view out-groups negatively, thus older adults may show a negative bias towards younger generations. The third method is to dis-identify with the in-group in order to maintain self-esteem, thus leading to the perception "other people my age are weak, forgetful, helpless, rigid, stubborn and selfish but I am different". This is known as "cutting off reflected failure" and it leads to members rejecting their in-group and developing out-group favouritism [19]. When older adults have held strong ageist beliefs throughout life, to the extent that not even their own experience of positive ageing can counteract these beliefs, they develop out-group rather than in-group favouritism [14]. Weiss and colleagues demonstrated this in a study which found that older adults were more likely to dissociate themselves from their age group when primed with negative stereotypes about ageing [20]. This dissociation is a protective mechanism as it prevents negative stereotypes about ageing from threatening self-esteem [21]. This is likely to explain results from Levy and Schlesinger's 2005 survey in which older adults showed favouritism for the younger generation and a negative bias against programmes to favour their own age cohort [18].

However, ageing attitudes and reactions to them are not homogenous. While some people dis-identify with their own age-cohort, others will maintain a strong group-identity. How, so, do these people reconcile the ageist beliefs that they held when they were younger, with their own experiences of their peers if they have not been negative? Becca Levy, who has written extensively on the topic of age stereotypes, proposes that the negative stereotypes do not change or disappear but rather they become internalised [22]. This means that older

adults begin to believe that negative stereotypes about ageing are true reflections of themselves as they age. Thus previously held negative stereotypes about *other* people become negative perceptions of oneself and one's future.

The Association between Age Stereotypes and Ageing Perceptions

The theory that negative stereotypes become internalised with age has been tested experimentally: Kotter-Gruhn and colleagues found that older adults primed with negative stereotypes about ageing showed poorer self-perceptions of ageing. As no effect was found in younger or middle-aged adults it suggests that, in line with Levy's theory, only when the age stereotypes are self-relevant do they affect self-perceptions [23]. Similarly, Kornadt et al found that stereotypes about ageing in older participants were predictive of how they rated both their current and future selves [24]. Stronger negative stereotypes appeared to taint both their current views of themselves and their expectations for the future. A third study which followed 3000 participants over 16 years found that there was a strong relationship between older subjective age (the age that the participants felt rather than their chronological age) and lower life satisfaction, but only in those whose attitudes towards ageing had been negative throughout life [25]. These findings tend to confirm Levy's theory by suggesting that holding negative stereotypes about ageing in early life may be predictive of holding negative self-perceptions of ageing in later life.

Two other studies, meanwhile, have found opposing results. Macia and colleagues conducted a survey of attitudes in Moroccan and French older adults in which they found that adults' perceptions of societal attitudes to ageing were not associated with their self-perceptions of ageing [26]. However, only 40% and 23% of French and Moroccan participants respectively perceived *any* negative societal attitudes towards ageing suggesting that this could have been a particularly positively-focussed sample. Pinquart and colleagues meanwhile primed one group with negative information about ageing and another group with neutral information and then assessed their perceptions of themselves [27]. They found that self-perceptions actually increased in positivity in the experimental group. However, they did not measure age-related self-perceptions but rather general self-perceptions with questions such as "Whatever I plan, I have difficulties in attaining the goal and most of the time I

do not achieve it". This may capture a more permanent, personality-focussed perception of the self rather than age-related perceptions and expectations. It also highlights the potential differences in responses to age stereotypes. It is possible that the people in Pinquart's sample were those who were more likely to dis-identify with their age group, as outlined in the study by Weiss and colleagues above. They may therefore have been boosting their own self-esteem by comparing themselves favourably against an age-cohort that they wanted to distance themselves from.

In sum, these results highlight tentative support for the hypothesis that negative stereotypes about ageing may become internalised as negative perceptions of ageing in later life. This indicates diversity in the ways through which older adults respond to ageist beliefs. Levy and colleagues thus outlined 5 stages through which it becomes increasingly likely that negative stereotypes will be internalised:

1) They are prevalent from a young age;
2) They are reinforced by society throughout childhood and adulthood;
3) They are acquired and applied unconsciously;
4) They are more salient in later life when they become self-relevant;
5) They are strengthened by their operation on psychological, behavioural and physiological factors in later life.

We have discussed the first two points in our study on ageism in younger and older adults. The final three apply to our second question which we will address in the next section: what effects does ageism have on the health of older adults?

2) The effects of ageism on older adults

Ageism is thought to be a relatively new concept in the history of humanity that developed with the advent of two major cultural changes: the invention of the printing press and the industrial revolution. In agrarian times the elders of any community were regarded as the bearers of knowledge, tradition and history. With the introduction of the printing press in the 1500's however, their role was surpassed by the convenience of the written word. Meanwhile, during the industrial revolution, employability was based on mobility and large swathes of the population moved closer to industrial centres. As older people were less mobile it increased the gap between generations and limited the perceived utility

of older people in society. These changes, it is suggested, heralded the modern concept of ageism [28]. An interesting study in 2006 suggested that these same changes are only happening now in South Korea, where rapid rates of socioeconomic change and urbanisation are creating generational chasms. They found that young Koreans were most anxious about ageing and were fearful of older adults to an even greater extent than their American peers [29]. This is in contrast with traditional views of Asian cultures in which respect for the knowledge and position of elders as cultural leaders was paramount.

Today, the mere number of anti-ageism campaigns globally highlights the problems associated with ageism. Older adults are likely to experience discrimination in healthcare, workplace, medical and social situations [30-33]. One study found that 77% of adults surveyed had experienced one or more incidents of ageism, including being ignored or not taken seriously, being patronised, and being told 'You're too old for that' [31]. The omnipresence of negative attitudes such as these, and the inequalities that result from them, illustrate the strong effects of ageism on society. Perhaps more worryingly, however, is the body of research which investigates, not the general societal effects of ageism on older adults, but the internal responses to ageism in older people who experience it. In other words how ageist beliefs affect the behavioural, psychological, and physiological experience of older adults.

A large number of experimental studies have tested the effects of priming older adults with negative stereotypes about ageing that are similar to those expressed in daily life. Perhaps unsurprisingly, studies have found that priming older adults with negative stereotypes about ageing results in people feeling older and losing confidence in their abilities to carry out tasks such as driving [23, 34]. There are, however, even more sinister results reported by Levy and colleagues, who found that older adults subliminally primed with negative stereotypes about ageing were less likely to choose life-prolonging medical interventions for potentially fatal illnesses when asked to respond to hypothetical medical situations. Negative stereotypes were therefore affecting older adults' will to live [35]. Furthermore, the effects of negative ageing stereotypes on older adults are not limited to psychological responses but also affect objectively measured health-outcomes. A large number of studies have found that adults primed with negative ageing stereotypes show immediate declines in objectively measured cognition, walking speed and even have

heightened cardiovascular reactivity in response to stress [2, 36-53]. Positive stereotypes about ageing, meanwhile, can boost older adults' performance on a number of these tasks [45-47, 54]. It is important to note that these detrimental effects were caused not only by explicitly primed stereotypes – with participants' awareness – but also by implicitly primed stereotypes where participants were unaware that they had been primed but were still affected.

Stereotypes, as far as they have been activated in these studies, are external threats exacerbated by a person's desire not to conform to the expected norm. However these do not necessarily incorporate the internalised self-perceptions of one's own ageing process which Levy hypothesised may be detrimental to health [22]. Three longitudinal studies have explored longer-term effects of stereotypes finding that adults who held negative stereotypes about ageing in mid-life had an increased risk of having a cardiovascular event, developing poorer hearing and having poorer memory [55-57]. However it is not clear through what mechanisms these effects work as there been few studies which have investigated the effects of self-perceptions about ageing on health. A number of studies have reported effects of self-perceptions of ageing on psychological or self-reported outcomes including activities of daily living (ADLs), number of illnesses, self-reported physical function, self-rated health, mood, life satisfaction and mortality [58-64]. Aside from mortality, however, these outcomes were subjective reports of function leading to the criticism that self-perceptions of ageing will inevitably lead to poorer subjective ratings of health. One study, however, has examined the effect of self-perceptions of ageing on an objective composite measure of physical function and found that poorer perceptions were associated with longitudinal decline in physical function, after statistically controlling for other health factors [65].

Although more research is required on the relationship between self-perceptions of ageing and objectively measured health outcomes, there does seem to be increasing evidence to suggest that there is an effect of external and internal ageism on health. What is currently little understood, however, is exactly how this psychological process impacts upon health. In the next section we discuss three categories of potential mediators in the relationship between negative stereotypes, negative self-perceptions and health: psychological, physiological and behavioural.

3) How Ageism May Affect Health

Psychological Factors

We will discuss psychological mediators in two sections. The first section will discuss the mechanisms which underpin the association between stereotype activation and behaviour. We will outline two key theories: associative behaviour and stereotype threat. The second section discusses the psychological mediators of the association between negative perceptions of ageing and health.

Associative Behaviour Underlying Stereotype Activation

Stereotypes are activated through implicit, largely unconscious, associative processes whereby concepts which have been frequently linked together acquire the power to activate one whenever the other is cued. A key researcher in this domain has been John Bargh, who famously found that implicitly priming undergraduate students with words associated with negative age stereotypes resulted in them walking more slowly than those who had been primed with positive words [2]. Bargh and colleagues proposed that priming implicit stereotypes causes an effect on stereotype-related activities, because the activation of the association between "elderly" and "slowness" in the mind increases the likelihood that the behaviour, "slowness", will be activated. A number of problems with the interpretation of this finding were later identified, although a study which accounted for these potential confounds by using automatic, rather than human, methods to measure walking speed, successfully replicated the original Bargh findings [52]. Even when the experimenter was blind to condition, and when walking speed was measured objectively, walking slowed after priming with age stereotypes, suggesting there is some real effect of associative cues on walking speed. Furthermore, another study with young participants showed that priming with negative age-related stereotypes resulted in declines in memory, albeit only in those students who had a relatively high frequency of contact with older people [39]. They suggested that the frequency of contact with older people increased the frequency with which the students, consciously or unconsciously, activated age-related associations and this caused their behaviour to be more easily affected by the experimental priming.

Nevertheless, it is clear from other failures to replicate the Bargh et al. findings, that the factors playing out in their study were much more complex than simple

associative priming of negative stereotypes. A high-profile attempted replication of the original Bargh study in 2012 failed to produce the same effects in a double blind condition where experimenters did not know the hypotheses of the study [66]. They did, however, find an effect of priming on walking speed when experimenters were aware of the study aims and when they measured walking speed subjectively. This suggested that it was the experimenter's, likely unconscious, desire to support the hypothesis which had caused them to perceive participants as walking slower. Strikingly and unexpectedly, however, the same study also found an effect when experimenters were aware of the study aims *and* when walking speed was measured objectively by sensors. Thus participants in the experimental prime condition really were walking more slowly but only when the experimenters knew which condition they were in [66]. This leads to intriguing questions about the social and behavioural cues which experimenters may have imparted to participants, consciously or unconsciously, and which caused this change in walking speed.

It is clear that the associative mechanisms associated with activating ageing stereotypes can have significant behavioural effects, for instance on speed of walking and memory, although there are important methodological safeguards which must be taken to demonstrate these effects. One additional limitation which is common to the Bargh, Doyen, Stanislavova and Dijksterhuis studies is that they were all conducted using samples of young undergraduate students and, furthermore, psychology students who may have had an awareness of the general aims of these types of experiments. Furthermore, while the associative behaviour theory may explain the association between age-related stereotypes and behaviours such as slow walking speed because of the 'slowness' prime, it cannot explain the association between, for example, age-related stereotypes and increased cardiovascular reactivity for which there is no associative prime. In addition, a number of studies conducted on both older and younger participants have found that younger adults are not as strongly affected by explicit age-related stereotypes as older adults. This suggests that the theory of associative behaviour alone cannot explain all of the variance in reaction to stereotypes and that there may be more complex, multifaceted mechanisms which explain the association between stereotype activation and behaviour.

Stereotype Threat and Anxiety as Mediators of Stereotype-Conforming Behaviour

In order to explore the association between ageism and health in later life, it is necessary to turn to studies which have included older adults as participants. As outlined above, a number of studies which have included both younger and older adults as participants have found strong effects of explicit negative age-related stereotypes in older adults but not in younger adults [41, 45, 53, 67]. One of the key hypotheses as to why this occurs is due to an important additional component: stereotype threat. Younger adults explicitly primed with specifically age-related stereotypes will not believe that the stereotype is relevant to them and thus may be able to consciously counteract the associative behaviour link that Bargh and colleagues outlined. Older adults primed with age-related stereotypes, however, have to contend with the additional burden of the self-relevancy of the stereotypes. This increases what is known as stereotype threat - the anxiety that one will conform to a negative stereotype. Stereotype threat was a term coined following a set of famous experiments in 1995 which explored the association between stereotypes about race – namely that African-American children were not as intellectually able as white children. Steele and Aronson found that, when participants were asked to list their race before completing a test of intelligence, African-Americans performed much worse than white Americans. There was no difference in test performance when their race was not made salient prior to testing [68]. This suggests that the anxiety associated with the stereotype, that African-Americans were not as intelligent as white Americans, caused the discrepancy in test scores rather than a true difference in underlying abilities. This theory of stereotype threat has since been applied to older adults in relation to tests of cognitive performance due to the stereotype that all older adults are forgetful. One of the most striking of these studies primed half of older participants with information about the inevitability of cognitive decline in ageing and half with information about the diversity of cognitive function in ageing. Although there was no difference in groups at baseline, and no obvious cognitive impairment prior to priming, they found that older adults in the negative group performed much more poorly than those in the neutral group. Such was the size of the effect that 70% of participants in the negative group performed at a level below that which would be defined as diagnostic of dementia on the Addenbrooke's Cognitive Examination – Revised

(ACE-R) test. Only 14% of those in the neutral group performed at this low level [40]. This effect has been replicated in a number of other studies and, in studies which tested younger participants as well as older, has been found to affect only older adults [41, 45, 53, 67]. This suggests that stereotype threat and resulting anxiety may explain the association between age-related stereotype and poor performance. When older adults are primed with the idea that memory decline is inevitable they become threatened, anxious and fearful and thus show real declines in memory performance. Younger adults, however, do not show the same strong effects because they do not expect their memory to decline in the near future.

Interestingly, when younger participants are primed with memory related stereotypes which are not age-specific, they also show stereotype threat effects on performance. Popham and colleagues found that when younger adults were primed with college course-related cognitive stereotypes (for example telling humanities students that engineering students are better at cognitive tests) the younger participants also showed declines in memory similar to those seen when older adults were primed with age-related stereotypes [51]. This suggests that anxiety may be mediating the relationship between stereotype activation and performance. Interestingly, participants with better emotion regulation abilities were not as badly affected by the primes, suggesting that they may have been able to counteract the anxiety caused by stereotype threat in order to perform to a higher standard. The manner in which cognition declined was also different in younger and older participants. While older participants showed decreased speed but increased accuracy on the tests, younger participants showed decreased accuracy and a decline in the availability of cognitive resources such as working memory. These findings have led to a debate on the different mechanisms by which stereotype threat-linked anxiety interferes with cognition. There are two key hypotheses: *executive control interference,* and *regulatory focus*.

Executive Control Interference

Executive control interference theory proposes that working memory capacity – heavily dependent on frontal lobe function – is depleted by the processing of the threat and anxiety aroused by the stereotypes. This means that these crucial cognitive resources are less available for other cognitive functions such as

memory, leading to impairment in performance [37, 49]. Mazerolle and colleagues found evidence for this in a study in which older participants in a stereotype threat condition had impaired performance on controlled memory performance but not on non-working-memory-dependent performance. Meanwhile, there were no differences in cognitive performance on any task between younger and older participants in a reduced-threat condition suggesting that anxiety-related stereotype threat was responsible for the decline in controlled cognitive performance in older adults [49]. Popham and Hess (2013), however, showed no effect of stereotype threat on working memory in older adults, a finding which is inconsistent with the executive control interference theory. This led Barber et al. to offer an alternative theory of how stereotype-threat-activated anxiety might interfere with cognition. They called this *regulatory focus theory* [37].

Regulatory Focus Theory

Regulatory focus theory proposes that, in cognitive tasks, people are focussed on either promotion (acquiring gains) or on prevention (avoiding losses) [37]. In conditions in which participants are threatened by a stereotype they will tend to focus on avoiding matching the stereotype rather than performing to the best of their ability. They will therefore focus on a prevention strategy over a promotion strategy. Typical cognitive tasks used in clinical and experimental settings tend to require promotion strategy, for example, asking participants to remember as many words as possible. A less typical prevention strategy, however, would be to ask people to forget as few words as possible. Consistent with this, Barber and colleagues found that older adults primed with negative stereotypes about ageing performed better in a cognitive task which required a prevention rather than a promotion strategy [37]. They divided their participants into two groups and asked one group to remember as many words as they could and the other group to forget as few words as possible. They found that in the normal, promotion type tasks, priming older adults with stereotypes resulted in poorer performance. When asked to complete the prevention task, however, older adults primed with negative stereotypes about ageing outperformed even those older adults who had not been primed with stereotypes but who were completing the promotion task. They suggested that this shows that true memory abilities are not affected by stereotypes but only the ability to complete a specific type of task. The regulatory focus theory may

also be what we saw in the Popham et al study where older adults primed with negative stereotypes about ageing became slower but more accurate in the task at hand. They may have been adopting a preventative strategy in which they sacrificed speed to prevent failing at the task. The younger adults, however, showed decreased accuracy *and* a decline in working memory ability suggesting that the executive control interference theory may be more relevant to reactions to stereotype threat in younger adults [51]. Two further studies partially support the theory that self-regulation can override the effects of stereotype threat. Hess et al and Stein et al found that older adults who were aware that they had been primed with ageing stereotypes did not show declines in performance on a subsequent memory test. Those who were unaware that they had been primed, however, did show a decline [53, 67]. This suggests that the aware group may have actively tried to regulate their anxiety in response to stereotype threat and subsequently succeeded in overriding it.

There thus appears to be some evidence that older adults use strategies in the face of stereotype threat in order to maximise their performance. The strategies can include different means of approaching the task (preventative versus promotion) or means of regulating emotion so as not to be overcome by anxiety. When the task does not correspond to the type of strategy used, older adults perform poorly. This finding may suggest that ageing attitudes do not present a real risk to cognition but merely an illusion of poor performance due to the way the tasks are designed. However, cognitive tasks in real life are mostly centred on a promotion rather than a prevention task. People have to remember all of the items they need when they go to the shop, they have to remember to go to appointments on the right day and they have to remember how to carry out complex tasks. Remembering *most* of the items on the shopping list, remembering to go to an appointment but not which day to go on or remembering one part of a complex task are not successful uses of memory in everyday life. If age stereotypes impair older adults' abilities to use their memory in promotion focussed tasks then they may have real and long lasting consequences on daily functioning.

Other Strategies in the Face of Stereotype Threat

In terms of everyday functioning, however, there are a number of strategies which are frequently used and effective tools to aid memory. One of these tools

is clustering. Clustering involves mentally categorising or 'clustering' words as they are encoded in order to aid retrieval. It is easier to remember a group of words, which are associated with each other, than a large number of solitary words. For example, when someone is trying to remember a shopping a list they may encode the dairy products simultaneously, followed by the fresh products, followed by the dry goods. When they arrive in the shop and need to remember all of the items on the list, they will be able to retrieve all of the dairy items at once instead of individually. Humans use this method of memory retrieval frequently and often unconsciously. Due to this realisation, Hess and colleagues tested the hypothesis that stereotype threat impedes the ability to use strategies [41]. They hypothesised that this would explain poor performance in cognitive tasks when older adults are primed with age-related stereotypes. They did not find that strategy use mediated the relationship between negative stereotypes and memory, but they did find that it mediated the relationship between priming with *positive* stereotypes and memory performance. Adults who were primed with positive stereotypes about ageing were more likely to use a clustering strategy in completing the memory task and were therefore performing better than their peers who had been primed with negative stereotypes or those who did not use clustering. What was different between those who had been primed with positive and those who had been primed with negative stereotypes? On examination of the wording used to prime stereotypes it becomes clear that a key element of stereotype threat may be its effects on feelings of control.

Control and Strategy Use in the Face of Stereotype Threat

Feeling in control of a situation or a task is an important predictor of mental well-being. Feelings of lack of control are strongly associated with adverse outcomes such as depression and ill-health [69, 70]. In the study by Hess and colleagues outlined above they primed negative stereotypes about ageing by asking participants to read a newspaper article including the statement: "...in order to maintain adequate levels of functioning, older adults may have to increasingly depend upon the help of memory tools as well as friends and family." In the positive groups, however, the statement read: "...these findings suggest that the degree of memory loss is to a certain extent under control of the environment and the individual." The positive group were therefore given a feeling of control over their memory before doing a memory task and this may

have led to increased motivation to use strategies to improve performance. Supporting this, a second experiment found that adults who normally felt in control over their memory had better performance in word list recall tasks than those who did not. This improved performance was partially mediated by their use of strategies to aid memory [71]. Furthermore, two additional studies found that priming older adults with negative stereotypes about ageing resulted simultaneously in lower control beliefs and poorer memory [72, 73].

In conclusion, stereotype threat provokes anxiety and poor performance on cognitive tasks in older adults. This, however, can be at least partially overcome by the use of cognitive and emotional regulation strategies. The use of these strategies may be determined by how in control participants feel. When participants are led to feel in control of their memories they are more likely to use strategies to overcome stereotype threat. Priming with negative stereotypes, however, can induce feelings of a lack of control over memory and a resulting decline in performance. I am not aware of any studies on stereotype threat and strategy use which have used outcomes other than cognition. It is possible, however, that strategy use may explain some of the effects of stereotype activation on physical activities as well. For example, falls are a common risk factor associated with increased age. Walking slowly is a strategy often used by older adults to avoid falls, particularly in those who have fallen previously and are afraid of falling again [74]. We discussed Popham et al.'s study in which the adults primed with negative stereotypes engaged a strategy in which they performed the task slower in order to minimise errors. It is possible that older adults primed with negative stereotypes about physical function in ageing may engage a strategy of walking slower to ensure that they don't fall. However the resulting anxiety and use of cognitive resources to concentrate on *not* falling may, paradoxically, lead to an increased likelihood of falls as both fear of falling and use of cognitive resources while walking are associated with falls [75, 76].

The two theories outlined thus far – associative behaviour and stereotype threat – explain how some behaviour is affected by the activation of age-related stereotypes and why some people are able to overcome it. There is, however, a growing body of evidence to suggest that the effects of stereotype activation are not universal but rather some people are more affected than others. The

next section will outline who is more likely to succumb to stereotype threat and why.

Self-Relevance, Identity and Self-Efficacy

Self-Relevance and Identity

Some stereotypes are more "self-relevant" than others. For instance, physical appearance factors such as hair greying might be personally distressing to one person but a sign of distinguishment to another. Similarly, someone who has always prided themselves on their memory ability may be fearful that their memory will decline as they age while another person, who has always felt that they have a poor memory, will not feel as worried about the effects of memory decline. A recent imaging study explored what happened in the brains of people confronted with self-relevant age-related stereotypes. Using functional magnetic resonance imaging (fMRI) the authors found greater activation of brain regions associated with self-reflection (precuneus) and autobiographical memory (parahippocampal gyrus) in older adults who reported that negative stereotypes were relevant to themselves compared to older adults who reported that positive stereotypes were relevant to themselves [77]. They suggested that participants who highlighted negative stereotypes as being personally relevant may have been drawing on a store of memories of times when they had conformed to the stereotype presented, thus explaining the enhanced parahippocampal activity [77]. It may also be that these memories caused self-reflective ruminations, or continued repetitive negative thoughts, which caused repeated activation of this autobiographical area.

In terms of the effects of this self-relevancy, Becca Levy proposed that the impact of negative stereotype activation on behaviour should be much greater when the stereotype is self-relevant or personally important [22]. This is particularly true of stereotypes related to ageing. We outlined earlier how some people identify with their own age cohort when they are older and some distance themselves from it as a protective mechanism against feeling 'old'. According to Levy's theory, only those who identify with their own age cohort should be strongly affected by the activation of negative age-related stereotypes. Indeed, this is what O'Brien and Hummert found in a study on memory performance under stereotype threat [50]. They told one group of middle aged adults that their memory would be compared to those aged 70 and over and another group

that their memory would be compared to those aged 25 and under. Although all participants in the latter group performed slightly worse than those in the former group, the effect was strongest in those who implicitly identified themselves as being 'old'. They called this 'implicit age identity' to refer to the process whereby individuals feel that they have made the transition from middle to older age. Although all of the participants were roughly the same age, some identified as being part of an old age cohort, and others as being part of a middle aged cohort. The effects of stereotype threat were much greater on those who identified as being part of an old age cohort because the stereotype was more self-relevant. This finding was replicated by Kang and colleagues who found that perceived age-related stereotype threat decreased cognitive performance but only in those who strongly identified with their age-group. Those who did not feel strongly identified with the older age group appeared to be able to buffer the effects of the experimental prime [44].

Identity is a key component of each person's psychological make-up. It is composed of a set of categories by which we and others defines ourselves starting with the most basic of age, sex and race, and moving through more complex definitions including, but not limited to, nationality, sexuality, profession, hobbies and personality traits, until each person has a unique set of categories by which they can be defined. For example, an 80 year old Caucasian man living in the United States may define himself as an American, a married man, a father, a grandfather, an easy-going personality, a carpenter and a baseball player. Each of these are components of his overall identity but which, to him, is the most important? Although he may identify as a being part of an older-age cohort he may not necessarily see this as a key component of his identity, but rather see his status as a carpenter and a married man as the categories which define him most accurately. The importance of identity in the face of stereotype threat was shown in work by Hess and colleagues who found that the greater the value older adults placed on their memory, the worse the effects of negative stereotype priming on memory were [41]. In a later study they found that those affected most strongly by negative stereotype priming were young-older participants (those aged 60 to 70) who had high levels of education and who were strongly aware of stigma or stereotypes associated with ageing [42]. They suggested that older adults with high levels of education are more likely to place a high value on their cognitive function as a key aspect

of their identity, and thus the ensuing clash between two parts of their identity - 'older age cohort' and 'excellent memory' – when age-related stereotypes are activated will cause heightened anxiety in the face of stereotype threat. On a positive note, however, Andreoletti et al found that providing positive information about cognition in ageing could be protective in this group. They found that providing older adults with counter-stereotype information negated the effects of stereotype priming in older adults with high levels of education, but not in those with low levels of education [36]. Those who place a high value on their cognitive function may be more willing to actively seek out and accept information which disconfirms the stereotype that all older adults have poor cognitive function.

Those who place a high value on their cognitive function also likely have high self-efficacy in terms of cognition – or a strong belief in their own cognitive abilities. The effects of higher education on stereotype threat may be due to self-efficacy beliefs such that higher education leads, not only to greater value being placed on one's cognitive abilities, but also to the belief that one's cognition is above average. Stereotype threat in this population may lead to poorer cognitive function by weakening this strong belief in ability. Indeed, Levy found that priming older adults with negative stereotypes about ageing decreased not only performance in a subsequent cognitive task, but also in participants' beliefs in their own memory abilities [45]. Another study explored this further, finding that providing positive feedback while participants were carrying out a cognitive task increased self-efficacy and performance simultaneously [78]. Crucially, the positive feedback also increased the amount of attention which participants' gave to the task [78]. This feeds back into our discussion of perceived control and strategy use as the positive feedback likely gave participants a renewed sense of control and motivation to perform well, which resulted in the use of strategies. Particularly interestingly, in relation to this, an imaging study in young participants found that the functional activation of the brain was different in those who had low versus high memory self-efficacy beliefs. Kalpouzos et al used fMRI to image participants' brains while they were encoding new information. They found that the low self-efficacy group activated more areas of the brain in general and had higher activation in areas associated with visuospatial episodic memory (hippocampus and medial parieto-occipital regions specifically). The high self-efficacy group, meanwhile, showed greater

activation in areas associated with cognitive control such as the dorsal anterior cingulate cortex [79]. They thus suggested that the two groups were using different methods to encode the information. The low self-efficacy group may have been using simple visualisation techniques, while the high self-efficacy group may have been using high level, effortful strategies. What is not clear is whether the low self-efficacy group were *unable* to use these higher level strategies or just did not use them and therefore performed more poorly.

Stereotypes thus appear to act more potently on cognitive ability when they are self-relevant and when they threaten self-esteem, important components of identity, and perceived abilities. We have thus far discussed mostly experimental studies which have examined the causes and consequences of stereotypes in laboratory settings. Yet all older adults must, at some stage in their real lives, experience an age-related stereotype which should cause a decline in performance. How so, do we explain those adults who maintain positive perceptions of ageing throughout life and appear unaffected by societal ageism? Furthermore, what role do negative or positive self-perceptions of ageing play in the face of real threats to abilities caused by uncontrollable factors such as illness as people age? In the next section we will focus on the factors which determine the causes and consequences of self-perceptions of ageing.

Self-Perceptions of Ageing and Health

One valid criticism of any hypothesis proposing that self-perceptions of ageing affect objective health outcomes is that people may have negative perceptions of ageing because they have already experienced an illness or an adverse health event that leads them to have realistically negative expectations for ageing. This was addressed in 2007 in a study which looked at change in self-perceptions of ageing and change in illness over time. Wurm and colleagues found that perceptions were a stronger predictor of illness longitudinally than illness was of negative perceptions of ageing longitudinally [63]. This finding has been supported by two other studies, albeit regarding stereotypes rather than self-perceptions, which found that positive age stereotypes were stable over 10 years and 7 months respectively, regardless of hospitalisations, bereavement and onset of acute myocardial infarctions [80, 81]. Yet how, in the face of such traumatic changes, do some adults remain positive about the future while

others, with no evidence of illness, remain strictly negative? This is known as the paradox of well-being and is thought to depend on two key factors: personal control and identity.

The Paradox of Well Being

Identity Process Theory

Identity process theory proposes that people's identity is challenged by different events over time including illness and major life changes. For instance, imagine a woman who used to enjoy long distance running is diagnosed with a debilitating cancer and is no longer able to continue running. This is psychologically challenging because she previously described herself as 'a runner' and she felt that this was a key part of her identity. Identity Process Theory suggests that the responses to these changes come under three categories: assimilation - in which identity is stridently maintained in the face of changes; accommodation – in which people make exaggerated changes to their identity; and balance – in which a generally consistent view of identity is maintained while accommodation for changes is made [82]. The women who was diagnosed with cancer could therefore refuse to accept that she is no longer able to be physically active to the same level, continue to describe herself as 'a runner' and be constantly reminded of her inability to run (assimilation). Alternatively, she could halt all physical activity in her life and identify purely as 'a cancer sufferer' (accommodation); or, she could continue to do as much physical activity as she is still able to do while recognising the limitations her illness puts upon her (balance). People who experience physical changes due to ageing and who respond through accommodation – i.e. by making dramatic changes to their identity – are more likely to suffer from depression as a result of those changes [83].

There is some evidence to suggest that having positive perceptions of ageing may help people to respond to adverse change using a balanced approach. In an early study on this topic Wurm el al found that having positive views on ageing was associated with having higher life satisfaction and subjective health *even* when participants had suffered a setback due to a serious health event [64]. They later found that participants with negative perceptions of ageing were less likely to use adaptive strategies in the face of a serious health event and that this resulted in the poorer life satisfaction. Adaptive strategies included

changing goals, which were no longer possible due to illness, to more realistic and attainable objectives. Furthermore, a later study by the same authors found that the association between negative perceptions of ageing and decreased self-reported physical function was partially mediated by optimism [61]. Participants who were prepared for physical decline as they aged, but who remained optimistic about the future, did not show as strong a decline in physical function and in mood as those who displayed both pessimism and negative perceptions of ageing.

David Weiss and colleagues have conducted a number of studies on the influence of negative stereotypes about ageing on identity in older adults. As outlined earlier in this article, they found that older adults were more likely to dissociate from their age group in the face of age-related stereotype threat and that this protected self-esteem [20, 21]. Although dissociation is a protective mechanism in the short-term moment of stereotype threat, however, they suggest that continuous use of this strategy may also be detrimental as people are rejecting a component of their identity [20]. Furthermore, continuous dissociation from one's peers may prevent people from reaching important developmental stages in later life as they may be unwilling to act as their peers do and make preparations for potential future adverse events such as ill health, financial strain or disability [20]. This could also be related to adaptation as those older adults who continuously dissociate may also refuse to accept age-related changes such as decreased physical performance and, as a result, be unwilling or unable to use goal adaptation strategies to manage if adverse events do occur. Dissociation may thus cause older adults to act using an assimilation response to adverse events. Older adults who can recognise limitations but change their responses and overcome them, however, have a balanced response.

Being flexible in response to ageing changes is thus a key component in preventing the negative effects of age-related stereotypes and self-perception. Being flexible in response to changes, however, is contingent on whether one feels in control. The woman who was diagnosed with cancer may wish to remain physically active but may be physically unable to move while she is ill. If she has responded to her ill health through assimilation she will therefore feel that she has no control over what is happening to her and may lose hope. If she has had a balanced response to her health changes she may retain some feeling of

control over her health management even if she cannot remain as fit as she used to be. The theory of identity process is therefore strongly linked to the second component of the paradox of well-being theory and our final proposed psychological mediator: perceived control.

Perceived Control

Control is an important psychological factor that is predictive of well-being and health [70, 84]. There are two types of control: primary control and secondary control. Primary control beliefs are beliefs which are aimed at generating effects on the environment. For example, one person with primary control beliefs may feel that by working hard on a project in work they will inevitably get a promotion. Secondary control beliefs are those beliefs in shaping cognitive, emotional or motivation responses to events or the environment. Another person with secondary control beliefs, may therefore feel that, whether they succeed in getting a promotion in work or not, the experience of doing the project will have been worthwhile [82]. Generally primary control has an inverted-u shape with age such that beliefs in shaping one's environment is low in childhood, increases in middle life and declines in later adulthood. Secondary control, however, is thought to show a logarithmic association with age such that older adults continually improve in shaping their responses to events and the environment [82]. In relation to identity process theory adults who cannot control events or the environment, but who can control their responses to them, will be less negatively affected by adverse changes. Those who can neither control their responses to the environment nor change their responses or, alternatively, those who continually change their identity on the basis of environmental changes, will show more negative effects with increasing numbers of changes as they age. There is a large literature on how control beliefs affect health and cognitive function in older adults through mechanisms such as stress and anxiety [71, 85-87]. As negative attitudes towards ageing may be associated with beliefs that adverse outcomes in ageing are inevitable, and thus uncontrollable, control beliefs may provide one candidate mechanism to explain how age perceptions act upon health.

In support of this, control beliefs have been found to partially mediate the relationship between ageing stereotypes and cognition, ageing stereotypes and self-rated functional health and ageing perceptions and disability [59, 72, 88]

Are ageing perceptions, therefore, just control beliefs in another form? The evidence suggests that while control may be an important contributor to the effects of ageing perceptions, it does not explain the whole effect. The studies outlined above only found partial mediation effects of control. Wurm and colleagues explicitly tested the hypothesis that self-perceptions of ageing were control beliefs by another name. They found, however, that perceptions of ageing independently predicted declines in self-rated physical function after adjustment for control beliefs [63]. To add to this, a recent study found that older adults in receipt of care were more likely to have depressive symptoms and that this was mediated by declining self-perceptions of ageing. Loss of control when included in the same model, however, was not a predictor of depression [89]. Control may thus be an important contributor to the detrimental effects of negative self-perceptions of ageing but it does not fully explain the relationship.

We have thus far outlined 4 psychological factors which may elucidate the pathways through which stereotypes and self-perceptions of ageing act upon physical and psychological health: Continued activation of negative stereotypes about ageing may cause an automatic association with stereotype-related behaviours, making it more likely that the behaviour will be activated when the stereotype is. However, conflicting findings in experiments which have tested this theory suggest that automatic association alone is not enough to fully explain the relationship. Instead, a number of other studies have suggested that stereotypes and perceptions of ageing may act through anxiety caused by stereotype threat. Anxiety may take over working memory processes in those experiencing stereotype threat making it more likely that they will perform poorly and conform to the stereotype. An alternative view is that anxiety to perform well causes people under stereotype threat to focus on damage-limitation rather than optimum performance. There is therefore a mismatch between their aims and the aims of the tests they are asked to perform, which are usually focussed on attaining optimum performance. This mismatch causes them to perform poorly. However, not everyone who is faced with stereotype threat displays deficits in performance as a result. Thus self-relevance and importance of the stereotype for self-identity are key mediators in determining whether negative ageing attitudes affect people. Finally, stereotypes and negative perceptions of ageing threaten perceptions of control. People who hold

strong control beliefs have better health outcomes possibly due to the use of strategies to maintain function in the face of health threats. Control beliefs do not, however, explain all of the variance in the association between ageing attitudes and health outcomes.

These psychological factors alone are not enough to explain the association between ageing attitudes and health unless we also turn to the accompanying physiological factors which they, in turn, affect. We now consider three potential physiological elements which may explain why ageing attitudes predict health: cortisol, inflammation and cardiovascular factors.

Physiological Mediators

Cardiovascular Reactivity

In one of the earliest experimental studies on priming age stereotypes, Levy and colleagues found that adults primed with negative ageing stereotypes and then given mathematical and verbal challenges as a way of inducing stress, had increased blood pressure, heart rate and skin conductance responses. Particularly interestingly, however, the stereotypes were implicitly primed so participants were unaware that they had been exposed to negative stereotypes about ageing. Furthermore, they found that participants primed with positive stereotypes about ageing showed reduced responses to stress and improved cognitive scores [46, 48]. Thus negative stereotypes about ageing may reduce the ability to deal with stressful events resulting in increases in blood pressure and heart rate even without older adults' awareness. Repeated exposure to both negative stereotypes and challenge may cause multiple events of cardiovascular stress and all of the accompanying health risks. Cardiovascular stress including high blood pressure has frequently been found to increase risk of dementia and other health difficulties [90]. Indeed a review on psychosocial stress and cardiovascular disease proposed that repeated exposure to perceived stress alone may account for 40% of atherosclerosis in patients with no other known cause [91]. Previous work from the Whitehall study on socioeconomic status and cardiovascular reactivity found that low socioeconomic status is associated with delayed cardiovascular recovery following mental stress. Steptoe and colleagues suggest that low socioeconomic status may be a source of chronic strain leading to enhanced allostatic load and impaired cardiovascular recovery

which then leads to heightened risk of cardiovascular disease [92]. Negative perceptions of ageing and repeated exposure to negative stereotypes or challenge may represent another source of chronic strain in older adults and act on cardiovascular function through a similar pathway. Further support for the role of cardiovascular reactivity in this relationship is to be found in a study by Levy and colleagues who found that participants who held negative stereotypes about ageing when they were 49 years or younger were more likely to experience a cardiovascular event up to 38 years later [55].

It is not clear from the studies conducted to date whether negative stereotypes about ageing induce heightened cardiovascular responses independently or whether the response is fully mediated by stress. It is possible that it is not stress alone which affects cardiovascular reactivity but rather that older adults faced with negative stereotypes about ageing experience a decrease in their perceived abilities to carry out a challenging task and that this results in increased stress. As outlined earlier, Levy and colleagues found that negative stereotypes about ageing reduced older adults' perceived self-efficacy beliefs in their memory [45]. Interestingly, reduced self-efficacy in the face of a challenging task has also been found to be associated with increased cardiovascular reactivity. Sanz and colleagues grouped adults, in this case younger adults, into high or low self-efficacy and high or low incentive conditions. Self-efficacy was manipulated by giving participants positive or negative feedback on their performance and incentive was manipulated by telling people that an electric stimulus was to be applied if they were doing poorly which would either be imperceptible (low incentive) or slightly painful (high incentive). They found that participants in the low self-efficacy groups had a greater increase in heart rate, systolic pressure, skin temperature and pulse pressure and a lesser increase in diastolic pressure during task performance. This was moderated by incentive such that those in the high incentive group had much greater cardiovascular reactivity [93]. As I outlined in the previous section, the effects of stereotype primes are more potent when they threaten identity and perceived abilities. This may also be true of cardiovascular reactivity such that older adults who are exposed to negative stereotypes about ageing, and who have resulting declines in self-efficacy, will have impaired stress responses causing a surge in cardiovascular reactivity and, potentially, a greater risk for accompanying health deficits. Cardiovascular reactivity may thus be a

potent physiological mediator in the relationship between negative attitudes towards ageing and health outcomes.

Cortisol

If negative ageing attitudes influence health through stress and resulting physiological changes, then we would expect to find an accompanying increase in stress hormones such as cortisol. Cortisol is released as part of the hypothalamic-pituitary-adrenal (HPA) axis stress response. Although it is a necessary response to challenge in the environment, over-activity can have damaging consequences. Cortisol has been found to suppress the immune system and in large quantities is toxic to neurons in the hippocampal area of the brain [91, 94]. Higher levels of cortisol in older adults are also associated with muscle weakness and poor grip strength [95]. Surprisingly, however, there has been very little work examining the association between ageing attitudes and cortisol in the older population.

I found one study which explored the relationship between perceptions of ageing, depressive symptoms, cortisol and self-rated memory complaints. In a cross-sectional analysis they found that while negative perceptions of ageing were associated with increased depressive symptoms and memory complaints, there was no association between perceptions of ageing and cortisol [96]. This may suggest that the heightened cardiovascular reactivity discussed in the preceding section may not be due to stress but to other factors such as decreased self-efficacy. However, before we conclude this, we also have to consider that the Sindi et al negative findings may be due to methodological considerations. In this study only two measures of cortisol were taken (daytime and night-time) and these were analysed as separate outcomes rather than as a continuous measure of cortisol throughout the day - known as the diurnal cortisol response - which is a more common measure. If our hypothesis is that frequent exposure to negative age stereotypes causes frequent stress reactivity in older adults then it would be useful to examine diurnal cortisol rather than cortisol at one time point. Previous work indicates that chronic stress is in fact associated with lower levels of cortisol secretion or a 'flatter' curve when measured at multiple time points due to "burnout" of the stress response [97]. We would thus hypothesise that older adults repeatedly exposed to negative stereotypes about ageing and resulting stress may ultimately show flatter

diurnal cortisol levels. Although high levels of cortisol are damaging, particularly to cognitive function, so too are low levels of cortisol secretion. There is a 'goldilocks zone' of cortisol whereby too little and too much hamper cognitive performance equally, while just enough allows an improvement in cognitive performance [98].

Studies on cortisol reactivity in other groups experiencing social-related stress may provide some clues to cortisol in relation to ageing perceptions. A study on stress-reactivity in social situations found that when men felt that they had more social influence in a group of other men they had a decrease in cortisol secretions. There was, however, no similar effect with men in a group of women, or women in any group [99]. The study suggests that social influence for men is a salient factor of masculinity and thus losses of social influence in a group of other males results in a threat to their identity. We discussed earlier how stereotype threat appears to have a stronger effect when it threatens a key component of identity, such as cognitive performance in those with higher education. This may also be true for cortisol responses such that greater threat to identity leads to greater levels of cortisol secretion and poorer resulting outcomes. Furthermore, we also showed that threats to identity can be counteracted by adaptability in one's response. Another study found that African-American respondents who reported experiencing greater levels of prejudice in life - for example they agreed with statements such as: "people act as if they think you are not smart" - had steeper (healthier) diurnal cortisol slopes than white Americans reporting prejudice against themselves [100]. The authors suggested that African Americans who could recognise and report prejudice may have developed more adaptive strategies to cope than those who did not report it. Alternatively, previous research has shown that African Americans have much greater drops in self-esteem when they are convinced that negative attitudes towards them are not to do with race [101]. Therefore, it may be that those African Americans who experienced prejudice could blame negative attitudes on somebody else's attitudes to race and not as a reflection on their own abilities, thus allowing themselves to protect their self-esteem. This may be what we see in experimental studies showing that age stereotypes only affect older adults who strongly identify with their age group. When older adults who do not feel "old" are faced with negative stereotypes about ageing they may see this as somebody's attitude toward age but will not perceive the

negative attributions as being relevant to themselves. They will thus experience less spikes in cortisol and a healthier diurnal cortisol slope over time. Those who are constantly challenged and stressed by stereotypes, however, will have repeated exposure to stress hormones resulting, eventually, in the flatter diurnal cortisol slope associated with chronic stress and poorer cognitive function. The importance of adaptability was further shown in a study on cortisol and disability. Wrosch and colleagues found that high cortisol in older adults was associated with increased levels of disability but only in those adults who did not use adaptive health control strategies [102]. Those who adapted to health challenges by gaining perceived or actual control over their health may also have regulated their stress and limited the damage of over production of cortisol to their health.

Although there has been little work carried out on the association between cortisol and negative attitudes toward ageing we can form hypotheses on the basis of work on other groups. Continuous exposure to negative stereotypes about ageing may cause repeated spikes in cortisol secretion which lead to a dysfunctional HPA axis response characterised by dampened levels of normal cortisol secretion. As dysfunctional cortisol secretion is associated both with poorer cognitive and physical function, cortisol may be a plausible physiological mediator between attitudes towards ageing and health. Further studies in older adults will be needed to test this hypothesis.

Inflammation

Cardiovascular responses and cortisol secretions may thus be two of the physiological factors that mediate the relationship between ageing attitudes and objective health. The common companion of these two physiological responses is inflammation. Any injury to the body, be it external or internal, can initiate an inflammatory response. This starts through the release of pro-inflammatory cytokines, such as interleukin-6 (IL-6), which in turn sends acute phase proteins, such as C-reactive protein (CRP), to the site of the injury. Usually the inflammatory process is terminated once the problem has been resolved but when the process is activated too frequently the inflammatory state becomes chronic [103]. Chronic inflammation is associated with a range of health difficulties including, particularly in older people, muscle weakening and cognitive decline [103, 104]. It is also known that the inflammatory process can

be initiated not only by foreign pathogens entering the body but also by psychosocial factors such as stress and low mood. Corticosteroids, released through the HPA axis in response to stress, can have both suppressive and permissive effects on the inflammatory system [91]. In the early stages of a stress response they suppress the immune system but repeated stress resulting in chronic activation of the HPA axis results in the opposite effect whereby corticosteroids enhance the inflammatory response [91, 105]. This repeated activation of the stress and inflammatory systems results in chronic inflammation.

If cardiovascular and cortisol reactivity is increased in response to stereotype activation, then we might expect to see increased levels of inflammatory cytokines in older adults faced with negative attitudes to ageing as well. Surprisingly, however, we did not find any studies which investigated inflammatory responses to ageing attitudes. Nevertheless one recent study on another type of stereotype found that participants from low socio-economic (SES) backgrounds primed with stereotypes about intellectual ability and SES performed worse on a verbal skills test and showed heightened IL-6 in response to the challenge [106]. Further research needs to be conducted on this before generalising the results to the older population faced with age-related stereotype threats, but it may suggest that inflammation is one of the physiological mediators in the association between negative attitudes towards ageing and health.

In conclusion, there is some evidence to suggest that stereotype threat is associated with increased cardiovascular reactivity, increased cortisol secretion and the activation of inflammatory processes. These are all natural processes associated with healthy responses to changes in the environment. However, chronic activation of the processes are associated with a domino-like cascade of negative effects. Individually and together, these three factors are all implicated in poorer health outcomes. Cardiovascular disease is the leading cause of death in the world and high blood pressure is associated with a number of adverse outcomes including cognitive impairment and vascular dementia [107, 108]. Increased secretion of stress hormones are also damaging as overactive glucocorticoid receptors in the brain are neurotoxic to the memory-associated hippocampal areas and to muscle function [94, 95]. Chronic inflammation, meanwhile, is associated with a wide range of both physical and cognitive

problems, particularly in ageing [104]. If these are activated by the presence of negative ageing attitudes then this may explain the association with adverse health outcomes. However, as with the psychological response to stereotype threat, the physiological response is probably not universal and unidimensional. Physiological reactivity to ageing attitudes may depend on facets of one's identity, resilience, prior experience and levels of current psychological stress. That the physiological reactions appear to map onto the psychological predictors of reactions to ageing attitudes – for example, independent studies show that poor self-efficacy predicts a more potent response to stereotypes about ageing and poor self-efficacy also predicts heightened cardiovascular stress - gives us more confidence that these may be plausible mediators in the process. However further investigations are needed into the subtle and complex association between these psychological and physiological factors.

Behavioural Mediators

The final factor which we will consider as a mediator between ageing attitudes and health is behaviour. Behaviours such as physical activity, diet, social connectedness and health maintenance are important predictors of health throughout life. However, the association between any attitude and any resulting behaviour is complex and involves multiple factors. A recent meta-analysis on attitude-behaviour relations found that attitudes and behaviours have a relatively low correlation of 0.52 [109]. However, this is the general correlation and there are a number of important factors through which attitudes are more likely to predict behaviours:

1) attitudes correlate more strongly with behaviour when they are easy to recall and stable over time;
2) when participants have direct experience with the subject of the attitudes;
3) when they report their attitudes frequently and when they are held with confidence;
4) when the information that guided people into forming the attitude is still relevant or diagnostic at the time they perform the behaviour [109].

Although this meta-analysis included studies on all types of attitudes and situations we can take each of these components to predict whether ageing attitudes should predict future behaviours.

1) We know that in general attitudes to ageing are formed in early life and do not show significant changes in the face of adverse health events or bereavement [22, 80, 81]. They are thus easy for people to recall and stable over time.
2) We know that younger participants who have more direct experience with older people show greater effects of priming with age-related stereotypes [39]. Furthermore, we have seen that age-related stereotype threat is more potent for older adults when they have made an identity transition from middle to older age and thus have "direct experience" of ageing [50].
3) We suspect, with some supporting evidence, that participants who hold negative stereotypes earlier in life tend to have negative self-perceptions of ageing when they are older suggesting that they have frequently expressed, at least to themselves, negative attitudes towards ageing [22, 25, 62].
4) We do not know the exact combination of factors that cause one person to have negative attitudes towards ageing and another to have positive, but if someone identifies with their age-group, feels a lack of control over outcomes as they age, and is less flexible in adapting to changes then we could hypothesise that these elements will draw attention towards age-related cues and thus direct behaviour.

Based on these four necessary elements we can hypothesise that attitudes towards ageing are likely to influence behaviours. Indeed a number of studies have found that adults with more negative attitudes towards ageing are less likely to engage in health promoting activities such as exercising, eating a healthy diet and visiting health professionals [110-114]. Older adults with positive attitudes towards ageing, meanwhile, are more likely to engage in these activities. Interestingly, in a longitudinal study of older adults' walking habits, Wurm et al found that older adults with poor health walked the same amount as older adults with good health if they had positive views on ageing [114]. Over 6 years, adults with positive views on ageing not only maintained a regular walking pattern but even increased their levels of walking. This may suggest that positive ageing attitudes encourage behaviours which support health in later life. The increase in levels of walking in those with positive attitudes may suggest a strategy through which older adults compensated for age-related

losses by increasing their levels of physical activity to maintain function. Strategies and goal-setting abilities have previously been found to be important predictors of health in later life. In a later study, Wurm and colleagues found that older adults with positive attitudes towards ageing were more likely to engage in self-regulation strategies. They defined self-regulation strategies as the ability to set appropriate goals, optimise existing abilities to achieve these goals, and set alternate goals when age-related losses mean the original goal is no longer attainable. They found that older adults who experienced a major health event and who used these types of strategy had higher self-rated health and life satisfaction. However the use of these strategies was moderated by views on ageing. Older adults with negative perceptions of ageing were less likely to engage in these adaptive strategies and, as a result, had poor self-rated health and life satisfaction [115].

Engagement with adaptive strategies in the face of ill health may be partially associated with control beliefs. Stewart et al. found that adults with chronic disease who attributed their illness to "old age" over any other cause, including genetics and poor lifestyle factors, had worse self-reported symptoms over time and an increased risk of death. They were also much less likely to visit the doctor about their symptoms [116]. The authors suggested that this may be related to control beliefs: as ageing is inevitable they must also believe that their disease is inevitable. One would expect that if control was the only aspect predicting behaviour then the same effect would be seen for those older adults who attributed their illness to genetics as a similarly uncontrollable factor, however this was not the case. Furthermore, the study adjusted for health-related control beliefs and found that 'old age' attribution remained independently associated with all outcomes. This suggests that there is an additional factor at play which predicts behaviour and health in relation to views on ageing. It is possible that one such factor may be attentional or confirmatory bias. As humans, we like stability in our world view and, as a result of this and in order to lessen cognitive demands, we will seek out information which confirms a preferred attitude over information which disproves it. Those adults who hold strong and stable beliefs that they will only experience negative consequences associated with ageing will therefore feel justified and confirmed in this belief if they experience a challenge to their health. This is likely only to strengthen their negative attitudes towards ageing and, in line with Glasman and Albarracin's fourth point above, when their

perception that old age means ill health is 'confirmed' by their personal experience of ill health it will enhance the likelihood that they will engage in maladaptive behaviours [109]. In addition, we know that attitudes become stronger if the thoughts that precede them are seen to originate from the self rather than being culturally determined [117]. Thus confirmations of negative attitudes about ageing coming from the self may be more harmful than those which are assumed from other people's experiences of ageing. For example, an older adult who believes that cognitive decline is inevitable may have an attentional bias towards information that confirms their point of view. If they are tired one day and forget somebody's name this will confirm to them that they have started to lose their memory. Meanwhile, somebody with more positive attitudes towards ageing might dismiss the memory failure as a common occurrence in people of all ages. With a number of 'confirmations' such as this the person with negative perceptions of ageing may regard all memory problems as being due to age and they will be less likely to engage in helpful strategies to help them to remember names. This will result in further memory failures and may ultimately lead them to withdraw from situations which would require remembering people's names as they will feel that they are unable to cope. There will thus follow a cycle of decline whereby withdrawal from social engagement, a factor which is known to be protective against cognitive impairment, will increase their risk of true cognitive decline and further confirm their original opinion.

Interestingly, there is some evidence that ageing attitudes can be changed through attribution retraining and that this, in turn, can change behaviour. One study conducted an attribution retraining programme in tandem with a physical activity class. The attribution retraining included classes in which participants were told that becoming sedentary with age is not inevitable and that they should look for the real, controllable reasons as to why they were not physically active. Three weeks after the intervention participants were walking more and had improved expectations for ageing [118]. A more recent randomised controlled trial with similar aims found that older adults in a group which both challenged misconceptions about ageing, and taught people to recognise and change automatic negative thoughts about ageing, had much higher rates of physical activity at follow up in a physical activity intervention trial compared those who were in a physical activity without views-on-ageing group and an

active control group. Furthermore, change in attitude was associated with change in physical activity but not vice versa [119]. Although these studies show promising inroads into changing perceptions of ageing and, as a consequence, behaviour, it is not yet clear which aspects of the intervention were most successful. Both studies used a complex intervention in which participants were taught about general misconceptions of ageing at the same time as being trained to challenge their own thoughts and attributions about age-related changes. It would be interesting to know which of these components was a more powerful predictor of change.

Negative attitudes about ageing may thus affect health through ill-adaptive behaviours such as ignoring symptoms, refusing to go to the doctor and not maintaining health through exercise and diet. Although we have cited some evidence showing the association between ageing attitudes and behaviours, it is limited to a small number of studies. Most of these studies have measured a single scale of general health behaviours which makes it difficult to understand if attitudes to ageing predict specific components, such as purely physical activity, or whether they also predict other factors such as diet. Furthermore although we hypothesise that attitudes to ageing may result in decreased social activity there is currently no literature that we are aware of which has covered this. Two studies investigated whether negative ageing attitudes were associated with levels of social activity but this was encompassed within scales which also included questions on exercise, visiting health professionals and diet which makes it difficult to disentangle the separate components [110, 113]. Psychosocial factors such as feelings of connectedness, social engagement and purpose in life are now recognised as being important determinants of health in ageing and particularly in maintaining cognitive function [120, 121]. It will be important to determine which, if any, of these factors are affected by attitudes towards ageing if we are to further disentangle the negative effects of attitudes on health related behaviours and health outcomes.

Discussion

Negative attitudes towards ageing are a common facet of today's society. Ageism is responsible for discrimination in employment, medical and social situations. More worryingly, however, negative attitudes about ageing may affect both physical and psychological health. This review posed three questions

about ageism: Why are we ageist? What effects does ageism have on health? Why does ageism affect health? We have outlined a number of studies illustrating the psychological reasoning behind why both younger and older people can be prejudiced against older people. Broadly speaking, ageism is often used as a protective mechanism against psychological stress. We have also outlined a number of studies to address our second question. These studies have shown that experimentally priming adults with negative stereotypes about ageing results in declines in a number of areas including cognitive function, physical function, mood and confidence. Holding negative stereotypes about ageing early in life is predicted to lead to an internalisation of stereotypes when one is older and subsequent negative perceptions of one's own ageing. This review has also outlined a small number of longitudinal studies which suggest that the effect of negative ageing attitudes on outcomes is not just temporary but may have longitudinal detrimental effects on health as people age. However most of the research to date has been limited to assessing self-reported outcomes which may therefore be confounded by subjective perceptions of ageing. Finally, in response to our third question, we hypothesis that there are three main categories which mediate the relationship between ageism and health. These include the psychological, physiological and behavioural factors which interact with each other to increase the possibility of adverse ageing outcomes occurring.

There are a number of limitations to this area of research which require further study. One of the most obvious criticisms is that negative attitudes towards ageing may merely be a realistic assessment of one's own health status and expected declines in health. Although the longitudinal studies which we have outlined controlled for baseline health, they did not control for changes in health over the study period. Additionally, most of the longitudinal research in this area has assessed the effect of attitudes on self-reported health measures rather than objective measures. Self-reported health has been shown to be less strongly correlated with objective health and more strongly associated with psychological factors such as depression and life satisfaction [122]. As we know that ageing attitudes affect life satisfaction it may be possible that the longitudinal effects seen thus far are acting through a subjective pathway. Longitudinal studies exploring the relationship between perceptions of ageing

and objective outcomes such as physical and cognitive function are still lacking in this area.

Another further direction for research in this area is the effect of ageing attitudes on behaviour. Although there is a multitude of literature exploring how and why attitudes affect behaviours, there has been surprisingly little research, to my knowledge, exploring how negative perceptions about ageing may affect lifestyle factors. There is accumulating evidence that factors such as social engagement and cognitive stimulation play a crucial role in maintaining physical and cognitive health as one ages. For example, the association between Alzheimer's Disease pathology and cognitive function is negated when social network size is taken into account and social isolation is an independent predictor of mortality [120, 123]. Discovering what predicts sustained social engagement as people age may thus be crucial to developing interventions to maintain cognitive function. We have hypothesised that ageing perceptions may impact social and physical behaviours but there is limited evidence to support this theory in an ageing context.

There is also limited research looking at the interaction between perceptions of ageing and multiple health outcomes. For example, if perceptions of ageing interact through psychological, physiological and behavioural pathways then it is likely that older adults with negative perceptions of ageing will enter into a cycle of decline rather than just showing poor outcomes in one or other areas of health. Most of the research to date has explored the relationship between perceptions of ageing and health in isolated areas. Future research is needed to determine whether older adults who develop poor health in one area, partly due to perceptions of ageing, are also at greater risk of developing poor health in other areas.

In sum, the literature to date suggests that ageing perceptions have an independent effect on short-term outcomes and may also affect long-term health. Furthermore, these effects often operate without the conscious awareness of people, based on external environmental cues and internal thoughts. This has serious implications for how we attempt to address ageism in society today. Worryingly, it has been shown that caregivers in nursing homes speak in slower and shorter sentences to older adults regardless of their physical and cognitive function [124]. "Elderspeak", as this manner of talking is termed,

may not only be demoralising to residents but may actually affect their health outcomes. As this would increase not only the burden on the individual, but also on the carers, this is something that needs to be addressed when training caregivers. It is also vital that other clinical settings address this: We described the study which found that 70% of adults primed with negative stereotypes about cognition in ageing performed below a cut-off designed to diagnose dementia, compared with 14% of those in the positive group [40]. The "white coat" effect on blood pressure is now well recognised in medical circles and steps are taken to avoid it by repeating blood pressure measures. However no similar effect is recognised in relation to hospitals, GP surgeries or memory clinics which conduct cognitive assessments. The Haslam study primed their participants with stereotypes merely by telling them that they were at the older end of the spectrum of participants and by asking them to read a brief article describing the association between memory and ageing. This suggests that even signposting and information leaflets in the waiting rooms of clinics which assess memory could be inducing negative stereotypes and giving false cognitive results in testing. We would thus suggest that a "white coat" effect should be recognised, and steps taken to avoid it, in neuropsychological assessments.

Finally, many anti-ageism campaigns currently use materials depicting vulnerable older people to show how ageism affects this section of the population, and to persuade the younger population to question and change their attitudes. One example is a campaign which depicted older people's faces underneath the labels "useless, grumpy, past it and burden" while a younger smiling person was labelled merely with their name. Although campaigns such as this encourage the rest of the population to reconsider ageism, they may also be reinforcing negative stereotypes about ageing with such associations. The first studies into ageing attitudes and resulting behaviours illustrated that merely unconscious associations between "elderly" concepts and behaviours can elicit declines in physical function [2, 66]. We also know that attitudes predict behaviours when the attitudes are repeatedly reinforced [109]. Furthermore, many of the experimental studies we described primed implicit negative stereotypes about ageing merely using words associated with ageing such as those used by the anti-ageism campaign [2, 39, 46-48, 50, 53]. Anti-ageism campaigns may thus need to consider lessons from the ageing stereotypes

literature while developing campaigns in order to ensure that the campaigns benefit those they are intended to benefit and do not do further harm.

As the global population rapidly ages, it is becoming more necessary to develop interventions designed at sustaining health and quality of life. Ageing perceptions may be one targetable factor which, if modified, could improve both psychological, physiological and behavioural outcomes. It would likely prove difficult to change attitudes to ageing on a global scale, but it may be possible to help people develop coping mechanisms and adaptability to ageing changes to help them counteract negative age stereotypes. We have cited one study which improved people's attitudes through discussion about ageing attitudes and through challenging automatic negative thoughts [119]. By providing older adults with the tools to challenge both society's and their own negative attitudes towards ageing we may break the cycle of negative ageing attitudes which have perpetuated in society since the 1500s. If more research begins to attempt to change negative ageing attitudes in the younger and older populations we can hope to soon be able to answer a fourth and vital question: how best can we use attitudes towards ageing to improve health?

Ageing Perceptions, Frailty and Cognition

In light of the review on perceptions of ageing and health the aim of this thesis is to explore some of the unanswered questions it brought to light. It is known that priming older adults with negative attitudes towards ageing results in immediate declines in cognitive and physical function but it is not yet clear whether these negative perceptions have long-lasting consequences. I therefore chose to explore the association between perceptions of ageing and two health issues which can affect older adults: physical frailty and cognition. Frailty is a syndrome characterised by increasing weakness and an increased risk of disability, hospitalisation, institutionalisation and death [125]. Severe cognitive decline in later life can lead to dementia which is also associated with increasing dependency, disability and death [126]. There is currently no treatment available for either frailty or cognitive impairment yet delaying the onset of dementia by just one year would reduce the prevalence of cases by 800,000 in the United States alone [127].

The second reason behind examining frailty and cognition in relation to perceptions of ageing is that the two syndromes are often interlinked. Previous research has found that older adults who are frail are also more likely to develop cognitive impairment and that these two syndromes may illustrate a cycle of decline. As most of the literature on perceptions of ageing to date has dealt with isolated health outcomes, examining frailty and cognition will allow an assessment of the effect of perceptions of ageing on two individual health outcomes and on their relationship to each other.

The second introductory chapter of this thesis therefore consists of a literature review on frailty, cognition and the proposed causal mechanisms in the relationship between them. This review has already been published in Ageing Research Reviews [128].

Background: Frailty and Cognitive Impairment: A Review of the Evidence and Causal Mechanisms

Abstract

Incidence rates of cognitive impairment and dementia are rising with the ageing population. Meanwhile, the limited success of current treatments has led to a search for early markers of dementia which could predict future progression or improve quality of life for those already suffering from the disease. One focus has been on the correlation between physical and cognitive measures with an increasing interest in the association between frailty and cognitive decline. Frailty is an age-related syndrome described as the decreased ability of an organism to respond to stressors. A number of epidemiological studies have reported that frailty increases the risk of future cognitive decline, and that cognitive impairment increases the risk of frailty, suggesting that cognition and frailty interact within a cycle of decline associated with ageing. This paper reviews the evidence for an association between frailty and cognitive impairment and outlines some of the mechanisms that potentially underpin this relationship from brain neuropathology and hormonal dysregulation to cardiovascular risk and psychological factors.

Introduction

One of the greatest achievements of public health in the twentieth century has been the almost doubling of life expectancy in the Western world [129]. Yet this now ageing population brings new challenges as the prevalence of little-understood geriatric conditions increases. One of the biggest challenges facing modern healthcare is the economic and medical burden of caring for dependent older people limited by physical and mental impairments. Two of the most common, and yet least understood, of these are frailty and cognitive impairment.

Frailty is a reduction in the ability to respond to stressors and an increased vulnerability to adverse outcomes [130]. Although the trajectory of decline varies widely, it is most commonly characterised by a progression of physiological decline leading to dependency and disability [130, 131]. Frailty can be preceded by, but also occurs in the absence of, chronic disease [132]. The highest prevalence is found in the older population and advanced age is a major risk factor [130]. Frailty has significant implications for the ability to maintain independent, high quality living and carries an increased risk of hospital visits, disability, institutionalisation and death [125]. There is no consensus on how best to operationalise or define frailty but two types of definitions have emerged as the most commonly used constructs:

1) The Cumulative Burden Index as proposed by Rockwood et al. [133, 134]: frailty is defined as an accumulation of health conditions and deficits. The index of deficits is not limited to those included in the original model but can include any domains that fulfil the criteria laid out by Rockwood and colleagues.

2) The Biological Syndrome Model as proposed by Fried et al. [130]: a person is deemed to be frail if they present with three or more of: poor grip strength, slow walking speed, low levels of physical activity, exhaustion or unintentional weight loss.

A number of variations on these models of frailty have emerged over the past decade but the underlying constructs remain broadly similar. The Fried and Rockwood models are moderately correlated with each other and are associated with the same adverse outcomes [132].

Cognitive impairment is the decline of intellectual functions such as thinking, remembering, reasoning and planning. It is common among older people but the effects range from mild forms of forgetfulness to severe and debilitating dementia. Mild cognitive impairment (MCI) is a term used to define a state of cognitive decline that is not accompanied by any significant functional disability [135, 136]. It has a high rate of progression to all types of dementia in which severe cognitive impairment is accompanied by increasing physical decline, eventually leading to full physical dependency. The Medical Research Council Cognitive Function and Ageing Study, a 10 year population-based cohort study of individuals 65 and over in England and Wales, reported that dementia has a prevalence of around 10% in the population aged 65 and over, and a prevalence at death of one in three [137]. Up to one quarter of hospital beds in the UK are in use by people over 65 years old with dementia and the prevalence is around 50% among those in institutional care [138, 139]. Dementia has an enormous impact on the individual, their families, healthcare systems and wider society, with a direct cost of healthcare services associated with each person with dementia of $17,700 per year [140].

Many pathological processes contribute to cognitive impairment, leading to several possible avenues for dementia prevention. A significant fraction of dementia in the population is attributable to neuropathology such as the neuritic plaques and neurofibrillary tangles associated with Alzheimer's disease (19%) or cerebrovascular pathology (21%) but much remains unexplained [141, 142]. Age is consistently reported as the most important independent risk factor for cognitive impairment and dementia, and so it is likely that many of the age-associated processes that lead to frailty in older people are also responsible for brain ageing and consequent cognitive decline. The benefits of understanding the relationship between cognition and frailty are twofold: First, the frail are likely to be at high risk of cognitive impairment and vice versa. Second, understanding the link between frailty and cognition may lead to new interventions for the prevention and management of both conditions.

The place of cognitive impairment in a definition of frailty has been widely debated. Fried's model does not include cognitive function in its definition, while Rockwood's model allows poor cognition to be included as one of the possible deficits. Recent consensus papers have suggested that an operational definition of frailty should include components from the domains of nutrition, mobility,

physical activity, strength, endurance, balance, cognition, senses, mood, coping, social relations and social support, although researchers do not agree on diagnostic procedures to achieve this definition of frailty [143, 144]. A recent review of frailty measures found that the most commonly included components in an operational definition of frailty were physical function, gait speed and cognition, with cognition being included in 50% of the definitions [145]. On the other hand, statistical analyses on these proposed components of frailty suggest that, while physical activity, mobility, energy, strength and mood aggregate as one concept, cognition does not correlate strongly with this and therefore may not be part of the frailty syndrome [146, 147]. Furthermore, a recent study of Alzheimer's dementia (AD) patients found that 22% had no indications of frailty [148]. It seems most useful therefore to treat frailty and cognitive impairment as related but distinct concepts which frequently co-occur.

A 2011 review described several studies illustrating a link between frailty in dementia and 'pre-dementia' cognitive states, highlighting the scarcity of information at that time on the magnitude of the association and mechanisms underlying the link [149]. Interest in this field has rapidly developed over the course of two years. Many epidemiological studies from different countries have since explored this association and, of particularly relevance, many have disentangled the broad concepts of frailty and cognition into their specific components in order to better understand the relationship. Here, we update the 2011 review to include these new studies on the relationship between frailty and cognitive impairment, the possible mechanisms behind this association, and its significance with respect to the possibility of future interventions to interrupt the progression of either frailty or cognitive decline.

Methods

We searched PubMed for papers published before May 2013 – we did not specify a lower date limit - using combinations of the following keywords: frail, frailty, cognition, dementia and Alzheimer's disease. One thousand, three hundred and fourteen abstracts were reviewed for relevance including those already contained within the Panza et al. review. We did not apply strict inclusion or exclusion criteria but included all papers which examined cognition and an operationalised definition of frailty in the ageing population. We also included papers of interest from the reference lists of the selected articles. We excluded

papers based on frailty in specific patient populations, such as HIV and cancer sufferers, as well as any study which did not define their measurement of frailty.

Results

Evidence for the relationship between frailty and cognition

The relationship between cognitive impairment and frailty has been demonstrated both cross-sectionally and longitudinally by a number of epidemiological and clinical studies. These are described in tables 1 and 2.

Cross-sectional studies

Several cross-sectional studies have demonstrated higher rates of cognitive impairment in frail compared to pre-frail or robust older people. Data from the Three City Study suggests that 22% of frail participants had cognitive impairment (defined as being in the lowest quartile of both the Isaac's Set Test and the Mini Mental State Examination (MMSE)) compared to only 12% and 10% in the pre-frail and robust populations [150]. The relationship between global cognitive function and frailty has also been consistently demonstrated in cross-sectional studies which have used both Fried's biological model [150-154] and Rockwood's cumulative burden index [132, 155] (Table 1).

Frailty and dementia also co-occur. A study of 23,952 home care recipients found that 40% of participants classified in the frailest category, using Rockwood's frailty index, had a diagnosis of dementia compared to 11% of those in the least frail category [156]. This relationship remained consistent when other frailty definitions were used. In another study of 313 outpatients attending a geriatrics clinic in Italy, Bilotta et al. found that 33% of robust participants and 32% of pre-frail participants had a diagnosis of dementia compared to 45% of frail participants, although this difference was not statistically significant. [157]. Conversely, in another study using only 109 patients diagnosed with dementia, 50% were frail, 28% were pre-frail only and 22% had no indications of frailty [148].

Longitudinal studies

A number of longitudinal studies have suggested that higher levels of frailty predict cognitive decline [155, 158-160]; and incident dementia [161-166]. This relationship has been observed in samples both of community living older people [160, 161, 164, 165, 167] and among samples also including participants in long term care facilities [155, 159, 166]. The reciprocal relationship, that cognitive impairment indicates future frailty, has also been reported in three epidemiological studies based on samples of community dwelling older adults [168-170] (see tables 2 and3).

Some studies, however, have failed to find this relationship, or have only seen associations with frailty and specific dementia subtypes. The Three City Study found that the excess risk of incident dementia associated with baseline frailty was explained by adjusting for baseline social and health conditions [150]. In a later analysis of the Three City Study, an effect of frailty on incident vascular dementia but not with AD or other dementias was found [161]. Data from the Italian Longitudinal Ageing Study [165] and the population-based Adult Changes in Thought study [164] also suggest an association between frailty and incident non-AD dementia, but not with AD. In a study of 1306 French older adults admitted to emergency departments, frailty measured at admission was not associated with cognitive decline over the subsequent year irrespective of the frailty definition employed [171].

Existing cognitive impairment is linked to frailty and is a strong risk factor for further cognitive decline and dementia incidence, and so absent or inadequate control for baseline cognitive status may lead to spurious associations being observed. Several studies do find a residual effect of frailty on cognitive decline and incident dementia after adjusting for baseline cognition [155, 158, 159, 164-166], however two do not [150, 171]. Multiple regression including baseline cognition, multi-level models that account for the covariance between baseline cognition and baseline frailty, and models based on transitions from one cognitive state to another have all been used to account for the potentially confounding effects of baseline cognitive function, however controlling for cognition is known to be difficult due to within person variation in day-to-day testing and it is possible that observed effects may yet represent a residual confounding due to these measurement errors [172].

Cognitive function and indicators of frailty

Some indicators of frailty have been shown to better predict cognitive decline than others. Boyle et al. found that timed walk and grip strength were the significant predictors of subsequent diagnosis of Mild Cognitive Impairment (MCI) but unintentional weight loss and exhaustion were not [162]. Auyeung et al. showed that the frailty measures predicting cognitive decline varied by sex, such that after adjustment for age, years of education and baseline MMSE score only grip strength predicted lower MMSE scores in women while weight loss, grip strength and chair stands predicted lower MMSE scores in men [158]. Low gait speed was the only indicator of frailty significantly associated with incident vascular dementia among ACT study participants [164], although other indicators may have contributed. Strong links have been found between cognition and poor grip or muscle strength [154, 173-175], slow gait speed [154, 176-179], weight loss [180-182] and low levels of physical activity [183, 184]. These relationships fall outside the scope of the current review but have been reviewed by other authors (e.g. [185] [184] and [176])

Domains of cognition impaired in frailty

As well as considering the effect of frailty on dementia subtypes, a number of recent papers have also begun to explore the effect of frailty on specific cognitive domains, however only two of these have been large scale epidemiological studies. The Rush Memory and Aging Study found that frailty was significantly associated with global cognition and perceptual speed but not with episodic memory, semantic memory, working memory or visuospatial ability [162]. Frailty was, however, associated with a more rapid rate of decline in all domains. The Brazilian FIBRA study found that frail participants were more significantly impaired on the MMSE, orientation, commands, immediate memory, verbal fluency and the clock drawing test, but not on delayed memory [152, 154]. In a smaller sample of 83 community living older people, executive functions and processing speed were significantly associated with frailty while global cognition, episodic memory, working memory or verbal abstract reasoning were not [186]. Among 61 inpatients on a geriatric rehabilitation ward, higher scores on a cumulative burden of illness scale were associated, after adjustment for age and depression, with executive function, reasoning, dual-attentional processing, verbal fluency, and processing speed, but again not

with memory [187]. Poorer sustained attention has also been linked to frailty in community dwelling older people [188].

The pattern emerging from these studies suggests that gait speed or grip strength are the components of frailty most strongly associated with cognitive function while the executive function and attention domains of cognition are consistently related to frailty. Gait speed is particularly affected by impairment in executive functions (see also [179, 189, 190]) and this may be one explanation for the link between frailty and cognition. Patrick et al and Langlois et al. also suggested that their findings may be partly explained by cardiovascular factors as both frailty and executive function impairment have been associated with cardiovascular disease and risk factors [186, 187]. Memory does not appear to be strongly related to frailty [154, 187] however, in most of these studies frail participants did have poorer memory scores than robust participants that fell just short of the criteria for statistical significance [152, 154, 162, 186] (Table 4).

Mechanisms Behind the Link

Although there is now significant epidemiological evidence linking elements of frailty and cognitive decline, little work has directly explored mechanisms underlying this link. A number of papers outlined below have suggested mediators or possible pathways but there is a lack of experimental evidence to support these suggestions.

AD Pathology

It is possible that indicators of frailty are directly affected by neuropathology that also leads to cognitive impairment. Using brain autopsies from participants of the Rush Study, Buchman and colleagues compared level of frailty (as defined by a composite measure of grip strength, timed walk, body composition, and fatigue) approximately 6 months before death to levels of AD pathology (specifically neurofibrillary tangles and plaques), Lewy Bodies and cerebral infarcts at autopsy [191]. Only AD pathology was associated with increased level of frailty and this remained significant in persons with and without dementia. Consistent with this finding, the Religious Orders Study found that substantia nigra neurofibrillary tangles, but not cerebral infarcts, were linked to gait impairments regardless of whether or not the participants had a diagnosis of

dementia [192]. There is a discrepancy between these results and those from the neuropsychological studies outlined above, which suggest that frailty is more strongly linked to non-AD dementia and to non-amnestic cognitive domains. Indeed Panza et al. suggested that as the Religious Orders Study and Rush Memory and Ageing study did not directly assess motor brain regions, they may be underestimating the effects of cerebral infarcts in frailty, particularly as damage to the motor cortices in dementia has previously been associated with components of frailty [149]. A further study from the Religious Orders Study reported that participants with MCI who had a history of stroke were significantly impaired on gait speed compared to participants with no cognitive impairment while those with MCI but no history of stroke were not impaired on motor measures [193]. Low gait speed did, however, significantly increase the risk of developing AD after accounting for stroke. There is thus a small amount of research suggesting that different components of Fried's definition of frailty may be related to changes in the brain including AD pathology and cerebral infarcts. However we found only one study which included a full measure of frailty as opposed to individual components of Fried's definition. It is likely that some level of neurodegenerative brain pathology is common to both frailty and cognition but there is not yet enough evidence to suggest that this pathology is the aetiology of each rather than a common consequence of another underlying cause.

Hormones

Two recent reviews have also suggested that reduced testosterone and other androgen hormones may be involved in the development of frailty and cognitive decline [194, 195]. Testosterone is thought to have protective effects on cognition through its promotion of synaptic plasticity in the hippocampus and its regulation of the accumulation of amyloid beta protein [194]. Furthermore, age related depletion of testosterone is thought to be associated with declining muscle mass, an important factor in the development of frailty [195]. It is thus possible that reduced testosterone may be a mediator in this relationship or common underlying factor to both frailty and cognitive decline. Insulin is another proposed mediator in the relationship between frailty and cognition as insulin resistance (thought to be age-associated decline of insulin sensitivity) has been found to be associated both with increased risk of developing frailty, even after adjustment for confounders such as chronic illness, and also with poor cognitive

function [196]. Overproduction of cortisol is also associated both with decreased cognitive function and muscle mass [95, 98].

Nutrition

Nutrition may also play a role in the link between cognition and frailty due to both the biological and the behavioural effects of diet. Sarcopenia is thought to be strongly associated with development of frailty and cognitive impairment, perhaps due to oxidative stress [103, 197]. Adherence to a Mediterranean diet, high in antioxidants, has been linked to both lower frailty and better cognitive function [103, 198]. Findings from the EPIDOS cohort, however, found that poor cognitive function was not associated with any of 6 different definitions of sarcopenia but was independently associated with poor grip strength and slow walking speed suggesting an association caused by factors other than muscle weakness due to sarcopenia [199]. Nutrition may also be related to frailty through behavioural changes such as not remembering or being willing to eat or inability to plan a healthy diet. Wirth et al. found that female gender and cognitive impairment were risk factors for unintentional loss of fat mass and this, they suggested, was most likely due to behavioural factors such as forgetting to eat, being easily distracted at mealtimes, increasing apathy and inability to plan for and maintain a healthy diet [182].

Chronic Inflammation

Chronic inflammation has also been linked to both frailty and cognitive function [103, 149, 197, 200]. Metabolic changes, chronic illness, lifestyle factors, stress and other factors can initiate an inflammatory response. Proinflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor (TNF)-α, are released in response to injury and coordinate a local inflammatory response at the site of the injury, as well as starting a systemic response which involves the release of acute phase proteins such as C-reactive protein (CRP). IL-6 and TNF-α have previously been associated with frailty [103]. Usually the inflammatory processes are terminated by anti-inflammatory factors but if the body is under continuous attack by subclinical infections, the inflammatory state will become chronic [103]. Chronic inflammation as a process of ageing (immunosenescence or inflammaging) is a rapidly evolving area and has been found to be associated with poor physical performance and weakened muscle mass. A recent review also suggested that as the central nervous system and the immune system are

in constant communication, inflammation in one area of the body may be expected to lead to inflammation in the brain [104]. If, for example, there is an inflammatory response in cerebro-vascular areas this may trigger cells in the blood-brain barrier to also release inflammatory cytokines into the brain. Inflammatory cytokines such as IL-6 are thought to interrupt adult neurogenesis and as IL-6 receptors are located in the hippocampus and pre-frontal cortex this heightened inflammatory state could have serious consequences for cognitive function, in particular for memory and executive functions [104]. We found one study which directly tested the relationship between frailty, cognition and inflammation. Canon and Crimmins found that levels of circulating C-reactive protein mediated the relationship between muscle strength and poor cognitive function, albeit only in women [200]. Chronic inflammation is also known to be involved in disruption to brain mechanisms, hormonal dysregulation, oxidative stress, cardiovascular disease and social vulnerability, all of which may be implicated in the relationship between frailty and cognition [103, 104, 195, 201, 202].

Cardiovascular Risk

Cardiovascular risk may be another factor in the link between frailty and cognition. Frailty has previously been found to be associated with higher rates of cardiovascular disease [203] and it is known that vascular risk factors play a key role in the development of cognitive decline and dementia [204]. In addition to inflammation, cardiovascular factors may contribute to frailty through impaired muscle function [205]. Specifically, small-vessel disease and low-grade inflammation would impair blood flow to skeletal muscles thus causing sarcopenia and muscle weakness. Two epidemiological studies also found that participants who were frail at baseline had a significantly increased risk of developing vascular dementia, over other types of dementia, compared to non-frail participants [161, 165]. This may be particularly interesting in light of the cognitive findings outlined above as executive function is thought to be more significantly impaired by vascular disease than memory [206].

Mental Health

Mood disorders such as depression have been found to be both a risk factor for and a consequence of frailty [207, 208]. Depression is also known to affect cognitive function (for a recent meta-analysis see [209]). This suggests that

one mechanism underlying the link between frailty and cognition may be due to psychological factors such as mood. Once again the vascular link may be important as the Health and Retirement Survey recently found that participants with vascular depression at baseline were significantly more likely to develop frailty [208]. Fifty five per cent of participants with vascular depression became frail within four years compared to 35% of participants with a high cerebrovascular burden alone and 25% of participants with neither. This may suggest that the interaction between the vascular burden and mood effects of depression is an important consideration in understanding frailty.

Personality and perceptions of ageing may also play a role through their effects on mental, physical and social activity. In one review on the frailty syndrome Lang et al. suggested that frailty could be described as a cycle whereby age-related changes to bone density and muscle cause an increase in the effort required to be physically active [210]. As the perception of exercise effort increases, older individuals start to avoid exercise leading to a cycle of increasing sarcopenia and declining physical activity. We found one paper which tested this theory; young participants, who at first became fatigued and weaker when asked to rapidly perform a grip strength test with their dominant hand, could later overcome fatigue when a mirror box superimposed a picture of the non-dominant hand where their dominant hand was gripping. This suggests that the weakness and fatigue were not a cause of muscle fatigue per se but of perceived fatigue and weakness [211]. Physical exercise in later life, even less vigorous activities such as walking, slows down cognitive decline [212]. It is possible that the cyclical model which Lang and colleagues outlined may also be amended to include cognitive decline such that perception of weakness causes older adults to both limit their physical activity and to become objectively weaker, therefore losing the benefits that physical activity had on maintaining cognitive function. Limited physical activity may be reduced further by social isolation, a known contributor to both frailty and cognitive decline. In a longitudinal study of non-institutionalized adults aged 62+ depression and social isolation were significant risk factors for developing frailty at follow up. Meanwhile, data from the Canadian Study of Healthy Ageing reported that individuals who scored highly on a social vulnerability index had a 36% increased chance of experiencing cognitive decline at 5 year follow up [213, 214]. Interestingly, the social vulnerability index was most highly associated

with poor performance in executive function and verbal fluency but not in measures of memory and other cognitive domains [215]. However, this finding was based solely on cross-sectional data and thus it is not clear whether the impairments were long-standing or newly developed as a cause of the social vulnerability. It is, however, an area which merits further investigation given the evidence for an association between frailty and impairment to executive function. (We have included Figure 1 to highlight the associations between these and all other possible causal mechanisms).

Interventions

Although evidence for interventions into frailty coupled with cognitive decline is limited, a small number of studies point to the cognitive benefits of physical activity. A 2010 review found that physical activity protected against both sarcopenia and cognitive decline in experimental training trials and in observational studies [184]. Furthermore, a number of studies showed that aerobic exercise training could reduce levels of both CRP and IL-6 in middle-aged or older persons suggesting that the positive effects of the physical exercise training may be through a reduction of inflammation. We found one intervention study for frailty and cognitive decline which was consistent with our criteria of an operationalised definition of frailty. Langlois et al. found that an aerobic exercise and strength training programme for both frail and non-frail elderly adults over the course of 12 weeks improved scores in functional capacity and physical endurance (although not grip, gait or mobility), cognition and quality of life [216]. The significant improvements in cognition were due to increased scores in measures of working memory, processing speed and executive function. The improvements in quality of life centred on personal and social components of quality of life such as relationships, leisure activities and perceived physical health rather than abilities such as managing finances or housekeeping. Considering the suggested association between social vulnerability, frailty and cognition, it is important that future studies untangle the effects of physical activity from the increased social activity which may have improved mood and self-perception, decreased social isolation and led to reduced subjective weakness. Although much larger, and many more, intervention studies will be required before we can suggest that physical activity is beneficial to participants with frailty and cognitive impairment, it is a promising start to interventions in these two debilitating conditions.

Conclusions

Brain health is strongly linked to physical health, and physical function is, to a large extent, cognitively mediated. It should therefore be no surprise that physical frailty and poor cognitive function are related. Fried's definition of frailty is composed of five parts and each of these, individually, has previously been found to be associated with cognitive decline. It is thus not surprising that combining these elements together will create a measure that predicts cognitive decline. However, this definition of frailty was not envisioned as a collection of symptoms, but rather as a collection of indicators of an underlying syndrome which involves cumulative decline or failure across multiple physiological systems. Fried described the five components as the end point of frailty, that is the point at which somebody has already experienced the failure in multiple systems, and the point at which this collection of symptoms becomes clinically apparent [130]. It is this concept which makes the Song et al. and Rockwood et al., definitions of frailty particularly interesting in light of cognitive impairment. These definitions capture frailty at a point at which the decline in multiple symptoms is still occurring either at clinical or subclinical level. The Song et al. finding, that it is not the type of deficits which one measures which predict cognitive decline but rather the number of deficits, even those not traditionally associated with cognition, is particularly interesting as it illustrates that it is likely the underlying frailty, and not solely the symptoms of Fried's definition of frailty, which are linked to cognitive decline. Unlike the Fried definition of frailty, therefore, the definition used by Song et al. cannot be thought to be linked to cognitive impairment through mechanisms already understood to link physical and cognitive function such as low levels of activity and muscle wastage.

A number of mechanisms – AD pathology, hormones, nutrition, chronic inflammation, cardiovascular risks and mental health – have been proposed to explain the link between frailty and cognition. It is likely that a number of factors contribute to the relationship. Alzheimer's disease pathology may lead to frailty independently of cognitive function. Frailty and cognitive impairment share risk factors such as chronic disease and poor cardiovascular health, inflammation, or hormonal dysregulation. Both frailty and cognitive impairment can lead to, or be caused by, social isolation, and it is likely that behavioural changes as a result of cognitive impairment contribute to frailty through limited physical activity and impaired nutrition.

Epidemiological studies have established the link between frailty and cognitive domains of executive function, attention and processing speed, and have provided some evidence that frailty can be an early indicator for subsequent cognitive decline even after taking account of baseline cognitive function. However, more work on the predictive value of frailty measures in identifying those at risk of preventable cognitive decline is needed.

Understanding how and why frailty is linked to cognitive impairment has implications for the management of patients with dementia and MCI and for older people in general. Frailty leads to disability and loss of independence and so those with cognitive impairment should be assessed for frailty in order to maintain independence for as long as possible. If frailty is shown to lead to cognitive impairment, then interventions to reduce frailty may be targeted at the frail with the goal of preventing or even reversing further cognitive decline.

Finally, there are some fundamental questions which remain to be explored. Studies of the relationships between specific aspects of frailty and cognitive impairment are inconsistent. Further studies are needed to determine which measures of frailty could be used to best identify those at risk of cognitive decline over the course of ageing and vice versa. A better understanding of the direction of the relationship between frailty and cognition and the specific aspects involved, will help to validate the causative hypotheses outlined in this paper and suggest, crucially, what interventions may be able to break the frailty cycle.

Table 1. Cross-sectional studies showing an association between frailty and cognitive impairment or dementia.

Reference	Population Characteristics	Demographics	Measure of Frailty[a]	Measure of Cognition	Findings
Ávila-Funes et al., 2009	Three City Study: Population based sample of community dwelling adults aged 65+ from Bordeaux, Dijon and Montpellier.	N = 6,030 Age: 74.1 (5.2) 61.4% female.	Fried criteria	MMSE and Isaacs Set Test of verbal fluency. Cognitive impairment defined as lowest quartile.	CI in 22% of frail population, 12% of pre-frail and 10% among robust.
Macuco et al., 2012 / Yassuda et al. 2012	Population based sample of community dwelling adults aged 65+ from low socio-economic area of Brazil.	N = 384 Age: 72.3 (5.8) 67.2% female.	Fried criteria.	The Brief Cognitive Screening Battery. MMSE and sub-domains.	CI in 39% of frail population, 22% of pre-frail and 16% of robust.
Jurschik et al., 2012	Sample taken from population based sample of community dwelling adults aged 75+ in Spain.	N = 628 Age: 81.3(5) 60.3% female.	Fried criteria.	Pfeiffer's Test for Cognitive Function. Cognitive impairment is ≥ 3 errors.	CI in 20% of frail population compared to 5.3% of robust population.
Rockwood et al., 2007	CSHA study. Population based sample of adults in the community and in institutionalised care in Canada.	N = 716 in long term care. N=1589 community dwelling.	Fried criteria & Rockwood Frailty Index.	Modified Mini Mental State Examination (3MS)	Fried (r = -.58) and Rockwood (r = -.35) models negatively correlated with 3MS
Armstrong et al., 2010	Database of 23,952 patients receiving community care in the home or in long-term care institutions across Ontario, Canada.	N = 23,952. Age: 81.7 (7.4) 69.4% female.	Frailty index.	Reported Diagnosis of Dementia.	Dementia in 40% of frailest (top 15% of FI) compared to 11% of least frail (lowest 60% of FI).
Bilotta et al., 2012a	Participants attending an outpatient geriatric clinic in Italy.	N = 313. Age: 81.5 (6.8) 71% female.	SOF criteria.	Diagnosis of dementia.	Dementia in 45% of frail participants compared to 32% in pre-frail and 33% robust (not statistically significant).
Bilotta et al., 2012b	Participants attending an outpatient geriatric clinic in Italy who had already been	N = 109. Age: 82.8 (7.1) 77% female.	SOF criteria.	MMSE	50% of patients with dementia were frail, 28% were pre-frail and 22%

	diagnosed with dementia or who were subsequently diagnosed in the clinic.		were robust. Frail participants with dementia had significantly lower MMSE than robust participants with dementia.

Fried criteria: Definition similar to that described in Fried et al 2000.
SOF criteria: Study of osteoportic fractures criteria: Frailty defined as 2/3 of i) unintentional weight loss> 5%, ii) inability to rise from a chair 5 consecutive times without using the arms and iii) negative answer to the question 'do you feel full of energy?'
MMSE: Mini-mental state examination; CI: Cognitive impairment.

Table 2. Longitudinal studies showing the effect of frailty on cognitive decline or dementia incidence.

Reference	Study population	Sample characteristics	Baseline Measure of Frailty	Follow-up period and measure of cognitive change	Baseline covariates accounted for.	Findings
Ávila-Funes et al., 2009	Three City Study: Population based sample of community dwelling adults aged 65+ from Bordeaux, Dijon and Montpellier.	N = 6,030 Age: 74.1 (5.2) 61.4% female.	Fried criteria	4 year incidence of dementia	Age; sex; education; income; smoking; drinker; number of chronic diseases; SRH; CES-D, mobility, IADL and ADL	Pre-frail vs robust: HR = 1.29 (0.86-1.93) Frail vs robust: HR=1.14 (0.58-2.21)
Ávila-Funes et al., 2012	Three City Study: Population based sample of community dwelling adults aged 65+ from Bordeaux, Dijon and Montpellier.	N = 5480. 61.7% female. Mean age: 74 (5.2)	Fried criteria.	7 years incidence of dementia (all dementia, AD and VaD) after 7 year follow up.	Age, sex, education, cardiovascular risk factors, diabetes mellitus, hypercholesterolemia, history of coronary disease, APOE genotype, ADLs.	Dementia: Pre-frail vs robust: HR=1.20 (0.96-1.51) Frail vs robust: HR=1.24 (0.94-2.01) AD: Pre-frail vs robust: HR=1.19 (0.92-1.53) Frail vs robust: HR=1.23 (0.79-1.91) VaD: Pre-frail vs robust: HR=1.74 (0.89-3.39) Frail vs robust: HR=2.73 (1.05-7.13)
Samper-Ternent et al., 2008	HEPESE study. Population based sample of Mexican-American adults in the community aged 65+.	N = 1370. Total sample age and gender not given.	Fried criteria.	Ten year decline in MMSE.	Age, sex, marital status, education, stroke, heart attack, hypertension, diabetes, high depressive symptoms, arthritis, visual impairment.	Frailty but not pre-frailty associated with cognitive decline.

Mitnitski et al., 2011a	CSHA study. Population representative sample of adults in Canada.	N = 9266. Age: 75.8 (7.1) 60.2% women.	Rockwood's Frailty Index.	Five year change in errors on 3MS grouped into categories of 3	Cognition, age, sex, education	Frailty associated with cognitive change in men and women
Mitnitski et al., 2011b	Subset of CSHA study. Population representative sample of adults in Canada.	N = 2305. Age: 83.1 (6.9). 62.1% female.	1. Fried criteria. 2. Frailty Index. 3.Clinical Frailty Scale	Five year change in errors on 3MS grouped into categories of 3	Cognition, age, sex, education.	All measures associated with cognitive decline
Drame et al., 2011	SAFEs study. Participants aged 75+ admitted to ED in hospitals around France.	N = 1306. Age: 85 (5.9) 64.7% female. Baseline MMSE: 16 +- 5	Four different indices including Rockwood index.	1 Year Rapid Cognitive Decline (RCD): loss of ≥ 3 points on MMSE	None	Exact tests showed no association between frailty and RCD.
Buchman et al., 2007	Rush Memory and Aging Project. Participants from residential centres, social services and church groups across Chicago.	N = 823. Age: 80.4 (6.9) 74.6% female.	Z-score based on grip strength, timed walk, BMI and exhaustion.	7 years incidence of AD	Age, sex, education (adjusting for additional vascular factors or disease did not affect estimate)	HR=1.94 (1.31-2.87) *
Boyle et al., 2010	Rush Memory and Aging Project. Participants from residential centres, social services and church groups across Chicago.	N = 750. Age: 79 (7.1) 76.4% female.	Z-score based on grip strength, timed walk, BMI and exhaustion.	12 years incidence of MCI	Age, sex, education depression, disability, vascular risk factors, and vascular diseases.	HR=1.6 (1.3-2.1) *
Gray et al., 2013	ACT study. Population based sample of	N=2,619 Age: 76.8 (5.9) 60.1% female.	Fried criteria.	16 year incidence of dementia, classified as	Age, sex, education, race, BMI, depression,	Frail vs robust: Dem: HR=1.20 (.85-1.69).

	individuals aged 65+ from a health maintenance organisation in Seattle.			possible/probable AD or non-AD.	anti-depressants, cardiovascular health, smoking, cognition	AD: HR= 1.08 (.74-1.57) non-AD: HR=2.57 (1.08-6.11).
Song et al., 2011	CSHA study. Population based sample of adults in the community and in institutionalised care in Canada.	N = 5,909. Age and sex not given	Frailty Index of 'non-traditional' risk factors for dementia.	5 year incidence of AD or other dementia.	Age, sex, education, cognition	Non-traditional risk factors combine to increase risk of dementia and AD.
Solfrizzi et al., 2012	ILSA study. Randomly selected, population based sample of free-living or institutionalised participants aged 65 to 84 years.	N = 2581. 45% female. Age 73.1 (5.6)	Fried criteria.	3.5 year incidence of AD, VaD and other dementia.	Age, sex, education, smoking, IADL, MMSE, co-morbidity and serum albumin	AD: HR=0.62 (0.20-1.89) VaD: HR=2.68 (1.16-7.17) Other dem: HR=2.69 (0.51-14.13)
Auyeung et al., 2011	Community dwelling, cognitively normal people aged 65+ living in Hong Kong.	N = 2737. Age: Male:71.6(4.58). Female:71.5 (4.85). 44.7% female.	BMI, grip strength, chair stand, step length, slowed walk, composite score on neuromuscular tests.	Four year change in MMSE.	Age, education and MMSE.	Only grip strength predicted lower MMSE at follow up in women. Underweight, grip strength and chair stand led to cognitive decline in men.

AD: Alzheimer's disease; VaD: Vascular dementia; MMSE: Mini-mental state examination; 3MS: Modified mini-mental state examination; Dem: dementia; BMI: Body mass index; ADL: Activities of daily living; IADL: Instrumental activities of daily living; HR: Hazard ratio. * HR for one unit increase in frailty Z-score.

Table 3. Longitudinal studies of the effect of cognitive impairment on risk of frailty.

Reference	Study population	Sample characteristics	Measure of cognition	Follow-up period and measure of frailty	Baseline covariates accounted for	Findings
Aranda et al., 2007	HEPESE study. Representative sample of Mexican-American adults in the community aged 65+.	N = 963. Age and sex not given.	MMSE	Two year change in Fried criteria with the exclusion of physical activity.	Age, gender, education, language, finances, private insurance, medical conditions, being underweight and ADLs, positive affect, living alone, emotional support, neighbourhood.	Incident frailty linked to baseline cognition
Raji et al., 2010	HEPESE study. Population based sample of Mexican-American adults in the community aged 65+.	N = 942. Total sample age and gender not given.	MMSE dichotomised into cognitive impairment (MMSE < 21) or none.	Ten year change in Fried criteria with the exclusion of physical activity.	Age, gender, marital status, education, medical conditions	Incident frailty linked to baseline cognition
Doba et al., 2012	Sample taken from larger longitudinal study of community dwelling participants in Japan aged 70+.	N = 407. Age: 78(4). 54.79% female.	Minimum Data Set cognitive performance scale. Self-reported cognitive change.	Five year change in Canadian Study for Health and Aging Clinical Frailty Scale (CSHA-CFS),	Age, sociodemographics, frequency of going out, anorexia, insomnia, exercise tolerance, mood, fatigue, history of falls, vision and hearing, height, weight, BMI, body fat ratio, grip strength, timed walk, resting metabolic ratio, bone mineral density, blood pressure, heart rate, brachial-ankle pulse wave velocity, blood count, creatinine, blood urea nitrogen, serum electrolytes, cholesterol,	Subjective cognitive changes at baseline were significantly associated with development of frailty at follow up. There was no significant association between MDS and development of frailty at follow up.

		protein albumin, haemoglobin, cortisol, luteinizing hormone, deyhdropiandrosterone, C-reactive protein, interleukin-6, lymphocyte count.

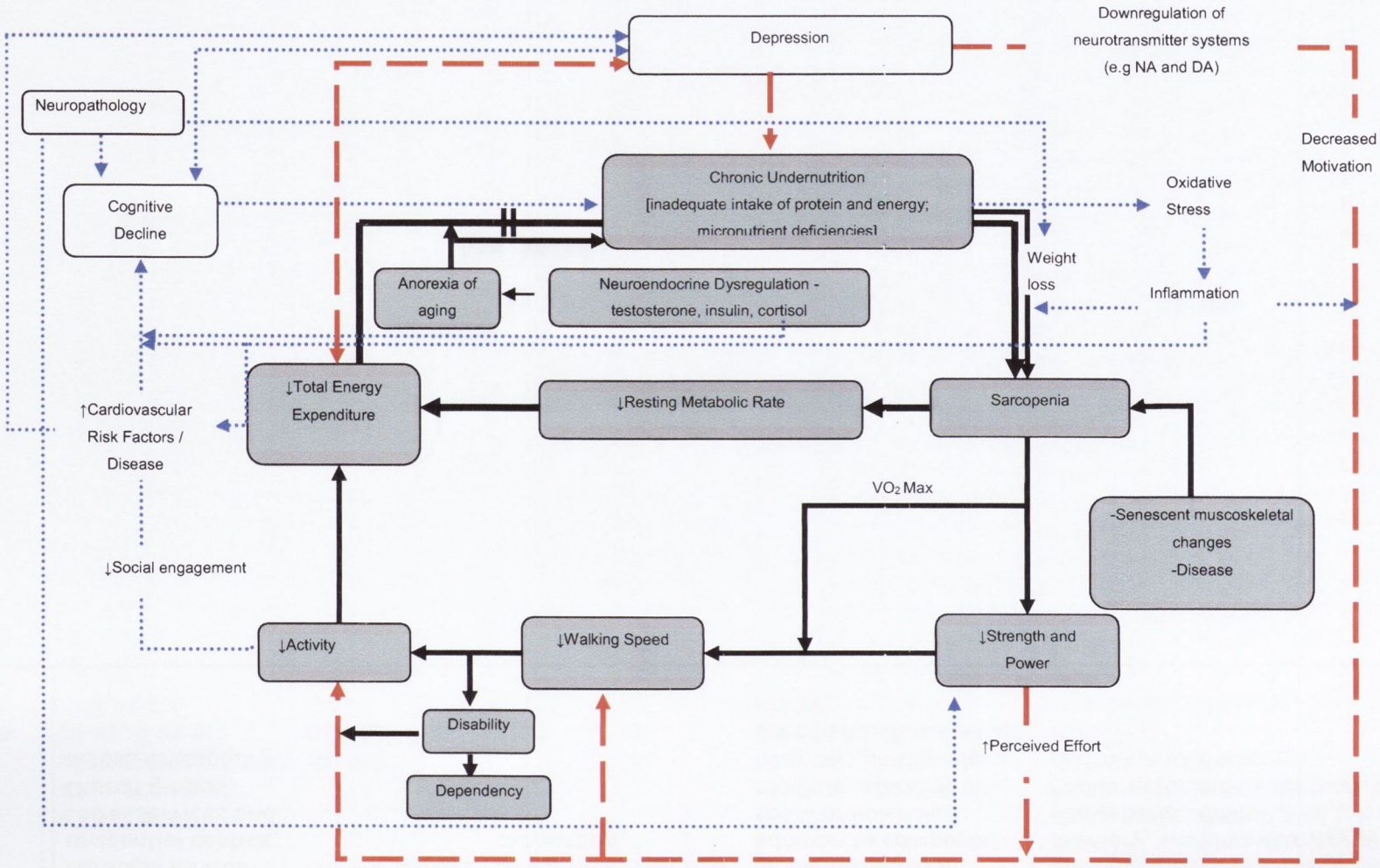
Table 4. Specific aspects of cognition which have been found to be impaired in frailty

Reference	Study population	Demographics	Measure of Frailty	Measure of Cognition	Results
Langlois et al., 2012	Community dwelling adults aged between 69-81 recruited through advertisement in newspapers and locally.	N = 83. Total sample age and gender not given.	Frail if 2/3 of: -Fried frailty -Rockwood frailty -Low score on Modified Physical Performance Test.	MMSE, verbal abstract reasoning, episodic memory, working memory, speed of processing and executive function.	Frailty liked to impaired executive function and processing speed. No effect on working memory, episodic memory or abstract verbal reasoning.
Patrick et al., 2010	Sample of patients admitted consecutively to geriatric rehabilitation inpatient services in Ottawa, Ontario.	N = 61. Age: 82.7 (5.8) 72% female.	Cumulative Illness Rating Scale (CIRS): Physician rated severity of illness in 13 potential categories.	Visuospatial ability, verbal fluency, abstract reasoning, social comprehension, sustained attention, episodic memory, verbal learning & executive function.	CIRS cross-sectionally linked to poorer reasoning, dual-attentional processing, verbal fluency and speed of processing. but not memory after adjusting for age and depressive symptoms.
O'Halloran et al., 2011	Cross-sectional convenient sample of community dwelling participants over 60.	N = 384. Total sample age and gender not given.	Fried criteria.	Sustained Attention Response Time (SART) Task.	More errors and greater variability in performance speed in frail compared to robust participants.
Macuco et al., 2012 / Yassuda et al., 2012	Population based sample of community dwelling adults aged 65+ from low socio-economic area of Brazil.	N = 384 Age: 72.3 (5.8) 67.19% female.	Fried criteria.	The Brief Cognitive Screening Battery measuring delayed memory, verbal fluency and the Clock Drawing Tests. MMSE and sub-domains.	Frailty associated with time orientation, commands and immediate memory, and all BCSG domains. Adjustment for sociodemographic factors only verbal fluency and clock drawing remained linked to frailty. Delayed memory not linked to frailty.

Boyle et al., 2010	Rush Memory and Aging Project. Participants from residential centres, social services and church groups across Chicago.	N = 761. Age: 79 (7.1) 76.4% female	Composite measure of grip strength, timed walk, BMI and exhaustion.	MMSE, composite cognitive score of global cognition in addition to composite score of episodic memory, working memory, perceptual speed and visuospatial ability.	Frailty at baseline associated with baseline perceptual speed but not episodic memory, semantic memory, working memory or visuospatial ability. Frailty associated with more rapid decline in all domains.

Figure 1. The cycle of frailty and cognitive impairment.

Fried et al.'s (2001) model is outlined in the grey shaded boxes. Our additions to this model are the mental health cycle outlined in red (dashed) and the cognitive decline cycle outlined in blue (dotted) lines.



Research Aims

There is a large body of literature to suggest that frailty and cognitive impairment are associated syndromes. Meanwhile, the psychological literature suggests that perceptions of ageing have a direct influence on the health of older adults. The aim of this thesis is to combine these two areas of research in order to assess whether perceptions of ageing play a role in the development of frailty and cognitive impairment. I will do this through 5 empirical studies.

Paper 1. Cognitive Function in the Pre-Frailty and Frailty Syndrome.
The aim of this paper is to determine whether frailty is associated with cognition in the TILDA sample. Previous literature has shown an association between frailty and global cognitive function but it is not clear what the association is between frailty and individual cognitive domains as the small number of studies on this have provided conflicting results. This study will therefore add to the existing literature by exploring the relationship between frailty and cognition across five cognitive domains – global cognition, executive function, memory, attention, processing speed and memory. Based on previous studies I hypothesise that frailty will be associated with global cognitive function, executive function, attention and processing speed.

Paper 2. Negative Perceptions of Ageing and Slow Walking Speed: A Self-Fulfilling Prophecy.
The aim of this paper is to assess whether perceptions of ageing are longitudinally associated with objective walking speed, a key component and proxy measure of frailty. I hypothesise that older adults with negative perceptions of ageing will have slower walking speed over two years.

Paper 3. Negative Perceptions of Ageing Predict Longitudinal Decline in Cognitive Function.
This paper assesses whether perceptions of ageing are longitudinally associated with cognitive function. I hypothesise that older adults with negative perceptions

of ageing will have poorer objective and subjective cognitive function over two years.

Paper 4. Negative Perceptions of Ageing Moderate the Relationship Between Frailty and Cognition.

This paper explores whether negative perceptions of ageing moderate the association between frailty and cognition. I hypothesise that older adults with negative perceptions of ageing who are frail will be more likely to have poorer cognitive function. Frail older adults with positive perceptions of ageing, however, will not necessarily have poorer cognitive function than their robust peers.

Paper 5. Ageing Perceptions Predict Engagement with Social and Cognitively Stimulating Activities.

This final paper aims to assess whether perceptions of ageing are associated with any of the social behaviours which are known to be protective against physical and cognitive decline in later life. If perceptions of ageing affect engagement with social and cognitively stimulating behaviours I hypothesise that this may be a first step in explaining the pathway through which perceptions affect cognition and physical function in later life. There is no previous study, to my knowledge, which has explored this.

Methodology

Data

Data for this thesis was taken from the Irish Longitudinal Study on Ageing (TILDA), a prospective, population-representative sample of adults aged 50 and over living in the Republic of Ireland.

Participants were randomly recruited for the study using the Irish Geodirectory which is a comprehensive listing of all residential addresses in the Republic of Ireland. A sample of residential addresses was chosen through the RANSAM sample procedure, a computer-based random sampling design developed by the Economic and Social Research Institute of Ireland [217]. Addresses are first divided into clusters based on District Electoral Divisions each containing 500-1180 addresses. These are stratified according to socio-economic status, age and geographical location. 640 of these clusters were chosen based on the probability of being selected proportionate to the number of addresses containing a person aged 50 years or older. 40 addresses in each of the 640 clusters were chosen as an initial sample from which to obtain the target sample of N = 8000.

A letter of invitation to participate in the study was sent by post to all selected households with a unique address and delivered by hand to those households that did not have a unique address. Interviewers then travelled to each of the selected households one week after the initial invitation letter to determine whether there was an eligible person living in the household. Anyone over 50, and their spouse of any age, was eligible to participate. Participants judged by the interviewer to have dementia or a cognitive impairment severe enough to prevent them from personally being able to consent to the study were excluded. Ethical approval was obtained from the Trinity College Dublin Research Ethics Committee and all participants provided written informed consent.

Wave 1

The response rate for wave 1 was 62%. 8,504 participants, of which 8,175 were aged 50 and over, agreed to participate in the study. Data collection for wave 1 took place between January 2009 and July 2011. There were three parts to wave

1 which included: 1) a computer-assisted personal interview (CAPI); 2) a health or home assessment and 3) a self-completion questionnaire (SCQ).

The CAPI was administered by trained professional social interviewers in the participants' homes. The questionnaire included details questions on socio-demographics, living standards, income and wealth, medication use, health-care utilisation and physical, mental and behavioural health. In addition, participants completed some short cognitive assessments including immediate and delayed recall, verbal fluency, and prospective memory tasks.

Following the CAPI interview participants were invited to participate in the health assessment. Health assessments were conducted by trained nurses in one of two dedicated centres in Dublin and Cork. Participants were reimbursed for the cost of attending the centres. The duration of the assessment was approximate 150 minutes and included: Anthropometric measurements including height, weight and waist circumference; cardiovascular measurements including heart rate variability, blood pressure and pulse wave velocity; gait, balance and sensory measurements including the Timed Up-And-Go task, gait assessment using a sensored mat, visual acuity and contrast sensitivity; bone and muscle strength including grip strength and heel ultra-sound; cognitive measurements including tests of global cognition, sustained attention, executive function, visual memory, speed of processing, and macular degeneration including macular pigment optical density and retinal photography. In order to maximise participation in the health assessment section of wave 1 participants who were unable or who refused to attend a health assessment centre were offered a home assessment conducted by a study nurse. 6,150 participants completed a home or health assessment.

Finally, participants were asked to complete and return a self-administered questionnaire which included questions on anxiety, worry, loneliness, perceived stress, stressful life events, quality of life, alcohol use and attitudes to ageing.

For further information on TILDA sample selection and data collection see Kearney et al. (2011) [218].

Wave 2

Wave 2 data was collected between March and December 2012, approximately 2 years after wave 1. The mean time difference between interviews was 741.46 (85.19) days which is equal to 2.03 years. 6,995 participants (86%) returned to participate in wave 2 leaving an attrition rate of 14%. Of those participants who had no wave 2 follow up 809 refused, 205 were deceased and 144 were untraceable. Wave 2 data collection consisted of the CAPI and the SCQ but no health assessment as these are due to take place every 4 years while the CAPI and SCQ will be administered every 2 years. Instead, interviewers were trained to administer some elements from the health assessment during the CAPI. These included the Mini Mental State Examination (MMSE) test of global cognitive function, grip strength and the Timed Up-And-Go task.

Current Work

This thesis uses data from both wave 1 and wave 2 of TILDA including measures taken from the CAPI, health assessment and SCQ. Specific measures used in each analysis will be detailed in the relevant chapters.

Statistical Analyses

Statistical analyses for this work were conducted using Stata version 12.1. The specific analyses used for each paper will be outlined in individual methodology sections. One note which is common to all of the analyses, however, is the question of whether to correct for multiple comparisons using Bonferroni adjustments to the p-value. This is a relatively common approach in small datasets but many epidemiologists argue that Bonferroni adjustments are not useful and, furthermore, may cause more harm by over-inflating the Type II error rate [219-221]. This is particularly the case in large studies such as TILDA in which multiple researchers conduct multiple analyses on the same dataset. Epidemiologists argue that, should we take the approach that Bonferroni corrections should be used for all cases of multiple testing, then all future papers published on one dataset would have to adjust for the p values produced in the first analysis of that dataset [220]. There are, however, some situations in which Bonferroni corrections can be useful to reduce the Type I error rate [220, 221]. In a situation in which there are multiple comparisons without any a-priori hypotheses a Bonferroni correction can be used to reduce the risk of making a

Type I error and to ensure that statistical significance is not the result of a 'fishing expedition' [220]. Based on these arguments this thesis has only used Bonferroni corrections in one analysis (Paper 1, analysis 2) in which no a-priori hypotheses were formed. For all other analyses the hypotheses were formed in advance and the number of comparisons limited to those that were strictly necessary to test them.

Introduction to Paper 1

The second introductory chapter of this thesis reviewed the evidence for an association between frailty and cognition. A large number of studies have found that older adults who are frail are more likely to have worse cognitive function than their robust peers. Although much evidence has shown that global cognitive function is associated with frailty, however, only a small number of studies have explored the association between frailty and individual cognitive domains. Additionally, most research has focussed solely on frailty and less is known about the association between pre-frailty and cognitive function. The aims of the first empirical study in this thesis were thus threefold: 1) to assess whether the frail population in our sample had poor cognitive function; 2) to establish whether the same was true of pre-frail participants; 3) to test whether the relationship between pre-frailty, frailty and cognitive function was similar across six cognitive domains.

This paper was published in the Journal of the American Geriatrics Society [222].

Paper 1: Cognitive Function in the Pre-Frailty and Frailty Syndrome

Abstract

Introduction

Cognitive decline and frailty are two common problems faced by older people. While previous research indicates that frailty is associated with dementia, it is not clear whether this is only in the end stages or whether frailty is an early marker of poor cognitive function. We sought to explore cognitive function in participants defined as pre-frail or frail.

Methods

Participants from wave 1 of The Irish Longitudinal Study on Ageing, a population representative study of adults aged 50+ in the Republic of Ireland, completed a health centre-based nurse-led assessment. Participants with a history of stroke, Parkinson's Disease or an MMSE < 18 were excluded (N = 4,650). Measures of cognitive function included the MMSE, MoCA, Color Trails Test, CAMDEX memory and executive function, 10-word recall, SART and choice reaction time. These were used to generate composite scores of cognitive domains. Frailty was assessed through the five Fried criteria of weakness, slowness, exhaustion, low physical activity and weight loss.

Results

Cognitive function, across all domains except self-rated memory and processing speed, was significantly worse in pre-frail and frail participants compared to robust after full adjustment. Weakness and walking speed were most consistently linked to poorer cognition, while low activity and weight loss were not independently associated with any cognitive domain. Exhaustion was associated with global cognition (B = -.18, ± .06) with some evidence of links to objectively measured and self-rated memory.

Conclusions

Cognitive function is worse across multiple cognitive domains in pre-frail or frail over 50s compared to those who are robust, although the absolute differences are small after adjusting for confounding factors.

Introduction

Although frailty is a relatively newly defined concept it has recently been suggested that it should be termed as one of the 'geriatric giants' that define geriatric medical practice [223]. Frailty is characterised by the body's inability to respond adequately to external stressors and an increased risk of adverse outcomes including disability, hospitalisation, institutionalisation and death [125]. However, the precursors to frailty and the associations between frailty and other geriatric syndromes are still relatively unknown. One of these questions is to what extent frailty is associated with another geriatric giant, cognitive impairment, and the different domains of cognitive function.

A number of cross-sectional and longitudinal studies have shown that frail people are more likely to have dementia or cognitive impairment and that those already suffering from dementia are more likely to be frail [128, 150, 162, 164-166, 169, 170]. This raises important questions about frailty as a potentially modifiable risk factor for dementia and vice versa. Furthermore, frailty and cognitive impairment share a number of common risk factors including cardiovascular disease and depression [208, 224-226]. A recent study addressed some of these risk factors by engaging frail and non-frail participants in an intensive exercise programme over 12 weeks [216]. Both non-frail and frail participants showed an increase in cognitive ability, physical function and quality of life, thus raising the possibility of interventions to delay or reverse frailty and cognitive impairment [216, 227].

While a large number of studies have analysed the relationship between frailty and cognition, most have focussed on dementia or change in global cognition as measured by the Mini Mental State Examination (MMSE) [152, 154, 162, 186, 187]. Very few have examined the association between frailty and individual cognitive domains and, in those that have, the results have been inconsistent. The Rush Memory and Ageing Study found that frailty was associated with a faster rate of decline in cognitive scores across all six domains measured including memory [162]. Other studies, however, suggest that memory is less affected than executive function [152, 154] and, consistent with this finding, three prospective studies have shown that frailty is more strongly associated with vascular than Alzheimer's type dementia [154, 161, 165, 186]. In order to understand why there is an association between these two syndromes it is

necessary to further explore the relationship between frailty, individual frailty indicators and specific cognitive domains. Understanding the relationship may also infer possible causal pathways that can be targeted by interventions. Furthermore, few studies have examined cognitive performance in pre-frailty as well as frailty.

Previous studies on this topic have used convenience samples or have restricted their analysis to specific populations such as low socioeconomic groups which are not generalizable to other populations [152, 154, 162, 186]. Our study examines the association between frailty and cognitive function in a large population-representative sample of adults aged 50 years and older. Our middle aged and older participants have been analysed both independently and together thus allowing comparison of the association between frailty and cognition across a broad range of age and severity including those in the early (pre-frail) stages.

Methods

Population

Data was taken from Wave 1 of The Irish Longitudinal Study on Ageing (TILDA), a prospective study of a sample representative of the population of the Republic of Ireland aged 50 and older living in the community (i.e. not in long term care facilities). Participants who reported a doctor's diagnosis of dementia or who were unable to personally consent to participation due to a severe cognitive impairment (judged at an interviewer's discretion) were not included in wave one of the study. The full cohort and assessment has been described in detail elsewhere [218], but in brief 8,175 participants aged 50 and older were interviewed in their own homes followed by a nurse-administered health assessment at one of two dedicated health centres. Participants unable or unwilling to attend a health assessment centre received a modified nurse-delivered health assessment in the home. The response rate to the interview was 62.0%, and 61.6% of participants (N=6,150) completed the health (N = 5,274) or home (N= 876) assessment.

Data from participants who had participated in a full health centre assessment which included all of the physical and cognitive items needed to compose a measure of frailty together with the battery of neuropsychological measures were used.

Consistent with the definition of frailty by Fried et al. we excluded participants who had Parkinson's Disease (N=16), a history of stroke (N=67), those taking anti-depressants (N =284), those on dementia medication (N = 6) or Sinemet (N=1) and those with an MMSE of less than 18 (N=11) [130].

Assessment of frailty

We used the Fried phenotypic definition of frailty as this incorporates a definition of both pre-frailty and frailty [130]. Participants were classified as frail if they met three of the following five criteria: poor grip strength, slow gait speed, low levels of physical activity, unintentional weight loss and exhaustion [130]. Poor grip strength was assessed using a dynamometer. Two readings from the dominant hand were taken and the mean strength calculated. The 20^{th} percentile was calculated and population-specific cut-offs were derived after adjustment for age, gender and BMI. Gait speed was measured using the GAITRite portable electronic walkway system (CIR Systems Inc, Havertown, PA). Participants walked at their usual pace along a 4.88m (16ft) walkway with an extra 2.5m at either side to allow for acceleration and deceleration. A mean gait speed was calculated from two walks. Participants who fell below the gender and height adjusted 20^{th} percentile were considered to have slow gait speed as defined by Fried et al.'s (2001) methodology [130]. Physical activity was measured using the short form of the International Physical Activity Questionnaire which converts levels of physical activity in various domains into predicted kilocalories expended per week [228]. Unintentional weight loss was assessed by the question 'In the past year have you lost 10 pounds (4.5 kg) or more in weight when you were not trying to'. Exhaustion was assessed using 2 questions from the 20-item Centre for Epidemiological Studies Depression (CES-D) scale: "I could not get going" and "I felt that everything I did was an effort" with four possible responses to each question: never, rarely, sometimes or often. A response of 'sometimes' or 'often' to either question was classified as exhaustion [229]. Participants with three or more indicators were defined as frail, those with one or more as pre-frail and those with none as robust [130].

Assessment of cognitive function

The cognitive battery included tests of global cognition, attention, memory, executive function and speed of processing, and composite scores were calculated for each of these domains. Although each of the tests measure more than one domain of cognitive function we classified them based on the main cognitive component involved.

Global cognition was assessed using the MMSE and Montreal Cognitive Assessment (MoCA) [230, 231]. Attention was assessed by 2 tasks: part 1 of the Color Trails Test and the Sustained Attention to Response Task (SART) [232, 233]. The Color Trails Test involves two parts; the first requires participants to draw a line connecting circles numbered 1-25 in consecutive order. The second part requires connecting numbered circles while alternating between pink and yellow circles e.g. pink 1, yellow 2, pink 3. The first part assesses visual scanning and attention while the mental flexibility involved in the switching task of part 2 involves executive function. The SART tests the ability to sustain attention for long periods of time during a repetitive task. Participants were shown a computer screen which repeated a sequence of numbers from 1-9 for approximately 4 minutes. Numbers appear every 300ms and participants were asked to click in response to each number except the number three.

Memory was assessed by 3 methods: the Picture Recognition and Recall subtests of the Cambridge Mental Disorders of the Elderly Examination (CAMDEX), a ten-word immediate and delayed recall test using a list of ten words previously developed for the Health and Retirement Survey [234, 235] and self-rated memory measured with the question: 'How would you rate your day-to-day memory at the present time? Would you say it is: excellent, very good, good, fair or poor.'

Executive function was assessed by 3 tasks: the Visual Reasoning subtest of the CAMDEX – participants are asked to identify which of six objects would complete a pattern of three similar objects, part 2 of the Color Trails Test and the MoCA verbal fluency subtest – participants are given 1 minute to name as many words beginning with F as they can think of [231, 232, 234].

Processing speed was assessed using a computer-based programme in which participants had to respond to a stimulus by depressing one button and pressing

another. Participants were instructed to press a central button on the keyboard and wait for a stimulus (yes/no) to appear on screen. When the stimulus appeared participants depressed the central button and pressed one of two further buttons labeled 'yes' and 'no' to correspond with the stimulus on screen. The full task involves approximately 100 repetitions of this. Cognitive processing speed is measured as the time taken to depress the first button.

Composite scores for each cognitive domain were calculated by obtaining z-scores for each cognitive test and combining them to create total scores for global cognition (MoCA and MMSE), executive function (visual reasoning, Color Trail Test part 2, MoCA 'F letter' subtest), memory (visual recall, visual recognition, immediate memory, delayed memory), attention (Color Trail Test part 1 and SART), and speed of processing (Choice Reaction Time). The standardised versions of these scores constituted the composite cognitive score for each domain. Using Z-scores allows the tests to be combined which leads to more reliable estimates of the effects on each domain, reduces the number of independent tests being conducted and allows the predictive value of frailty indicators across each domain of cognitive function to be compared in a standardised way. These lead to estimates of effects for each domain in the population which can be approximately related back to differences in individual tests using the population standard deviations for each test.

Covariates and Exclusion Criteria

Education was categorised as primary or below, secondary or tertiary and above. History of stroke and chronic conditions, including joint problems, cataracts, glaucoma, age-related macular degeneration, lung disease, asthma, arthritis, osteoporosis, any type of cancer, Parkinson's disease, peptic ulcer, liver disease, varicose ulcer, alcohol or substance abuse, chronic pain and incontinence, were ascertained by a self-report of a doctor's diagnosis. Height and weight were measured and used to calculate gender adjusted cut-offs for the frailty measures. Participants were also asked to record all of the medications taken on a regular basis and, where possible, interviewers asked to see the packages to confirm.

Statistical Analyses

Sociodemographic characteristics were compared across the three groups (frail, pre-frail and robust). The relationship between frailty and each of the individual cognitive tests was then assessed using linear regression models.

Owing to large differences in mean age across groups, it was not deemed useful to compare cognitive test scores across frailty groups without taking demographic factors into account. Therefore, for descriptive purposes, the marginal mean score for each cognitive test across frailty groups was estimated using regression models adjusted for age (as a continuous variable, including an age-squared term to account for non-linear relationship between cognitive function and age), sex and educational attainment.

Second, regression models were used to estimate the association between frailty and pre-frailty with each cognitive domain as measured by composite z-scores and these were plotted to compare the relative effect of frailty across domains. This analysis was adjusted for age, age squared, gender, education, all chronic conditions reported and number of regular medications. Beta coefficients from these analyses represent differences in cognitive scores between frailty groups in terms of standard deviation of that cognitive domain among the population.

Finally, the association of each frailty indicator on each domain of cognitive function was assessed using separate models with the composite cognitive scores as an outcome variable and all frailty indicators as binary variables adjusted for age, age squared, gender, education, chronic conditions and medications as above. For models including individual indicators of frailty we only considered an outcome statistically significant at $p < .008$ (.05/6) in order to avoid potential false positives caused by the large number of hypothesis tests.

Analyses were performed using STATA, version 12.1 (College Station, TX: StataCorp LP).

Results

Of 4,650 people aged 50 and over included in our analysis, 90 (1.9%) were frail and 1,445 (31.1%) were pre-frail. The prevalence of each frailty indicator in our population was roughly similar (Exhaustion = 7.8%, Weight loss = 5.6%, Slowness = 8.6%, Weakness = 8.9%) although 'low physical activity' had a higher prevalence of 14.2%. The most common combination of frailty indicators in our frail sample was slow walking speed, poor grip strength and low levels of physical activity (24.4% of frail sample) followed by walking speed, grip and exhaustion (15.6%). Frail participants were significantly older (mean age 69.3 ± 11.1) compared to pre-frail (63.8 ± 9.1) and robust participants (60.7 ± 7.7), F (2, 4638) = 111.1, $p < .001$) and they were significantly less likely to have completed third level education (18.9% of frail participants compared to 33.1% of pre-frail and 39.3% of robust) (χ^2 (4) = 51.4, $p < .001$). Although a greater proportion of frail participants were female (57.8% vs. 53.9% and 53.1% in pre-frail and robust groups), this was not statistically significant, χ^2 (2) = .95, p = .62 (see Table 5 for full demographics).

An analysis of performance across individual cognitive measures indicated that frail participants achieved significantly lower scores across the majority of cognitive tests after accounting for age, gender and education. Table 6 shows the sample means and marginal means for each cognitive test after standardising to the sample average age, sex and educational attainment. For example, the mean (standard deviation) MMSE score for frail participants was 27.6 (± 2.2) compared to 28.8 (± 1.5) for robust participants. The marginal means (shown with standard errors) adjusted for age, gender and education remained statistically significantly different although the difference was attenuated compared to the unadjusted sample means. For example, the marginal mean MMSE among the frail was 28.0 (± .2) compared to 28.7 (± .03) among robust participants. Only two tests – visual recall and visual recognition - did not show a significant difference between frail and robust participants.

Using composite scores representing the six cognitive domains – global cognition, executive function, memory, attention, processing speed and self-rated memory - we conducted linear regression to determine whether being pre-frail or frail significantly predicted poorer scores in each cognitive domain. Figure 3 indicates a dose-response relationship whereby pre-frail participants scored

statistically significantly less well than robust participants and frail participants scored significantly lower than pre-frail participants among tests of global cognitive function, executive function, memory and attention after adjusting for all other covariates. Processing speed and self-rated memory were not significantly worse among the frail although the direction of the observed effect was similar to other cognitive domains. For example, global cognitive function was B=0.14±0.03 standard deviations worse among the pre-frail and B=0.43±0.13 standard deviations worse among the frail compared to robust participants. This corresponds well to the differences seen in individual test scores adjusted for demographic difference. For example there is a marginal mean difference in MoCA score of 0.6 points between pre-frail and robust and a difference of 1.3 points between frail and robust (with the population standard deviation for MoCA approximately 3 points). (Figure 3)

We conducted the same analysis across three age categories (50-64, 65-74 and 75+). While we found a similar relationship between frailty and global cognitive function across all ages, executive function was only associated with frailty in the 75+ age group (B=-.37, ± SE = .16, p = .026) while memory was only associated with frailty in the 50-64 group (B=-.35, ± .13, p = .005). However the numbers with frailty were very small when broken into age categories (N = 34, 20 and 36 in each age category respectively) which necessitates caution in interpreting these results (see Appendix).

Finally, we regressed the score for each cognitive domain on the five individual frailty indicators simultaneously after adjusting for all covariates, with the cut off for statistical significance of $p<0.008$ used to account for multiple testing. Processing speed, attention and executive function were statistically significantly poorer among participants with slow gait speed. Executive function was also lower in participants with poor grip strength. Objectively measured memory and self-rated memory were not statistically significantly associated with any specific frailty indicator at the $p<0.008$ level (see Table 7). Weight loss and low levels of physical activity were not independently associated with any cognitive domain.

Discussion

Middle aged and older participants of a large population-representative sample who are pre-frail or frail have statistically significantly poorer performance across multiple domains of cognitive function compared to their robust peers, after adjusting for age, gender, educational attainment, chronic conditions, number of medications and excluding those with stroke, severe cognitive impairment and anti-depressant use. While the absolute difference in mean cognitive function between the groups after adjusting for confounders is small, the dose-response relationship between increasing levels of frailty and lower cognitive function supports the association, and small differences in cognitive scores could be considered substantial with respect to the variability of cognitive tests in this population. For instance, while the absolute differences in global test scores between the frail and robust participants are small in clinical terms (around one point in each case), they represent changes of around 0.4 standard deviations with respect to the distribution of scores in this relatively young and healthy population.

We also conducted this analysis stratifying by age group (50-64, 65-74, 75+) which suggested that attention may be associated with frailty only in those over 75 while memory may be associated with frailty only in those aged 50-65, however the numbers of frail participants in these groups were small and so the results should be interpreted with caution. Individual indicators of frailty are also independently associated with cognitive function across different domains. Processing speed, executive function and attention are associated with weak grip strength and slow walking speed but memory and self-rated memory are not independently associated with the indicators of frailty after adjustment for chronic conditions and medication.

Our findings contradict some previous studies suggesting that frailty is not significantly associated with poor memory [152, 154, 186] but concur with findings from the Rush Memory and Ageing study which found that higher levels of frailty were associated with a faster rate of decline across all cognitive domains [162]. This discrepancy may have occurred due to the small or homogeneous samples in previous studies [152, 154, 186].

Previous work has suggested that only slow gait speed and weak grip strength were associated with increased risk of developing Mild Cognitive Impairment

(MCI) or non-AD dementia [162, 164]. Our results may support the latter findings to some extent as gait speed and grip strength were associated with lower executive function, one of the hallmark cognitive domains of non-AD dementia.

Several mechanisms have been suggested as mediators in the relationship between frailty and cognition. These include both biological and psychological factors including neuropathology, cardiovascular disease, inflammation, hormonal changes, nutrition, social isolation and social vulnerability [128]. A recent review by our group on the topic of cognitive impairment and frailty developed a hypothetical model outlining how these mechanisms interact with each other to influence the cycle of frailty and cognition [128]. Our results in this paper suggest that the model could be further refined to include specific cognitive domains becoming impaired at different parts of the model and at different ages, for example, slow walking speed may be indicative of lower executive function specifically. This is interesting in light of previous work on gait speed and cognition which found that both were associated with smaller volume of the prefrontal area of the brain [236]. It is possible that the aetiology behind frailty and cognitive decline may differ depending on which indicators of frailty are present.

The strength of this study lies in its comprehensive, nurse-led health assessment which includes an extensive battery of cognitive tests and objective assessments of both gait speed and grip strength. The current body of knowledge on the link between frailty and specific cognitive domains is limited to a small number of studies [128]. The main limitation is the cross-sectional nature of the data, which limits the scope for causal inference. Nevertheless, understanding cross-sectional associations between frailty and cognitive function is important for understanding the challenges of managing each syndrome. The lack of a gold standard for calculating frailty is a problem common to all studies; however, we applied a definition very close to the original phenotypic definition of frailty. Conceptually separating the frailty syndrome from the indicators used to define it is also difficult. We have shown that gait speed and grip strength are specifically associated with executive function, processing speed and attention and that those who are defined as frail have lower cognitive scores across most tests compared to those who are defined as pre-frail or robust, suggesting that frailty defined in this way is valid for the

purpose. Finally, the mean of this cohort is relatively young (mean age 61.8, range 50-93) and as such may not be representative of the patients who are regularly seen in geriatric clinics. Our cohort will be followed up over a number of years and future studies will determine the longitudinal outcomes of our pre-frail, frail and robust populations as they age.

In conclusion, in this cohort of individuals with a mean age in the early-60's, there were statistically significant, albeit small, differences in cognitive function between those who were robust, pre-frail, and frail as defined by Fried's definition and independent of age, gender, education, chronic conditions or medication use. Importantly, cognitive function is affected even in pre-frailty. Phenotypic frailty and cognitive function have a complex and probably interdependent relationship. Small absolute effects suggest that, although we controlled for a range of confounders, residual confounding is a possibility and that longitudinal data are needed to validate the association

Figure 2. Flow Chart of Participation.

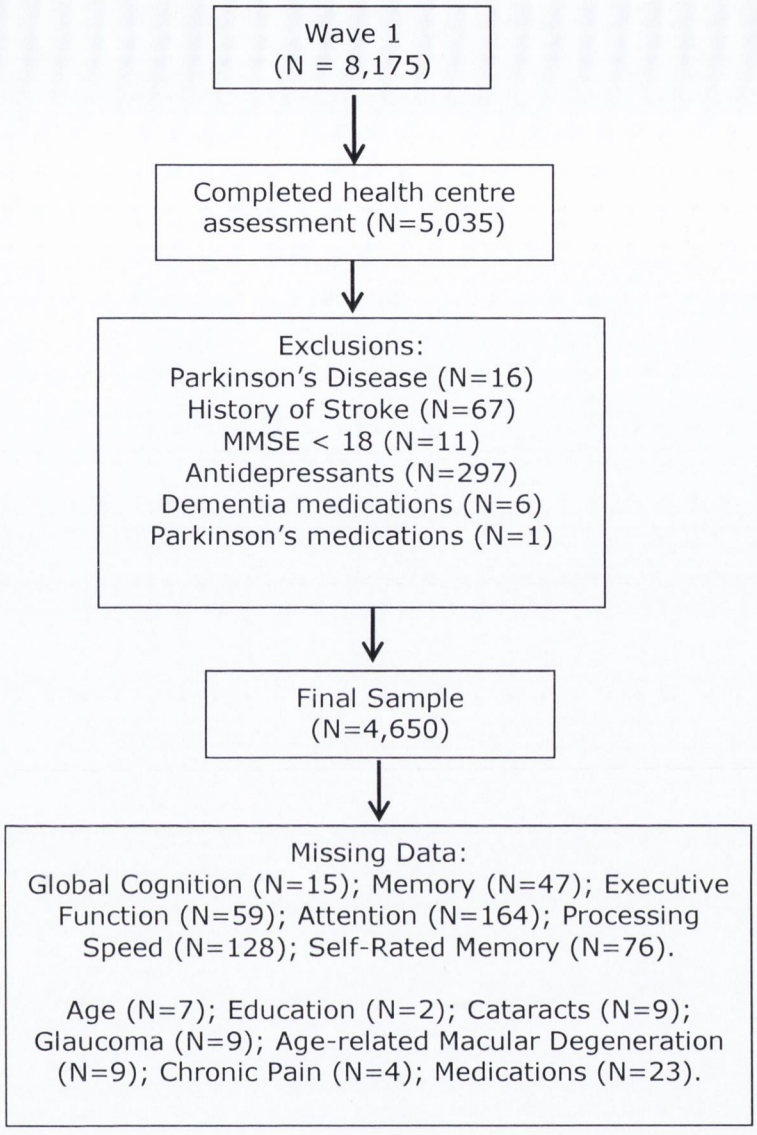


Table 5. Characteristics of non-frail, frail and robust community dwelling participants.

	Robust	**Pre-Frail**	**Frail**	**Total**
	N = 3115	**N = 1445**	**N = 90**	**N = 4650**
Age (mean ± SD)	60.7 (7.7)	63.8 (9.1)	69.3 (11.1)***	61.81 (8.4)
Female (%)	53.1%	53.9%	57.8%	53.5%
3rd Level Education (%)	39.3%	33.1%	18.9%***	36.9%
MMSE (mean ± SD)	28.8 (1.5)	28.4 (1.8)	27.6 (2.2)***	28.7 (1.7)
No. of Medications	1.8 (2.1)	2.8 (2.8)	5.1 (3.1)***	2.2 (2.4)

*** = $p < .001$. Statistical significance refers to difference in means between robust, pre-frail and frail participants as calculated using a one-way ANOVA.

Table 6. Sample Means and Adjusted Marginal Mean Scores for Individual Cognitive Measures Across Frailty Categories.

	Sample mean			Marginal mean		
Cognitive Test(range/unit)	**Robust (N=3115) Mean(SD)**	**Pre-Frail (N=1445) Mean(SD)**	**Frail (N=90) Mean(SD)**	**Robust (N=3115) Mean(SE)**	**Pre-Frail (N=1445) Mean(SE)**	**Frail (N=90) Mean(SE)**
Global Cognition						
MMSE(0-30)	28.8(1.5)	28.4(1.8)	27.6(2.2)	28.7(.03)	28.6(.04)***	28.0(.2)***
MoCA(0-30)	25.6(3.0)	24.7(3.5)	23.2(3.7)	25.5(.05)	24.9(.08)***	24.2(.4)***
Executive Function						
Vis. Reasoning(0-6)	3.2(1.3)	3.0(1.3)	2.5(1.3)	3.2(.02)	3.1(.03)*	2.8(.1)**
CTT B(seconds)	103.0(35.1)	115.9(42.5)	139.1(58.9)	105.7(.6)	111.4(.9)***	119.7(3.7)**
Verbal Fluency(NA)	12.6(5.0)	11.7(5.0)	9.8(4.5)	12.5(.08)	11.9(.1)***	10.7(.5)***
Memory						
Visual recall(0-6)	3.3(1.1)	3.2(1.1)	2.9(1.2)	3.3(.02)	3.2(.03)*	3.2(.1)
Vis. recognition(0-6)	5.7(.6)	5.6(.7)	5.5(.8)	5.7(.01)	5.6(.02)*	5.6(.07)
Immediate(0-10)	6.1(1.6)	5.8(1.6)	5.0(1.5)	6.1(.03)	5.9(.04)**	5.5(.2)***
Delayed(0-10)	6.5(2.2)	6.0(2.2)	4.9(2.2)	6.4(.04)	6.2(.05)**	5.6(.2)**
Self-Rated [a](0-5)	2.4(.9)	2.6(.9)	2.9(.9)	2.5(.02)	2.6(.02)***	2.8(.1)**
Attention						
CTT A(Secs)(NA)	51.4(20.7)	59.5(27.5)	78.6(43.2)	53.1(.4)	56.7(.6)***	66.7(2.3)**
SART Mean Time(NA)	370.3(95.5)	393.6(103.6)	428.8(105.5)	372.9(1.8)	388.9(2.6)***	410.7(10.9)**
SART Omission Errors(0-200)	5.9(8.1)	8.7(11.2)	13.5(16.3)	6.4(.2)	7.9(.2)***	10.2(1.0)*

SART Commission Errors(0-25)	3.4(3.5)	4.5(4.3)	5.6(4.6)	3.6(.07)	4.1(.1)***	4.2(.4)
Processing Speed						
CRT(ms)	489.9(91.6)	505.9(100.1)	550.3(134.3)	492.9(1.7)	500.2(2.5)*	529.2(10.4)*

a. Scores for self-rated memory correspond to 1 – excellent, 2- very good, 3 – good, 4 – fair, 5 – poor.

* $p < .05$, ** = $p < .01$, *** = $p < .001$. Stars indicate statistically significant differences from 'robust' group. Marginal means are estimated using a regression model and are standardised to the population average age, sex and educational attainment such that the confounding effect of these factors is removed.

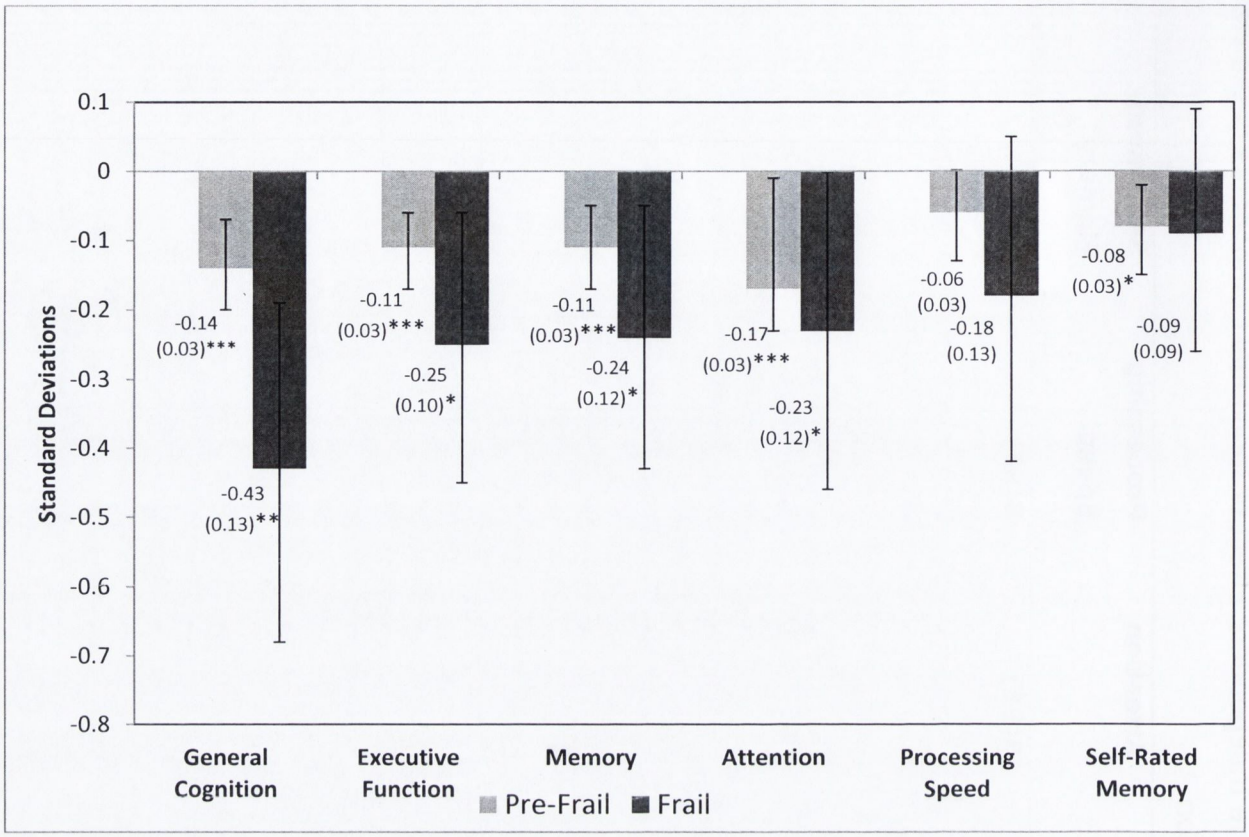
CRT = Cognitive Reaction Time. SART = Sustained Attention to Response Task. Higher scores indicate better cognitive function for all measures except the Color Trails Test, self-rated memory, SART mean time, SART errors and cognitive reaction time for which lower scores are better. MMSE = Mini Mental State Examination; MoCA = Montreal Cognitive Assessment; Vis. Reasoning = Visual Reasoning (CAMDEX); CTT = Color Trails Test; SART = Sustained Attention to Response Task.

Table 7. Results of Multivariate Linear Regressions Estimating the Independent Effect of Individual Components of the Frailty Syndrome on Standard Composite Domains of Cognitive Function.

	Global cognition	**Executive Function**	**Memory**	**Attention**	**Processing Speed**	**Self-Rated Memory**
	B(SE)	**B(SE)**	**B(SE)**	**B(SE)**	**B(SE)**	**B(SE)**
Exhaustion	**-.18 (.06)***	-.04 (.05)	-.14 (.06)	-.02 (.06)	-.02(.06)	-.13 (.06)
Weight Loss	-.07 (.06)	-.01 (.06)	-.02 (.06)	-.02 (.07)	.02 (.07)	.02 (.06)
Activity	-.08 (.04)	-.04 (.04)	-.09 (.04)	-.09 (.04)	-.01 (.04)	-.09 (.04)
Slow Gait	-.11 (.06)	**-.20 (.05)***	-.13 (.06)	**-.25 (.05)***	**-.16 (.06)***	.06 (.05)
Weak Grip	**-.26 (.06)***	**-.14 (.05)***	-.09 (.05)	-.14 (.05)	-.14 (.05)	-.09 (.05)

* = $p < .008$. Adjusted for age, age-squared, gender, level of education, chronic conditions and no. of medications. B = Beta Coefficient; SE = Standard Error. Beta coefficients (with standard errors) indicate the independent effect of each frailty indicator on each cognitive domain. For example, individuals with self-reported 'exhaustion' score 0.18 standard deviations less on tests of global cognitive function after other frailty indicators are taken into account.

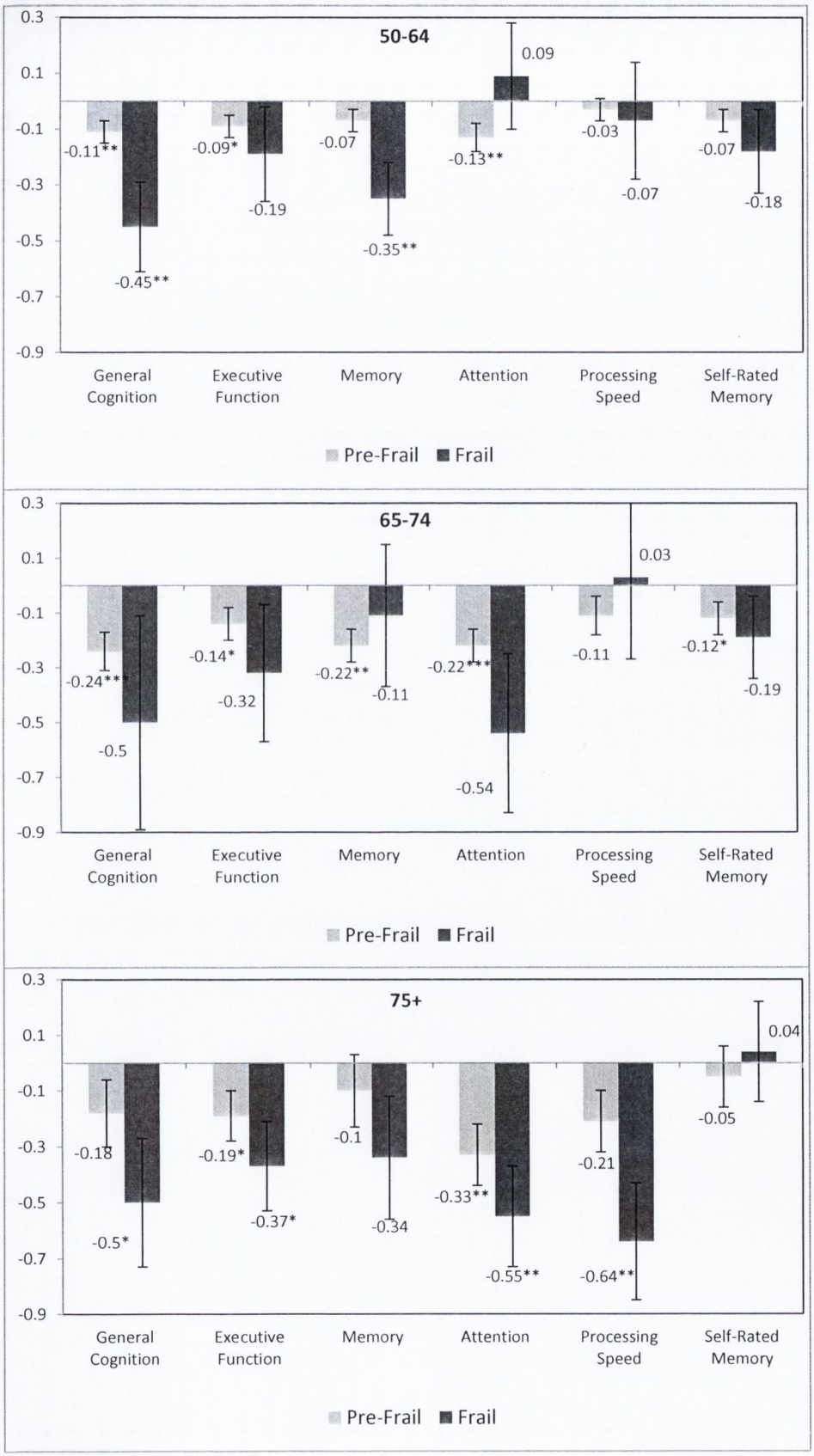
Figure 3. The Relationship Between Pre-Frailty, Frailty and Cognitive Function.



* = $p < .05$, ** = $p < .001$, *** = $p < .001$. Results of a multivariate linear regression adjusted for age, age-squared, gender, level of education, chronic conditions and no. of medications. Showing beta coefficient (standard error) and 95% confidence intervals. Robust group compared to pre-frail and frail. Z-scores are standardised such that the mean domain score among robust individuals is zero, with the score indicating the difference in terms of standard deviation of composite cognitive domain scores. For example, frail individuals score 0.43 standard deviations less than robust individuals on global cognitive tests, after adjusting for covariates.

Appendix

Figure 4. The Relationship Between Frailty and Cognitive Function by Age Group.

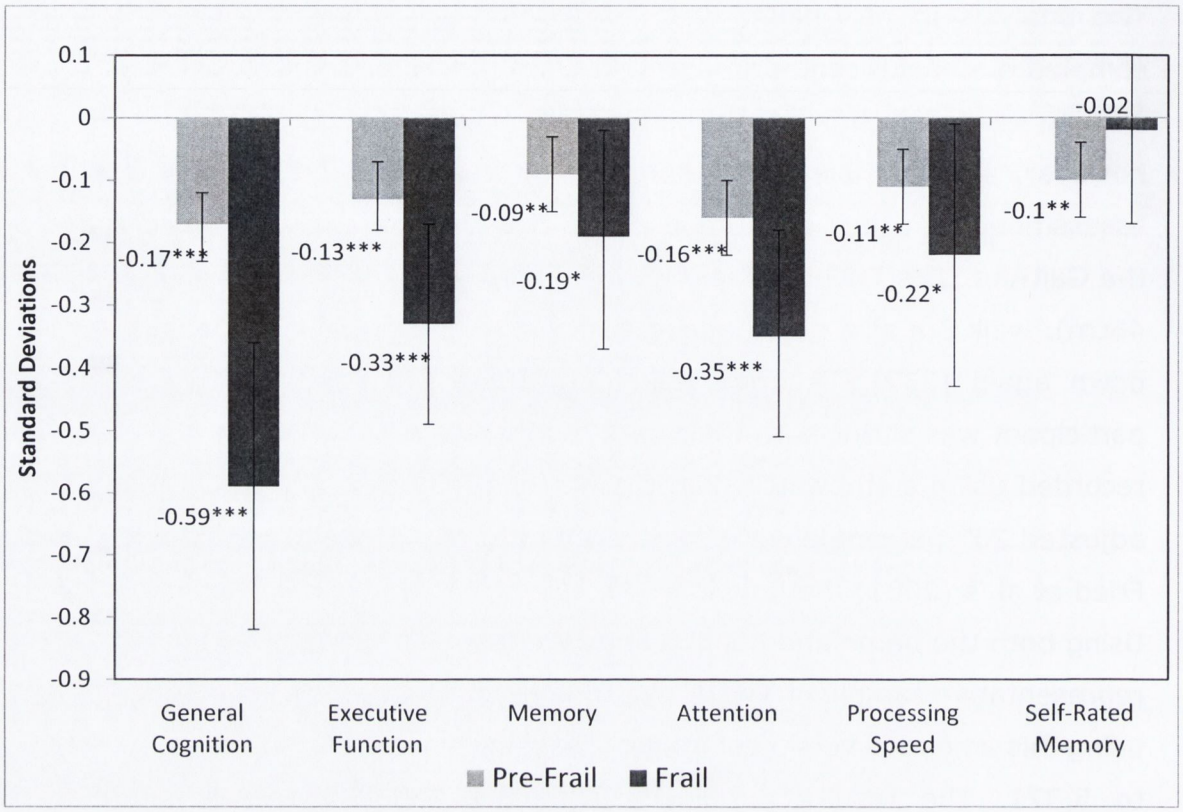


* = $p < .05$, ** = $p < .001$, *** = $p < .001$. Results of multivariate linear regression adjusted for age, age-squared, gender, level of education, chronic conditions and no. of medications. Showing beta coefficient (standard error). Robust group compared to pre-frail and frail. Z-scores are standardised such that the mean domain score among robust individuals is zero, with the score indicating the difference in terms of standard deviations. For example, frail individuals score 0.43 standard deviations less than robust individuals on global cognition.

Update

The analysis in this paper was carried out only on participants who had completed a health centre assessment as this included the GaitRite measure of walking speed which is one of the five components of the frailty measure. It is, however, also possible to assess frailty in those who had completed a home assessment with the substitution of the Timed Up and Go (TUG) measure for the GaitRite. The TUG tasks asks participants to rise from a chair (seat height 46cm), walk 3m at a normal pace, turn around, walk back to the chair and sit down again [237]. The time taken from the command "Go" to when the participant was sitting with their back resting against the back of the chair was recorded using a stopwatch. Participants who fell below the gender and height adjusted 20th percentile were considered to have slow gait speed as defined by Fried et al.'s (2001) methodology. All other frailty measures remain the same. Using both the home and health centre assessment allows us to assess a more representative sample of TILDA. We thus reran the analysis from paper 1 again using this amended version of frailty. The sample size thus increased from 4,650 to 5,371. The results remained unchanged for all variables aside from processing speed which, in this analysis, was significantly associated with pre-frailty and frailty. We have included these results in the figure below.

Figure 5. The Relationship Between Pre-Frailty, Frailty and Cognitive Function in the Home and Health Centre Assessment Sample.



* = $p < .05$, ** = $p < .001$, *** = $p < .001$. Results of a multivariate linear regression adjusted for age, age-squared, gender, level of education, chronic conditions and no. of medications. Showing beta coefficient (standard error) and 95% confidence intervals. Robust group compared to pre-frail and frail. Z-scores are standardised such that the mean domain score among robust individuals is zero, with the score indicating the difference in terms of standard deviation of composite cognitive domain scores

Introduction to Paper 2

The second introductory chapter of this thesis reviewed the evidence for an association between perceptions of ageing and health. There is sufficient evidence to suggest that negative perceptions of ageing may have an independent effect on physical function, however, most studies on this topic thus far have used self-reported measures rather than objective measures of function. As these are subjective assessments they are liable to the criticism that perceptions of ageing merely affect perceptions of function with no evidence that actual function is affected. For example, someone who holds negative perceptions of ageing who is asked the question "could you climb a flight of stairs easily" may answer no because when they climb stairs they feel out of breath and attribute this to age. Someone with more positive perceptions of ageing, however, may attribute the breathlessness to being slightly unfit rather than to age and answer that they are able to climb the same stairs.

The purpose of the following study was therefore to investigate whether perceptions of ageing show any longitudinal association with objective physical function. I used the Timed Up and Go (TUG) task in this study which is also an appropriate proxy measure for frailty. I could not use the full frailty measure due to the unreliability of some of the components (grip strength and physical activity) when assessed in wave 2 which made it unfeasible to compare frailty in wave 1 to frailty in wave 2 [238, 239]. However, the TUG task has previously been found to be a good proxy for the Fried frailty measure [240]. Furthermore, the Fried criteria contain a number of self-reported elements (exhaustion, physical activity and weight loss) thus using the TUG task instead of frailty allows us to assess the impact of perceptions of ageing on an objective measure of physical function. Previous longitudinal studies have not had access to the broad range of objective health measures which we have in TILDA, nor have they had repeated measurements of these. I thus aimed to assess the relationship between perceptions of ageing and objective physical function while controlling for baseline health factors and for changes in health status between waves.

This paper is accepted for publication in PLOS ONE [241].

Paper 2: Negative Perceptions of Ageing and Decline in Walking Speed: A Self-Fulfilling Prophecy

Abstract

Introduction

Walking speed is a meaningful marker of physical function in the ageing population. While it is a primarily physical measure, experimental studies have shown that merely priming older adults with negative stereotypes about ageing results in immediate declines in objective walking speed. What is not clear is whether this is a temporary experimental effect or whether negative ageing stereotypes have detrimental effects on long term objective health. We sought to explore the association between baseline negative perceptions of ageing in the general population and objective walking speed 2 years later.

Method

4,803 participations were assessed over 2 waves of The Irish Longitudinal Study on Ageing (TILDA), a prospective, population representative study of adults aged 50+ in the Republic of Ireland. Wave 1 measures – which included the Aging Perceptions Questionnaire (APQ), walking speed and all covariates - were taken between 2009 and 2011. Wave 2 measures – which included a second measurement of walking speed and covariates - were collected 2 years later between March and December 2012. Walking speed was measured as the number of seconds to complete the Timed Up-And-Go (TUG) task. Participations with a history of stroke, Parkinson's disease or an MMSE < 18 were excluded.

Results

After full adjustment for all covariates (age, gender, level of education, disability, chronic conditions, medications, global cognition and baseline TUG) negative perceptions of ageing at baseline were associated with slower TUG speed 2 years later (B=.03, 95% CI = .01 to 05, p< .01).

Conclusions

Walking speed has previously been considered to be a consequence of physical decline but these results highlight the direct role of psychological state in

predicting an objective ageing outcome. Negative perceptions about ageing are a, potentially modifiable, risk factor for some elements of physical decline in ageing.

Introduction

"The true evil of old age is not the weakening of the body, but the indifference of the soul."

André Maurois An Art of Living [242]

Walking speed is a simple but meaningful marker of adverse outcomes in ageing. Previous work has shown that adults who experience a significant decline in walking speed over just 2 years have a 90% increased risk of mortality, while slow walking speed can also predict future hospitalisation and disability [243, 244]. Current models describe the association between walking speed and adverse outcomes in ageing as a reflection of advancing sarcopenia, increased inflammatory processes or chronic disease leading to death [243, 245]. There is, however, an increasing body of research suggesting that how people think about ageing can affect how they age.

Ageing is an automatic category by which humans naturally define each other. Along with other automatic categories, such as race and gender, it is subject to group biases such that humans in one age, race or gender group define those in other groups more negatively than those in their own group. The negative beliefs about other groups are referred to as stereotypes. Unlike race and gender, however, age is not a stable category but rather humans are part of different age cohorts throughout life. How, so, do people reconcile the negative stereotypes elicited about older age groups when they are younger with their own experiences when they themselves become part of an older age cohort? Becca Levy proposes that these negative stereotypes do not change or disappear but become internalised such that people who held negative stereotypes about older people when they were younger hold those beliefs to be true to themselves as they age [22]. Negative stereotypes originally held about other people therefore become negative self-perceptions of ageing in later life. Further work may explain the cognitive mechanism behind this as older adults who are either primed with negative stereotypes about ageing, or who already hold implicit negative views of ageing, show decreased self-perception, in the form of self-esteem, when reminded of the similarities between themselves and other older adults [21].

Unsurprisingly, a number of studies have illustrated the negative effects of holding negative perceptions of ageing on factors of psychological well-being including life satisfaction and mood [21, 61, 64]. Interestingly, however, a growing body of research is indicating that negative ageing perceptions may not only affect psychological well-being as people age but also physical health. A number of studies have shown that holding negative perceptions of ageing at baseline are associated with a decrease in self-reported performance in activities of daily living (ADLs), increased number of illnesses, decreased self-reported physical function, self-rated health and increased risk of mortality [58, 59, 61-64]. Aside from mortality and illness, however, these outcomes are self-reported, subjective assessments of function which may be confounded by the subjective nature of perceptions of ageing. One more recent study showed that older adults with negative perceptions of ageing exhibited decline in a composite measure of objective physical function over 16 years [88].

We sought to expand upon the work of Sargent-Cox and colleagues by investigating whether specific aspects of perceptions of ageing are associated with decline in a physical health measure. Perceptions of ageing encompass a range of cognitions including emotional responses to ageing, feelings of control, and expectations for health, behavioural or social changes. The studies to date have used uni-dimensional measures of ageing perceptions which encompass these cognitions within the scale but which cannot separate the components to examine their independent effects on health. We thus investigated the impact of perceptions of ageing using the short form of the Aging Perceptions Questionnaire (B-APQ) which includes 5 domains: the saliency of ageing in one's thoughts, emotional reactions to ageing, expectations for positive consequences, feelings of control and expectations for negative consequences.

In addition, we used a specific and simple measure of walking speed that it is commonly used in clinical settings. The Timed Up-And-Go task is a strong correlate of frailty which is a state of vulnerability to stressors and one of the biggest predictors of disability, hospitalisation and nursing home admission in older adults [237, 240]. We thus sought to investigate which of the five domains of ageing perceptions encompassed within the B-APQ could predict longitudinal decline in performance on the TUG task in a population representative sample of older adults. We hypothesised that negative emotional responses to ageing,

feelings of lack of control and negative expectations would predict decline in performance while positive responses and feelings of control would be protective. We did not make a directional hypothesis for the saliency of ageing related thoughts.

Methods

Sample

The Irish Longitudinal Study on Ageing (TILDA) is a large prospective cohort study of the social, economic and health circumstances of community-dwelling older people in Ireland. Analyses are based on the first wave of data collected between January 2009 and July 2011 and follow-up data collected between March and December 2012. The mean time difference between interviews was 744.12 days (24 months) (inter-quartile range = 114). The Irish Geodirectory - a listing of all residential addresses in the Republic of Ireland - was used as a sampling frame to randomly select households in which individuals aged 50+ lived. The full procedure has been described in detail elsewhere [218]. Household residents aged 50 or over and their spouses/partners (of any age) were eligible to participate in the study. The response rate was 62% leading to a final sample size of 8,504 participants. Ethical approval was obtained from the Trinity College Dublin Research Ethics Committee and all participants provided written informed consent.

The study design has been described in detail elsewhere [218]. Briefly, data collection involved (i) a computer-assisted personal interview (CAPI) carried out by trained social interviewers that included detailed questions on socio-demographics, wealth, health, lifestyle, social support and participation and use of health and social care (ii) a self-completion questionnaire which included questions about perceptions of ageing, social networks and social participation (iii) a health assessment carried out by research nurses. Participants who were unwilling or unable to attend a health assessment in a designated health centre were offered a home-based health assessment. In wave 2 the computer-assisted personal interview and key elements of the health assessment were combined into a home interview and assessment carried out by trained interviewers.

In total, 8,175 individuals aged 50 years and over were interviewed at baseline (N=8,504 includes partners younger than 50) and 5,895 (72%) of these individuals also completed a health assessment. Follow up data for wave 2 was available for 6,995 (86%) participants of which 78 (.01%) were proxy interviews and were thus not included in the sample for this analysis. Follow up data was unavailable for 1,180 (14%) participants due to death (N=205); refusal (N=809) or no contact (N=166). We also had a number of missing data values which are outlined in table 9. Exclusion criteria for the present analysis included a doctor's diagnosis of Parkinson's disease (N=35), a history of stroke (N=91) or an MMSE of < 18 (N=20) at baseline or between waves 1 and 2. Our final sample included participants who had completed both a wave 1 health assessment and a wave 2 follow up, who had returned the self-completion questionnaire and who did not meet any of the exclusion criteria. The final sample size was 4,803 (for a flow chart of sample selection see Figure 6).

Data Collection

Covariates

All covariates were measured at baseline and at wave 2. Longitudinal analyses controlled for change in covariates between waves.

Age, gender, employment and education were obtained by self-report. Education was categorised as having completed some or all of primary schooling, having completed some or all of secondary schooling or having completed any third level education or higher.

Global cognition was assessed using the Mini Mental State Examination (MMSE) [230]. Chronic conditions were ascertained by self-report of a doctor's diagnosis and included: joint problems, cataracts, glaucoma, age-related macular degeneration, lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson's disease, peptic ulcer, liver disease, varicose ulcer, alcohol or substance abuse and chronic pain. Number of chronic conditions were included in this analysis. Basic and instrumental activities of daily living (ADLs and IADLs) were collected through self-report. Participants were asked "Because of a health or memory problem, do you have any difficulty doing any of the activities on this card?" They were then shown a card listing 6 basic ADLs including dressing, walking

across a room, bathing or showering, eating, getting in and out of bed and using the toilet. An ADL disability was defined as difficulty in at least one of the activities listed on the card. Participants were then asked the same question and given a second card listing instrumental ADLs (IADLs) including preparing a hot meal, doing household chores, shopping for groceries, making telephone calls, taking medications and managing money. An IADL disability was defined as difficulty in at least one of these tasks. The level of disability with each activity was not assessed. For cross-sectional analyses participants were classified into 4 categories: no disability, ADL only, IADL only or both ADL and IADL. For longitudinal analyses we assessed change in disability between waves. Due to the small numbers in groups when change in disability was categorised into both ADLs and IADLs we collated the information and assessed 4 levels: no disability in wave 1 or wave 2, stable level of disability in wave 2, reduced level of disability since wave 1, any new disability in wave 2. Participants were also asked to record all of the medications taken on a regular basis and interviewers saw the packages to confirm. A continuous count of the different medications was used in this analysis as this reflects both the possible effects of medications themselves and underlying comorbidity.

Depressive mood was assessed through the 20 item Centre for Epidemiological Studies Depression Scale (CES-D)[246]. Cronbach's alpha for the 20 items in this sample showed good internal consistency (α=0.87). Self-rated health was assessed with the question: "In general, compared to other people your age, would you say your health is...excellent, very good, good, fair or poor?" Participants were also asked if they were past or current smokers.

Timed Up-and-Go

The Timed Up-and-Go (TUG) task was measured in both waves. Participants were asked to rise from a chair (seat height 46cm), walk 3m at a normal pace, turn around, walk back to the chair and sit down again [237]. The time taken from the command "Go" to when the participant was sitting with their back resting against the back of the chair was recorded using a stopwatch. TUG was assessed using the same procedure in the home assessment and in wave 2. Researchers in the home assessments in wave 2 sought and conducted the test using a hard-backed chair that matched the health centre chair as closely as possible in height (46cm). TUG is a measure of walking speed, balance and

coordination [237]. It is strongly correlated with measures of gait speed and predicts the same health outcomes in later life including global health, disability and falls [237, 247]. In TILDA time taken to complete the TUG measure is strongly correlated with gait speed as assessed using the GAITRite portable electronic walkway system (CIR Systems Inc, Havertown, PA) (spearman's rho = -0.75) [240]. The advantage of using TUG speed for this study was that the TUG measure was taken in both waves 1 and wave 2, therefore allowing us to assess changes in TUG speed, while gait speed using the GAITRite system was only assessed in wave 1. Higher scores on the TUG task (in seconds) indicate slower walking speed.

Aging perceptions Questionnaire (B-APQ)

The short form of the Aging Perceptions Questionnaire (B-APQ) comprises 17 Likert scale items that ask participants to rate their level of agreement with questions about the ageing experience and their expectations about ageing in the future. The model was based on Leventhal's self-regulation model of ill health which proposes that the way people think about their own health or illness can be categorised into different themes [248]. The questions are categorised into 5 domains: timeline (e.g. "I am conscious of getting older all of the time"); positive consequences (e.g. "As I get older I continue to grow as a person"); positive control (e.g. "As I get older there is much I can do to maintain my independence"); negative consequences and control (e.g. "Slowing down with age is not something I can control"); and emotional representations (e.g. "I get depressed when I think about getting older") [249]. Participants rated their level of agreement with each statement as strongly disagree, disagree, neither, agree or strongly agree (range 1-5). The score for each of the five domains was calculated as the average rating of questions within each domain. Cronbach's alpha showed good internal consistency for each of the domains (Timeline α = 0.75; Positive Control α = 0.85; Negative Control and Consequences α = 0.80; Positive Consequences α = 0.77; Emotional Representations α = 0.75).

Statistical Analysis

Descriptive statistics were first ascertained for all main variables. TUG time had a skewed distribution which was best corrected with a log transformation.

Rather than conducting the analysis on a log-transformed TUG variable, which would have provided output only in the log scale, we conducted a linear regression analysis with a link log function as this allows the predictor to act on the log of the outcome variable while providing marginal mean output in the original scale. This allows for easier interpretation of results.

To test the effect of ageing perceptions on change in TUG speed we estimated a second linear regression with follow-up TUG as the outcome, controlling for TUG at baseline as well as all baseline covariates and change in covariates between waves. To better understand the effect of ageing perceptions on TUG time we estimated and plotted marginal mean scores of the TUG for five points of the ageing perceptions scale (1, 2, 3, 4 and 5) which represent the level of agreement with the domain (1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree). Marginal means represent the mean in the outcome variable after accounting for the confounding effect of all variables which have been controlled for in the model.

Attrition weights were used due to differences between respondents who participated in both wave 1 and 2 and respondents who participated only in wave 1 on key variables (see Table 9). Attrition weights were calculated as the inverse of the probability that the respondent participated in wave 2 given their participation in wave 1 and their survival up to wave 2. We calculated this using logistic regression in which the dependent variable was whether a respondent had returned in wave 2 or dropped out of the study and the independent variables were multiple measures taken at baseline to try to explain the probability of attrition including measures of baseline mood, cognitive function, physical health, health behaviours and sociodemographic factors. This is multiplied by an initial inverse probability weight reflecting the probability that a member of the Irish population aged 50 years and older participated in the study. This method has previously been reported as an appropriate strategy to minimise bias due to attrition in survey data [250].

Sensitivity Analyses

We conducted a number of sensitivity analyses to check the validity of our findings. We had small numbers of missing data in our outcome and covariate

variables (<1%) but around 5% of cases for the APQ domains were missing (for numbers (see Figure 6). We thus imputed the missing APQ scores using multiple chained imputations. The imputed scores were calculated based on non-missing APQ questions, TUG speed, age, sex and disability.

As a further sensitivity analysis we conducted two further regression analyses which accounted for residual confounding due to measurement error in the baseline TUG measure. Controlling for baseline measures in regression is known to be difficult due to the day-to-day variation within people when taking measures such as walking speed [172]. For the first check we assessed measurement error of the TUG using a second dataset - the Irish data for the Study of Health, Ageing and Retirement in Europe (SHARE) data – which has been described in detail elsewhere [251]. This sample included 77 participants who had 2 TUG measures taken with a median lag between assessments of 88 days (IQR 70-104). We then estimated a linear regression using the covariant measurement error (cme) package in Stata 12.1 which estimates the effect of the independent variable on the dependent variable after accounting for the known measurement error of the dependent variable [252]. As there was a 2-6 month gap in measures in the SHARE data we could not control for the possibility that true changes in health accounted for some of the changes in TUG measures rather than purely measurement error. A previous study found that test-retest reliability for the TUG in a sample similar to ours was .97 when the measures were taken within the same day [253]. We thus conducted a second analysis in which we used errors-in-variables regression (EIVREG in Stata V12.1) which is a similar analysis to the covariant measurement error package but which allows input of previous report test-retest reliability coefficients. It has previously been reported to be an appropriate method of analyses of this kind [172].

Finally, we conducted a regression analysis using a change score of TUG time between wave 1 and wave 2 as the dependent variable, both as a sensitivity analysis and in order to calculate marginal mean change in TUG adjusted for all covariates. We conducted a number of further sensitivity analyses including adjustment for type as well as number of chronic conditions and medication. All statistical analyses were conducted using Stata version 12.1.

Results

Of 5,895 participants who had completed a health assessment and returned in wave 1, 4,944 also completed self-completion questionnaire in wave 1 and a health assessment in wave 2. After exclusion criteria had been implemented final sample size was 4,803 as illustrated by Figure 6. Also included is the number of missing data values for each variable. Mean baseline age of this sample was 62.8 (9.0) years, 54.6% of the sample were female and 35.1% had a third level education. Mean TUG speed in wave 1 was 8.9 (3.0) seconds and 2 years later, in wave 2, was 9.8 (3.9) seconds. Full demographic details are presented in table 9 including the difference in key variables between participants who returned for wave 2 (N=4,803), those who died between waves (N=205) and those who were not followed up due to refusal to participate (N=809) or inability to contact them (N=166). Table 8 illustrates the bivariate correlations between individual domains of the B-APQ and continuous variables.

Table 10 shows the results of the cross-sectional analysis: model 1 indicates the association between the domains of perceptions of ageing and walking speed without adjustment for covariates; Model 2 indicates the relationship after adjusting for socio-demographic variables and Model 3 displays the results for the fully adjusted model. All five domains of ageing perceptions remained statistically significantly associated with walking speed after full adjustment. The *emotional representations* and *positive control* domains were associated with quicker time in the TUG (Emotional representations: B = -.01 (95% CI: -.02, -.0003); Positive control: B=-.01 (95% CI: -.02, -.001)). The *timeline* (B=.03 (95% CI: .02, .04)), *negative control and consequences* (B=.02 (95% CI: .01, .03)) and, surprisingly, the *positive consequences* (B=.01 (95% CI: .002, .02)) domains were associated with slower TUG times.

Table 11 shows the results of the longitudinal analysis. Model 1 indicates the association between the domains of perceptions of Ageing and walking speed without adjustment for covariates; Model 2 indicates the relationship after adjusting for socio-demographic variables and Model 3 displays the results for the fully adjusted model including change in covariates between waves. The only domain which was statistically significantly associated with change in walking speed was the *negative control and consequences* domain (B=.03 (95%

CI: .01, .05)) which was associated with an increase in time taken to complete the TUG task. Figure 7 displays the marginal mean scores in TUG time in wave 2 by five points along the scale. This represents a difference of approximately 1 second in time taken to complete the task between those who strongly disagreed with the *negative control and consequences* domain and those who strongly agreed with it. We also reran the analysis with change in TUG as the outcome variable which estimated a within-person marginal mean decline of 1.38 seconds (95% CI: .99, 1.76) over two years in those who strongly agreed with the domain versus a decline of .54 seconds (95% CI: .21, .87) for those who did not.

Finally, we ran a number of sensitivity analyses to check our results. We have included the results of these as supporting information. We imputed the missing data for the APQ questions and reran the analysis using the imputed scores. The results were unchanged– namely that the *negative control and consequences* domain was statistically significantly associated with slower TUG speed at wave 2 (B=.08 (95% CI: .03, .12) (Table 12). The marginal means indicated a slightly stronger relationship in the imputed model with participants who strongly disagreed with the domain taking an average of 8.27 seconds to complete the TUG task and adults who strongly agreed with the scale taking 11.18 seconds to complete. We have also included the results of the test-retest reliability and measurement error analyses in the appendix section, our findings remained unchanged. Finally, we re-ran all analyses adjusted for category rather than number of medications (specifically sedative load) and type rather than number of chronic conditions. These changes did not alter our findings and thus we have not presented the data here.

Discussion

Middle aged and older people who express stronger beliefs in the lack of control and negative consequences of ageing have a greater decline in walking speed over 2 years than those who do not. This relationship is not explained by baseline walking speed, age, gender, years of education, chronic disease, disability, medication, depressed mood, global cognition or changes in health status over the period. Furthermore, this effect is seen in a relatively healthy

cohort free of stroke, dementia and Parkinson's disease and with an average age of 62.8 years.

One previous study showed that general negative perceptions of ageing were associated with decline in objectively measured physical function [88]. Our work expands upon this study to suggest that it is specifically feelings of control and expectations for negative consequences in people's perceptions of ageing which affects decline in walking speed. The saliency of thoughts about ageing or the negative emotions associated with ageing beliefs do not appear to have an effect. This corroborates previous work by Levy and colleagues who found that the association between self-perceptions of ageing and self-reported physical function was partially mediated by perceived control [59]. There is a large body of literature which illustrates the influence of perceived control on health outcomes including cardiovascular disease, depression and functional abilities [70]. Some of the mechanisms thought to explain the relationship between perceived control and health include feelings of decreased self-efficacy, reduced health behaviours and increased stress reactivity [70]. As it appears from our work and Levy et al.'s previous study that control may play an important role in ageing perceptions, it is likely that some of the same mechanisms are at play. Here we outline two potential mechanisms which may explain why it is specifically the elements of control beliefs and expectations for negative consequences in ageing perceptions that appear to affect decline in objective physical function. We will discuss health behaviours, psychological responses including coping mechanisms and visual feedback.

Health Behaviours

Previous work has shown that those who blame 'old age' as the reason for a chronic condition over any other cause show a decrease in health maintenance behaviours such as having a nutritious diet, participating in exercise, visiting health professionals and getting consistent levels of sleep [116]. Stewart et al. suggested that as ageing is uncontrollable, those who blame their condition on old age also see their health as uncontrollable and thus do not act even when the action may be beneficial. Our results indicate that even in a relatively healthy cohort, and after controlling for the presence of chronic conditions, it is the control and expectations for negative consequences aspects of ageing

perceptions which affect physical function. It is thus possible that these are the same people who blame any health deficits on 'old age' and who are less likely to stay physical active, maintain a healthy diet and visit the doctor. Previous work on ageing perceptions has shown that adults with positive ageing perceptions engage in more exercise, have healthier diets and are more likely to take medications as prescribed than those with negative perceptions regardless of health status [111, 114]. These types of health behaviours are activities which are carried out through the lifespan and not just in older age. It seems unlikely, therefore, that people with negative perceptions of ageing make a conscious decision to stop engaging in health maintenance as soon as they reach a certain age. Instead, attentional and confirmatory biases likely reinforce negative perceptions as they age and result in a gradual removal from activities. Psychologically, humans work towards stability in their world view and will give more credence and attention to information which confirms an attitude than to information which disproves it [109]. Adults who have negative perceptions of ageing will therefore look for information which confirms that ageing is unpleasant. For example, an older adult who believes that severe physical decline is immediately inevitable will have an attentional bias towards the information which confirms this point of view. If they go for a walk and feel more tired than usual after it they will likely attribute this to 'old age' rather than considering alternative explanations such as a lack of sleep or a busy week. The negative response to the walk on this occasion may be taken as a sign that walking will always be unpleasant from now on and they will gradually disengage from the activity. As their sedentary behaviour will result in real threats to health, their negative beliefs will be confirmed and the behavioural risks will increase.

Psychological Factors and Coping Mechanisms

The pathway between negative perceptions of ageing and declining physical function may not be limited to behavioural explanations but also to psychological responses. We might have expected that the negative emotions elicited by holding negative perceptions of ageing would affect walking speed. After all, the effects of depression on walking speed are well documented [254, 255]. Surprisingly, however, although depressed mood was associated with decline in TUG performance, the effect of ageing perceptions remained significant after

controlling for depression. Furthermore, the emotional representations domain of the B-APQ was not statistically significantly associated with change in TUG in the longitudinal models.

Stress is a potential biological mediator of this effect. Feelings of a lack of control and expectations for negative events are individually associated with increased stress responses both psychologically and physiologically [70, 256]. When a stressful event occurs it activates the hypothalamic-pituitary-adrenal axis which results in spikes in cortisol secretion. Over-activity of this process and resulting sustained high levels of cortisol are damaging to muscle mass [95]. Thus older adults who believe that negative consequences are forthcoming and inevitable, and who believe that they have no control over events, likely experience increased stress and spikes in cortisol secretion which may reduce muscle mass as they age resulting in slower walking speed.

Control beliefs can take two forms: primary control is the belief that behaviours will generate desired effects while secondary control is the belief that one can shape one's cognitive, emotional or motivation responses to events in the environment [82]. Primary control decreases with age while secondary control increases [82]. Older adults become continuously better at shaping their response to the environment. These coping strategies include selecting and adapting relevant goals in the face of adverse change. For example, an older adult who used to go to the gym daily but who develops a serious illness which prevents them from going could either give up the goal of fitness or could adapt it such that they may aim to be able to walk up a flight of stairs once a day instead. Previous work has shown that older adults with positive perceptions of ageing are better at using these goal adaption strategies in the face of serious health events and have higher life satisfaction as a result [64]. Previous work has also shown that older adults primed with negative stereotypes about ageing are more likely to dissociate themselves from their peer group [20]. Although this protects self-esteem in the short-term it may also have damaging psychological effects as part of the identity is essentially rejected. Weiss and colleagues suggest that age dissociation may prevent people from reaching important developmental stages in older age such as advance preparation for potential adverse events [20]. This may be related to goal adaptation such that older adults who hold negative perceptions about ageing, and who dissociate

themselves from their age group as a result, may initially be less likely to prepare themselves for potential adverse events and then less willing to use goal adaptation strategies if adverse events do occur. We thus propose that those adults with positive perceptions of ageing are better able to use adaptive strategies to overcome difficulties and are therefore less likely to experience the surge in psychological and physiological stress responses that can affect physical function. It is curious that we did not see a protective effect of the positive control or positive consequences domains on walking speed considering there was a detrimental effect of negative control and consequences. Having examined the individual questions within the domains, however, we suspect that this may be due to the nature of the questions. The positive consequences domain includes statements such as "As I get older I get wiser" which may tap into a different construct than beliefs about physical decline. Similarly, the positive control domain is mostly constructed of questions about the quality of relationships (e.g. "The quality of my relationships with others in later life depends on me") which, particularly with close family and friends, may not be expected to decline merely due to age.

Visual Feedback

Finally, there may be a direct association between ageing perceptions and physical outcomes through a visual feedback system in the brain. A recent study found that dominant hand fatigue caused by performing repetitive dominant hand handgrips at maximal voluntary contraction levels was attenuated by looking at a mirror reflection of the non-dominant hand [38]. The participants thus perceived that the mirror reflection of their non-dominant hand was the dominant hand and falsely believed that their dominant hand was not fatigued [38]. This has interesting ramifications for our findings as there may be a similar process involved with our participants such that those who believe that they will inevitably become weaker and slower as they age truly become slower through this visual feedback system.

Strengths and Limitations

The strength of this study lies in its large, population representative sample and longitudinal data collection. The extent of the measures collected also allowed us to control for a large number of potential confounders which might otherwise

explain the association between ageing perceptions and physical outcomes, although it is possible that some unmeasured confounding remained. There was some attrition between waves and those who refused at wave 2 had slower walking speed and stronger beliefs in the negative perceptions of ageing than those who participated in both waves. However, we attempted to control for the confounding effects of this using attrition weights.

One potential limitation of our study is the missing data values spread across variables. These were small numbers for the majority of variables (for example N=1 for education and N=7 for age) but larger for the ageing perceptions domains. This is likely due to the nature of the self-completion questionnaire which respondents had to fill in and return to the study themselves. Missing data values were more likely in adults who were older, less educated and less physically able. These, however, are the same variables which the attrition weights attempt to control for and thus some bias due to missing values will have been removed while controlling for attrition although additional confounding may remain. We also imputed the missing data for the ageing perceptions domains based on multiple chained imputations but did not find any difference in our results. In fact, the results were slightly stronger in the multiple imputation model suggested that our original model may be conservative.

A second limitation is that we only had one measure of ageing perceptions at baseline and not at follow-up. This allowed us to assess the independent effect of ageing perceptions on TUG speed at wave 2 but not vice versa. It is thus still possible that there could be a reverse causality with an already declining walking speed prior to wave 1 affecting perceptions of ageing. We will, however, be taking measures of ageing perceptions in future waves of TILDA and thus will be able to update the analysis at a later date in order to assess the change in ageing perceptions against change in walking speed.

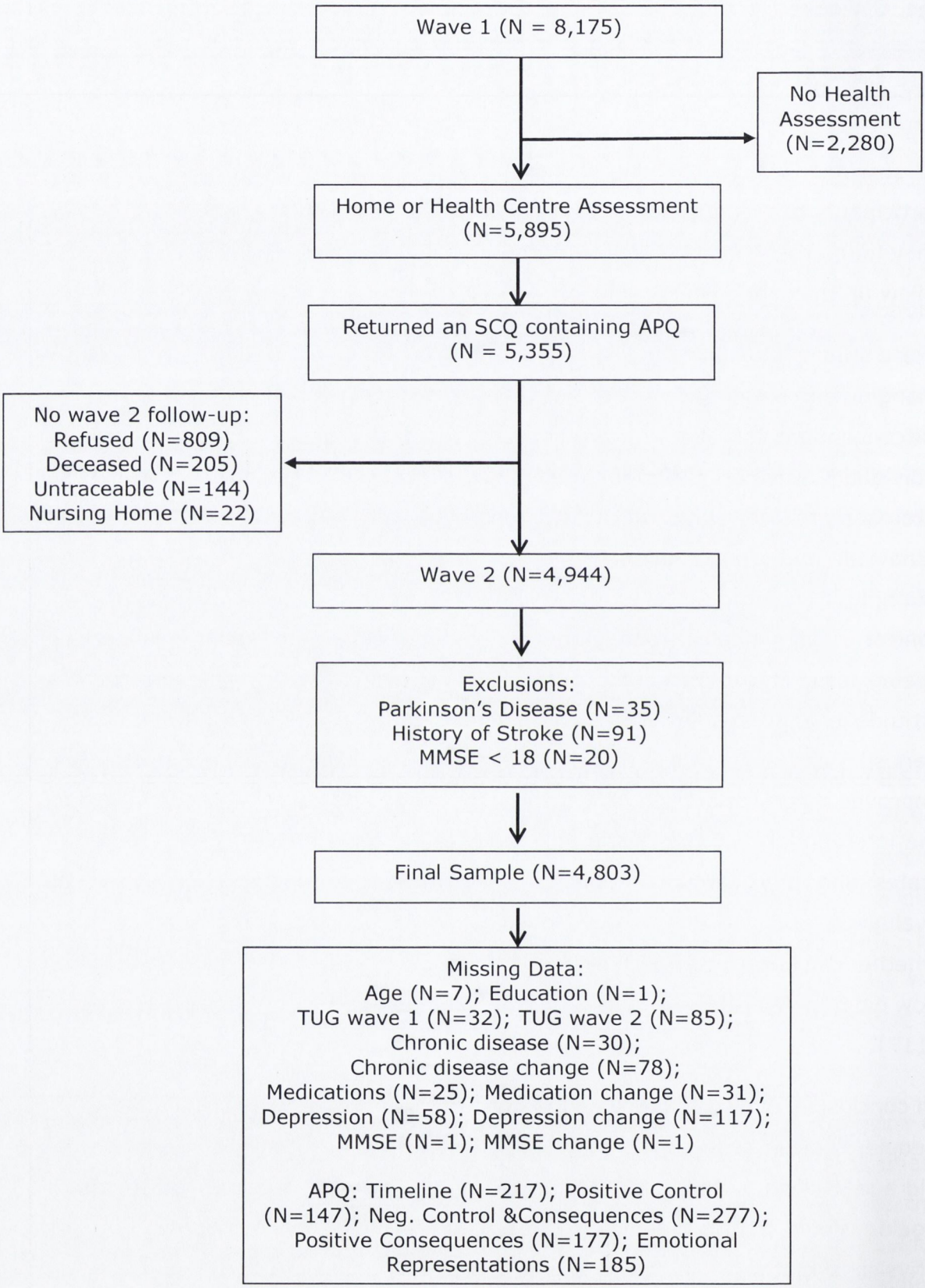
This study provides evidence for the damaging role of negative perceptions of Ageing on an objective health outcome and highlights the need for awareness of these potentially modifiable effects. Two previous studies have explored the possibility of changing attitudes towards ageing in order to change behaviour (in both cases physical activity). The first study included attribution retraining and physical activity classes in combination. Participants were taught that becoming sedentary is not an inevitable part of ageing and that failure to be

physically active should be attributed to controllable causes rather than to old age. 3 weeks after the intervention participants were walking more and had increased expectations for ageing [118]. The second study was a randomised controlled trial in which adults were categorised into a 'physical activity only' or a 'physical activity with views on ageing' group. The latter group were engaged in sessions which challenged misconceptions about ageing and taught participants to recognise and challenge their own automatic negative thoughts. They found that those in the latter group had higher rates of physical activity at follow up than those in the 'physical activity only' group [119].

These studies highlight the promising possibility of changing behaviour through changing perceptions of ageing. Both studies used a dual model in which general misconceptions of ageing were challenged at the same time as changing individual's attributions about their own experiences of ageing. It would be interesting to know which of these components were more effective in changing behaviour and what elements of perceptions of ageing they acted upon. For example, it would be interesting to know whether the participants felt more in control of their health, more hopeful about the future or just thought about ageing less. Future research could also explore whether the behaviour and attitude change results were long-lasting and what factors determine this. Sarkisian and colleagues, in the 2007 study, found that participants reported improved mood, decreased pain, improved energy and improved sleep following the intervention but they were only followed up for a further 3 weeks. Bodily states and physical perceptions are known to be important predictors of evaluation and attitude formation so it would be interesting to determine whether the improved bodily states of participants changed their experience of how old they felt and resulting in improved self-perceptions of ageing in general [117].

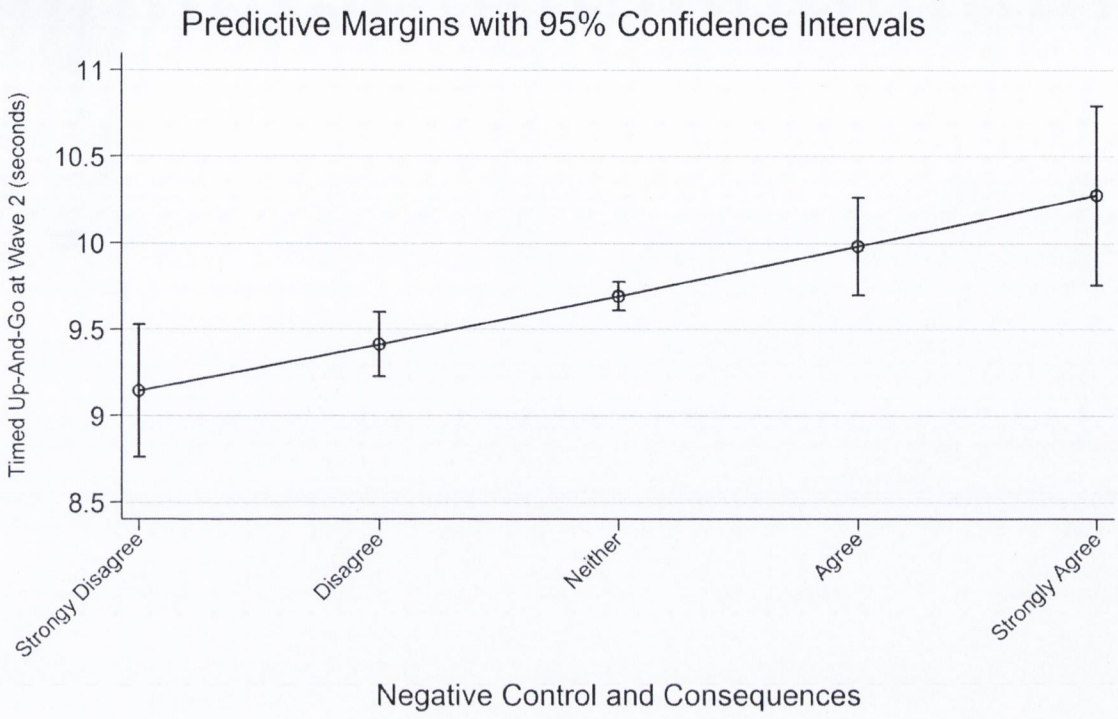
In conclusion, slow walking speed, a good marker of overall health among older people, is often seen as a physical, and sometimes inevitable, consequence of old age. Our study indicates that psychological factors, specifically attitudes to ageing, could play a significant role in determining the development of this physical symptom.

Figure 6. Flow Chart Indicating Participants Remaining From Waves 1 – 2.



SCQ = Self Completion Questionnaire; APQ = Aging Perceptions Questionnaire; MMSE = Mini Mental State Examination.

Figure 7. Marginal Mean Timed Up-And-Go in Seconds by Level of Agreement with the Negative Control and Consequences Domain of Ageing Perceptions.



Calculated from a linear regression model in which perceptions of ageing were the predictor variables and TUG at wave 2 was the outcome variable. Marginal means represent the mean TUG time in wave 2 after adjustment for all other confounders in the model. Error bars represent 95% Confidence Intervals.

Table 8. Bivariate Correlation Between Domains of the Short-Form Aging Perceptions Questionnaire and all continuous covariates.

	TC[a]	PC[a]	NCC[a]	PCq[a]	ER[a]	TUG time	Age	Chronic Disease	Medications	Depressed Mood
TC	1									
PC	-0.07***	1								
NCC	0.55***	-0.13***	1							
PCq	-0.05***	0.32***	-0.13***	1						
ER	0.50***	-0.07***	0.54***	-0.11***	1					
TUG time	0.24***	-0.10***	0.26***	-0.05***	0.13***	1				
Age	0.23***	-0.09***	0.32***	-0.11***	0.05***	0.42***	1			
Chronic disease	0.19***	-0.03*	0.25***	-0.03*	0.18***	0.28***	0.30***	1		
Medications	0.22***	-0.05***	0.26***	-0.07***	0.16***	0.31***	0.41***	0.45***	1	
Depressed Mood	0.22***	-0.03*	0.24***	-0.08***	0.34***	0.12***	-0.03*	0.23***	0.17***	1
MMSE	-0.18***	0.1***	-0.25***	0.06***	-0.12***	-0.29***	-0.32***	-0.12***	-0.18***	-0.08***

***p < .001, **p < .01, * p < .05. TC = Timeline Chronic; PC = Positive Control; NCC = Negative Control and Consequences; PCq = Positive Consequences; ER = Emotional Representations.

Table 9. Descriptive Statistics.

Variable (Possible Range)	Total Sample N=4803	Dead N = 205	Refused/No Follow Up N = 975
		Mean (SD) or %	
Age	62.8 (9.0)	73.9 (11.2)***	64.3 (10.2)***
Sex (female)	54.6% (N=2,624)	43.4% (N=89)**	55.8% (N=544)
Education (third level)	35.1% (N = 1,685)	16.2% (N=33)***	22.5% (N=219)***
TUG time 1	8.9 (3.0)	13.5 (7.1)***	9.5 (3.3)***
TUG time 2	9.8 (3.9)	NA	NA
No. of Chronic Diseases	1.4 (1.4)	2.0 (1.5)***	1.3 (1.4)
Disability			
No disability	90.03% (N=479)	66.3% (N=136)***	88.4% (N=862)***
IADL only	2.33% (N=112)	10.2% (N=21)	4.1% (N=40)
ADL only	5.00% (N=240)	5.4% (N=11)	3.7% (N=36)
IADL and ADL	2.64% (N=127)	18.1% (N=37)	3.8% (N=37)
No. of Medications	2.5 (2.6)	4.4 (3.3)***	2.4 (2.6)***
Depression (CES-D) (0-60)	8.0 (6.3)	7.1 (7.4)**	6.2 (7.7)**
MMSE (0-30)	28.5 (1.8)	26.1 (3.5)***	27.6 (2.8)***
Domains of APQ			
Timeline (0-5)	2.4 (.8)	2.9 (1.1)***	2.5 (.87)*
Positive Control (0-5)	4.0 (.6)	4.0 (.69)	3.8 (.77)***
Negative Control and Consequences (0-5)	2.8 (.7)	3.4 (.85)***	3.0 (.80)***
Positive Consequences (0-5)	3.8 (.7)	3.7 (.80)	3.7 (.72)***
Emotional (0-5)	2.3 (.8)	2.4 (.87)	2.4 (.83)*

Characteristics of total sample compared to participants who died following wave 1 and those who refused follow up.
***$p < .001$, **$p < .01$, * $p < .05$. Statistical significance was calculated using t-tests for continuous variables and chi-square tests for categorical variables.

Table 10. Cross-Sectional Relationship Between Perceptions of Ageing and TUG Time.[ab]

Timed Up and Go (seconds)	**Model 1**	**Model 2**	**Model 3**
	Coefficients and 95% Confidence Intervals		
Timeline	0.05***(0.04,0.06)	0.04***(0.03,0.04)	0.03***(0.02,0.04)
Positive Control	-0.02**(-0.03,-0.01)	-0.01*(-0.02,-0.00)	-0.01**(-0.02,-0.001)
Negative Control & Consequences	0.08***(0.07,0.09)	0.03***(0.02,0.04)	0.02***(0.01,0.03)
Positive Consequences	-0.0004(-0.01,0.01)	0.01(-0.0004,0.02)	0.01*(0.002, .02)
Emotional Representations	-0.03***(-0.04,-0.02)	-0.005(-0.01,0.005)	-0.01*(-0.02,-0.0003)
Age		0.01***(0.01,0.01)	0.01***(0.01,0.01)
Gender		0.01*(0.001,0.03)	0.01(-0.01,0.02)
Education			
Comparison: Primary			
Secondary		-0.03***(-0.05,-0.02)	-0.01(-0.02,0.01)
Third/higher		-0.06***(-0.07,-0.04)	-0.02*(-0.04,-0.00)
No. of chronic diseases			0.01***(0.01,0.02)
Disability			
Comparison: none			
IADL only			0.05*(0.01,0.08)
ADL only			0.09***(0.06,0.12)
IADL and ADL			0.28***(0.24,0.32)
No. of medications			0.01***(0.01,0.01)
Depressed mood			0.001*(0.0001,0.002)
MMSE			-0.01***(-0.02,-0.01)

Multivariate Regression Model with Coefficients and 95% Confidence Intervals Indicating Relationship between TUG speed and Perceptions of Ageing Cross-Sectionally.

[a] 95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

[b]ADL = Activities of Daily living; IADL = Instrumental Activities of Daily Living; MMSE = Mini-Mental State Examination.

Table 11. Longitudinal Relationship Between Perceptions of Ageing and TUG at Wave 2

Wave 2 TUG (seconds)	**Model 1**	**Model 2**	**Model 3**
	Coefficients and 95% Confidence Intervals		
Timeline	0.02(-0.004,0.04)	0.01(-0.01,0.03)	0.003(-0.02,0.02)
Positive Control	-0.05(-0.02,0.01)	0.001(-0.01,0.01)	0.001(-0.01,0.01)
Negative Control & Consequences	0.09***(0.06,0.12)	0.06***(0.03,0.09)	0.03*(0.01,0.05)
Positive Consequences	0.01(-0.02,0.03)	0.01(-0.01,0.03)	0.01(-0.01,0.02)
Emotional Representations	-0.03**(-0.06,-0.01)	-0.01(-0.04,0.01)	-0.01(-0.03,0.001)
Baseline TUG	0.05***(0.05,0.05)	0.05***(0.05,0.05)	0.05***(0.04,0.05)
Age		0.01***(0.003,0.01)	0.004***(0.003,0.01)
Gender		0.04**(0.01,0.06)	0.02*(0.005,0.04)
Education			
Comparison: Primary			
Secondary		-0.02(-0.06,0.01)	0.01(-0.02,0.04)
Third/higher		-0.02(-0.05,0.01)	0.01(-0.02,0.05)
Depressed Mood			0.001(-0.001,0.003)
Depressed Mood (change)			0.004**(0.001,0.01)
No. of chronic diseases			0.01*(0.002,0.03)
Change in chronic diseases			0.02**(0.01,0.04)
Disability			
Comparison: none			
Ongoing disability			0.23***(0.15,0.36)
Reduced disability			0.10**(0.03,0.14)
New disability			0.12**(0.04,0.19)
No. of medications			0.005(-0.002,0.01)
Medications (change)			0.005(-0.0001,0.01)
MMSE (baseline)			-0.02**(-0.02,-0.01)
MMSE (change)			-0.01(-0.02,0.0001)

Multivariate linear regression analysis indicating the relationship between baseline perceptions of Ageing and walking speed 2 years later.

[a] 95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[b] MMSE = Mini Mental State Examination

Appendix

Table 12. Multivariate linear regression analysis in which approximately 5% of APQ values have been imputed using multiple chained imputations. Indicates the relationship between ageing perceptions and walking speed 2 years later.

Wave 2 TUG (seconds)	**Model 1**	**Model 2**	**Model 3**
	Beta Coefficients and 95% Confidence Intervals		
Timeline	-.002 (-0.07,0.06)	-0.01 (-0.07,0.05)	-.02 (-0.05,0.01)
Positive Control	0.04 (-0.08,0.15)	0.04 (-0.08,0.15)	0.04 (-0.03,0.12)
Negative Control & Consequences	0.16*** (0.07,0.25)	0.11* (0.08,0.05)	0.08*** (0.03,0.12)
Positive Consequences	-0.02 (-0.08,0.04)	-.01 (-0.08,0.05)	-.02 (-0.06,0.02)
Emotional Representations	-0.003** (-0.07,-0.06)	-0.01 (-0.04,0.01)	-0.01 (-0.03,0.001)
Baseline TUG	0.02*** (0.01,0.04)	0.02*** (0.01,0.03)	0.02*** (0.01,0.03)
Age		0.01*** (0.004,0.01)	0.006*** (0.005,0.01)
Gender		0.08** (-0.01,0.16)	0.05* (0.01,0.08)
Education			
Comparison: Primary			
Secondary		-0.05 (-0.09,0.001)	-0.003 (-0.03,0.03)
Third/higher		-0.05** (-0.09,-0.02)	-0.003 (-0.04,0.03)
Depressed Mood			0.01** (0.004,0.02)
Depressed Mood (change)			0.01*** (0.005,0.02)
Chronic disease			0.01*(-0.00004,0.03)
Chronic disease (change)			0.003 (-0.02,0.03)
Disability			
Comparison: none			
Ongoing disability			-0.004 (-0.27,0.26)
Reduced disability			0.05* (0.003,0.10)
New disability			0.24*** (0.16,0.33)
No. of medications			0.007* (0.001,0.01)
No. of medications (change)			0.02** (.01,0.04)
MMSE (baseline)			-0.02** (-0.03,-0.01)
MMSE (change)			-0.03*** (-0.05,-0.01)

95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 13. Multivariate linear regression analysis indicating the relationship between baseline perceptions of ageing and walking speed 2 years later adjusted for test-retest reliability.[a]

Wave 2 TUG Go (seconds)	**Model 1**	**Model 2**	**Model 3**
	Beta Coefficients and 95% Confidence Intervals		
Timeline	-0.04 (-0.17,0.09)	-0.03 (-0.16,0.10)	-0.07 (-0.20,0.05)
Positive Control	0.01 (-0.13,0.16)	0.017 (-0.13,0.16)	0.03 (-0.11,0.17)
Negative Control & Consequences	0.42*** (0.27,0.57)	0.38*** (0.22,0.54)	0.20** (0.05,0.36)
Positive Consequences	0.06 (-0.07,0.20)	0.06 (-0.08,0.20)	0.03 (-0.10,0.16)
Emotional Representations	-0.01 (-0.15,0.13)	0.001 (-0.14,0.14)	-0.04 (-0.18,0.10)
Baseline TUG	1.05*** (1.01,1.09)	1.02*** (0.98,1.07)	0.98*** (0.93,1.02)
Age		0.02** (0.01,0.03)	0.01 (-0.00,0.02)
Gender		0.28** (0.10,0.45)	0.20* (0.02,0.37)
Education			
Comparison: Primary			
Secondary		-0.13 (-0.36,0.11)	0.10 (-0.13,0.33)
Third/higher		-0.07 (-0.31,0.17)	0.18 (-0.07,0.43)
Depressed Mood			0.03*** (0.02,0.05)
Depressed Mood (change)			0.05*** (0.03,0.06)
No. of chronic diseases			0.05 (-0.03,0.13)
No. of chronic diseases (change)			0.09 (-0.01,0.18)
Disability			
Comparison: none			
Ongoing disability			2.16***(1.60,2.73)
Reduced disability			0.28 (-0.08,0.65)
New disability			1.50*** (1.03,1.96)
No. of medications			0.0001 (-0.04,0.04)
No. of medications (change)			0.07** (0.02,0.12)
MMSE (baseline)			-0.14*** (-0.21,0.07)
MMSE (change)			-0.13*** (-0.20,0.07)

[a] Test-retest reliability = .97 taken from Steffen et al., 2002. 95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 14. Multivariate linear regression analysis indicating the relationship between baseline perceptions of Ageing and walking speed 2 years later adjusted for measurement error.[a]

Wave 2 TUG (seconds)	**Model 1**	**Model 2**	**Model 3**
	Beta Coefficients and 95% Confidence Intervals		
Timeline	-0.003(-0.01,0.01)	-0.002(-0.01,0.01)	-0.004(-0.01,0.00)
Positive Control	-0.004(-0.01,0.01)	-0.004(-0.01,0.01)	-0.004(-0.01,0.01)
Negative Control & Consequences	0.03***(0.02,0.04)	0.03***(0.02,0.04)	0.02**(0.01,0.03)
Positive Consequences	0.007(-0.00,0.02)	0.01(-0.00,0.02)	0.007(-0.00,0.02)
Emotional Representations	-0.001(-0.01,0.01)	0.002(-0.01,0.01)	-0.002(-0.01,0.01)
Baseline TUG	0.85***(0.81,0.88)	0.79***(0.75,0.83)	0.70***(0.66,0.75)
Age		0.002***(0.00,0.00)	0.002***(0.00,0.00)
Gender		0.02**(0.01,0.03)	0.01(-0.00,0.02)
Education		-0.01(-0.03,0.01)	0.007(-0.01,0.02)
Comparison:Primary			
Secondary		-0.01(-0.03,0.01)	0.009(-0.01,0.03)
Third/higher			0.002**(0.00,0.00)
Depressed Mood			0.003***(0.00,0.00)
Depressed Mood (change)			0.01*(0.00,0.01)
No. of chronic diseases			0.01*(0.00,0.01)
No. of chronic diseases (change)			0.18***(0.15,0.22)
Disability			0.03**(0.01,0.06)
Comparison: none			
Ongoing disability			0.09***(0.06,0.12)
Reduced disability			0.004**(0.00,0.01)
New disability			0.004*(0.00,0.01)
No. of medications			-0.01***(-0.01,-0.01)
Medications (change)			-0.01**(-0.01,-0.00)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.
a. Measurement error estimated as the within-person variance in TUG speed in 77 participants from the Study of Health, Ageing and Retirement in Europe.

Introduction to Paper 3

Having illustrated that negative perceptions of ageing are associated with longitudinal decline in physical function I now turn my attention to cognition. As the introductory chapter to this thesis illustrated, there is an abundance of experimental evidence illustrating that priming older adults with negative stereotypes about ageing results in immediate declines in cognitive function. It is not clear, however, whether this association persists longitudinally. Only one other study has examined perceptions of ageing and cognition longitudinally. Levy and colleagues found that holding negative perceptions of ageing at baseline was associated with decline in a visual memory score [257]. I sought to expand on this work with two improvements: Firstly, I wished to examine the association between perceptions of ageing and a number of cognitive domains. These included those which are most important for daily functioning such as executive function, prospective memory and verbal memory. Secondly, I wished to test this association while controlling for additional health factors which may confound the association. Levy and colleagues were able to control for baseline variables of gender, education, marital status, number of chronic conditions, race, self-rated health and depression scores over time. However there are a number of other important potential confounders which might otherwise explain an association between perceptions and cognition: cardiovascular factors are both life threatening - therefore possibly affecting perceptions of ageing – and damaging to cognitive function; medication use can affect both motivation and cognition; disability may be an indicator of unrecognised cognitive impairment; loneliness may be as a result of social isolation which is known to affect cognitive function. I also wished to control for changes in these factors longitudinally. This was an attempt to control for the possibility that, for example, a participant may feel ill at baseline and thus have resulting negative perceptions of ageing. They may not have been diagnosed by the time they were interviewed in wave 1 but by the next wave they may have a diagnosis of, for example, diabetes. The negative perceptions of ageing would thus be falsely attributed to causing cognitive decline which is really due to initially unrecognised diabetes or high blood pressure.

This paper is under review in Psychology and Aging.

Paper 3: Negative Perceptions of Ageing Predict Longitudinal Decline in Cognitive Function

Abstract

Older adults faced with negative stereotypes about ageing show significantly poorer performance on cognitive measures. The majority of studies in this area, however, have been short-term experimental studies. It is thus not clear whether negative perceptions about ageing have long-term effects on cognitive function. We explored the association between negative perceptions about ageing and cognitive function across a number of domains in a population representative sample of adults aged 50 and over. The sample was assessed twice over 2 years. Negative perceptions of ageing at baseline were independently associated with longitudinal decline in executive function, prospective memory and self-rated memory over a 2 year period after adjustment for physical and mental health. These findings suggest that negative perceptions of ageing play a role in cognitive decline in the older population. Furthermore, ageing perceptions may be a modifiable factor to target for future interventions to prevent or delay cognitive decline.

Introduction

Negative stereotypes about ageing are a widespread phenomenon of Western and other cultures [3]. The number of anti-ageism campaigns globally each year indicates the level of the problem with older adults likely to experience discrimination in healthcare, workplace, medical and social situations [30-32]. Like other types of stereotypes, ageing stereotypes are maintained by an in-group/out-group bias whereby the younger population see older adults as different or less capable. Ageing stereotypes, however, are different to other forms of group bias because the groups do not remain stable across the life course but rather younger people who hold stereotypes about older people will one day enter the older age cohort themselves.

For this reason, research in recent years has begun to focus on older adults who hold ageing stereotypes about their own age cohort and about themselves. A recent theory of how ageing stereotypes are maintained posits that children are exposed to age stereotypes from a young age and the effect of this accumulates over the lifespan. A combination of societal ageism and personal views about ageing lead stereotypes to become internalised when they gain self-relevance. In other words, when people feel that they are 'old' they will also believe ageing stereotypes to be true to themselves and these will become their own perceptions of ageing [22].

Perceptions of ageing include a broad range of thoughts, feelings and expectations for ageing. As older adults internalise negative perceptions about ageing they begin to self-stereotype. Previous work has shown that these internalised negative perceptions are predictive of poorer life satisfaction, increased self-reported chronic illness symptoms, lack of adherence to health maintenance behaviours and increased risk of mortality [59, 64, 116]. Interestingly, however, the effects of negative ageing perceptions may not be limited to impacting upon psychological factors, such as life satisfaction, but may also affect objective health measures. Older adults who are experimentally primed with negative ageing stereotypes show immediate declines on objective physical and cognitive measures [36, 37, 41, 49, 67]. One experimental study found that 2 groups who had no differences in cognitive measures at baseline were statistically significantly different after one group had been primed with negative ageing stereotypes and the other with positive stereotypes. Such was

the size of the effect that 70% of the negative stereotypes group scored below a conservative cut-off point designed to detect dementia despite there being no apparent cognitive impairment at baseline [40]. Furthermore, another experiment found that age differences between young and older adults in tests of delayed recall were eradicated when positive ageing stereotypes were primed before testing [41].

The majority of research in this area has been conducted in an experimental setting and there is limited evidence to indicate how non-experimentally primed ageing stereotypes interact with cognition in the general population. One previous study found that adults who held negative ageing stereotypes at baseline showed declines in a visual memory test up to 38 years later [257]. However, this is the only other paper, to our knowledge, which has explored the association between negative ageing perceptions and cognition longitudinally. As it focussed on one cognitive domain (visual memory) we sought to extend this research and explore the relationship between negative perceptions of ageing and a range of cognitive domains including executive function (specifically verbal fluency), verbal immediate and delayed memory, prospective memory and self-rated decline in memory. Furthermore, we aimed to test the strength of the relationship between ageing stereotypes and cognition after controlling for the impact of additional objective health and psychological factors which the previous study did not have access to.

Methods

Sample

Data was taken from Irish Longitudinal Study on Ageing (TILDA), a large prospective cohort study of the social, economic and health circumstances of community-dwelling older people in Ireland. Analyses are based on the first wave of data collected between January 2009 and July 2011 and follow-up data collected between March and December 2012. Irish Geodirectory, a listing of all residential addresses in the Republic of Ireland, was used as a sampling frame. A clustered sample of addresses was chosen, and household residents aged 50 or over and their spouses/partners (of any age) were eligible to participate in the study. Ethical approval was obtained from the Trinity College Dublin

Research Ethics Committee and all participants provided written informed consent.

The study design has been described in detail elsewhere [218]. Briefly, data collection involved (i) a computer-assisted personal interview carried out by trained social interviewers that included detailed questions on socio-demographics, wealth, health, lifestyle, social support and participation, and use of health and social care (ii) a self-completion questionnaire which included questions about social networks, social participation and ageing perceptions (iii) a health assessment carried out by research nurses. Participants who were unwilling or unable to attend a health assessment in a designated health centre were offered a home-based assessment. In wave 2 the computer-assisted personal interview and key elements of the health assessment were combined into a home interview carried out by trained interviewers.

Brief Ageing Perceptions Questionnaire

The Brief Aging Perceptions Questionnaire (B-APQ) measure comprises 17 Likert scale items that ask participants to rate their level of agreement with questions about the ageing experience and their expectations about ageing in the future. The model was based on Leventhal's self-regulation model of ill health which proposes that the way people think about their own health or illness can be categorised into different themes. The validated B-APQ proposes that representations of ageing can be divided into similar themes that encompass how often people think about ageing, their expectations of the positive or negative consequences, their belief in the level of control they have over how they age and their emotional responses to thoughts about ageing [248]. The scale is comprised of ageing 5 domains: timeline (e.g. "I am conscious of getting older all of the time"), positive consequences (e.g. "As I get older I continue to grow as a person"), positive control (e.g. "As I get older there is much I can do to maintain my independence"), negative consequences and control (e.g. "Slowing down with age is not something I can control") and emotional representations (e.g. "I get depressed when I think about getting older"). Participants rate their level of agreement with each statement within each domain. Higher scores indicate a greater level of agreement with that domain [249]. This measure was captured with the self-completion questionnaire at wave 1.

Cognitive Measures

The cognitive battery included tests of executive function – specifically verbal fluency -, immediate, delayed, prospective and self-rated memory.

Verbal fluency was assessed through the animal naming task in which participants were asked to name as many animals as they could think of in 1 minute. *Immediate and delayed memory* were assessed using a ten-word list recall previously developed for the Health and Retirement Survey [235]. Participants were twice read a list of ten words and then asked to recall as many words as possible in any order after each reading and again after a short delay. *Prospective memory*, or remembering to remember, was assessed with two tasks: Participants were asked to remember at the start of the cognitive session to remind the interviewer to record the time at the end of the cognitive section (task 1), and participants were asked to remember to write their initials in the top left-hand corner of a page when handed a pen (task 2). The first task was based on a similar task in the Rivermead Behavioural Memory Test and the second task was based on a similar task used in the Medical Research Council Cognitive Function and Ageing Study [258, 259]. These measures were assessed at both wave 1 and wave 2. Self-rated memory in wave 1 was assessed with the question: 'How would you rate your day-to-day memory at the present time? Would you say it is: excellent, very good, good, fair or poor' such that higher scores were indicative of poorer self-reported memory. A second self-rated memory question was asked in wave 2: 'Compared to the last time we interviewed you would you say your memory is better now, about the same, or worse now than it was then?' Due to the small numbers of participants who indicated that their memory had improved (N=80) we dichotomised this measure into same/better and worse.

Covariates

All covariates were measured at baseline and at wave 2.

Sociodemographics

Age, gender, employment, education, employment status and marital status were obtained by self-report at baseline. Education was categorised as primary or below, secondary and tertiary. In longitudinal analyses we also included

change in employment status to capture the number of people who had retired since wave 1.

Health Factors

Chronic conditions including joint problems, cataracts, glaucoma, age-related macular degeneration, lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson's disease, peptic ulcer, liver disease, varicose ulcer, alcohol or substance abuse and chronic pain were ascertained by a self-report of a doctor's diagnosis. We conducted analyses on both number of chronic conditions and type of chronic condition in which the conditions were included in the model as binary covariates (0 = absent, 1 = present). In addition, participants were asked to record all conditions which were later categorised as indications of high cardiovascular risk including high blood pressure, angina, previous heart attack, heart failure, previous transient ischemic attack (TIA), high cholesterol, a heart murmur, an abnormal heart rhythm or any other reported condition. We included all cardiovascular conditions as binary covariates in the cross-sectional model (0 = absent, 1 = present). In the longitudinal model we included these as categorical variables to incorporate change between waves (never had condition, had condition in wave 1 and still has it in wave 2, had the condition in wave 1 but no longer has it in wave 2, has developed the condition since wave 1).

Basic and instrumental activities of daily living (ADLs and IADLs) were collected through self-report. Participants were asked "Because of a health or memory problem, do you have any difficulty doing any of the activities on this card?" They were then shown a card listing 6 basic ADLs including dressing, walking across a room, bathing or showering, eating, getting in and out of bed and using the toilet. An ADL disability was defined as difficulty in at least one of the activities listed on the card. Participants were then asked the same question and given a second card listing instrumental ADLs (IADLs) including preparing a hot meal, doing household chores, shopping for groceries, making telephone calls, taking medications and managing money. An IADL disability was defined as difficulty in at least one of these tasks. The level of disability with each activity was not assessed. For cross-sectional analyses participants were classified into 4 categories: no disability, ADL only, IADL only or both ADL and IADL. For longitudinal analyses we assessed change in disability between waves. Due to

the small numbers in groups when change in disability was categorised into both ADLs and IADLs we collated the information and assessed 4 levels: no disability in wave 1 or wave 2, stable level of disability in wave 2, reduced level of disability since wave 1, any new disability in wave 2.

Finally, the interviewer recorded the number and type of medication that each participant was taking on a regular basis. Number of medications was included in this analysis.

Psychological Factors

Loneliness was assessed using a question from the Centre for Epidemiological Studies Depression Scale (CES-D) scale which asked participants to rate how often in the past two weeks they had felt lonely: rarely, sometimes, often or always [246].

Depressive mood was assessed using the sum score of CES-D questions with the exclusion of the loneliness question [246].

Self-rated health was assessed with the question: "In general, compared to other people your age, would you say your health is...excellent, very good, good, fair or poor?"

All longitudinal analyses controlled for change in covariates between waves.

Exclusions

Participants with a history of stroke, Parkinson's Disease or suspected dementia at baseline, or in the intervening 2 years between waves, were excluded due to the effect of these conditions on cognition.

Statistical Analyses

Descriptive statistics were used to explore the differences in key variables (ageing perceptions and cognitive domains) between participants included in our sample, those who had died between waves and those who had been lost to follow up for reasons other than death. For cross-sectional data we conducted linear regression analyses for continuous outcome variables (verbal fluency, delayed, immediate), ordered logistic regression for ordinal variables (self-rated memory) and modified poisson regression analysis with robust error variance

for binary variables (prospective memory 1 and 2). Although logistic regression is commonly used for binary outcome analyses the odds ratios which are produced are not suitable for prospective studies due to their sensitivity to sample size. Converting odds ratios to relative risk ratios has been shown to provide overinflated estimates as sample size increases thus in order to use directly calculated relative risk ratios and conservative estimates we used the modified poisson regression technique [260].

Each regression included 3 models: bivariate analyses to ascertain the relationship between perceptions of ageing and cognition; a second model controlling for socio-demographic factors (age, gender, education, marital status and employment status); and a fully adjusted final model including socio-demographic, health and psychological covariates.

In order to estimate the effect of ageing perceptions on verbal fluency, immediate and delayed memory longitudinally we again conducted linear regression analyses with cognition at wave 2 as the outcome variable and baseline cognition as an additional covariate. In order to assess the relative risk of ageing perceptions on the binary variables (prospective memory and self-rated decline in memory) in wave 2 we conducted a modified poisson regression model with robust error variance. We only assessed the relationship between the domains of perceptions of ageing which had been statistically significantly associated with cognition cross-sectionally.

Additionally, for all longitudinal analyses we estimated the marginal mean cognitive scores – the mean score after adjusting for all covariates in the analysis - for 5 points along the scale indicating increasing levels of agreement with the domain (i.e. the cognitive score for those who, on average, strongly agreed with the domain versus slightly agreed, were neutral, disagreed or strongly disagreed). Attrition weights were used due to differences between respondents who participated in both wave 1 and 2 and respondents who participated only in wave 1 on key variables (see Table 16). Attrition weights were calculated as the inverse of the probability that the respondent participated in wave 2.

Finally, we conducted a number of sensitivity analyses to check the validity of our findings. We had small numbers of missing data in our outcome and covariate variables (<1%) but around 5% of cases for the APQ domains were

missing (for numbers see Figure 8). We thus imputed the missing APQ scores using multiple chained imputations. The imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status, disability, cardiovascular conditions and loneliness as there was no – or very small numbers - of missing data in these variables. Secondly, as measures of cognition can vary, due both to day-to-day variation within people and error in the measure, we used errors-in-variables regression (EIVREG in Stata V12.1) which allows the user to input known test-retest reliability estimates to correct bias in regression estimates. This method has been reported elsewhere as an appropriate analysis for measuring change in cognition [172]. Test-retest reliability for our verbal fluency measure (0.73) was taken from the Whitehall II study which retested 556 participants on the same measure at a 3-month interval [172]. Reliability for the delayed memory and immediate memory measures (0.64 and 0.62) was taken from the Consortium to Establish a Registery for Alzheimer's Disease (CERAD) battery which tested 278 adults aged 50 years and older on delayed recall twice with a one month interval [261]. We also re-ran the analyses adjusting for type rather than number of chronic conditions. All analyses were conducted in Stata version 12.1.

Results

8,175 individuals aged 50 years and over were interviewed at baseline (response rate 62.0%). Follow up data for wave 2 was available for 6,995 (86%) participants of which 78 (.01%) were proxy interviews and were thus not included in the sample for this analysis. Follow up data was unavailable for 1,180 (14%) participants due to death (n=205); refusal (n=809) or no contact (n=166). Exclusion criteria for the present analysis included a doctor's diagnosis of Parkinson's disease, a history of stroke or a mini mental state exam (MMSE) of < 18. Our final sample included participants who had completed both a wave 1 interview and a wave 2 follow up, who had returned the self-completion questionnaire and who did not meet any of the exclusion criteria. The final sample size was 5,896 (for a flow chart of sample selection see Figure 8 and for a description of sample characteristics including the difference between those included and not included in the sample see Table 15 and Table 16).

The mean age of this sample at baseline was 63.17 (9.26), 54.65% were female and 32.80% had completed third level education.

Cross-Sectional

Perceptions of ageing were statistically significantly associated with performance across all cognitive domains in bivariate regression analyses. After adjustment for all covariates, however, only verbal fluency, immediate memory, delayed memory, self-rated memory and prospective memory task 1 remained associated with perceptions of ageing. Table 17. outlines the results of the multiple linear regression analysis. Briefly, verbal fluency and delayed memory were associated with the *positive control* and *negative control and consequences* domains only. Immediate memory was associated with all domains except *emotional representations.* Self-rated memory was associated with the *timeline, negative control and consequences* and *positive consequences domains.* Prospective memory task 1 was associated with the *timeline* and *negative control and consequences domain.*

Longitudinal

In multivariate analyses controlling for covariates, baseline score and attrition weights, positive control was statistically significantly associated with higher scores in animal naming in wave 2 (B=0.43, 95% CI: 0.22, 0.64, p<.001). Having stronger beliefs in the negative control and consequences of ageing domain was associated with poorer scores in the animal naming task in wave 2 (B= -0.51, 95% CI: -0.71, -0.31, p<.001) (see Table 9). Marginal mean scores indicated a dose-response type relationship with decreasing numbers of animals named as level of agreement with the negative control and consequences domain increased and increasing numbers of animals named as level of agreement with the positive control domain increased (see Figure 9).

The negative control and consequences domain was also statistically significantly associated with increased likelihood of reporting a decline in subjective memory (IRR: 1.14, 95% CI: 1.04, 1.26, p<.01) in wave 2 (see Table 19). Margin mean scores indicated that participants who did not endorse the domain had a 14% likelihood of reporting that their memory had become worse while those who endorsed the domain most strongly had a 25% likelihood.

Finally, the timeline domain was statistically significantly associated with failure in the first prospective memory task, although participants were only 2% more likely to fail (IRR: 0.98 (0.96, 0.99) p<.05) (see Table 20).

We reran the analyses using the imputed APQ scores. This increased our sample size by approximately 500 participants per analysis (for numbers see Appendix). However, the results did not change. We also reran the verbal fluency longitudinal analysis adjusting for measurement error but this did not change the findings (see Appendix). Finally, we conducted all analyses adjusting for type rather than number of chronic conditions but this did not change the results and so for reasons of space we have not reported the results here.

Conclusion

Older adults who hold negative perceptions of ageing show longitudinal declines in executive function, prospective memory and self-rated memory independent of socio-demographic factors, physical health, mental health and medication use. These findings build upon experimental work which demonstrated the effect of priming negative ageing stereotypes on immediate cognitive performance [36, 37, 41, 49, 67]. Our results indicate that this is not just a short-term experimental effect but rather self-referential negative ageing perceptions are detrimental to objective cognitive function over a 2 year period. There are a number of mechanisms which may explain this relationship including: self-efficacy and control beliefs, levels of stress and cognitive health behaviours.

Self-efficacy and feelings of control over cognitive function are important predictors of actual cognitive performance [70, 85, 262]. We did not explore specifically cognitively-related self-efficacy and control beliefs but we could hypothesise that those who hold negative expectations for ageing may also hold negative beliefs about their current and future cognition. One study in younger adults found that the functional activation of the brain is different in those with low and high memory self-efficacy during encoding. Respondents with low self-efficacy activated more areas of the brain in general and specifically those related to visuospatial episodic memory (hippocampus and medial parieto-occipital regions) while those with high self-efficacy show increased activity in areas associated with cognitive control such as the dorsal anterior cingulate cortex [79]. The high self-efficacy group also performed statistically significantly better on tests of working memory.

The differential brain activation in the two groups may be explained either by the use of different strategy techniques during encoding or by a necessity, in the low self-efficacy group, to compensate for underperformance of some brain

regions by enlisting the support of multiple other regions [79]. It is possible a similar process occurs in our population such that poorer expectations for ageing and, as a result, of cognition, may be reflective either of underperformance of certain brain regions or of an encoding inefficiency such that higher cognitive functions and control processes are not utilised during encoding. This is partially supported by a previous study which found that older adults with higher self-efficacy and control beliefs were more likely to use cognitive strategies to maintain cognitive performance [263]. We found that older adults with ageing beliefs related to positive control had better performance in the executive function task over 2 years and thus it is possible that these same adults were also using specific cognitive strategies to maintain and improve performance.

The second mechanism which may explain the association between negative perceptions of ageing and decreased cognitive function is stress. Stress increases the activity of the hypothalamus-pituitary-adrenal (HPA) axis which produces glucocorticoids in the adrenal glands. Too low or too high levels of glucocorticoids are neurotoxic and cause atrophy in the hippocampal regions as well as depressing axonal transport in the pre-front cortex [264]. It is possible that adults who expect negative consequences as they age experience greater levels of stress in anticipating these events. Indeed, it is the anticipation of a stressful event, as much as the event itself, which induces high spikes in cortisol secretions and resulting declarative memory deficits [94]. While, we did not see longitudinal effects of negative perceptions on delayed memory in our study, we did find effects on executive function. It may be that there is simply more variability in the fluency measure - with a range of 0-50 compared to the relatively narrow range of 0-10 in the delayed memory measure - thus allowing us to pick up on smaller changes in cognition across the relatively small time period of our study. Additionally, Levy et al. (2012) looked at change in a visual memory measure over 38 years according to strength of negative ageing stereotypes. They found that the memory differences in groups were small initially but expanded dramatically over the course of the study. Verbal memory may thus be more likely to be affected in further waves of TILDA.

Stress may also mediate the relationship between negative perceptions of ageing and cognition through the cardiovascular system. Levy et al. found that older adults experimentally primed with negative ageing stereotypes and then faced with a stressful task showed heightened cardiovascular responses

including increased blood pressure and heart rate [46]. Vascular damage in the brain is known to be associated with decreased executive function and thus negative perceptions of ageing may influence cognition through this pathway [206].

Finally, negative perceptions of ageing may influence cognition through behaviour. The cognitive reserve hypothesis posits that the brain can be protected from displaying the cognitive effects of internal damage through increased stimulation across the lifespan. This includes partaking in social outputs, education, cognitive stimulation and physical activity [265]. It is possible that adults who hold negative expectations for ageing have less motivation to engage in these protective activities and thus put themselves at risk of cognitive decline. There is some evidence to support this hypothesis as a previous study found that older adults with chronic illness who blamed 'old age' as a reason for their health difficulties were less likely to engage in health maintenance behaviours and to take control over their symptoms with a resulting worsening of their illness [116]. Future research is needed to determine whether older adults are less likely to partake in social engagement and other forms of social cognitive stimulation but, if this is the case, it is possible that this is due to dissociation from their age group. Weiss and colleagues found that older adults who held negative stereotypes about ageing were more likely to dissociate themselves from their age group and to have lower self-esteem when required to think of similarities between themselves and their peers [20, 21]. An unwillingness to associate with one's peers could potentially result in increased social isolation and a resulting risk of cognitive decline. Furthermore, a study on social vulnerability found that older adults who were less involved in leisure activities, had less social support and felt less empowered had poorer performance on executive function tasks [215].

The strength of this study lies in its large-scale population representative sample and longitudinal follow-up data. We were able to control for a number of objective health variables which might otherwise be hypothesised to explain the relationship between negative perceptions and cognition. Finally, we had a cognitive battery which enabled us to test the effects of negative perceptions on a number of cognitive domains rather than just memory as has been reported in the past (Levy et al. 2012).

This paper has a number of limitations including, as is common to all longitudinal studies, attrition. We have achieved a relatively low attrition rate of 14%, some of whom have indicated that they may return for the next wave of data, indicating one mechanism for attrition is not illness. We also applied attrition weights to our analyses and as our results remained unchanged we can be more confident that attrition is not falsely driving our conclusions. Secondly, although we measured our cognitive variables longitudinally, 2 years in a relatively healthy sample of older adults is a short period of time. However, as future waves of TILDA are collected and measures repeated, we will gain better insight into the relationship between the variables. Finally, it is important to consider that we only had one measure of executive function, namely verbal fluency. There is an ongoing debate in the neuropsychological literature as to what executive function is and what tests capture it [266]. Indeed, a review of the ecological validity of executive function measures in 1998 suggested that, rather than being one construct, executive function could be split into three factors: inhibition, intentionality and executive memory with verbal fluency loading onto the executive memory factor [267]. The term executive function usually refers to higher level cognitive functions involved in the regulation and direction of goal related activities and verbal fluency is a commonly used measures to attempt to capture this [266, 268]. Anatomically, executive function is thought to be associated with activity in the frontal lobes [268]. A review of a number of executive function measures, of which verbal fluency was one, in 2006 revealed partial support for this hypothesis finding that frontal lobe lesions were associated with worse performance on all executive function measures [268]. The same measures also mapped onto activity of the frontal lobes in fMRI scans. However, the authors note that it is not a 'one-on-one' relationship between the frontal lobes and executive function measures as other brain regions were also involved. This is similar to a recent study by Salthouse et al. who found that most executive function measures were correlated with more cognitive domains than just executive function [266]. Verbal fluency was associated with perceptual speed and some memory measures. The definition of executive function is therefore still being refined and new measures may need to be developed to capture the concept more succinctly. Alternatively, we may need to consider that executive function is not a distinct concept but is rather a network of associated cognitive abilities that allow us to reason, plan and direct behaviour. The concept of executive function may be more ideally captured by

a composite of different tasks as was found by Gibbons et al in 2012. They composed a composite measure of executive function consisting of the Digit Symbol, Digit Span Backwards, Trail Making, Category Fluency, and Clock Drawing tasks [269]. When assessed in adults with MCI longitudinally they found that the composite measure had a greater ability to predict conversion to dementia over time than the individual measures. In relation to the MRI measures only the composite measures, Category Fluency, Digit Symbol and Trails B had any association with white matter hyperintensities and cortical thickness. In conclusion, therefore, verbal fluency is a well-recognised component of executive function but a better measure would be a composite of multiple tasks. Unfortunately we were only able to use verbal fluency in this study as the other executive function measures were not captured in wave 2 of the TILDA data. However, wave 3 is currently being collected and will include a wider range of executive function measures allowing us to repeat this analysis using a range of cognitive domains in the future.

The implications of our findings are that negative perceptions about ageing may be targetable factors to improve cognitive function in older adults. One possible way to change societal ageing attitudes may be through implicit routes with the use of media and literature. Previous work has shown that including persuasive messages within entertaining narratives can successfully change attitudes if people identify with the characters and if the story is engaging enough that the source of the persuasion can be forgotten [270]. It might therefore be possible to change attitudes gradually on a societal level through carefully crafted media and literature. A second method of changing individual attitudes is encased in cognitive dissonance theory in which people who are invited to behave in a manner that runs counter to their attitudes will subsequently change their attitude [271]. It may be possible to develop interventions for individuals with negative attitudes towards ageing which, for example, provide support for active management of their own health conditions or engagement with activities they would not previously have considered due to 'old age'. Such interventions may alter and challenge individual attitudes and feelings of control and help to maintain objective healthy ageing.

In conclusion, negative perceptions of ageing are associated with a longitudinal decline in executive function, prospective memory and self-rated memory. This may be mediated by differential brain activation while completing cognitive

tasks, repeated exposure to stress, or behavioural factors such as limited engagement in cognitively protective activities. Negative perceptions of ageing may thus be one potentially modifiable factor to improve and maintain successful physical and psychological ageing.

Figure 8. Flow Chart Indicating Participants Remaining From Wave 1 to Wave 2.

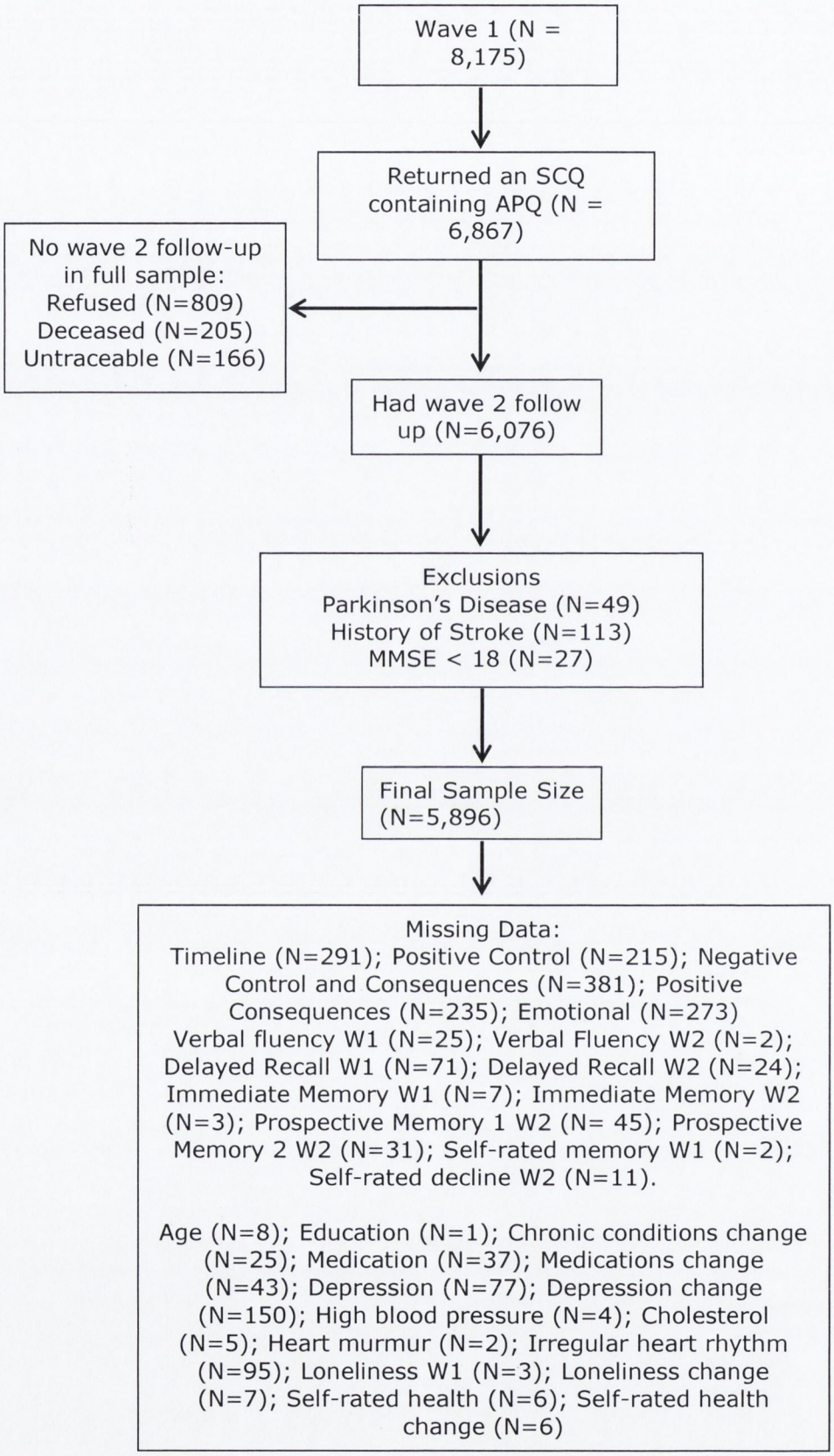


Table 15. Descriptive statistics for all variables included in the analyses.

Measure (Possible Range) N=5,896	**Mean (SD) or %**
Timeline Chronic (1-5)	2.42 (.85)
Positive Control (1-5)	3.98 (.65)
Negative Control & Consequences (1-5)	2.81 (.76)
Positive Consequences (1-5)	3.81 (.69)
Emotional Representations (1-5)	2.27 (.79)
Immediate Recall W1 (0-20)	13.50 (3.11)
Immediate Recall W2 (0-20)	13.84 (3.08)
Delayed Recall W1 (0-10)	6.10 (2.27)
Delayed Recall W2 (0-10)	6.13 (2.49)
Animal Naming W1	21.09 (6.93)
Animal Naming W2	19.44 (6.04)
Prospective Memory 1 W1	79.72% (N=4,700)
Prospective Memory 1 W2	80.36% (N=4,738)
Prospective Memory 2 W1	85.48% (N=5,040)
Prospective Memory 2 W2	85.11% (N=5,018)
Self-Rated Memory W1 (1-5 = excellent - poor)	2.57 (0.95)
Self-Reported Change in Memory (worse)	19.76% (N=1,165)
Age	63.17 (9.26)
Sex (female)	54.65% (N=3,222)
Education (third level)	32.80% (N=1,934)
Married	71.73% (N=4,229)
Employment status (employed)	38.16% (n=2,250)
Disability in W1 (no disability)	89.87% (N=5,299)
No. of Medications	2.47 (2.60)
No. of chronic conditions	1.66 (1.39)
High Blood Pressure	35.89% (N=2,116)
Angina	4.94% (N=291)
Heart Attack	4.10% (N=242)
Heart Failure	0.85% (N=50)
High Cholesterol	39.31% (N = 2,318)
Heart Murmur	4.97% (N=293)
Irregular Heart Rhythm	7.16% (N=422)
Other Cardiovascular Condition	3.27% (N=193)
Self-Rated Health (1-5 = excellent - poor)	2.34 (1.02)
Loneliness (0-3 = Rarely, sometimes, often, always)	1.27 (0.64)
Depression (CES-D) (0-60 = low - high)	5.53 (6.86)

Table 16. Characteristics of the total sample compared to participants who died following wave 1.

Measure (Possible Range)	Mean (SD) or %	Died Between Waves (N = 205)	Refused/No Follow Up (N = 975)
	Ageing Perceptions		
Timeline Chronic (1-5)	2.42 (.85)	2.89 (1.07)***	2.50 (.87)***
Positive Control (1-5)	3.98 (.65)	3.98 (.68)	3.82 (.77)***
Negative Control & Consequences (1-5)	2.81 (.76)	3.35 (.85)***	2.96 (.79)***
Positive Consequences (1-5)	3.81 (.69)	3.73 (.79)	3.70 (.72)**
Emotional Representations (1-5)	2.27 (.79)	2.42 (.87)	2.36 (.83)*
	Cognition		
Immediate Recall W1 (0-20)	13.50 (3.11)	10.42 (3.65)***	12.23 (3.42)***
Delayed Recall W1 (0-10)	6.10 (2.27)	4.23 (2.32)***	5.23 (2.32)***
Animal Naming W1	21.09 (6.93)	16.17 (6.67)***	18.36 (6.91)***
Prospective Memory 1 W1	79.73% (N=4,700)	50.73% (N=104)***	69.54% (N=678)***
Prospective Memory 2 W1	85.48% (N=5,040)	69.27% (N=142)***	78.25% (N=763)***
Self-Rated Memory W1 (1-5 = excellent - poor)	2.57 (.95)	2.95 (1.01)***	2.62 (.97)

***p < .001, **p < .01, * p < .05. Statistical significance was calculated using one way ANOVA for continuous variables and chi-square tests for categorical variables. TUG = Timed Up-and-Go task; CES-D = Centre for Epidemiological Studies Depression Scale; MMSE = Mini Mental State Examination; APQ = Ageing Perceptions Questionnaire; Timeline (how often people think about ageing e.g. "I am conscious of getting older all of the time"); Positive Consequences (e.g. "As I get older I continue to grow as a person"); Positive Control (e.g. "As I get older there is much I can do to maintain my independence"; Negative Control and Consequences (e.g. "Slowing down with age is not something I can control"); Emotional (e.g. "I get depressed when I think about getting older").

Table 17. Regression coefficients or Incident Risk Ratios, as appropriate, and 95% confidence intervals for multivariate regression analyses demonstrating the association between ageing perceptions and each of the cognitive domains cross-sectionally.

Ageing Perceptions Domains	**Verbal Fluency**	**Immediate Memory**	**Delayed Memory**	**Self-Rated Memory**	**Prospective Memory 1 (IRR)**	**Prospective Memory 2 (IRR)**
Timeline	-0.12	-0.13*	-0.04	0.13***	0.98*	0.99
	(-0.37,0.13)	(-0.24,-0.02)	(-0.12,0.04)	(0.05,0.20)	(0.96,1.00)	(0.98,1.01)
Positive Control	0.38**	0.15*	0.12**	-0.07	1.01	1.01
	(0.11,0.66)	(0.03,0.27)	(0.03,0.21)	(-0.15,0.01)	(0.99,1.03)	(0.99,1.03)
Negative Control &	-0.33*	-0.22**	-0.21***	0.18***	0.97*	1.002
Consequences	(-0.64,-0.03)	(-0.35,-0.09)	(-0.31,-0.11)	(0.10,0.27)	(0.95,1.00)	(0.98,1.02)
Positive	0.06	0.12*	0.03	-0.14***	1.01	1.003
Consequences	(-0.21,0.32)	(0.01,0.23)	(-0.05,0.12)	(-0.22,-0.06)	(0.98,1.02)	(0.99,1.02)
Emotional	0.09	0.10	0.04	-0.01	1.01	0.99
Representations	(-0.19,0.37)	(-0.02,0.21)	(-0.05,0.13)	(-0.09,0.07)	(0.99,1.03)	(0.98,1.01)
N	5682	5698	5627	5707	5708	5682

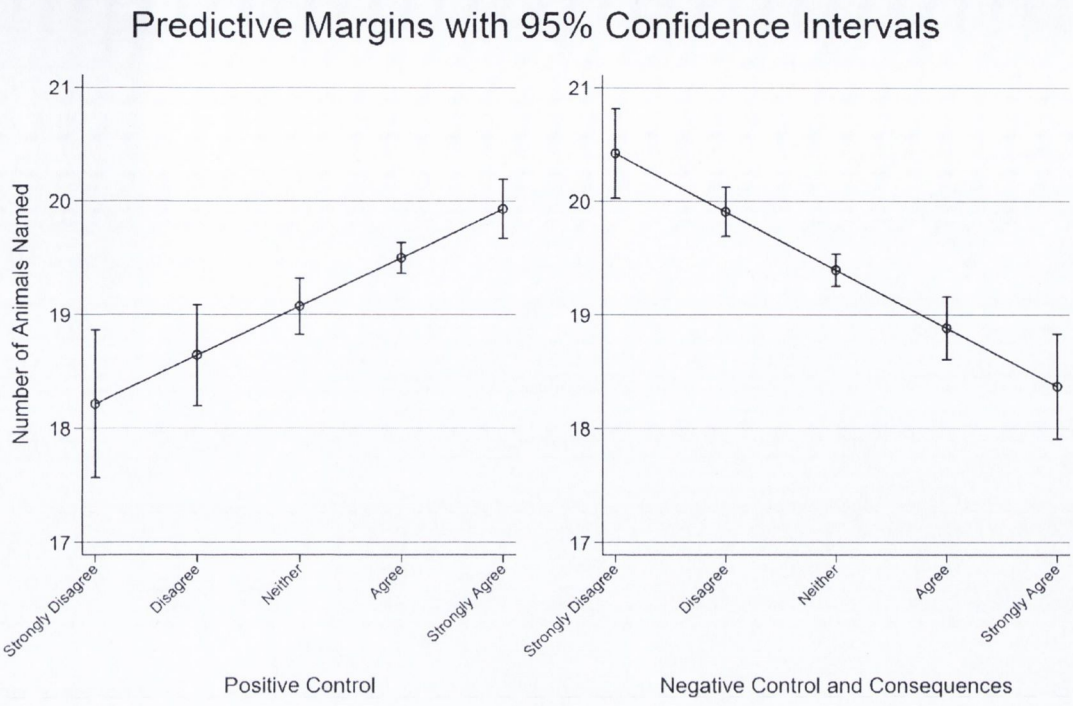
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets. RR = incident risk ratios. Multivariate analysis controlling for age, gender, education, marital status, employment status, number of chronic conditions, disability, number of medications, high blood pressure, angina, previous heart attacks, heart failure, stroke, high cholesterol, heart murmur, irregular heart rhythm, other cardiovascular condition, self-rated health, depressed mood and loneliness.

Table 18. Multiple linear regression coefficients and 95% confidence intervals indicating the relationship between baseline perceptions of ageing and verbal fluency 2 years later.

Verbal Fluency	**Model 1**	**Model 2**	**Model 3**
Positive Control	0.57***(0.36,0.79)	0.44***(0.23,0.65)	0.43***(0.22,0.64)
Negative Control & Consequences	-1.00***(-1.18,-0.82)	-0.60***(-0.79,-0.42)	-0.51***(-0.71,-0.31)
Verbal Fluency Baseline	0.42***(0.40,0.44)	0.37***(0.35,0.39)	0.36***(0.33,0.38)
Age		-0.08***(-0.10,-0.06)	-0.10***(-0.12,-0.07)
Gender		-0.37**(-0.65,-0.09)	-0.31*(-0.61,-0.01)
Education			
Comparison: Primary			
Secondary		0.83***(0.49,1.17)	0.79***(0.45,1.14)
Third/higher		1.98***(1.60,2.37)	1.94***(1.55,2.34)
Never married		-0.60***(-0.90,-0.30)	-0.62***(-0.93,-0.30)
Employment			
Comparison: working			
Retired at W1 & W2		0.35 (-0.04,0.74)	0.29 (-0.10,0.69)
No longer retired		0.84**(0.21,1.47)	0.60 (-0.03,1.23)
Newly retired		0.11 (-0.34,0.56)	0.12 (-0.34,0.58)
No. of chronic conditions			0.17 (-0.01,0.35)
Chronic conditions (change)			-0.01 (-0.18,0.15)
Abnormal heart rhythm			
Comparison: Never			
Ongoing			1.02**(0.35,1.70)
No longer			-0.27 (-1.33,0.79)
New			2.33 (-0.98,5.64)
Heart Attack			
Comparison: Never			
Before W1			0.35 (-0.37,1.07)
Since W1			1.81* (0.10,3.52)
TIA			
Comparison: Never			
Before W1			0.13 (-0.79,1.06)
Since W1			-1.79*(-3.40,-0.17)
Change in depressed mood			-0.07***(-0.10,-0.04)
Self-rated health			-0.27**(-0.47,-0.07)
Observations	5340	5331	5061

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets. For reasons of space only covariates which were statistically significant were included in this table. The full model was adjusted for baseline verbal fluency, age, gender, education, marital status, employment status, no. of chronic conditions, disability, medications, high blood pressure, heart failure, high cholesterol, heart murmur, abnormal heart rhythm, heart attack, angina, TIA, other cardiovascular conditions, depressed mood, loneliness, self-rated health and change in all variables between waves.

Figure 9. Marginal Mean Verbal Fluency Scores at Wave 2 by Level of Agreement with Perceptions of Ageing Subscales at Baseline.



Marginal means calculated following linear regression analyses in which perceptions of ageing at baseline were the predictor variable and verbal fluency at wave 2 was the outcome variable. Marginal means represent the mean score after adjustment for all confounders. Error bars represent 95% Confidence Intervals.

Table 19. Incident risk ratios and 95% confidence intervals from a modified poisson regression analysis indicating the relationship between baseline perceptions of ageing and self-reported decline in memory over 2 years..

Self-Rated Memory W2	**Model 1**	**Model 2**	**Model 3**
Timeline	1.15***(1.06,1.24)	1.12** (1.04,1.21)	1.06 (0.98,1.14)
Negative Control & Consequences	1.40***(1.28,1.53)	1.33*** (1.21,1.46)	1.14** (1.04,1.26)
Positive Consequences	0.90**(0.83,0.97)	0.91* (0.84,0.99)	0.97 (0.90,1.05)
Age		1.02*** (1.01,1.03)	1.02*** (1.01,1.03)
Gender		1.09 (0.97,1.22)	0.98 (0.86,1.10)
Education			
Secondary		1.05 (0.91,1.21)	1.15 (0.99,1.33)
Third/higher		1.13 (0.97,1.31)	1.24** (1.06,1.45)
Never married		0.94 (0.83,1.06)	0.86* (0.75,0.98)
No. of chronic conditions			1.09** (1.03,1.17)
Chronic conditions (change)			1.07* (1.01,1.14)
Disability			
Ongoing			1.18 (0.94,1.48)
No longer			0.95 (0.75,1.20)
New			1.26* (1.01,1.55)
High Blood Pressure			
Ongoing			0.86* (0.75,1.00)
No longer			0.80 (0.62,1.03)
New			0.82 (0.64,1.06)
Abnormal Heart Rhythm			
Ongoing			1.00 (0.78,1.29)
No longer			1.45 (0.90,2.32)
New			0.34* (0.12,0.91)
Heart Attack			
Before W1			1.14 (0.90,1.46)
Since W1			1.55* (1.01,2.38)
Other Cardiovascular			
Before W1			0.99 (0.73,1.36)
Since W1			2.74* (1.05,7.14)
Depressed mood			1.03*** (1.02,1.04)
Change in depressed mood			1.03*** (1.02,1.04)
Self-rated health			1.23*** (1.13,1.33)
Change in self-rated health			1.21*** (1.12,1.30)
Observations	5205	5196	4939

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets. For reasons of space only covariates which were statistically significant were included in this table. The full model was adjusted for baseline verbal fluency, age, gender, education, marital status, employment status, no. of chronic conditions, disability, medications, high blood pressure, heart failure, high cholesterol, heart murmur, abnormal heart rhythm, heart attack, angina, TIA, other cardiovascular conditions, depressed mood, loneliness, self-rated health and change in all variables between waves.

Table 20. Incident risk ratios and 95% confidence intervals from a modified poisson regression analysis indicating the relationship between baseline perceptions of ageing and prospective memory over 2 years.

Prospective Memory 2 W2	**Model 1**	**Model 2**	**Model 3**
Timeline	0.95***(0.93,0.97)	0.97***(0.95,0.99)	0.98*(0.96,0.99)
Negative Control & Consequences	0.94***(0.92,0.96)	0.99(0.96,1.01)	0.99(0.98,1.02)
Prospective Memory W1	1.36***(1.30,1.44)	1.25***(1.19,1.31)	1.23***(1.17,1.29)
Age		0.98***(0.98,0.99)	0.98***(0.98,0.99)
Gender		1.01(0.99,1.04)	1.03(1.00,1.05)
Education			
Secondary		1.09***(1.05,1.14)	1.08***(1.03,1.12)
Third/higher		1.13***(1.08,1.17)	1.11***(1.06,1.15)
Never married		0.92***(0.89,0.95)	0.93***(0.90,0.96)
Employment Status			
Retired in W1 & W2		1.12***(1.07,1.16)	1.11***(1.07,1.16)
No longer retired		1.02(0.94,1.09)	1.02 (0.95,1.11)
Newly retired		1.09***(1.05,1.14)	1.11***(1.06,1.15)
Disability			
Ongoing			0.99(0.89,1.09)
No longer			1.01(0.95,1.07)
New			0.90*(0.82,0.99)
No. of medications			0.99(0.98,1.00)
Change in medications			0.99(0.99,1.00)
Abnormal Heart Rhythm			
Ongoing			1.06(0.99,1.13)
No longer			1.10*(1.00,1.21)
New			0.83(0.64,1.08)
Depressed mood			0.99(0.99,1.00)
Change in depressed mood			0.99*(0.99,1.00)
Self-rated health			0.97**(0.96,0.99)
Change in self-rated health			0.96***(0.95,0.98)
Observations	5272	5263	5002

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets. For reasons of space only covariates which were statistically significant were included in this table. The full model was adjusted for baseline verbal fluency, age, gender, education, marital status, employment status, no. of chronic conditions, disability, medications, high blood pressure, heart failure, high cholesterol, heart murmur, abnormal heart rhythm, heart attack, angina, TIA, other cardiovascular conditions, depressed mood, loneliness, self-rated health and change in all variables between waves.

Appendix

Table 21. Multivariate linear regression analysis in which approximately 5% of the APQ values have been imputed using multiple chained imputations. Indicates the relationship between baseline perceptions of ageing and executive function 2 years later.

Verbal Fluency	**Coefficients and 95% Confidence Intervals**
Positive Control	0.44 (0.23, 0.64)***
Negative Control and Consequences	-0.47 (-0.67, -0.28)***
Verbal Fluency Baseline	0.36 (0.33, 0.39)***
Age	-0.09 (-0.11, -0.07)***
Gender	-0.31 (-0.59, -0.03)*
Education	
Secondary	0.73 (0.41, 1.06)***
Third/higher	1.96 (1.57, 2.34)***
Never married	-0.57 (-0.87, -0.28)***
Employment	
Retired at W1 and W2	0.21 (-0.17, 0.58)
No longer retired	0.61 (0.01, 1.21)*
Newly retired	0.09 (-0.34, 0.52)
No. of chronic conditions	0.18 (0.01, 0.35)*
High Cholesterol	
Ongoing	-0.06 (-0.43, 0.31)
No longer	-0.14 (-0.61, 0.33)
New	0.64 (0.16, 1.11)**
Abnormal heart rhythm	
Ongoing	0.85 (0.19, 1.51)*
No longer	-0.29 (-1.37, 0.79)
New	1.54 (-1.82, 4.90)
Change in depressed mood	-0.06 (-0.09, -0.03)***
Self-rated health	-0.29 (-0.48, -0.10)**
Observations	5539

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

Table 22. Modified poisson regression analysis in which approximately 5% of APQ values have been imputed. Indicates the relationship between baseline perceptions of ageing and self-rated decline in memory 2 years later.

Self-Rated Memory	**Incident Risk Ratios and 95% Confidence Intervals**
Timeline	1.05 (0.97, 1.12)
Negative Control and Consequences	1.14 (1.04, 1.25)**
Positive Consequences	0.98 (0.92, 1.06)
Age	1.02 (1.02, 1.03)***
Gender	1.00 (0.89, 1.12)
Education	
Secondary	1.16 (1.01, 1.33)*
Third/higher	1.30 (1.12, 1.51)***
Never married	0.84 (0.74, 0.95)**
No. of chronic conditions	1.09 (1.02, 1.15)**
Change in no. of chronic conditions	1.06 (1.00, 1.12)*
Disability	
Ongoing	1.10 (0.89, 1.37)
No longer	1.04 (0.85, 1.27)
New	1.27 (1.05, 1.54)*
No. of medications	0.973 (0.95, 1.00)*
High Blood Pressure	
Ongoing	0.86 (0.75, 0.99)*
No longer	0.78 (0.61, 1.00)*
New	0.81 (0.63, 1.02)
Abnormal Heart Rhythm	
Ongoing	1.05 (0.83, 1.32)
No longer	1.52 (1.02, 2.26)*
New	0.50 (0.15, 1.68)
Heart Attack	
Before W1	1.13 (0.89, 1.43)
Since W1	1.65 (1.13, 2.40)**
TIA	
Before W1	1.22 (0.91, 1.64)
Since W1	1.54 (1.01, 2.34)*
Depressed mood	1.03 (1.02, 1.04)***
Change in depressed mood	1.03 (1.02, 1.04)***
Self-rated health	1.23 (1.14, 1.33)***
Change in self-rated health	1.19 (1.11, 1.28)***
Observations	5558

95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 23. Modified poisson regression analysis in which approximately 5% of APQ values have been imputed. Indicates the relationship between baseline perceptions of ageing and prospective memory 2 years later.

Prospective Memory 2 W2	**Incident Risk Ratios and 95% Confidence Intervals**
Timeline	0.98 (0.96, 0.99)*
Negative Control and Consequences	0.99 (0.97,1.01)
Prospective Memory W1	1.26 (1.20, 1.32)***
Age	0.98 (0.98, 0.99)***
Gender	1.02 (0.99 1.05)
Education	
Secondary	1.08 (1.04, 1.13)***
Third/higher	1.11 (1.07, 1.15)***
Never married	0.94 (0.91, 0.97)***
Employment Status	
Retired in W1 and W2	1.1 (1.07, 1.16)***
No longer retired	1.02 (0.95, 1.10)
Newly retired	1.10 (1.05, 1.14)***
Disability	
Ongoing	1.01 (0.91, 1.11)
No longer	0.98 (0.91, 1.04)
New	0.91 (0.83, 0.99)*
Change in depressed mood	0.99 (0.99, 0.99)*
Loneliness	0.95 (0.91, 0.99)*
Self-rated health	0.97 (0.95, 0.99)**
Change in self-rated health	0.97 (0.05, 0.98)***
Observations	5526

95% confidence intervals in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 24. Error-in-Variables regression coefficients and 95% confidence intervals indicating the relationship between baseline perceptions of ageing and verbal fluency 2 years later after adjusting for test-retest reliability in the measure (0.73).[a]

Verbal Fluency	**Model 1**	**Model 2**	**Model 3**
Positive Control	0.45***(0.25,0.65)	0.37***(0.17,0.57)	0.37***(0.17,0.58)
Negative Control & Consequences	-0.77***(-0.95,-0.60)	-0.52***(-0.70,-0.34)	-0.49***(-0.69,-0.29)
Verbal Fluency Baseline	0.58***(0.55,0.60)	0.53***(0.50,0.56)	0.52***(0.49,0.55)
Age		-0.06***(-0.08,-0.04)	-0.07***(-0.09,-0.05)
Gender		-0.29**(-0.56,-0.03)	-0.24 (-0.52,0.05)
Education			
Comparison: Primary			
Secondary		0.59***(0.25,0.93)	0.57***(0.22,0.93)
Third/higher		1.27***(0.90,1.65)	1.27***(0.88,1.67)
Never married		-0.43***(-0.72,-0.13)	-0.47***(-0.79,-0.16)
Employment			
Comparison: working			
Retired at W1 & W2		0.28 (-0.09,0.66)	0.24 (-0.14,0.63)
No longer retired		0.81**(0.18,1.43)	0.61 (-0.04,1.26)
Newly retired		0.12 (-0.32,0.57)	0.16 (-0.29,0.61)
No. of chronic conditions			0.11 (-0.07,0.28)
Chronic conditions (change)			-0.05 (-0.20,0.10)
Abnormal heart rhythm			
Comparison: Never			
Ongoing			0.93**(0.25,1.60)
No longer			-0.22 (-1.48,1.04)
New			2.28 (-1.11,5.66)
TIA			
Comparison: Never			
Before W1			0.23 (-0.80,1.27)
Since W1			-1.90*(-3.51,-0.29)
Change in depressed mood			-0.07***(-0.10,-0.04)
Observations	5340	5331	5061

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

a. Measurement error was adjusted for using pre-published test-retest reliability coefficients for the outcome variable of interest. Test-retest reliability for verbal fluency was 0.73.

For reasons of space only statistically significant covariates were included in this table. The full model was adjusted for baseline verbal fluency, age, gender, education, marital status, employment status, no. of chronic conditions, disability, medications, high blood pressure, heart failure, high cholesterol, heart murmur, abnormal heart rhythm, heart attack, angina, TIA, other cardiovascular conditions, depressed mood, loneliness, self-rated health and change in all variables between waves.

Introduction to Paper 4

A literature review on the association between frailty and cognition at the start of this thesis suggested that perceptions of ageing may be one mechanism which explains the association between frailty and cognition. Having established that negative perceptions of ageing are associated with both physical and cognitive decline, the aim of the next empirical paper was to assess whether negative perceptions of ageing moderate the relationship between frailty and cognitive function. I hypothesise that older adults with negative perceptions of ageing are at greater risk of entering a cycle of decline in which both physical and cognitive functions are impaired. Older adults with positive perceptions of ageing, on the other hand, may still be at risk of frailty *or* cognitive impairment through other pathways but may be less likely to develop both frailty *and* cognitive impairment.

Paper 4: Negative Perceptions of Ageing Moderate the Relationship Between Frailty and Cognition

Abstract

Introduction

Older adults who are frail have poorer cognitive function and a greater risk of dementia compared to their robust peers. The mechanism behind this association has yet to be established but current hypotheses focus on both physiological and psychological causes. Previous work has shown that one particular psychological factor, namely negative perceptions of ageing, is associated both with physical and cognitive decline in older adults over time. We thus hypothesise that negative perceptions of ageing may also explain the association between frailty and cognitive decline.

Methods

4,901 participants from the Irish Longitudinal Study on Ageing who had completed both a health or home assessment and the self-completion questionnaire were included in this study. Perceptions of ageing were assessed using the Aging Perceptions Questionnaire (APQ). Five domains of cognitive function were assessed (global cognition, executive function, memory, attention and processing speed). Frailty was assessed according to the Fried criteria of slow walking speed, poor grip strength, low levels of physical activity, exhaustion and unintentional weight loss.

Results

Frailty was associated with poorer cognitive function in older adults with negative perceptions of ageing. There was no association between frailty and cognitive function in older adults without negative perceptions of ageing. The interaction effect between negative perceptions of ageing and frailty was statistically significant in the domains of global cognitive function (B= -0.11 (95% CI: -0.19, -0.04)), executive function (B= -0.08 (95% CI: -0.15, -0.02)) and attention (B= -0.08 (95% CI: -0.15, -0.002)). There was no interaction effect for the association between perceptions of ageing and frailty in predicting

memory (B=-.02 (95% CI: -.10, .06)) or processing speed (B=.04 (95% CI: -.05, .12)).

Conclusion

Negative perceptions of ageing may moderate the association between frailty and cognitive function in older adults.

Introduction

Older adults who are frail are more likely to be cognitively impaired. This association has been demonstrated both cross-sectionally and longitudinally across a large number of studies [128]. While the association appears to be well-established, however, the mechanisms underpinning the relationship have yet to be explained.

Frailty is usually considered to be a purely physiological syndrome characterised by a failure across multiple systems in older age [130]. The relationship between frailty and cognitive impairment is therefore also considered to be bound by a common underlying physiological mechanism. A number of physiological factors are common to both cognitive impairment and frailty suggesting that these may mediate the relationship between the two. The most common of these are cerebrovascular problems, inflammation, nutrition and hormonal changes (e.g. [128, 272]). The empirical evidence for these mechanisms, however, remains relatively weak. For example one study which tested the hypothesis that inflammation mediates the relationship between frailty and cognition found only partial support and only in women [200]. Cerebrovascular burden has also been proposed as a key component of frailty but the Health and Retirement Survey found that only 35% of participants with high cerebrovascular burden developed frailty, while 25% with no cerebrovascular burden also developed frailty, suggesting that this is likely not the sole cause [208]. Hormonal changes and nutrition have also been proposed to underpin the relationship but it is not yet clear which hormones or what elements of nutrition may be most important [103, 194]

As frailty is a cluster of symptoms it is probable that no single biomarker will predict the syndrome perfectly. Instead, a combination of impairments most likely contribute to frailty [273]. Indeed, a recent consensus review suggested that a definition of frailty should include components from the domains of nutrition, mobility, physical activity, strength, endurance, balance, cognition, senses, mood, coping, social relations and social support [143, 144]. However the latter four components are rarely, if ever, included in definitions of frailty despite the increasing body of evidence to suggest that psychological factors may play a role in the development and maintenance of the syndrome. For example, the Health and Retirement Survey found that while 35% of

participants with high cerebrovascular burden developed frailty four years later, 55% of those with high cerebrovascular burden and depression developed frailty. Furthermore, 41% of those with depression alone and no cerebrovascular burden developed frailty four years on [208]. This suggests that mood is a key element in predicting frailty and may have a stronger predictive ability than cerebrovascular problems alone. We also know that depression can predict cognitive decline and the onset of dementia suggesting that there may be a common psychological mechanism which binds both frailty and cognitive impairment together [274].

Recent research from our group has identified a second psychological factor which predicts both physical and cognitive function more strongly than, and independent of, depression. We found that people's perceptions of ageing predict a decline in both cognitive function and walking speed – a key component of frailty - over just two years, independent of actual health changes and depression [241, 275]. Perceptions of ageing encompass a range of beliefs about the ageing process including the expectations people have for themselves and their health as they age, their feelings of control, their emotional response to getting older and how old they feel regardless of how old they actually are. When these perceptions are negative they cause declines in mood, self-esteem, life satisfaction and self-rated health and, as our research has shown, objective cognitive and physical function [21, 61, 115]. Negative perceptions of ageing have also been associated with change to physiological pathways including increased cardiovascular reactivity in response to stress and a long term increased risk of vascular disease [46, 55].

One theory of frailty has touched on perceptions as a contributory factor to the development of the syndrome. Lang et al. (2009) suggest that frailty may consist of cycle of decline in which physiological changes interact with psychological responses to these changes. They suggest that when some older adults experience changes – for instance in bone density or muscle mass due to age – they have a resultant increase in their perception of the effort involved in remaining physically active . This perception of effort leads to a decline in actual levels of physical activity which puts them at further risk of depletion of muscle mass and frailty. In a recent review on frailty and cognition we suggested that Lang et al.'s theory could be expanded to include cognitive function, with the resulting hypothesis that older adults who reduce their levels of physical activity,

due to their perception of the effort involved in being physically active, will also put themselves at risk of cognitive decline [128]. In an additional amendment to Lang et al.'s theory we propose that the increased perception of effort may not be limited to physical activity but to social and cognitive activities as well. For example, if an older adult forgets an acquaintance's name one day they can either attribute this to age-related cognitive decline or to a multitude of other more transient reasons such as being distracted or fatigued on that particular day. How they respond, we hypothesise, depends on their perceptions of ageing: if they believe that all older adults will experience cognitive decline, and thus are expecting it to happen to them, then they will be more likely to attribute their forgetfulness to age. This may lead to a cycle of decline whereby their perception of these failings may lead them to retreat from situations which would test their cognitive function such as novel social situations or cognitively stimulating activities. They may simultaneously fail to compensate for small changes in cognitive function through strategies such as using a calendar and making to-do lists as they believe that their cognitive decline is inevitable. Using these compensatory strategies and engaging in cognitively stimulating activities are known to be protective against dementia and further cognitive decline [276]. Adults with negative perceptions of ageing who experience an age-related change and respond by withdrawing from physical activity, novel social situations and cognitive compensatory strategies may therefore be putting themselves at risk of real physical and cognitive impairment.

This paper hypotheses that perceptions of ageing may underpin the often-observed association between frailty and cognitive function. Following from Lang et al.'s original hypothesis and from our extension of it, we propose that older adults with negative perceptions of ageing who experience an age-related change will enter a cycle of decline of frailty and cognitive function. These older adults, we predict, will perceive changes as being inevitable and attributable to age which in turn will inhibit their use of protective physical and cognitive compensation strategies. This will then put them at further risk of real cognitive and physical decline. Using data from The Irish Longitudinal Study on Ageing (TILDA) we previously found that frailty was associated cross-sectionally with poorer global cognition, executive function, memory, attention and processing speed [222]. We thus sought to re-examine this relationship with the hypothesis

that the association between frailty and cognitive function will only exist in adults with negative perceptions of ageing.

Methods

Population

Data was taken from Wave 1 of The Irish Longitudinal Study on Ageing (TILDA), a prospective study of a sample representative of the population of the Republic of Ireland aged 50 and older living in the community. Participants who reported a doctor's diagnosis of dementia or who were unable to personally consent to participation due to a severe cognitive impairment (judged at an interviewer's discretion) were not included in wave one of the study. The full cohort and assessment has been described in detail elsewhere [218], but in brief 8,175 participants aged 50 and older were interviewed in their own homes followed by a nurse-administered health assessment at one of two dedicated health centres. Participants unable or unwilling to attend a health assessment centre received a modified nurse-delivered health assessment in the home. The response rate to the interview was 62.0%, and 61.6% of participants (N=6,150) completed the health (N = 5,274) or home (N= 876) assessment. This study only used data from participants who had participated in a health centre or home assessment as these included the full cognitive battery of tests as well as the items needed to create a measure of frailty.

Frailty

We used the Fried phenotypic definition of frailty [130]. Participants were classified as frail if they met three of the following five criteria: poor grip strength, slow gait speed, low levels of physical activity, unintentional weight loss and exhaustion [130]. Poor grip strength was assessed using a dynamometer. Two readings from the dominant hand were taken and the mean strength calculated. The 20th percentile was calculated and population-specific cut-offs were derived after adjustment for age, gender and BMI. Gait speed was measured using the Timed Up and Go (TUG) task. Participants were asked to rise from a chair (seat height 46cm), walk 3m at a normal pace, turn around, walk back to the chair and sit down again [237]. The time taken from the command "Go" to when the participant was sitting with their back resting against the back of the chair was recorded using a stopwatch. Participants who

fell below the gender and height adjusted 20th percentile were considered to have slow gait speed as defined by Fried et al.'s (2001) methodology [130]. Physical activity was measured using the short form of the International Physical Activity Questionnaire which converts levels of physical activity in various domains into predicted kilocalories expended per week [228]. Unintentional weight loss was assessed by the question 'In the past year have you lost 10 pounds (4.5 kg) or more in weight when you were not trying to'. Exhaustion was assessed using 2 questions from the 20-item Centre for Epidemiological Studies Depression (CES-D) scale: "I could not get going" and "I felt that everything I did was an effort" with four possible responses to each question: never, rarely, sometimes or often. A response of 'sometimes' or 'often' to either question was classified as exhaustion [229]. Participants with three or more indicators were defined as frail, those with one or more as pre-frail and those with none as robust [130].

Cognitive Function

The cognitive battery included tests of global cognition, executive function, memory, attention and processing speed. Composite scores were calculated for each of these domains.

Global cognition was assessed using the MMSE and Montreal Cognitive Assessment (MoCA) [230, 231]. Attention was assessed by 2 tasks: part 1 of the Color Trails Test and the Sustained Attention to Response Task (SART) [232, 233]. The Color Trails Test involves two parts; the first requires participants to draw a line connecting circles numbered 1-25 in consecutive order. The second part requires connecting numbered circles while alternating between pink and yellow circles e.g. pink 1, yellow 2, pink 3. The first part assesses visual scanning and attention while the mental flexibility involved in the switching task of part 2 involves executive function. The SART tests the ability to sustain attention for long periods of time during a repetitive task. Participants were shown a computer screen which repeated a sequence of numbers from 1-9 for approximately 4 minutes. Numbers appear every 300ms and participants were asked to click in response to each number except the number three.

Executive function was assessed by 3 tasks: the Visual Reasoning subtest of the CAMDEX – participants are asked to identify which of six objects would complete a pattern of three similar objects, part 2 of the Color Trails Test and the MoCA

verbal fluency subtest – participants are given 1 minute to name as many words beginning with F as they can think of [231, 232, 234].

Processing speed was assessed using a computer-based programme in which participants had to respond to a stimulus by depressing one button and pressing another. Participants were instructed to press a central button on the keyboard and wait for a stimulus (yes/no) to appear on screen. When the stimulus appeared participants depressed the central button and pressed one of two further buttons labeled 'yes' and 'no' to correspond with the stimulus on screen. The full task involves approximately 100 repetitions of this. Cognitive processing speed is measured as the time taken to depress the first button.

Composite scores for each cognitive domain were calculated by obtaining z-scores for each cognitive test and combining them to create total scores for global cognition (MoCA and MMSE), executive function (visual reasoning, Color Trail Test part 2, MoCA 'F letter' subtest), attention (Color Trail Test part 1 and SART) and processing speed (CRT). The standardised versions of these scores constituted the composite cognitive score for each domain.

Perceptions of Ageing

The Brief Aging Perceptions Questionnaire (B-APQ) measure comprises 17 Likert scale items that ask participants to rate their level of agreement with questions about the aging experience and their expectations about aging in the future [249]. The model was based on Leventhal's self-regulation model of ill health which proposes that the way people think about their own health or illness can be categorised into different themes. The validated B-APQ proposes that representations of aging can be divided into similar themes that encompass how often people think about aging, their expectations of the positive or negative consequences, their belief in the level of control they have over how they age and their emotional responses to thoughts about aging [248]. The scale is comprised of five domains: *timeline, positive consequences, positive control, negative control and consequences and emotional representations.* As our previous work indicates that the *negative control and consequences* domain predicts both physical and cognitive function we focused on this domain for this study. There are five statements contained within the *negative control and consequences* domain (e.g. 'As I get older I do not cope as well with problems that arise') and participants are asked to rate their level of agreement with each

statement. The mean score across all 5 statements was calculated with higher scores indicating a greater level of agreement with the domain. For the purposes of this analysis we used both a dichotomous version of the variable (above and below the median) and the continuous version. This measure was captured with the self-completion questionnaire at wave 1.

Covariates

Height and weight were measured and used to calculate gender adjusted cut-offs for the frailty measures. Age, gender and education were self-reported with education categorised as primary education or below, secondary level or tertiary level and above. Chronic conditions were ascertained by a self-report of a doctor's diagnosis and were included in the model individually as binary variables (0=does not have condition, 1 = has condition). The list of conditions included joint problems, cataracts, glaucoma, age-related macular degeneration, lung disease, asthma, arthritis, osteoporosis, any type of cancer, peptic ulcer, liver disease, varicose ulcer, alcohol or substance abuse, and chronic pain. Participants were also asked to record all of the medications taken on a regular basis and, where possible, interviewers asked to see the packages to confirm. Self-rated health was assessed with the question: "In general, compared to other people your age, would you say your health is...excellent, very good, good, fair or poor?"

Statistical Analyses

We ascertained descriptive statistics for key variables and covariates for the total sample, for those below the median on the ageing perceptions subscale, and for those above the median on the ageing perceptions subscale. Due to small numbers of participants who were categorised as being frail once participants were split by perceptions of ageing (N=15) we collapsed the pre-frailty and frailty groups into one category.

Linear regression models were used to estimate the association between frailty/pre-frailty and cognitive function across the five composite cognitive domains (global cognition, executive function, memory, attention and processing speed) in those below the median of the negative perceptions of aging subscale and those above the median. Regression coefficients from these

analyses represent differences in cognitive scores between frailty groups in terms of the standard deviation of that cognitive domain among the population.

Secondly, we tested the statistical significance of the interaction effect between pre-frailty/frailty and the continuous negative perceptions of ageing variable using a second set of linear regression models adjusted for all covariates. We estimated and plotted the marginal means of each cognitive domain (the means after adjusting for all covariates) for the two frailty groups (robust and pre-frail/frail) across five points of the negative perceptions subscale (1, 2, 3, 4 and 5) which represent the level of agreement with the domain (1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree).

As there was a greater proportion of frail participants who scored above the mean in the negative perceptions of ageing subscale measure and as we had collapsed the pre-frail and frail groups into one we considered that the higher proportion of frail participants in the latter group may be driving the effect. We therefore conducted the analyses a second time after dropping all frail participants as a sensitivity analysis. In addition, the largest numbers of missing data were in the ageing perceptions subscale. We thus imputed the missing APQ scores using multiple chained imputations. The imputed scores were calculated based on non-missing APQ questions, age, gender, education, the presence of joint problems, lung disease, arthritis, osteoporosis, cancer, peptic ulcers, liver failure, varicose ulcers, substance abuse, self-rated health and MMSE as these had no or very minimal numbers of missing data.

All analyses were performed using STATA, version 12.1 (College Station, TX: StataCorp LP).

Results

Of the 5,895 participants who had completed a health or home assessment, 5,355 returned a self-completion questionnaire. Consistent with the definition of frailty by Fried et al. we excluded participants who had Parkinson's Disease (N=26), a history of stroke (N=80), those taking anti-depressants (N =328), those on dementia medication (N = 6) or Sinemet (N=2) and those with an MMSE of less than 18 (N=14) [130]. The final sample size was 4,901 (for detailed description of sample see Figure 10). 29.6% of our sample (N= 1,407) were defined as pre-frail (1 or more indicators) and 2.4% (N=112) as frail (3 or

more indicators). Of this sample of pre-frail and frail participants (N=1642) 23.02% had one indicator, 6.62%% had 2 indicators, 1.82% had 3 indicators 0.57% had four indicators and 0.02% had five indicators.

The median score on the negative perceptions of ageing scale was 2.8 (interquartile range: 2.2-3.4). Table 25 gives descriptive statistics for all variables for the total sample and for the sample divided into those without negative perceptions of ageing (< 2.8) and those with negative perceptions of ageing (≥ 2.8). Those with negative perceptions of ageing were statistically significantly more likely to be frail, have worse cognition across all domains and have poorer health. Figure 11 illustrates the association between frailty and cognitive function in two groups, those with negative perceptions of ageing and those without. In linear regression analyses adjusted for all covariates (age, age-squared, gender, education, chronic conditions and medications) frailty was statistically significantly associated with cognitive function in four domains (global cognition, executive function, memory and attention) in the negative perceptions group but the effect disappeared or was attenuated for all domains in the no negative perceptions group. For example, there was a strong association between executive function and frailty in participants with negative perceptions of ageing (B= -0.19 (95% CI: -0.27, -0.12), $p<.001$) but no association in those without negative perceptions of ageing (B=-.01 (95% CI: -0.01, 0.08), $p > .05$). Processing speed was associated with frailty in participants without negative perceptions of ageing (B= -0.14 (95% CI: -0.24, -0.04) $p<.01$) and had a trend association in the negative perceptions of ageing group (B= -0.08 (95% CI: -0.16, 0.006), $p = .07$).

Tables 26, 27 and 28 display the results of linear regression analyses testing the interaction effect of negative perceptions of ageing and frailty on cognitive function. In these analyses we adjusted for all covariates as above and also self-rated health. As the Fried categorisation of frailty offers no means of measuring severity of frailty within categories of frailty we used self-rated health to attempt to capture the possibility that people with worse perceptions of ageing were also frailer than those without negative perceptions of ageing in the same frailty category. After adjustment for all covariates there was a significant interaction effect between frailty and negative perceptions of ageing in predicting global cognition (B= -0.11 (95% CI: -0.19, -0.04)), executive function (B= -0.08 (95% CI: -0.15, -0.02)) and attention (B= -0.08 (95% CI: -0.15, -0.002)) but not for

memory (B=-.04 (95% CI: -.12, .04)) or processing speed (B = 0.04, (95% CI: -0.05, 0.12)). Figures 12, 13 and 14 show the plotted marginal means of the interaction effect for the three cognitive domains (global cognition, executive function and attention). It illustrates that as agreement with the negative perceptions subscale increases cognitive function decreases across both the robust and pre-frail/frail groups. There is, however, no difference between the robust and pre-frail/frail participants in those at the lower end of the negative perceptions scale (those scoring 1 – 2) but an increasingly large difference between groups at the higher ends of the negative perceptions scale (those scoring 3-5). This pattern is replicated across all three cognitive domains.

We reanalysed the data after excluding all participants defined as frail (3 or more indicators) but this did not change our findings and so we have not presented the data here. We also reran the analyses using the imputed APQ scores however this made no difference to our results and so for reasons of space we have not presented the data here.

Discussion

Our results illustrate that older adults who are frail have poorer cognitive function but this association only exists in the added presence of negative perceptions of ageing. Consistent with the hypothesis tested, we found either no association or an attenuated association between frailty and cognitive function in older adults who did not hold negative perceptions of ageing. This suggests that perceptions of ageing may play a key role in initiating or maintaining the cycle of decline involving frailty and cognitive function.

Perceptions of ageing are associated with adaptation and coping in older age. As people get older, age-related changes and ill health can limit the achievability of specific goals and tasks. However, how people respond to these changes can often predict the resulting level of impairment. A previous study in this area found that older adults who faced ill health but who responded by using what they called SOC strategies (selection, optimisation and compensation) did not experience the negative effects of ill health to the same extent that older adults who did not use these strategies did [115]. SOC strategies involve *selection* of appropriate goals in the face of challenges, *optimisation* of current functions with regards to time and effort to reach goals and *compensation* for losses by using alternative means to reach a goal. Wurm et al found that older adults who

used these types of strategies in the face of ill health did not experience the dramatic declines in self-rated health and life satisfaction that other older adults did despite being challenged by ill health [115]. However only older adults without negative perceptions of ageing appeared able or willing to engage in these strategies. Adults with negative perceptions of ageing were less likely to use SOC strategies and had resulting declines in life satisfaction and self-rated health. We suggest that this may be one explanation as to why only older adults with negative perceptions of ageing are likely to experience both frailty and cognitive decline: they fail to engage in coping strategies to deal with age-related changes and, through consequent further reductions in physical and social activities, put themselves at risk of actual physical and cognitive decline.

Another factor which may influence the relationship is stress and resulting physiological processes such as increased cortisol production and decreased inflammatory suppression. If older adults constantly expect negative consequences as they age and feel that all negative changes are inevitable they are likely to experience heightened levels of psychological stress. Psychological stress is associated with the overproduction of the stress hormone cortisol which is itself damaging for both muscle mass and cognitive function [95, 264]. Furthermore, both frailty and cognitive decline are associated with over-active inflammatory cytokines including interleukin-6 (IL-6) [103]. Adults experiencing chronic psychological stress have a decreased ability to suppress levels of IL-6 suggesting that levels of psychological stress may contribute to the impaired physiological pathways [105].

While inflammation is a proposed mediator of the relationship between frailty and cognition, however, there has been little empirical work on this to date. One paper by Canon et al. measured muscle strength in place of frailty and found that circulating levels of C-reactive protein (CRP), another inflammatory cytokine, partially mediated the relationship between muscle strength and cognition but only in women [200]. There are no studies that we are aware of examining coping and adaptation, in relation to SOC strategies, in frailty but this would be an interesting aim for future research.

It is interesting that there was no interaction effect between negative perceptions of ageing and memory. This is consistent with the data presented in paper 3 in which executive function and prospective memory were associated

with negative perceptions of ageing but verbal memory was not. This may be due to the nature of the memory measure we used which has a smaller possible range (0-10), and therefore variance in scores, compared to the executive function and attention measures, which are assessed in time taken to complete and thus have an unbounded range. It is possible that in our relatively healthy sample of older adults there is merely not enough variance to pick up on subtle differences in memory between people. However this theory does not apply to processing speed which is also measured in time taken to complete the task. It is thus possible that there is a true difference in the impact of perceptions of ageing on memory and processing speed compared to the effects on executive function and attention. Unfortunately there are no other studies to our knowledge which have assessed the impact of perceptions of ageing on domains of cognitive function with which to compare these results. A previous study by Levy et al found a change in visual memory associated with negative perceptions of ageing but did not assess verbal memory as we have done [257]. It may be that executive function and attention reflect cognitive abilities which are heavily dependent on cognitive control and top-down processing and that negative perceptions of ageing affect this ability to keep one's mind on the task. In support of this, previous experimental work found that priming older adults with negative stereotypes about ageing affected their performance in controlled cognitive processes but not in automatic processes [49]. They suggested that stereotype threat occupied working memory in these older adults, limiting their ability to complete the parts of the task which required cognitive control. Furthermore, we know that processing speed is the only cognitive domain which starts to decline before the age of 50 suggesting that this may be a more uncontrollable and automatic process than other cognitive functions [277]. In addition, one of the hypothetical pathways in our model proposes that older adults who have negative perceptions of ageing are at increased risk of frailty and cognitive impairment due to declines in social and cognitive engagement. Previous work has found, albeit cross-sectionally, that decreased social engagement is associated with poorer executive function but not memory [215]. These findings may therefore reflect a true difference in the impact of negative perceptions of ageing on domains of cognitive function. Of course, future longitudinal research will be required to verify this.

This study has a number of strengths and limitations. One strength is the use of a population representative sample of Irish adults and a nurse-led health assessment which allows in-depth collection of objective data. We also had a large battery of cognitive measures which allowed us to compare the relationship over a number of cognitive domains. A limitation of this study is the cross-sectional nature of the data which does not allow us to determine causality. We will, however, be able to further explore these pathways using longitudinal data in wave 3 of TILDA during which a health assessment with the same measures will be carried out. The later waves of data will also result in a larger sample of frail adults as the study population ages. As this is a relatively young and healthy population the frail sample is limited which meant it was necessary to combine the pre-frail and frail categories into one group. This is not ideal but as the TILDA sample ages we will be better able to unpick the association between pre-frailty, frailty, perceptions of ageing and cognitive function.

In conclusion, this study suggests that the relationship between frailty and cognition is bound by a psychological construct: perceptions of ageing. Previous work from our group illustrates that perceptions of ageing contribute to both physical and cognitive decline suggesting that they could be a targetable, modifiable factor to delay impairment in some older adults. Promisingly, a recent paper found that implicitly improving older adults' perceptions of ageing during a 4-week intervention led to improved physical function. Furthermore, the effect of this intervention on physical function even surpassed the results of a 6 month exercise intervention [278]. Perceptions of ageing are only one pathway through which older adults may experience frailty and cognitive decline but, should interventions become widely available, we may be able to prevent some people from entering a cycle of decline which would lead them to develop these two debilitating conditions simultaneously.

Figure 10. Flow Chart of Participation

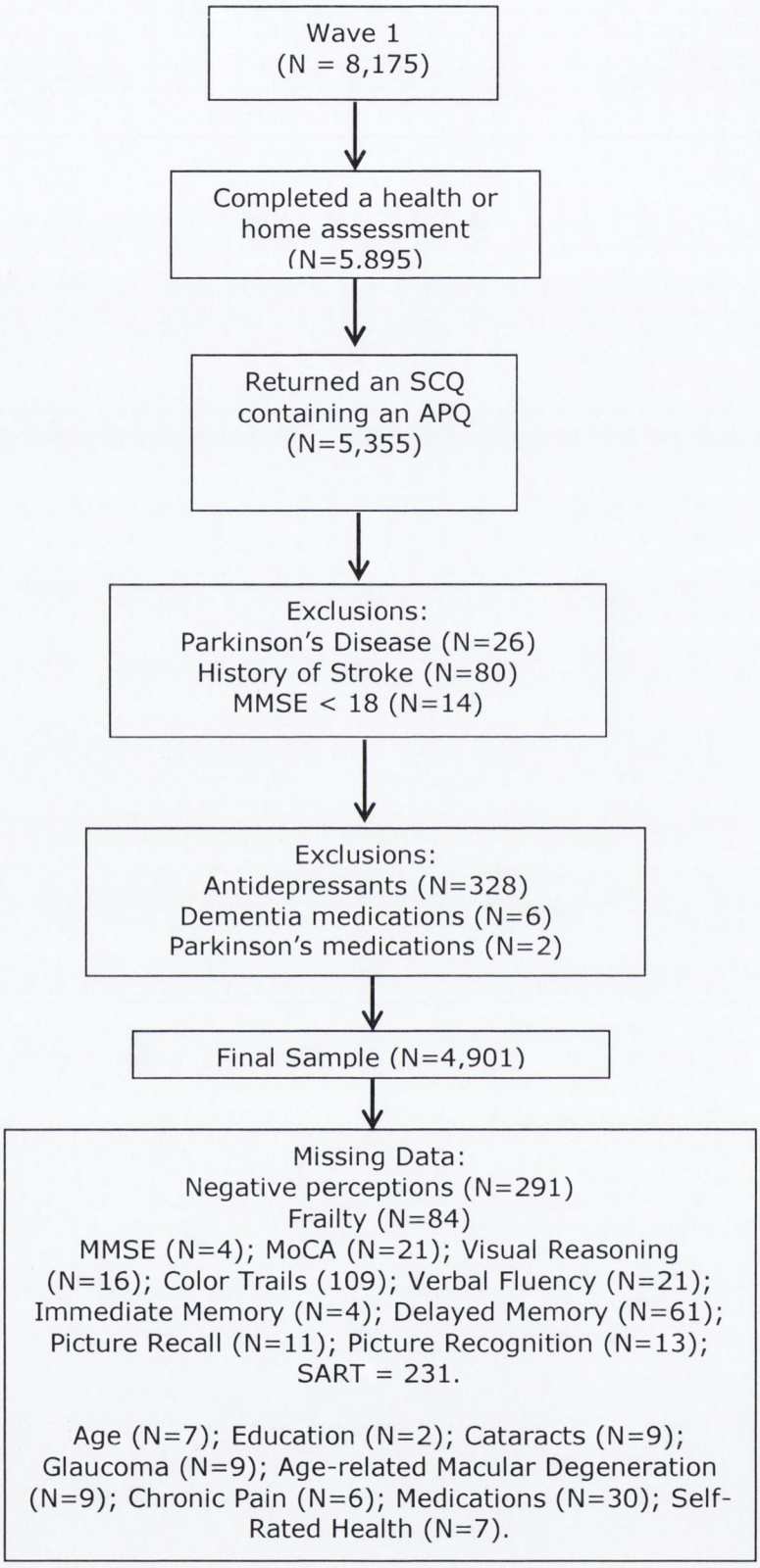


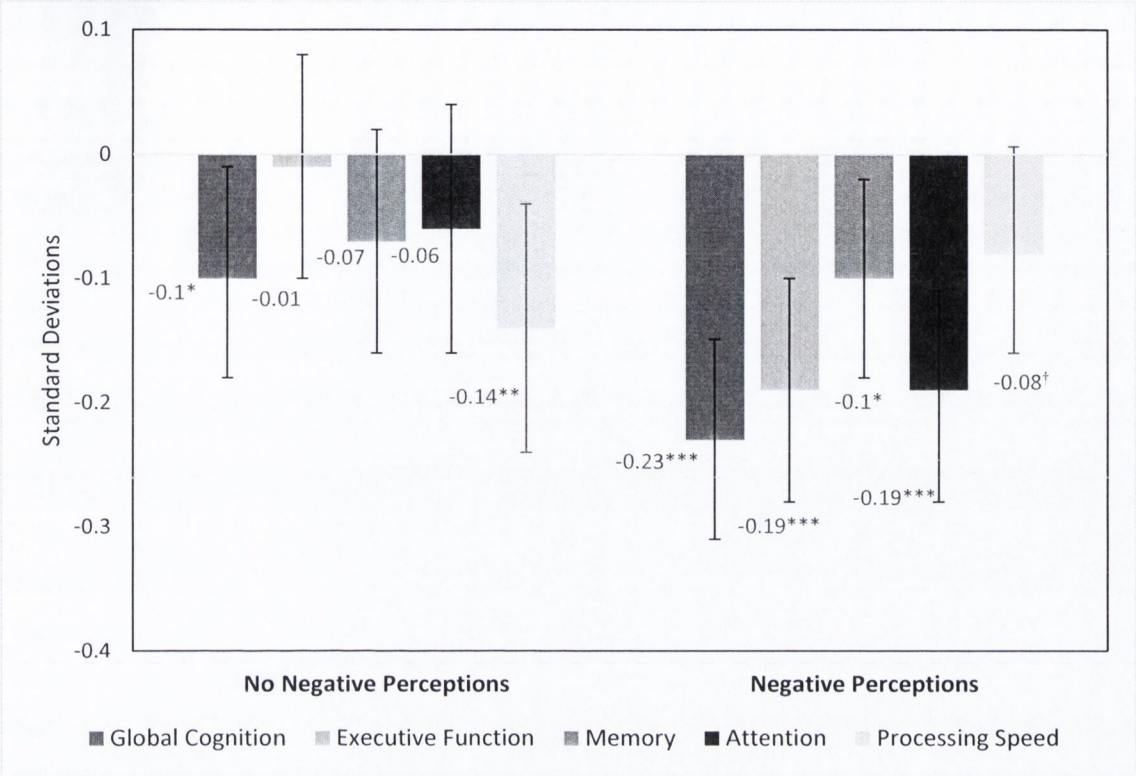
Table 25. Descriptive statistics for the total sample and the sample divided by perceptions of ageing across all variables.

Measure (Possible Range) N=4,901	**Mean (SD) or %**		
	Total Sample	**No Negative Perceptions**	**Negative Perceptions**
Frailty			
Robust	68.1% (N=3,241)	77.4% (N=1,632)	60.6% (N=1,440)***
Pre-Frail	29.6% (N=1,407)	21.9% (N=463)	35.5% (N=840)***
Frail	2.4% (N=112)	0.71% (N=15)	3.7% (N=88)***
Negative Control & Consequences (1-5)	2.8 (0.75)	2.15 (0.41)	3.36 (0.47)***
General Cognition			
MMSE (0-30)	28.5 (1.8)	28.9 (1.5)	28.2 (2.0)***
MoCA (0-30)	25.0 (3.5)	25.9 (2.9)	24.3 (3.7)***
Executive Function			
Visual Reasoning (0-6)	3.1 (1.3)	3.3 (1.3)	2.9 (1.3)***
Color Trails B (seconds)	111.1 (42.3)	99.6 (34.1)	119.4 (45.0)***
Verbal Fluency (no. of words)	11.9 (5.1)	12.9 (5.1)	11.3 (5.1)***
Memory			
Immediate Memory(0-10)	3.2 (1.1)	6.2 (1.6)	5.6 (1.6)***
Delayed Memory (0-10)	5.9 (1.7)	6.7 (2.1)	5.7 (2.3)***
Picture Recall (0-6)	3.2 (1.1)	3.4 (1.1)	3.1 (1.1)***
Picture Recognition (0-6)	5.6 (0.7)	5.7 (0.6)	5.5 (0.8)***
Attention			
SART Coefficient of Variability	0.3 (0.2)	0.3 (0.2)	0.3 (0.2)***
Color Trail A (seconds)	56.6 (27.8)	49.9 (20.9)	61.0 (29.9)***
Covariates			
Age	63.0 (9.2)	60.1 (7.5)	65.1 (9.7)***
Sex (female)	53.7% (N=2,630)	56.3% (N=1,220)	50.0% (N=1,220)***
Education (third level)	34.4% (N=1,687)	41.0% (N=889)	30.3% (N=740)***
Joint problems (yes)	6.5% (N=316)	4.0% (N=87)	8.1% (N=198)***
Cataracts (yes)	10% (N=490)	6.5% (N=140)	12.4% (N=12.4)***
Glaucoma (yes)	2.1% (N=105)	1.8% (N=39)	2.4% (N=58)
Age-Related Macular Degeneration (yes)	1.8% (N=89)	1.2% (N=26)	2.3% (N=56)**
Lung Disease (yes)	3.8% (N=188)	2.8% (N=61)	4.7% (N=115)***

Asthma (yes)	9.4% (N=459)	8.5% (N=185)	10.3% (N=251)*
Arthritis (yes)	26.6% (N=1,304)	19.1% (N=413)	32.2% (N=786)***
Osteoporosis (yes)	10.1% (N=496)	8.6% (N=186)	11.1% (N=272)**
Cancer (yes)	6.0% (N=298)	4.9% (N=107)	6.9% (N=169)**
Peptic Ulcer (yes)	7.1% (N=347)	5.8% (N=126)	8.2% (N=199)**
Liver Disease (yes)	0.53% (N=26)	0.6% (N=13)	0.4% (N=10)
Varicose Ulcer (yes)	3.4% (N=165)	2.1% (N=45)	4.3% (N=105)***
Substance Abuse (yes)	1.2% (N=59)	1.0% (N=21)	1.4% (N=34)
Chronic Pain (yes)	34.6% (N=1,696)	27.5% (N=595)	40.3% (N=984)
No. of Medications	2.4 (2.5)	1.8 (2.2)	2.8 (2.7)***
Self-Rated Health (1-5)	2.3 (1.0)	2.0 (0.9)	2.5 (1.0)***

***$p < .001$, **$p < .01$, * $p < .05$. Statistical significance was calculated using t-tests for continuous variables and chi-square tests for categorical variables.

Figure 11. The association between pre-frailty/frailty and cognitive function in those with no negative perceptions of ageing and those with negative perceptions of ageing.



* = $p < .05$, ** = $p < .001$, *** = $p < .001$. Beta coefficients and 95% confidence intervals from linear regression analyses adjusted for age, age-squared, gender, level of education, chronic conditions and no. of medications. Robust group is compared to pre-frail/frail group in those without negative perceptions of ageing and again in those with negative perceptions of ageing. Z-scores are standardised such that the mean domain score among robust individuals is zero, with the score indicating the difference in terms of standard deviation of composite cognitive domain scores. For example, frail individuals score 0.23 standard deviations less than robust individuals on measures of executive function after adjusting for all covariates.

Table 26. Results from a linear regression illustrating the interaction between frailty and negative perceptions of ageing in predicting global cognition.

Global Cognition	**Unstandardized Beta Coefficients and 95% Confidence Intervals**
Pre-Frail/Frail	0.19 (-0.03,0.40)
Negative Perceptions of Ageing	-0.10***(-0.13,-0.05)
Interaction (Frailty & Negative Perceptions of Ageing)	**-0.11** (-0.19,-0.04)**
Age	0.12***(0.07,0.16)
Age^2	-0.001***(-0.001,-0.001)
Gender	0.0004 (-0.05,0.05)
Education	
Comparison: Primary	
Secondary	0.57***(0.49,0.65)
Third/higher	0.90***(0.82,0.97)
Joint problems	-0.10 (-0.23,0.03)
Cataracts	0.07 (-0.03,0.16)
Glaucoma	-0.0001 (-0.17,0.17)
Age-related Macular Degeneration	0.08 (-0.11,0.26)
Lung disease	-0.08 (-0.21,0.06)
Asthma	-0.01 (-0.10,0.09)
Arthritis	0.06 (-0.001,0.12)
Osteoporosis	0.07 (-0.01,0.16)
Cancer	0.15** (0.05,0.24)
Peptic Ulcer	0.05 (-0.05,0.14)
Liver disease	0.21 (-0.12,0.54)
Varicose Ulcer	-0.13 (-0.30,0.04)
Alcohol or Substance Abuse	0.14 (-0.08,0.37)
Chronic pain	0.01 (-0.05,0.06)
No. of medications	0.01 (-0.01,0.02)
Self-rated health	-0.08*** (-0.11,-0.05)
Observations	4466

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets

Table 27. Results from a linear regression illustrating the interaction between frailty and negative perceptions of ageing in predicting executive function.

Executive Function	**Unstandardized Beta Coefficients and 95% Confidence Intervals**
Pre-Frail/Frail	0.16 (-0.05,0.37)
Negative Perceptions of Ageing	-0.13*** (-0.17,-0.08)
Interaction (Frailty and Negative Perceptions of Ageing)	**-0.08*(-0.15,-0.02)**
Age	-0.03 (-0.06,0.004)
Age^2	0.0002 (-0.0002,0.0003)
Gender	0.02 (-0.03,0.07)
Education	
Comparison: Primary	
Secondary	0.54***(0.47,0.60)
Third/higher	1.00***(0.93,1.07)
Joint problems	0.01 (-0.09,0.08)
Cataracts	-0.01 (-0.09,0.08)
Glaucoma	0.002 (-0.17,0.16)
Age-related Macular Degeneration	0.01 (-0.19,0.21)
Lung disease	-0.09 (-0.22,0.04)
Asthma	0.08 (-0.01,0.17)
Arthritis	0.05 (-0.01,0.11)
Osteoporosis	0.03 (-0.06,0.11)
Cancer	0.09† (-0.01,0.20)
Peptic Ulcer	-0.03 (-0.07,0.12)
Liver disease	0.20 (-0.15,0.56)
Varicose Ulcer	-0.14 (-0.29,-0.01)
Alcohol or Substance Abuse	-0.10* (-0.32,0.12)
Chronic pain	0.04 (-0.02,0.09)
No. of medications	0.002 (-0.01,0.01)
Self-rated health	-0.07*** (-0.10,-0.04)
Observations	4388

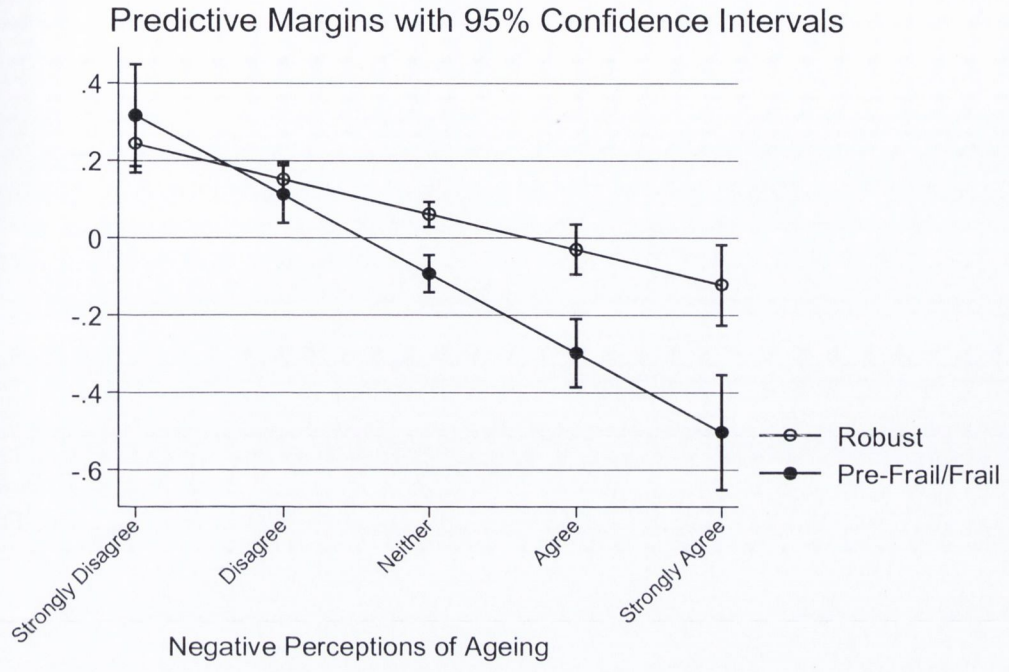
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

Table 28. Results from a linear regression illustrating the interaction between frailty and negative perceptions of ageing in predicting attention.

Attention	**Unstandardized Beta Coefficients and 95% Confidence Intervals**
Pre-Frail/Frail	0.13 (-0.10,0.35)
Negative Perceptions of Ageing	-0.07** (-0.12,-0.02)
Interaction(Frailty and Negative Perceptions of Ageing)	**-0.08** (-0.15,-0.002)**
Age	-0.02 (-0.06, 0.01)
Age^2	-0.0001 (-0.0003,0.0001)
Gender	0.001 (-0.05,0.06)
Education	
Comparison: Primary	
Secondary	0.30*** (0.24,0.37)
Third/higher	0.51*** (0.44,0.59)
Joint problems	0.06 (-0.04,0.17)
Cataracts	-0.10* (-0.18,-0.01)
Glaucoma	-0.05 (-0.21,0.10)
Age-related Macular Degeneration	0.07 (-0.14,0.27)
Lung disease	-0.15* (-0.28,-0.02)
Asthma	0.09† (-0.00,0.18)
Arthritis	0.03 (-0.04,0.09)
Osteoporosis	0.01 (-0.08,0.09)
Cancer	-0.01 (-0.11,0.10)
Peptic Ulcer	0.06 (-0.04,0.17)
Liver disease	-0.16 (-0.55,0.24)
Varicose Ulcer	-0.02 (-0.17,0.14)
Alcohol or Substance Abuse	-0.18 (-0.40,0.04)
Chronic pain	0.04 (-0.02,0.10)
No. of medications	0.003 (-0.01,0.02)
Self-rated health	-0.09*** (-0.12,-0.06)
Observations	4263

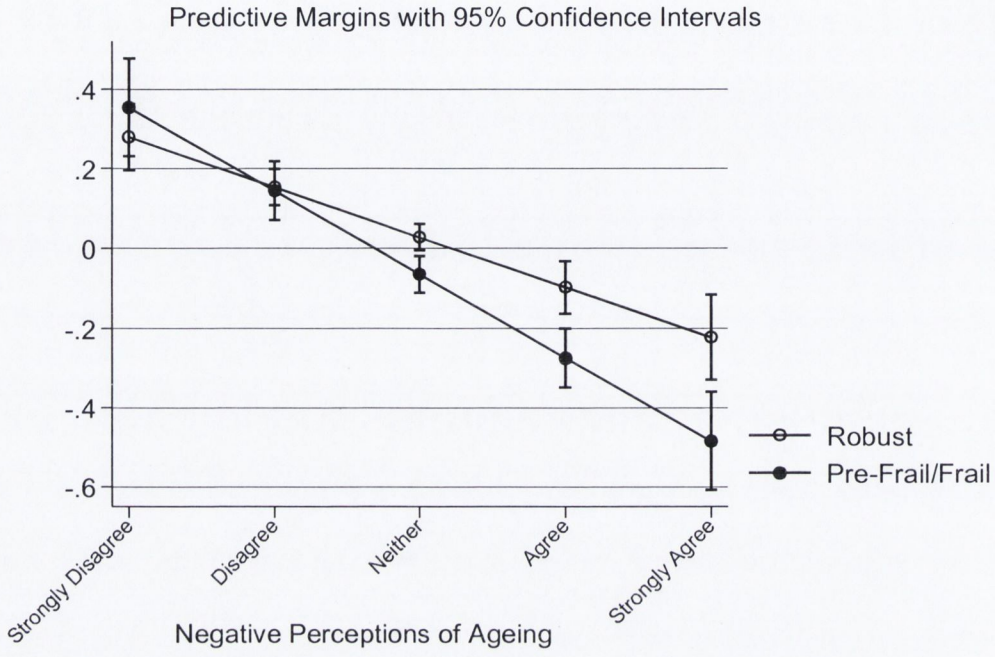
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

Figure 12. Marginal mean scores and 95% confidence intervals on a composite score of global cognition in robust participants and in pre-frail/frail participants across 5 levels of agreement with the negative perceptions of ageing scale.



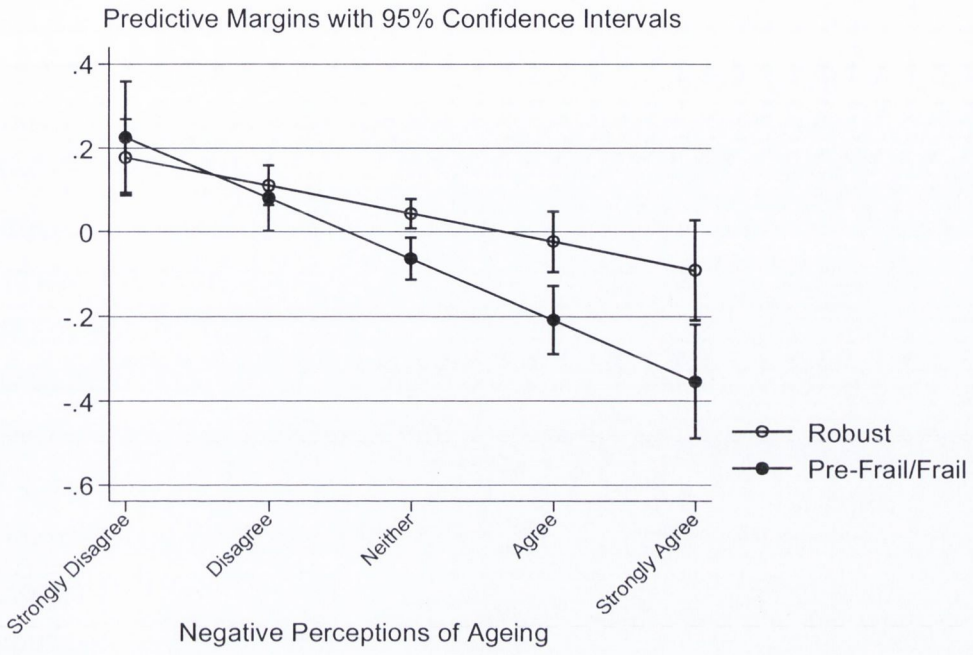
Marginal means are the mean scores in the cognitive domain after adjustment for confounding variables. This figure illustrates the interaction effect between the binary variable frailty (Robust vs Pre-Frail/Frail) and five points on the continuous negative perceptions of ageing subscale (1, 2, 3, 4 and 5) which represent increasing levels of agreement with the scale.

Figure 13. Marginal mean scores and 95% confidence intervals on a composite score of executive function in robust participants and in pre-frail/frail participants across 5 levels of agreement with the negative perceptions of ageing scale.



Marginal means are the mean scores in the cognitive domain after adjustment for confounding variables. This figure illustrates the interaction effect between the binary variable frailty (Robust vs Pre-Frail/Frail) and five points on the continuous negative perceptions of ageing subscale (1, 2, 3, 4 and 5) which represent increasing levels of agreement with the scale.

Figure 14. Marginal mean scores and 95% confidence intervals on a composite score of attention in robust participants and in pre-frail/frail participants across 5 levels of agreement with the negative perceptions of ageing scale.



Marginal means are the mean scores in the cognitive domain after adjustment for confounding variables. This figure illustrates the interaction effect between the binary variable frailty (Robust vs Pre-Frail/Frail) and five points on the continuous negative perceptions of ageing subscale (1, 2, 3, 4 and 5) which represent increasing levels of agreement with the scale.

Introduction to Paper 5

The papers in this thesis have been concerned with the association between perceptions of ageing, frailty and cognitive function. It has been shown that older adults with negative perceptions of ageing are more likely to experience physical decline, cognitive decline and to have both frailty and poorer cognitive function simultaneously. In the introductory literature review I hypothesised that perceptions of ageing may impact upon health through psychological, physiological and behavioural pathways. In relation to the latter, I hypothesised that older adults with negative perceptions of ageing may be more likely to withdraw from physical and social activities which would otherwise play a role in protecting them against physical and cognitive decline. It is outside the scope of this thesis to be able to examine potential mediating factors - the aim has been primarily to demonstrate the relationship – however, there is a dearth of evidence investigating what role perceptions of ageing play in determining social behaviours in later life. Although some studies have shown that perceptions of ageing are associated with exercise and healthcare utilisation, no studies that I am aware of have unpicked this relationship to assess the effect of perceptions of ageing on specifically social behaviours which are known to be protective against dementia. The aim of the final paper in this thesis was therefore to examine whether perceptions of ageing impact upon engagement with family and friends, participation in the community, participation in active leisure pursuits and cognitively stimulating activities in later life.

Paper 5: Ageing Perceptions Predict Engagement with Social and Cognitively Stimulating Activities.

Abstract

Introduction

Previous work has shown that older adults who hold negative perceptions about ageing are less likely to exercise, maintain a healthy diet and visit health professionals. However less is known about the impact of negative perceptions of ageing on social and cognitive behaviours which are known to be protective against physical and cognitive decline in later life. The purpose of this paper was to assess whether any domains of perceptions of ageing predict longitudinal change in social behaviours.

Methods

Data was taken from 5,499 participants from the Irish Longitudinal Study on Ageing. Perceptions of ageing were assessed using the Aging Perceptions Questionnaire (APQ) taken in wave 1. Social and cognitive behaviours were divided into four categories: relationships with family or friends, engagement in formal organisations outside of the workplace, participation in social or active leisure pursuits and engagement with cognitively stimulating activities. These were assessed in wave 1 and again in wave 2, 2 years later. Covariates including age, gender, education, household location, employment status, marital status, chronic conditions, disability, medications, depression, self-rated health and cognition were measured at wave 1 and wave 2.

Results

After full adjustment for all covariates and baseline involvement, participants with positive perceptions of ageing were more likely to have close relationships with family or friends (IRR = 1.02 (1.00, 1.04), $p<.05$)), more likely to be involved in organisations outside of the workplace (IRR: 1.04 (1.01, 1.06) $p<.05$) and more likely to be engaged with cognitive stimulating activities (IRR: 1.01 (1.00, 1.02) $p<.05$). Participants with more negative perceptions of ageing were less likely to engage in social and active leisure pursuits (IRR = 0.98 (0.97, 0.99), $p<.05$).

Conclusion

This is the first study to show that perceptions of ageing may influence change in social and cognitive behaviours in later life. This is important as these behaviours are known to be protective against dementia. Nevertheless, the risk ratios in this study were small and future research with a longer follow up period will be needed to determine whether perceptions of ageing predict long-term changes in behaviour.

Introduction

Older adults who are socially engaged and cognitively stimulated are less likely to develop dementia. The cognitive reserve theory proposes that, although these adults may have dementia-related pathology in their brains, larger social networks, higher levels of education and continued learning in later life can protect their cognitive function (e.g. [120, 265]). Yet while much research is attempting to elucidate how and why these psychosocial factors are protective, less is understood about the factors that determine why some people remain socially and cognitively active in later life and others do not. One potential explanation is that attitudes and beliefs about ageing determine such behaviours in later life.

Across the globe, attitudes towards ageing are mostly negative. Older adults are more likely to experience discrimination in relation to employment, medical care and social situations than younger adults. A survey of ageism in 2001 found that 77% of older adults surveyed had experienced at least one incident of ageism [31]. The omnipresence of negative attitudes towards ageing, particularly in the western world, means that older adults are faced with negative stereotypes on a daily basis. Most anti-ageism campaigns focus on the negative views of ageing held by younger members of society. However a large body of current research is focussing instead on negative attitudes towards ageing held by older adults themselves. Such is the strength of negative attitudes towards ageing that older adults show a preference for younger age groups over their own age groups in implicit tests of attitudes [17]. Furthermore, older adults with negative attitudes towards ageing are the strongest opponents of government-funded programmes, which would directly benefit them as older citizens, and the greatest supporters of youth-targeted programmes [18].

Becca Levy, a leading expert in this field, proposes that the saturation of negative stereotypes in today's society means that as some adults get older they internalise these stereotypes and believe them to be true to themselves and their own experiences [22]. They thus expect to become cognitively impaired and physically disabled and will act, or fail to act, accordingly. Indeed, previous work has shown that older adults who blame health deficits on 'old age', rather than lifestyle factors, are less likely to engage in health maintenance

behaviours, such as going to their doctor or taking medications as prescribed, and are therefore more likely to die from their illness [116]. The authors suggest that one reason for this may be a lack of perceived control. As ageing is inevitable then those older adults who blame illness on 'old age' will also believe that they have no control over their health and will fail to act to improve it. However the same study also measured adults' feelings of control and found that attributing illness to 'old age' had an effect on health maintenance behaviours and mortality beyond the effect of control suggesting that it cannot explain the full relationship. Furthermore, no similar effect was seen in those who believed their ill health was due to genetics, a similarly uncontrollable factor. There therefore appears to be a specific aspect of attributing ill health to old age which causes a change in behaviour.

One possible suggestion is that these older adults had an attributional or an attentional bias to symptoms of ill health which they then dismissed as being due to 'old age' rather than due to preventable or curable ill health. In healthy older adults with negative perceptions about ageing there may be a similar attentional bias which predicts whether people remain physically, socially and cognitively active. For example, an older adult with negative perceptions of ageing who believes that cognitive decline is inevitable and forthcoming may have an attentional bias towards their own memory performance. If this person has an everyday lapse in attention and forgets to buy something on their shopping list they will, rather than dismissing it as an act of absent mindedness, interpret it as confirmation that their cognitive function is beginning to decline. The sense of inevitability coupled with hyper-vigilance towards further signs of 'cognitive decline' may make them less likely to engage in the kinds of strategies which people use to remember everyday tasks, such as making shopping lists or using mnemonic strategies. A resulting series of failures will therefore 'confirm' to them that they have a cognitive impairment. This belief may erode their confidence and motivation to engage in other tasks which require cognitive abilities but which would, paradoxically, protect the brain from real cognitive decline. As there is still a stigma surrounding cognitive impairment in society today this may also erode motivation to engage in social situations in which the imagined cognitive impairment would become obvious to other people. A resulting withdrawal from cognitively stimulating activities would thus put those

older adults with negative perceptions of ageing at real and actual risk of cognitive impairment.

There is some support for the theory that negative perceptions of ageing affect behaviour in healthy older adults as a small number of studies have found that negative perceptions of ageing predict disengagement with health promoting activities such as exercising, eating a healthy diet and visiting health professionals [18, 110, 112-114]. A number of these studies have also included factors such as social and cognitive engagement, providing some support for our theory. However, the behavioural measures used in these studies have comprised of one-factor scales which encompass all of these domains together – exercise, diet, health professionals, cognitive stimulation, social engagement – and thus it is difficult to disentangle whether perceptions of ageing merely affect illness behaviours such as visiting health professionals or whether they also predict normal cognitive and social engagement. This aim of this paper was thus to explore whether perceptions of ageing are associated with social and cognitive engagement in older adults. Using follow-up data from the Irish Longitudinal Study on Ageing – a population representative sample of adults aged over 50 living in the Republic of Ireland – we explored whether perceptions of ageing at baseline independently predict levels of social participation and cognitive stimulation in four categories – intimate relationships, organisational involvement, social and active leisure and cognitive stimulation - two years later.

Methods

Sample

Data was taken from Irish Longitudinal Study on Ageing (TILDA), a large prospective cohort study of the social, economic and health circumstances of community-dwelling older people in Ireland. Analyses are based on the first wave of data collected between January 2009 and July 2011 and follow-up data collected between March and December 2012. Irish Geodirectory, a listing of all residential addresses in the Republic of Ireland, was used as a sampling frame. A clustered sample of addresses was chosen, and household residents aged 50 or over and their spouses/partners (of any age) were eligible to participate in the study. Ethical approval was obtained from the Trinity College Dublin

Research Ethics Committee and all participants provided written informed consent.

The study design has been described in detail elsewhere [218]. Briefly, data collection involved (i) a computer-assisted personal interview (CAPI) carried out by trained social interviewers that included detailed questions on socio-demographics, wealth, physical and mental health, medications, lifestyle, social support and participation and use of health and social care (ii) a self-completion questionnaire which included questions about social networks, social participation and ageing perceptions (iii) a health assessment carried out by research nurses. Participants who were unwilling or unable to attend a health assessment in a designated health centre were offered a home-based assessment. In wave 2 the computer-assisted personal interview and key elements of the health assessment were combined into a home interview carried out by trained interviewers.

In total, 8,175 individuals aged 50 years and over were interviewed at baseline (response rate 62.0%). Follow up data for wave 2 was available for 6,995 (86%) participants of which 78 (.01%) were proxy interviews and were thus not included in the sample for this analysis. Follow up data was unavailable for 1,180 (14%) participants due to death (n=205); refusal (n=809) or no contact (n=166). Our final sample included participants who had completed and returned the self-completion questionnaire in wave 1 (N=6,867), who had returned to the study in wave 2 (N=6,067) and who had completed the wave 2 self-completion questionnaire (N=5,499). For a flow chart of sample selection see Figure 15.

Brief Aging Perceptions Questionnaire

The Brief Aging Perceptions Questionnaire (B-APQ) measure comprises 17 Likert scale items that ask participants to rate their level of agreement with questions about the ageing experience and their expectations about ageing in the future. The model was based on Leventhal's self-regulation model of ill health which proposes that the way people think about their own health or illness can be categorised into different themes. The validated B-APQ proposes that representations of ageing can be divided into similar themes that encompass how often people think about ageing, their expectations of the positive or negative consequences, their belief in the level of control they have over how

they age and their emotional responses to thoughts about ageing [248]. The scale is comprised of 5 domains: timeline (e.g. "I am conscious of getting older all of the time"), positive consequences (e.g. "As I get older I continue to grow as a person"), positive control (e.g. "As I get older there is much I can do to maintain my independence"), negative consequences and control (e.g. "Slowing down with age is not something I can control") and emotional representations (e.g. "I get depressed when I think about getting older"). Participants rate their level of agreement with each statement within each domain. Higher scores indicate a greater level of agreement with that domain [249]. This measure was captured with the self-completion questionnaire at wave 1.

Social Engagement

The social engagement measures were also captured with the self-completion questionnaire at both wave 1 and wave 2. Participants were asked to indicate how frequently they participated in a list of 14 social and solitary leisure activities. The listed activities included: watching television, going to films, plays and concerts, attending classes or lectures, travelling for pleasure, working on the garden, home or car, reading books or magazines, listening to music and the radio, spending time on hobbies or creative activities, playing cards, bingo or other games, going to the pub, eating out of the house, participating in sport or exercise, visiting or phoning family or friends and doing voluntary work. Participants recorded how often they engaged in these activities. In addition, as part of the CAPI interview participants were asked: Do you participate in any groups such as a sports or social group or club, a church connected group, a self-help or charitable body or other community group or a day care centre? Answers were classified as yes or no. We structure our classification of these activities into four groups based loosely on the House et al. model: 1) intimate social relationships (visits to or from family and friends); 2) formal organisational involvement outside of work (religious services or meetings at voluntary associations); 3) active and social leisure participants (going to classes or lectures, movies, plays and concerns, playing cards or bingo, eating outside the house, taking part in sports); and 4) passive cognitively stimulating activities (working on the garden, home or car, reading books or engaging in creative activities) [279]. The original model included all solitary leisure activities within one group but, as we were interested in activities which may protect against future decline, we included only those activities which could be

considered to be cognitively stimulating. This was necessary as some of the passive activities, such as watching television, were not comparable, in terms of cognitive stimulation, with other activities including reading books and engaging in creative hobbies.

The intimate social relationships domain was captured through participants' reported frequency of contact with family or friends. Participants who reported daily or weekly contact with family or friends were reported as having intimate social relationships. Participants who reported doing voluntary work or being involved in other organisations outside of their workplace at a frequency of greater than once a year were reported as having formal organisational involvement. Participants who reported active and social leisure activities of more than once a month were considered to be socially active. Participants who reported working on the garden, home or car, reading books or magazines or engaging in hobbies or creative activities at least once a month were considered to be engaged in cognitive stimulation.

Covariates

All covariates were measured at baseline and follow-up.

Age, gender, education, household location, employment status and marital status were collected by self-report. Education was categorised as no education or primary only, secondary education or third level education and above. Household location was categorised as Dublin (capital city), another town or city in Ireland or a rural area. Employment status was categorised as employed, retired or other.

Chronic conditions were ascertained by self-report of a doctor's diagnosis and included: joint problems, cataracts, glaucoma, age-related macular degeneration, lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson's disease, peptic ulcer, liver disease, varicose ulcer, alcohol or substance abuse, and chronic pain. Number of chronic conditions at baseline and change in chronic conditions between waves were included in this analysis.

Basic and instrumental activities of daily living (ADLs and IADLs) were collected through self-report. Participants were asked "Because of a health or memory problem, do you have any difficulty doing any of the activities on this card?" They were then shown a card listing 6 basic ADLs including dressing, walking

across a room, bathing or showering, eating, getting in and out of bed and using the toilet. An ADL disability was defined as difficulty in at least one of the activities listed on the card. Participants were then asked the same question and given a second card listing instrumental ADLs (IADLs) including preparing a hot meal, doing household chores, shopping for groceries, making telephone calls, taking medications and managing money. An IADL disability was defined as difficulty in at least one of these tasks. The level of disability with each activity was not assessed. For cross-sectional analyses participants were classified into 4 categories: no disability, ADL only, IADL only or both ADL and IADL. For longitudinal analyses we assessed change in disability between waves. Due to the small numbers in groups when change in disability was categorised into both ADLs and IADLs we collated the information and assessed 4 levels: no disability in wave 1 or wave 2, stable level of disability in wave 2, reduced level of disability since wave 1, any new disability in wave 2.

Participants were also asked to record all of the medications taken on a regular basis and interviewers saw the packages to confirm. A continuous count of the different medications was used in this analysis as this reflects both the possible effects of medications themselves and underlying comorbidity.

Depressive mood was assessed using the sum score from Centre for Epidemiological Studies Depression Scale (CES-D) a well validated measure of depressive symptoms [246].

Self-rated health was assessed with the question: "In general, compared to other people your age, would you say your health is...excellent, very good, good, fair or poor?"

Cognitive function was assessed using two tasks, one memory measure and one executive function measure. Executive function was assessed through the animal naming task in which participants were asked to name as many animals as they could think of in 1 minute. Delayed memory was assessed using a ten-word list recall previously developed for the Health and Retirement Survey [235]. Participants were twice read a list of ten words and then asked to recall as many words as possible after a short delay. We used these two measures of cognition rather than a global score such as the MMSE as these were taken during the CAPI interview while the MMSE was taken during the health

assessment. Had we used the MMSE score we would have had to exclude all participants who did not have a health assessment.

Statistical Analysis

Descriptive statistics, t-tests and chi-square tests were first used to explore the differences between those involved in each of the four engagement categories (social relationships, organisational involvement, social and active leisure activities, and cognitively stimulating activities) and those not involved. Variables which showed a statistically significant difference between those involved and those not involved in the engagement categories were included as covariates in all further analyses. In order to assess the association between ageing perceptions and social engagement cross-sectionally we conducted multivariable logistic regressions, one for each of the domains of social and cognitive engagement.

Following this, we sought to assess the longitudinal relationship between perceptions of ageing and behaviour. Using only those domains of perceptions of ageing which had been statistically significant in cross-sectional analyses, we conducted modified poisson regression models with robust error variance to assess longitudinal relationships. Although logistic regression is commonly used for binary outcome analyses longitudinally, the odds ratios which are produced are not suitable for prospective data due to their sensitivity to sample size. Converting odds ratios to relative risk ratios has been shown to provide overinflated estimates in prospective data. In order to use directly calculated relative risk ratios, and thus conservative estimates, we used the modified poisson regression technique [260]. This technique was used to analyse relationships in three models: 1) the univariate association between perceptions of ageing and social engagement; 2) the association between perceptions of ageing and social engagement adjusted for sociodemographic factors and; 3) the association between perceptions of ageing and social engagement adjusted for all covariates and baseline levels of social engagement.

Finally, for all longitudinal analyses we estimated the marginal probability of social engagement – the probability after adjusting for all covariates in the analysis - for 5 points along the ageing perceptions scale indicating increasing levels of agreement with the domain (i.e. the probability of being involved in an

activity for those who, on average, strongly agreed with the domain versus slightly agreed, were neutral, disagreed or strongly disagreed).

Attrition weights were used due to potential differences between respondents who participated in both wave 1 and 2 and respondents who participated only in wave 1. Attrition weights were calculated as the inverse of the probability that the respondent participated in wave 2 given their participation in wave 1 and their survival up to wave 2. We calculated this using logistic regression in which the dependent variable was whether a respondent had returned in wave 2 or dropped out of the study and the independent variables were multiple measures taken at baseline to try to explain the probability of attrition including measures of baseline mood, cognitive function, physical health, health behaviours and sociodemographic factors. This is multiplied by an initial inverse probability weight reflecting the probability that a member of the Irish population aged 50 years and older participated in the study. This method has previously been reported as an appropriate strategy to minimise bias due to attrition in survey data [250].

We had small numbers of missing data in our outcome and covariate variables (<1%) but around 5% of cases for the APQ domains were missing (for numbers see Figure 15). We thus imputed the missing APQ scores using multiple chained imputations as a sensitivity analysis. The imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status and disability, all of which had no missing data

Results

The average age of the sample at wave 1 was 63.3 (9.2) and 55.1% were female (see Table 29 for sample descriptives). Analysis of the difference between those who engaged with each of the four categories of social engagement and those who did not indicated a number of covariates to be included in each of the models (see Table 30).

Cross-sectional Analyses

Multivariable cross-sectional analysis at wave 1 revealed statistically significant associations between perceptions of ageing and social and cognitive engagement (see Table 31). Participants who thought more about ageing and

who expected negative consequences with age were, respectively, 13% and 15% less likely to have intimate social relationships for every one point increase in agreement with the *timeline* and *negative control and consequences* subscales (Timeline: OR = 0.87 (95% CI = 0.78, 0.98), $p<.05$); Negative Control and Consequences: OR = 0.85 (0.73, 0.98), $p<.05$)). Participants who believed in the positive consequences of ageing and who expressed positive control beliefs were 20% more likely to have intimate social relationships for every one point increase in agreement with the *positive consequences* and *positive control* subscales (Positive Consequences: OR = 1.20 (1.06, 1.36), $p<.01$; Positive Control: OR = 1.20 (1.06, 1.35), $p<.01$)).

Participants who thought more about ageing were 12% less likely to be involved in organisations outside of the workplace for every one point increase in agreement with the *timeline* subscale (OR=0.88 (0.81, 0.96), $p<.01$) while participants who believed in the positive consequences of ageing were 14% more likely to be involved in these organisations for every one point increase in agreement with the *positive consequences* subscale (OR=1.14 (1.04, 1.25), $p<.01$)).

Participants who thought more about ageing and who expected negative consequences were, respectively, 14% and 28% less likely to be involved in social and active leisure activities for every one point increase in agreement with the *timeline* or *negative control and consequences* subscales (Timeline: OR=0.86 (0.76, 0.99), $p<.05$; Negative Control and Consequences: OR = 0.72 (0.60, 0.85), $p<.001$)).

Participants who expected negative consequences with age were 30% less likely to be involved in cognitively stimulating activities for every one point increase in agreement with the *negative control and consequences* subscale (OR=0.70 (0.51, 0.94), $p<.05$). Participants who expressed feelings of control over their life as they aged were 59% more likely to be involved in cognitively stimulating activities for every one point increase in agreement with the *positive control* subscale (OR=1.59 (1.25, 2.01), $p<.001$).

This, however, is cross-sectional data and thus it is not clear in which direction the relationship lies. We thus assessed the relationship two years later after controlling for all covariates and baseline levels of social and cognitive engagement.

Longitudinal Analyses

After full adjustment for all covariates and baseline levels of contact with family and friends, participants who expected positive consequences with ageing were more likely to have close friend or family relationships after two years (IRR = 1.02 (1.00, 1.04), $p<.05$) (see Table 32). This represents a 2% increase in the probability of engaging with family and friends for every one point increase on the positive consequences scale. Marginal probabilities indicated that participants with low expectations for positive consequences had a 79% likelihood of engaging with family and friends while those with high expectations for positive consequences had an 86% likelihood over the two years of follow up (see Figure 16 and Table 32).

After full adjustment for all covariates and baseline engagement in organisations outside the workplace participants who expected positive consequences with ageing were more likely to be involved in these organisations two years later (IRR: 1.04 (1.01, 1.06) (see Table 33). This represents a 4% increase in the probability that participants will be involved in formal organisations outside the workplace for every one point increase on the positive consequences domain scale. Those who did not expect positive consequences with ageing had a 64% likelihood of being involved in formal activities while those who strongly agreed with the positive consequences domain had a 74% likelihood of being involved (see Figure 17 and Table 33).

After full adjustment for all covariates and baseline engagement in active and social leisure activities, participants who felt little control over ageing and who expected negative consequences with age were less likely to engage in active and social leisure activities (IRR = 0.98 (0.97, 0.99), $p<.05$) (see Table 34). This represents a 2% decline in the likelihood of engaging with these types of activities over 2 years for every one point increase in the negative control and consequences domain. Margin probabilities indicated that participants who did not strongly agree with this domain had a 94% likelihood of engaging with active and social leisure activities while those who strongly agreed with the domain had an 87% likelihood (see Figure 18 and Table 34).

After full adjustment for all covariates and baseline engagement in cognitive stimulating activities participants who felt they had positive control as they aged were more likely be cognitively stimulated after 2 years (IRR: 1.01 (1.00, 1.02) (see Table 35). This represents a 1% increase in the likelihood of engaging in cognitively stimulating activities over 2 years for every one point increase in the positive control domain. Margin probabilities indicated that participants who did not strongly agree with this domain had a 94% likelihood of engaging in cognitive stimulating activities while those who strongly agreed with the domain had a 98% likelihood (see Figure 19 and Table 35).

We reran all analyses following imputation of missing APQ scores. The association between perceptions of ageing at baseline and relationship with family and friends at follow up was no longer statistically significant using the imputed data. All other results remained the same. We have outlined all results in the appendix section.

Discussion

This study suggests that perceptions of ageing may play a small role in predicting behaviour in later life. Strong beliefs in the positive consequences associated with ageing are associated with an increased likelihood of being involved in formal organisations outside of work. Having poor perceptions of ageing in the form of lack of control beliefs and an expectation of the negative consequences of ageing is associated with decreased likelihood of remaining involved with social and active leisure pursuits over two years. Having positive control beliefs, meanwhile, is associated with a longitudinally increased likelihood of participating in cognitively stimulating activities. Although the overall effects of perceptions of ageing on these behaviours are very small our study only covers a 2 year follow up period and therefore may indicate the initial stages of change in older adults' behaviour.

This paper builds on previous work which has shown that ageing attitudes predict behaviour in the domains of physical activity, health maintenance and diet [18, 110, 112-114]. Our study adds to this existing body of knowledge in indicating that perceptions of ageing may also predict social and cognitive engagement in later life. This is particularly important given the impact of social engagement and cognitive stimulation on protecting against ill health, physical decline and cognitive impairment [120, 265]. As we know that cognitive reserve,

an important factor in protecting against dementia, can be built up by social engagement and cognitive stimulation, perceptions of ageing may be an important predictor in determining whether older adults will partake in these protective activities.

It is interesting that different domains of perceptions of ageing predict behaviour in different social and cognitive domains. We found that positive consequences predicted engagement with friends and family as well as involvement in organisations outside of the workplace. The positive consequences domain includes statements such as 'as I get older I get wiser' and 'as I get older I continue to grow as a person'. Agreement with these types of statements may suggest an increased sense of purpose in life which is known to be highly protective against decline in later life [121, 280]. It is likely a cyclical pattern in which older adults who have responsibilities in organisations and within the family, perhaps caring for grandchildren or helping adult children, will also have a greater sense of purpose and this will increase their perceptions of the positive consequences of age. These positive perceptions may then increase the likelihood that older adults will remain involved in organisational work and family duties due to confidence in their abilities to do so and a sense of being needed.

On the other hand, we found that the only domain statistically significantly associated with decline in social and active leisure activities was the negative control and consequences domain. This domain of engagement included any social activities which are done as part of a group or outside of the home. As outlined above, we suggested that older adults who have negative perceptions of ageing may have an attentional bias towards change as they age. This bias will cause them to attribute events, such as forgetting an acquaintance's name or feeling tired after exercise, as being solely due to age, rather than any other number of transient factors, and make them more likely to see this as 'confirmation' of their immediate decline. These expectations that negative events are forthcoming may cause people to lose confidence in interacting in group situations leading to a gradual social withdrawal. This may be what we see in the social and active leisure activities domain. It is particularly interesting in light of previous work from our group which found that those participants who expressed strong agreement with the negative control and consequences domain had a decline in walking speed and cognitive function over 2 years [241,

275]. It is possible that decreased engagement in social and active leisure activities may be one pathway through which this occurs.

Finally, we found that positive control predicted increased engagement with solitary cognitively stimulating activities over 2 years. Previous work has shown that older adults with positive feelings of control who are faced with negative stereotypes about ageing are more likely to use strategies to improve cognitive performance when tested [41, 71]. It has also been shown that older adults who are faced with a serious health event in later life, but who have positive perceptions of ageing, are more likely to use adaptive strategies to help them to overcome the negative consequences of ill health [115]. Again, this is interesting in light of previous work in our group which found that older adults with strong feelings of positive control had improved executive function performance over two years [275]. It is possible that those who feel in control over their life as they age also make a conscious or unconscious effort to stay cognitively active, particularly when no longer working, as a result of these beliefs. Strikingly, there was no effect of executive function abilities on engagement with cognitively stimulating activities when it was included as a covariate in the analysis, although there was a small effect of memory ability. This suggests that the impact of positive control beliefs on cognitively stimulating behaviours may act independently of actual cognitive function.

There are a number of strengths to this paper including the large, population representative sample of older adults and the in-depth social participation questions which allowed us to unpick the effects of perceptions of ageing on social and cognitive engagement alone. Previous studies have only been able to measure the effect of perceptions of ageing on engagement combined with health maintenance behaviours and diet which may have confounded the effect. We were also able to look at different domains of perceptions of ageing including emotional saliency, control and expectations which allows us to make interesting comparisons of the effects of different types of perceptions on different types of behaviours. There are also, however, a number of limitations of this study. The first is the short follow-up time between waves. We only have two waves of data which were taken two years apart. It is unlikely that most people will change their behaviour dramatically over two years and thus a longer follow-up time would have been more advantageous. It is, however, interesting that we see any effect of perceptions of ageing on behaviour over so short a time period and

we will be able to follow up these participants as future waves of the TILDA data are collected. A second limitation is that we only had a measure of perceptions of ageing at baseline and not at follow-up. It would have been beneficial to assess whether perceptions of ageing changed over time and whether this was associated with change in behaviour. We will have a follow-up measure of perceptions of ageing in wave three of this study which will allow us to assess this.

In conclusion, this paper suggests that perceptions of ageing may predict behaviour in four social realms. Should this be replicated by other studies, and followed up over a longer time period, this may provide the basis for interventions to improve social engagement in older adults who are at risk of becoming disengaged. In addition, it may provide the basis for interventions to increase engagement with activities which would build up cognitive reserve and protect against dementia. The effects in this study are very small which has to be considered when interpreting these results but future waves of the TILDA study will allow us to assess the relationship over a longer time period in order to determine whether the behavioural changes associated with perceptions of ageing are long-lasting.

Figure 15. Flow Chart Illustrating Participants in Sample.

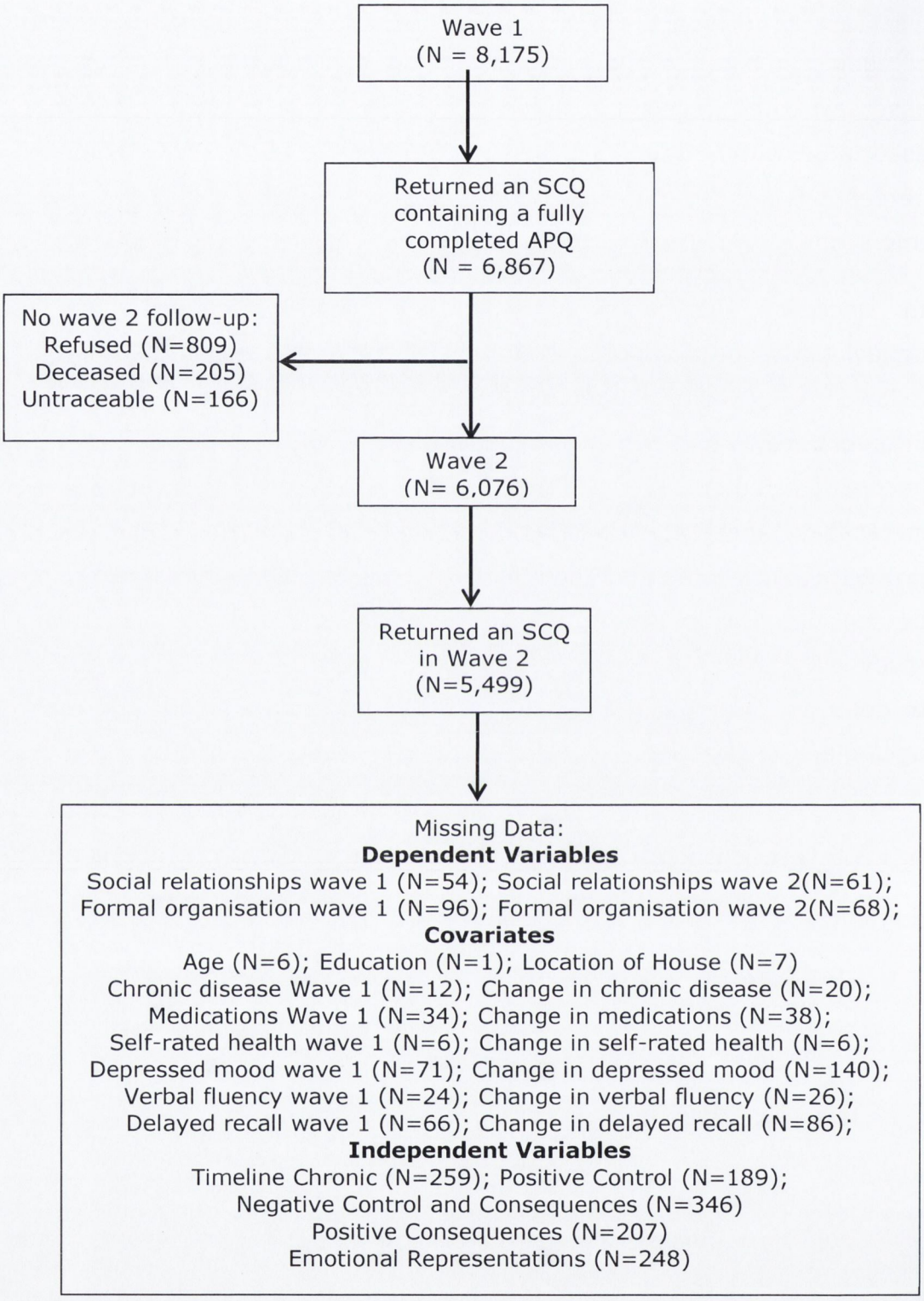


Table 29. Sample Characteristics.

Measure (Possible Range) N=5,499	**Mean (SD) or %**
Intimate Social Relationships Wave 1 (% involved)	85.5% (N=4,699)
Intimate Social Relationships Wave 2 (% involved)	83.1% (N=4,570)
Organisational Involvement Wave 1 (% involved)	65.9% (N=3,621)
Organisational Involvement Wave 2 (% involved)	68.4% (N=3,760)
Active and Social Leisure Wave 1 (% involved)	90.4% (N=4,970)
Active and Social Leisure Wave 2 (% involved)	90.0% (N=4,949)
Cognitive Stimulation Wave 1 (% involved)	97.0% (N=5,333)
Cognitive Stimulation Wave 1 (% involved)	96.6% (N=5,314)
Timeline Chronic (1-5)	2.4 (0.8)
Positive Control (1-5)	3.9 (0.6)
Negative Control & Consequences (1-5)	2.8 (0.8)
Positive Consequences (1-5)	3.8 (0.7)
Emotional Representations (1-5)	2.3 (0.8)
Covariates	
Age	63.3 (9.2)
Sex (female)	55.1% (N=3,029)
Education (third level)	33.0% (N=1,816)
Married in Wave 1	72.3% (N=3,978)
Marital Status Change (no longer married)	1.8% (N=97)
Employment in Wave 1 (employed)	37.0% (N=2,051)
Employment in Wave 2 (since retired)	11.2% (N=616)
Location of Household (rural)	46.9% (N=2,577)
No. of Chronic Diseases in Wave 1 (0-7)	1.3 (1.3)
Change in No. of Chronic Diseases in Wave 2	0.02 (0.9)
No. of Medications in Wave 1 (0-17)	2.6 (2.6)
Change in No. of Medications in Wave 2	0.7 (1.8)
Disability in Wave 1 (no disability)	89.7% (N=4,935)
Disability in Wave 2 (new disability)	4.5% (N=248)
Self-Rated Health in Wave 1 (1-5)	2.3 (1.0)
Change in Self-Rated Health in Wave	0.2 (1.0)
Depressed Mood in Wave 1 (0-53)	5.5 (6.8)
Change in Depressed Mood in Wave 2	-0.4 (6.6)
Verbal Fluency in Wave 1 (0-50)	21.1 (6.9)
Change in Verbal Fluency in Wave 2	-1.6 (6.4)
Delayed Recall in Wave 1 (1-10)	6.1 (2.3)
Change in Recall in Wave 2	-0.02 (2.2)

Table 30. Differences between those involved and not involved in each of the four domains of social and cognitive engagement.

Measure (Possible Range)	Involved in Social Activity	Not Involved in Social Activity
Intimate Social Relationships		
Age	63.7 (9.5)	62.8 (10.1)**
Sex (female)	58.5% (N=3,418)	29.3%*** (N=276)
Education (3rd level)	31.5% (N=1,841)	30.8% (N=290)
Marital status (married)	70.6% (N=4,124)	75.4%** (N=711)
Employment status (employed)	35.1% (N=2,053)	46.0%*** (N=434)
Household location (city)	24.4% (N=1,421)	22.9% (N=216)
Chronic diseases	1.3 (1.3)	1.1 (1.2)***
Medications	2.6 (2.7)	2.4 (2.7) **
Disability (no disability)	89.0% (N=5,200)	86.7% (N=818)
Self-Rated Health (excellent)	2.4 (1.0)	2.5 (1.0)***
Depression	5.6 (6.9)	6.3 (7.1)**
Verbal Fluency	20.7 (6.9)	20.5 (7.2)
Memory	6.0 (2.3)	5.8 (2.30)
Organisational Involvement		
Age	63.5 (9.2)	63.5 (10.2)
Sex (female)	53.3% (N=2,326)	55.7%* (N=1,311)
Education (3rd level)	37.6% (N=1,643)	20.6%*** (N=484)
Marital status (married)	72.4% (3,162)	69.5%* (N=1,634)
Employment status (employed)	38.6% (N=1684)	33.6%*** (N=789)
Household location (city)	25.1% (N=1,095)	22.5%* (N=529)
Chronic diseases	1.3 (1.3)	1.3 (1.3)
Medications	2.5 (2.6)	2.8 (2.9)***
Disability (no disability)	90.7% (N=3,960)	84.9%*** (N=1,997)
Self-Rated Health (excellent)	2.3 (1.0)	2.6 (1.1)***
Depression	5.2 (6.4)	6.6 (7.8)***
Verbal Fluency	21.4 (7.0)	19.5 (6.9)***
Memory	6.1 (2.3)	5.7 (2.3)***
Social and Active Leisure		
Age	63.3 (9.3)	66.7 (11.1)***
Sex (female)	53.3% (N=3,266)	64.4%*** (N=443)
Education (3rd level)	32.9% (N=2,017)	17.3%*** (N=119)
Marital status (married)	71.9% (N=4,408)	64.7% (N=445)
Employment status (employed)	37.8% (N=2,315)	26.3%*** (N=181)
Household location (city)	25.0% (N=1,531)	16.5%*** (N=113)
Chronic diseases	1.2 (1.3)	1.6 (1.4)***
Medications	2.5 (2.6)	3.5 (3.1)***
Disability (no disability)	89.9% (N=5,509)	77.5%*** (N=533)
Self-Rated Health (excellent)	2.3 (1.0)	2.8 (1.1)***
Depression	5.4 (6.7)	8.0 (8.8)***
Verbal Fluency	20.9 (7.0)	18.7 (7.0)***
Memory	6.0 (2.3)	5.3 (2.4)***
Cognitive Stimulation		
Age	63.5 (9.5)	65.8 (11.6)***
Sex (female)	55.0% (N=3,630)	34.0%*** (N=71)
Education (3rd level)	32.0% (N=2,110)	12.0%*** (N=25)
Marital status (married)	71.6% (N=4,726)	60.3%*** (N=126)
Employment status (employed)	36.8% (N=2,429)	32.1% (N=67)
Household location (city)	24.3% (N=1,599)	20.6% (N=43)
Chronic diseases	1.3 (1.3)	1.5 (1.4)*
Medications	2.5 (2.7)	3.4 (3.2)***
Disability (no disability)	89.3% (N=5,888)	72.3%*** (N=151)
Self-Rated Health (excellent)	2.4 (1.0)	3.0 (1.2)***

Depression	5.6 (6.9)	8.4 (9.0)***
Verbal Fluency	20.8 (7.0)	17.6 (6.7)***
Memory	6.0 (2.3)	4.8 (2.2)***

***p < .001, **p < .01, * p < .05. Statistical significance was calculated using t-tests for continuous variables and chi-square tests for categorical variables.

Table 31. Cross-Sectional Associations Between Perceptions of Ageing and Social/Cognitive Engagement at Wave 1.

	Relationships	**Organisational Involvement**	**Active/Social**	**Cognitive**
		Odds Ratios and 95% Confidence Intervals		
Timeline Chronic	0.87* (0.78,0.98)	0.88** (0.81,0.96)	0.86* (0.76,0.99)	0.84 (0.67,1.07)
Positive Control	1.20** (1.06,1.36)	1.02 (0.92,1.12)	1.07 (0.92,1.25)	1.59*** (1.25,2.01)
Negative Control & Consequences	0.85* (0.73,0.98)	0.98 (0.88,1.09)	0.72*** (0.60,0.85)	0.70* (0.51,0.94)
Positive Consequences	1.20** (1.06,1.35)	1.14** (1.04,1.25)	1.16* (1.01,1.34)	0.96 (0.75,1.22)
Emotional Representations	0.97 (0.85,1.10)	1.00 (0.91,1.10)	1.14 (0.98,1.32)	1.22 (0.94,1.58)
Age	1.002 (0.99,1.01)		0.98* (0.97,1.00)	1.02 (0.99,1.04)
Gender	3.34*** (2.79,4.00)	0.87* (0.77,0.99)	0.56*** (0.45,0.70)	2.78*** (1.89,4.09)
Never married	1.09 (0.90,1.31)	1.02 (0.89,1.16)	1.03 (0.83,1.27)	0.67* (0.47,0.97)
Employment				
Comparison: Employed				
Retired	1.56*** (1.24,1.96)	1.28** (1.10,1.48)	1.44* (1.08,1.92)	
Other	1.37** (1.10,1.72)	0.95 (0.81,1.11)	1.08 (0.83,1.40)	
Self-rated health	0.87** (0.80,0.96)	0.83*** (0.78,0.89)	0.79*** (0.71,0.88)	0.73** (0.60,0.89)
No. of medications	1.04* (1.00,1.08)	1.02 (0.99,1.04)	1.00 (0.96,1.04)	1.04 (0.97,1.12)
No. of chronic conditions	1.08 (1.00,1.16)		1.04 (0.95,1.13)	1.01 (0.87,1.16)
Depressed Mood	0.98** (0.97,0.99)	0.99* (0.98,1.00)	0.98** (0.97,0.99)	0.98 (0.96,1.01)
Education				
Comparison: Primary/none				
Secondary		1.32*** (1.14,1.53)	1.49*** (1.19,1.87)	1.15 (0.78,1.70)
Third/higher		2.27*** (1.92,2.69)	2.01*** (1.52,2.66)	2.38** (1.36,4.16)
Household Location				
Comparison: City				
Smaller town		0.94 (0.80,1.11)	0.73* (0.55,0.98)	
Rural area		1.09 (0.94,1.26)	0.63*** (0.48,0.82)	
Disability				
Comparison: No disability				
IADL disability only		0.87 (0.62,1.22)	0.67 (0.44,1.04)	0.76 (0.36,1.64)
ADL disability only		1.08 (0.81,1.43)	0.88 (0.57,1.33)	1.10 (0.50,2.40)
IADL and ADL disability		0.66* (0.46,0.94)	0.72 (0.46,1.13)	0.38** (0.20,0.73)
Verbal fluency		1.02*** (1.01,1.03)	1.01 (0.99,1.02)	1.04* (1.01,1.07)

Delayed recall		1.003 (0.97,1.03)	0.99 (0.95,1.04)	1.05(0.96,1.14)
N	5663	5536	5565	5568

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Odds Ratios; 95% confidence intervals in brackets.

Table 32. Results of Multivariable Regression Analysis Indicating Longitudinal Relationship Ageing Perceptions at Baseline and Social Relationships Two Years Later.

Intimate Social Relationships W2	**Model 1**	**Model 2**	**Model 3**
	Incident Risk Ratios and 95% Confidence Intervals		
Timeline Chronic	0.98**(0.96,0.99)	0.98*(0.96,1.00)	0.98(0.97,1.00)
Positive Control	1.003(0.98,1.02)	1.004(0.98,1.02)	1.01(0.99,1.03)
Negative Control & Consequences	0.99(0.97,1.01)	0.99(0.97,1.01)	0.99(0.97,1.01)
Positive Consequences	1.03**(1.01,1.05)	1.03*(1.01,1.05)	1.02*(1.00,1.04)
Intimate Social Relationships W1	1.64***(1.52,1.76)	1.58***(1.46,1.69)	1.59***(1.48,1.72)
Age		1.002*(1.00,1.00)	1.001(1.00,1.00)
Gender		1.11***(1.09,1.15)	1.11***(1.08,1.14)
Marital Status Comparison: Never married			
Married in W1 and W2		1.003(0.98,1.03)	1.002(0.98,1.03)
No longer married in W2		1.03(0.95,1.12)	1.03(0.94,1.12)
Newly married in W2		0.95(0.78,1.16)	0.94(0.75,1.16)
Employment Comparison: Employed in W1			
Retired in W1 and W2		1.04*(1.01,1.08)	1.04*(1.01,1.08)
No longer retired in W2		1.07***(1.03,1.12)	1.07**(1.02,1.12)
Retired since W1		1.05*(1.01,1.09)	1.04†(1.00,1.08)
Self-rated health			0.98*(0.96,1.00)
Change in self-rated health			0.98*(0.97,1.00)
Number of reported medications			1.003(1.00,1.01)
Change in medications			1.003(1.00,1.01)
No. of chronic diseases			1.01*(1.00,1.02)
Change in chronic diseases			1.02*(1.00,1.03)
Depressed mood			0.99*(0.99,1.00)
Change in depressed mood			0.99(1.00,1.00)
N	4686	4680	4573

†p = .059, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Incident Risk Ratios and 95% confidence intervals in brackets.

Table 33. Results of Multivariable Regression Analysis Indicating Relationship Ageing Perceptions at Baseline and Community Involvement 2 Years Later.

Formal Organisation W2	**Model 1**	**Model 2**	**Model 3**
	Incident Risk Ratios and 95% Confidence Intervals		
Timeline Chronic	0.95***(0.93,0.97)	0.96***(0.94,0.98)	0.98(0.96,1.01)
Positive Consequences	1.05***(1.03,1.08)	1.05***(1.03,1.08)	1.04**(1.01,1.06)
Formal Organisation W1	2.55***(2.38,2.73)	2.49***(2.32,2.67)	2.43***(2.26,2.62)
Gender		0.96*(0.93,0.99)	0.98(0.95,1.02)
Education			
Comparison: Primary/None			
Secondary		1.10***(1.05,1.16)	1.06*(1.01,1.12)
Third/higher		1.16***(1.11,1.22)	1.11***(1.06,1.17)
Marital Status			
Comparison: Never married			
Married in W1 & W2		1.03(0.99,1.07)	1.01(0.97,1.06)
No longer married in W2		0.95(0.82,1.11)	0.96(0.83,1.15)
Newly married in W2		1.04(0.82,1.30)	1.08(0.91,1.35)
Employment			
Comparison: Employed W1			
Retired in W1 & W2		1.04*(1.00,1.08)	1.06**(1.03,1.11)
No longer retired in W2		1.04(0.96,1.13)	1.06(0.97,1.15)
Retired since W1		1.06*(1.01,1.11)	1.05*(1.00,1.10)
Household location			
Comparison: City			
Smaller town		0.99(0.96,1.04)	1.004(0.96,1.05)
Rural area		1.00(0.96,1.04)	0.99(0.95,1.03)
Self-rated health			0.96**(0.94,0.99)
Self-rated health change			0.96***(0.94,0.98)
No. of medications			0.99(0.99,1.00)
Change in medications			1.002(0.99,1.01)
Disability			
Comparison: never			
Disability in W1 and W2			0.77**(0.70,0.95)
No longer has disability			0.98(0.90,1.06)
New disability in W2			0.90*(0.81,0.99)
Depressed mood			0.99**(0.99,1.00)
Depressed mood(change)			0.99**(0.99,1.00)
Executive function			1.00(1.00,1.00)
Executive function(change)			1.00(1.00,1.00)
Memory			1.003(0.99,1.01)
Memory(change)			1.01(1.00,1.01)
N	5007	4999	4759

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Incident Risk Ratios and 95% confidence intervals in brackets.

Table 34. Results of Multivariable Regression Analysis Indicating Longitudinal Relationship Ageing Perceptions at Baseline and Engagement with Social and Active Leisure Pursuits Two Years Later.

Social Activities W2	**Model 1**	**Model 2**	**Model 3**
	Incident Risk Ratios and 95% Confidence Intervals		
Timeline Chronic	0.99(0.98,1.01)	0.99(0.98,1.01)	1.00(0.99,1.01)
Negative Control & Consequences	0.96***(0.95,0.98)	0.97***(0.96,0.99)	0.98*(0.97,0.99)
Social Activities W1	1.76***(1.60,1.93)	1.73***(1.58,1.9)	1.68***(1.52,1.83)
Age		0.99***(1.00,1.00)	0.99*(1.00,1.00)
Gender		0.98**(0.96,0.99)	0.98**(0.96,0.99)
Education			
Comparison: Primary/None			
Secondary		1.01(0.98,1.04)	0.99(0.97,1.02)
Third/higher		1.05***(1.03,1.08)	1.03*(1.00,1.05)
Marital Status			
Comparison: Never married			
Married in W1 & W2		1.00(0.98,1.02)	0.99(0.98,1.02)
No longer married in W2		1.06*(1.00,1.12)	1.04(0.98,1.11)
Newly married in W2		0.97(0.84,1.11)	0.95(0.83,1.10)
Employment			
Comparison: Employed W1			
Retired in W1 & W2		1.03*(1.01,1.06)	1.02(1.00,1.05)
No longer retired in W2		0.99(0.94,1.04)	0.99(0.94,1.04)
Retired since W1		1.03*(1.00,1.06)	1.02(0.99,1.05)
Household location			
Comparison: City			
Smaller town		0.98(0.96,1.00)	0.99(0.97,1.01)
Rural area		0.99(0.97,1.01)	0.99(0.97,1.01)
Self-rated health			0.98***(0.97,0.99)
Change in self-rated health			0.98***(0.97,0.99)
No. of chronic conditions			1.01*(1.00,1.02)
Chronic conditions(change)			1.02**(1.00,1.03)
No. of medications			0.99(0.99,1.00)
Change in medications			1.00(1.00,1.01)
Disability			
Comparison: never			
Disability in W1 & W2			0.89*(0.83,0.99)
No longer has a disability			1.02(0.98,1.06)
New disability in W2			0.93*(0.86,0.99)
Depressed mood			0.99(1.00,1.00)
Change in depressed mood			0.99(1.00,1.00)
Executive function			1.00(1.00,1.00)
Change in executive function			1.00(1.00,1.00)
Memory			1.00(1.00,1.01)
Change in memory			1.00(1.00,1.01)
N	4934	4920	4669

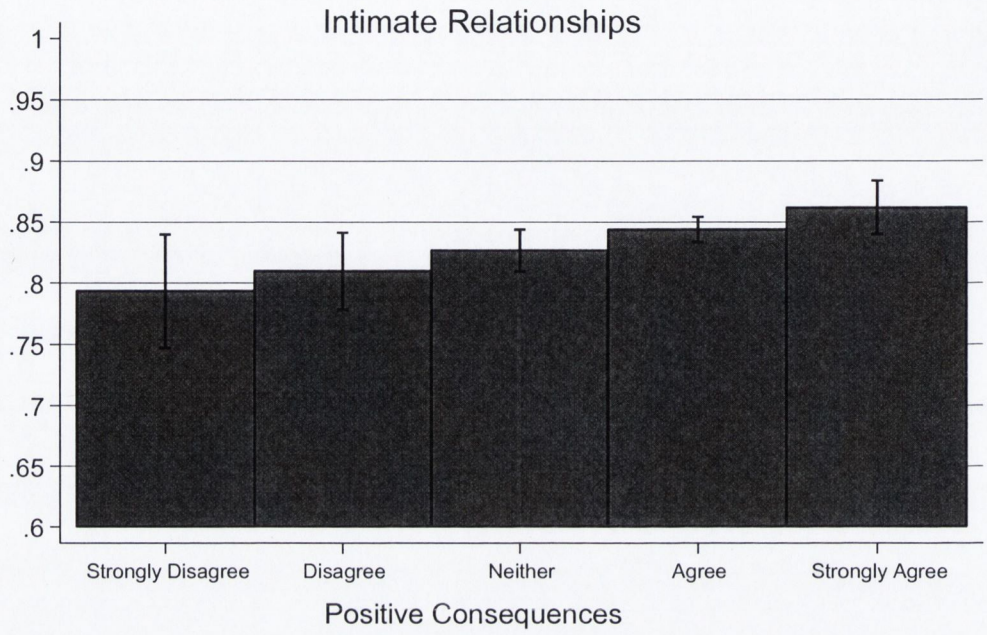
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Incident Risk Ratios and 95% confidence intervals in brackets.

Table 35. Results of Multivariable Regression Analysis Indicating Longitudinal Relationship Ageing Perceptions at Baseline and Engagement with Cognitively Stimulating Activities Two Years Later.

Cognitive Stimulation W2	**Model 1**	**Model 2**	**Model 3**
	Incident Risk Ratios and 95% Confidence Intervals		
Positive Control	1.01**(1.00,1.02)	1.01**(1.00,1.02)	1.01*(1.00,1.02)
Negative Control & Consequences	0.99***(0.98,0.99)	0.99**(0.98,1.00)	0.99(0.99,1.00)
Cognitive Stimulation W1	1.32***(1.18,1.48)	1.31***(1.17,1.47)	1.27***(1.13,1.42)
Age		1.00(1.00,1.00)	1.00(1.00,1.00)
Gender		1.01*(1.00,1.02)	1.01(1.00,1.02)
Education Comparison: Primary/None			
Secondary		1.02**(1.00,1.03)	1.02*(1.00,1.03)
Third/higher		1.03***(1.01,1.04)	1.02**(1.01,1.04)
Marital Status Comparison: Never married			
Married in W1 & W2		1.01(0.99,1.02)	1.00(0.99,1.02)
No longer married in W2		0.98(0.93,1.03)	0.97(0.92,1.02)
Newly married in W2		0.97(0.90,1.06)	0.97(0.88,1.06)
Self-rated health			0.99**(0.98,1.00)
Change in self-rated health			0.99*(0.99,1.00)
No. of chronic conditions			1.00(1.00,1.01)
Change in chronic conditions			0.99(0.99,1.00)
No. of medications			1.00(1.00,1.00)
Change in medications			1.002(1.00,1.00)
Disability Comparison: never			
Disability in W1 & W2			0.98(0.94,1.02)
No longer has a disability			1.02(1.00,1.04)
New disability in W2			0.96(0.93,1.00)
Depressed mood			1.00(1.00,1.00)
Change in depressed mood			1.00(1.00,1.00)
Executive function			1.00(1.00,1.00)
Change in executive function			1.00(1.00,1.00)
Memory			1.003*(1.00,1.01)
Change in memory			1.00(1.00,1.00)
N	4980	4973	4715

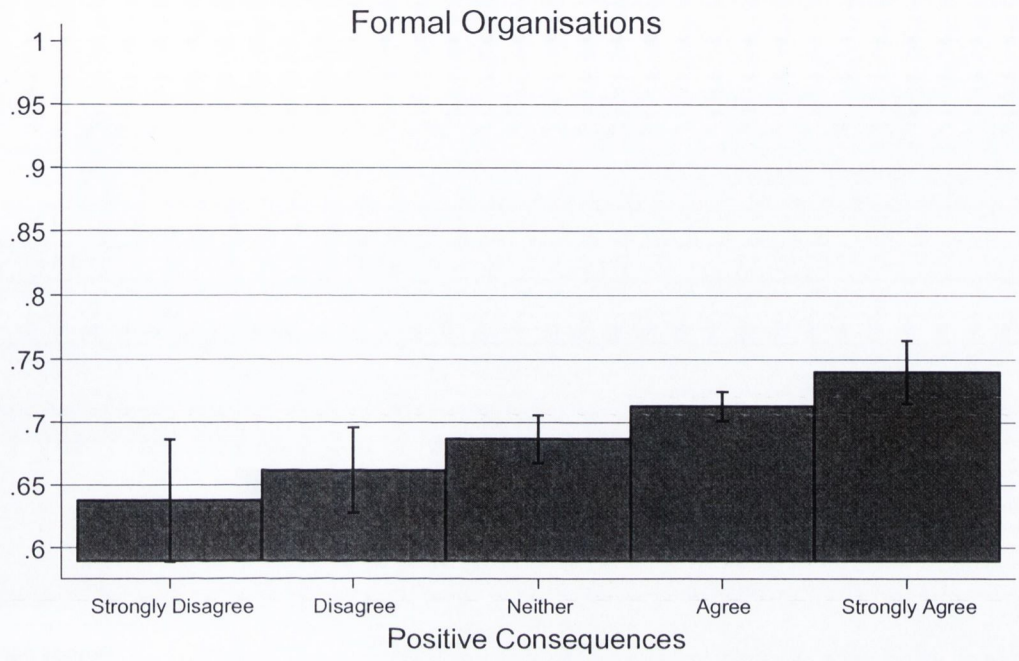
†p < .10 * p < 0.05, ** p < 0.01, *** $p < 0.001$. Incident Risk Ratios and 95% confidence intervals in brackets.

Figure 16. Marginal Predicted Probabilities of Having Intimate Social Relationships After Two Years By Levels of Agreement with the Positive Consequences Subscale.[a]



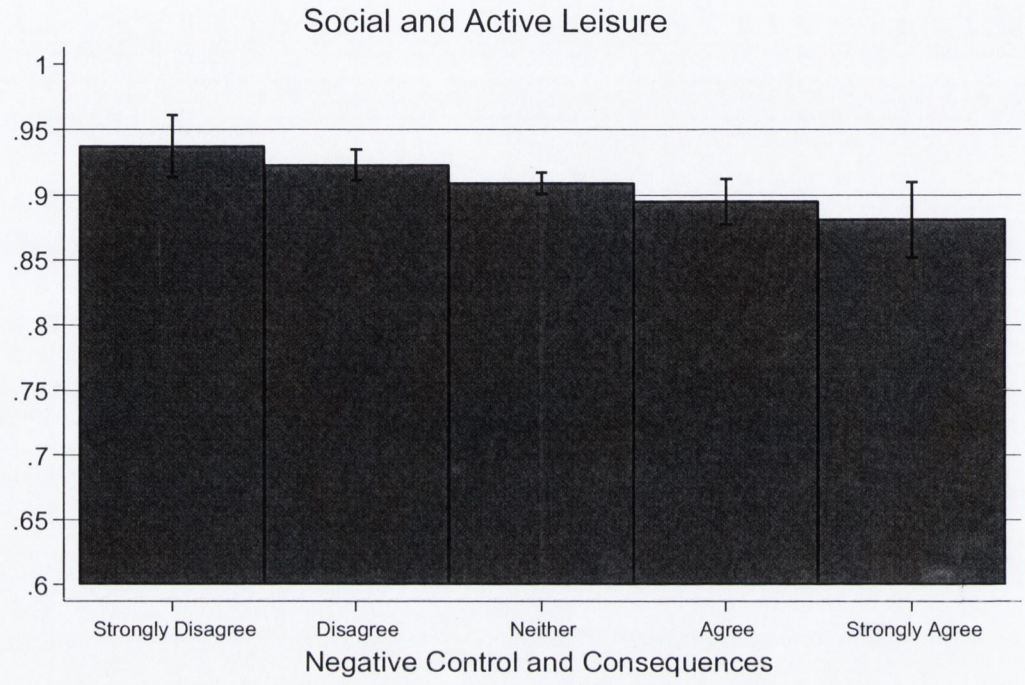
a. Marginal probabilities represent the probability of the outcome variable occurring after accounting for the confounding effect of all variables which have been controlled for in the model. These probabilities were calculated following a modified poisson regression analysis controlling for baseline involvement, age, gender, marital status, employment, self-rated health, medications, chronic disease, depression and change in health between waves. Error bars are 95% confidence intervals.

Figure 17. Marginal Predicted Probabilities of Being Involved in Organisations Outside of the Workplace After Two Years By Levels of Agreement with the Positive Consequences Subscale.[a]



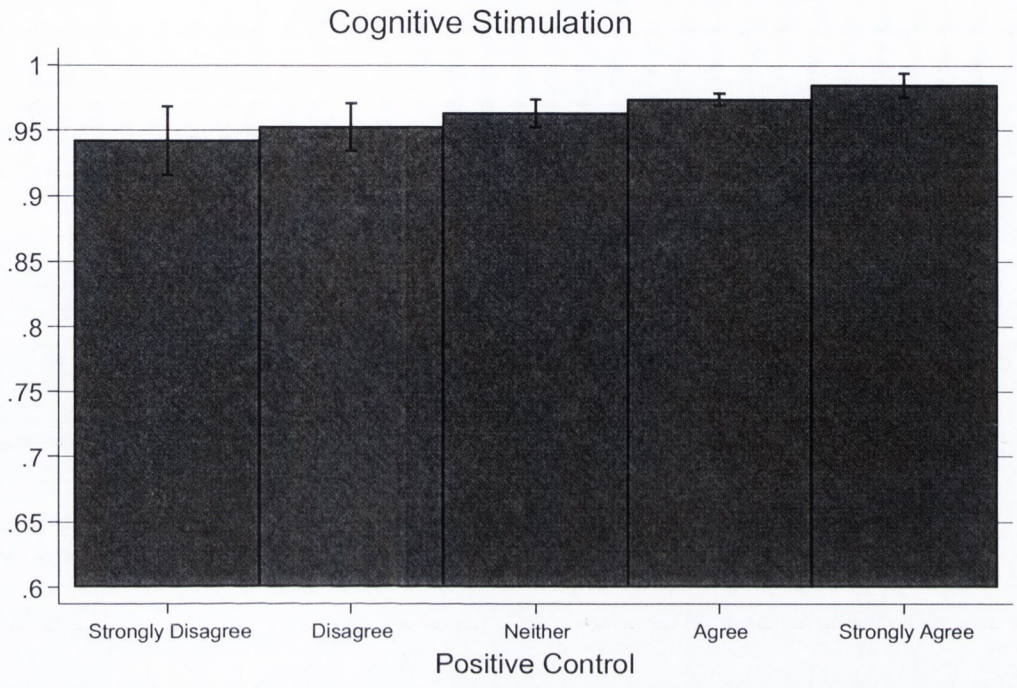
a. Marginal probabilities represent the probability of the outcome variable occurring after accounting for the confounding effect of all variables which have been controlled for in the model. These probabilities were calculated following a modified poisson regression analysis controlling for baseline involvement, gender, education, marital status, employment, household location, self-rated health, medications, chronic disease, disability, depression, cognitive function and change in health between waves. Error bars are 95% confidence intervals.

Figure 18. Marginal Predicted Probabilities of Being Involved in Social and Active Leisure Pursuits After Two Years By Levels of Agreement with the Negative Control and Consequences Subscale.[a]



a. Marginal probabilities represent the probability of the outcome variable occurring after accounting for the confounding effect of all variables which have been controlled for in the model. These probabilities were calculated following a modified poisson regression analysis controlling for baseline involvement, age, gender, education, marital status, employment, household location, self-rated health, medications, chronic disease, disability, depression, cognitive function and change in health between waves. Error bars are 95% confidence intervals.

Figure 19. Marginal Predicted Probabilities of Being Engaged with Cognitively Stimulating Activities After Two Years By Levels of Agreement with the Positive Control Subscale.[a]



a. Marginal probabilities represent the probability of the outcome variable occurring after accounting for the confounding effect of all variables which have been controlled for in the model. These probabilities were calculated following a modified poisson regression analysis controlling for baseline involvement, age, gender, education, marital status, self-rated health, medications, chronic disease, disability, depression, cognitive function and change in health between waves. Error bars are 95% confidence intervals.

Appendix

Table 36. Modified poisson regression analysis in which approximately 5% of the APQ values have been imputed using multiple chained imputations. Indicates the relationship between baseline perceptions of aging and social relationships 2 years later.

Intimate Social Relationships W2	**Risk Ratios and 95% Confidence Intervals**
Timeline Chronic	0.98 (0.97, 1.00)
Positive Control	1.01 (0.99, 1.03)
Negative Control and Consequences	0.99 (0.96, 1.01)
Positive Consequences	1.02 (0.99, 1.04)†
Intimate Social Relationships W1	1.60 (1.49, 1.71)***
Age	1.00 (0.99, 1.00)
Gender	1.12 (1.10, 1.15)***
Marital Status	
Comparison: Never married	
Married in W1 and W2	1.01 (0.99, 1.04)
No longer married in W2	1.03 (0.95, 1.13)
Newly married in W2	0.92 (0.74, 1.14)
Employment	
Comparison: Employed in W1	
Retired in W1 and W2	1.04 (1.01, 1.08)**
No longer retired in W2	1.07 (1.03, 1.12)**
Retired since W1	1.04 (1.00, 1.08)*
Self-rated health	0.98 (0.96, 0.99)**
Change in self-rated health	0.98 (0.97, 0.99)*
Number of reported medications	1.01 (1.0, 1.01)
Change in medications	1.00 (0.99, 1.01)
No. of chronic diseases	1.01 (0.99, 1.02)
Change in chronic diseases	1.01 (1.00, 1.03)*
Depressed mood	0.99 (0.99, 1.0)*
Change in depressed mood	1.0 (0.99, 1.00)
N	5187

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status and disability, all of which had no missing data.

Table 37. Modified poisson regression analysis in which approximately 5% of the APQ values have been imputed using multiple chained imputations. Indicates the relationship between baseline perceptions of aging and community involvement 2 years later.

Formal Organisation W2	**Risk Ratios and 95% Confidence Intervals**
Timeline Chronic	0.98 (0.96, 1.00)
Positive Consequences	1.05 (1.02, 1.07)***
Formal Organisation W1	2.42 (2.26, 2.59)***
Gender	0.97 (0.94, 1.01)
Education	
Comparison: Primary/None	
Secondary	1.07 (1.02, 1.12)**
Third/higher	1.11 (1.05, 1.6)***
Marital Status	
Comparison: Never married	
Married in W1 & W2	1.01 (0.97, 1.04)
No longer married in W2	0.95 (0.81, 1.11)
Newly married in W2	1.04 (0.85, 1.27)
Employment	
Comparison: Employed in W1	
Retired in W1 & W2	1.05 (1.01, 1.09)**
No longer retired in W2	1.09 (1.01, 1.18)*
Retired since W1	1.05 (1.00, 1.11)*
Household location	
Comparison: City	
Smaller town	1.00 (0.96, 1.04)
Rural area	1.0 (0.96, 1.03)
Self-rated health	0.97 (0.94, 0.99)**
Change in self-rated health	0.96 (0.94, 0.98)***
Number of reported medications	0.99 (0.99, 1.00)
Change in medications	1.00 (0.99, 1.01)
Disability	
Comparison: never	
Disability in W1 and W2	0.79 (0.68, 0.90)**
No longer has a disability in W2	0.98 (0.91, 1.06)
New disability in W2	0.89 (0.80, 0.99)*
Depressed mood	0.99 (0.99, 0.99)*
Change in depressed mood	0.99 (0.99, 0.99)*
Executive function	1.00 (0.99, 1.00)
Change in executive function	0.99 (0.99, 1.00)
Memory	1.00 (0.99, 1.01)
Change in memory	1.01 (0.99, 1.01)
N	5066

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status and disability, all of which had no missing data.

Table 38. Modified poisson regression analysis in which approximately 5% of the APQ values have been imputed using multiple chained imputations. Indicates the relationship between baseline perceptions of aging and engagement with social and active leisure pursuits 2 years later.

Social Activities W2	**Risk Ratios and 95% Confidence Intervals**
Timeline Chronic	0.99 (0.98, 1.01)
Negative Control & Consequences	0.98 (0.97, 1.00)*
Social Activities W1	1.70 (1.56, 1.85)
Age	0.99 (0.99, 0.99)**
Gender	0.98 (0.96, 0.99)**
Education	
Comparison: Primary/None	
Secondary	1.00 (0.98, 1.03)
Third/higher	1.03 (1.01, 1.06)*
Marital Status	
Comparison: Never married	
Married in W1 & W2	0.99 (0.97, 1.01)
No longer married in W2	1.02 (0.96, 1.09)
Newly married in W2	0.95 (0.94, 1.08)
Employment	
Comparison: Employed in W1	
Retired in W1 & W2	1.02 (0.99, 1.05)
No longer retired in W2	0.99 (0.94, 1.04)
Retired since W1	1.03 (1.00, 1.06)*
Household location	
Comparison: City	
Smaller town	0.99 (0.97, 1.01)
Rural area	0.99 (0.97, 1.01)
Self-rated health	0.97 (0.96, 0.99)***
Change in self-rated health	0.97 (0.96, 0.99)***
No. of chronic conditions	1.01 (1.00, 1.02)*
Change in chronic conditions	1.01 (1.00, 1.02)*
Number of reported medications	1.0 (0.99, 1.00)
Change in medications	1.00 (0.99, 1.01)
Disability	
Comparison: never	
Disability in W1 and W2	0.90 (0.82, 0.97)**
No longer has a disability in W2	1.02 (0.98, 1.06)
New disability in W2	0.91 (0.85, 0.97)**
Depressed mood	0.99 (0.99, 0.99)*
Change in depressed mood	1.0 (0.99, 1.00)
Executive function	1.00 (0.99, 1.00)
Change in executive function	1.00 (0.99, 1.00)
Memory	1.00 (0.99, 1.01)
Change in memory	1.00 (0.99, 1.01)
N	5133

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status and disability, all of which had no missing data.

Table 39. Modified poisson regression analysis in which approximately 5% of the APQ values have been imputed using multiple chained imputations. Indicates the relationship between baseline perceptions of aging and engagement with cognitively stimulating activities 2 years later.

Cognitive Stimulation W2	**Risk Ratios and 95% Confidence Intervals**
Positive Control	1.01 (1.00, 1.02)*
Negative Control & Consequences	0.99 (0.99, 1.00)
Cognitive Stimulation W1	1.29 (1.16, 1.43)***
Age	1.00 (0.99, 1.00)
Gender	1.01 (0.99, 1.02)
Education	
Comparison: Primary/None	
Secondary	1.02 (1.00, 1.03)**
Third/higher	1.02 (1.01, 1.04)**
Marital Status	
Comparison: Never married	
Married in W1 & W2	1.00 (0.99, 1.01)
No longer married in W2	0.97 (0.92, 1.02)
Newly married in W2	0.97 (0.90, 1.05)
Self-rated health	0.99 (0.98, 0.99)**
Change in self-rated health	0.99 (0.98, 0.99)*
No. of chronic conditions	1.0 (0.99, 1.00)
Change in chronic conditions	1.0 (0.99, 1.01)
Number of reported medications	1.00 (0.99, 1.00)
Change in medications	1.00 (0.99, .100)
Disability	
Comparison: never	
Disability in W1 and W2	0.97 (0.93, 1.01)
No longer has a disability in W2	1.01 (0.99, 1.03)
New disability in W2	0.97 (0.94, 1.01)
Depressed mood	1.00 (0.99, 1.00)
Change in depressed mood	1.0 (0.99, 1.00)
Executive function	1.00 (0.99, 1.0)
Change in executive function	0.99 (0.99, 1.00)
Memory	1.00 (1.00, 1.00)**
Change in memory	1.00 (0.99, 1.00)
N	5134

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Imputed scores were calculated based on non-missing APQ questions, age, gender, marital status, employment status and disability, all of which had no missing data.

Conclusion

This thesis began with two questions – are older adults with negative perceptions of ageing at greater risk of developing either frailty, cognitive decline or both? A literature review revealed that negative attitudes towards ageing are associated with short-term declines in cognitive and physical function but little is known about the long-term effects. Meanwhile, a literature search for the association between frailty and cognition revealed six potential candidate mechanisms to explain the relationship including neuropathology, inflammation, hormonal dysregulation, cardiovascular factors, nutrition and perceptions of ageing. There is as yet relatively little empirical data to support these hypotheses and the data that exists has often produced conflicting results. While the first five physiological mechanisms are generally considered to be largely uncontrollable factors that occur as one ages, the sixth potential mechanism is interesting as it suggests that the frailty-cognition cycle may in part be influenced by a controllable psychological or behavioural factor. This has important ramifications for future interventions as, if it is the case that frailty and cognition are linked by a psychological variable, there may be an inexpensive psychological or behavioural intervention to prevent or delay the onset of these two debilitating conditions. These interventions could have extensive life course and societal implications therefore offering widescale public and policy engagement opportunities. There are no studies to my knowledge which have explored the relationship between perceptions of ageing, frailty and cognition and thus it was the aim of this thesis to tease out the nature of the relationship between these three factors.

The hypothesis that perceptions of ageing may contribute to the development of both frailty and cognitive impairment was developed on the basis of two literature reviews which form the introductory chapters of this thesis. The first review, on whether and how perceptions of ageing are associated with health in later life, revealed a large number of experimental studies showing that priming older adults with negative stereotypes or negative information about ageing causes immediate declines in physical and cognitive function but there is a paucity of literature on this association longitudinally. The second review resulted in a hypothetical model for the association between perceptions of ageing, frailty and cognition based on an expanded form of a theory of frailty put forward by Lang and colleagues in 2009 [210]. They suggested that some

older adults who experience age-related changes to muscle mass or bone density, and who become consciously aware of such changes, may lose motivation to remain physically active as their perception of the effort involved in doing so increases. The resulting lower levels of physical activity cause an acceleration in the loss of muscle mass putting them at risk of becoming physically frail. The current thesis proposes that the hypothesis could be expanded in two ways: firstly, this chain of events may also explain the association between frailty and cognitive impairment as lower levels of physical activity would put older adults at risk, not just of physical decline, but also of cognitive decline. Secondly, older adults who are consciously aware of bodily changes to such an extent that they change their behaviour, likely have an attentional or attributional bias towards age-related changes. In other words, these adults may be constantly expecting adverse changes and, as a result, are hyper-aware when any changes do occur. This attentional bias may be precipitated by their perceptions of ageing throughout life, since older adults who have negative perceptions of ageing - such that they are vigilant for negative changes and expect any changes to be uncontrollable - are probably more likely to lose motivation to remain physically active as they will no longer see the benefit. Similarly, if these adults see no benefit to healthy activities as they age then they may be more likely to limit other effortful activities such as active community engagement, social participation or cognitively demanding tasks such as continued learning. Thus older adults with negative perceptions of ageing may be at greater risk of entering a cycle of decline during which they develop both frailty and cognitive impairment through a number of behavioural pathways.

As outlined above, there is a paucity of literature on the impact of perceptions of ageing on health over longer time periods but the studies which have been conducted have found some interesting results: older adults with negative perceptions of ageing are more likely to experience cardiovascular events, have a greater number of illnesses and die earlier than those with positive perceptions of ageing [55, 60]. In relation to behavioural changes, a small number of studies found that negative perceptions of ageing were associated with a decreased likelihood of being physically active independent of actual physical ability [114]. There have been no equivalent studies which have examined changes in other types of behaviours such as social engagement or cognitively effortful activities.

There is thus some evidence to suggest that perceptions of ageing may influence decline in physical and cognitive function, albeit based on subjective measures, as well as in physical activity: this provides support for the first part of our hypothetical model.

We then explored the existing literature for clues as to the mechanisms which may explain the relationship between perceptions of ageing and health. We found three categories of potential mediators: behavioural (declines in physical and social activities), psychological (reduced ability to use coping strategies in the face of age-related changes) and three physiological mediators namely cardiovascular stress, cortisol overproduction and chronic inflammation. Interestingly, these form three of the five physiological mediators also hypothesised to explain the association between frailty and cognition.

In response to these two literature reviews and the formation of our hypothetical model we conducted five empirical studies using data from waves 1 and 2 of the TILDA study. The first empirical study assessed the relationship between frailty and cognition in greater detail than had previously been explored. Our initial literature review revealed that while much evidence found that frailty was associated with global cognitive function, very few studies had examined the relationship between frailty and individual cognitive domains. We found that older adults who were pre-frail or frail had poorer performance in global cognitive function, memory, attention and executive function in a dose-response-type relationship.

The second empirical study returned to the perceptions of ageing hypothesis in order to assess whether negative perceptions of ageing were associated with longitudinal decline in physical function. We were unable to use the full frailty measure for this study due to unreliability of some components of the measure ([238] [239]) but we used walking speed which is an important component of frailty. We found that older adults with negative perceptions of ageing – specifically those who expected negative consequences with age and felt they had little control over them – had a decline in physical function over two years after controlling for baseline physical function and for changes in multiple other health variables.

The third empirical study asked the same question in relation to cognitive function. We found that older adults with negative perceptions of ageing showed

declines in executive function, self-rated memory and prospective memory. The fourth empirical study returned to the relationship between frailty, cognition and perceptions of ageing. Based on our findings that perceptions of ageing are associated with decline in both cognitive and physical function, we hypothesised that perceptions of ageing may explain the relationship between frailty and cognitive impairment in some older adults. Supporting this hypothesis, we found an association between frailty and cognition in older adults with negative perceptions of ageing but no association between frailty and cognition in older adults without negative perceptions of ageing. This relationship was repeated for global cognitive function, executive function and attention but not for memory. This is consistent with paper 2 which found no association between perceptions of ageing and memory.

Finally, the fifth empirical paper tested the association between perceptions of ageing and social and cognitive behaviours. We found that older adults with more negative perceptions of ageing were less likely to remain engaged in social and active leisure pursuits over two years, while those with positive perceptions were more likely to participate in cognitively stimulating activities and to be involved in the community.

We have summarised the findings from this thesis, along with associations known from previous research and additional hypothetical associations, in Figure 20. Becca Levy's work suggests that people who hold negative age-related stereotypes when they are younger are also more likely to have negative perceptions of themselves as they age [22]. When these people experience normal age-related changes they may have both an attentional bias towards them, such that they focus on changes more than other people do, and also have an attributional bias such that they assume all events are a sign of uncontrollable, inevitable age-related decline. Based on our review of ageing perceptions we suggest that these people will be more challenged when faced with either ageism or real health challenges as they age. This will affect health through a psychological pathway - we know that older adults with negative perceptions of ageing are less able to use coping strategies in the face of adverse events [115] – and also through physiological pathways associated with increased stress, including spikes in cortisol, chronic inflammation and increased cardiovascular reactivity. Both the psychological and physiological pathways may directly or indirectly influence behaviour, cognitive function and the

development of frailty. These changes will, in turn, provided confirmations of the initial negative view of ageing and increase attributional and attentional biases towards negative age-related information, thus feeding back into the cycle of decline. Of course, these are likely not the only physiological and psychological mechanisms involved in the development of either frailty or cognitive function. This is merely a hypothetical model of one part of a complex process.

This thesis has illuminated the first and last stages of this model - namely that perceptions of ageing are associated with physical function, cognitive function and behaviours in later life - but other intervening stages remain to be explored. For example, although frailty is associated with chronic inflammation, it is not yet clear whether inflammation is a cause or a consequence of the syndrome [273]. Similarly, although negative perceptions of ageing are associated with both decreased coping strategies and disengagement with social and physical activities, we do not know if this is the primary pathway between perceptions of ageing and social behaviours.

Limitations

The most obvious criticism of this work is that the pathway could be in the opposite direction: older adults who have already experienced bad health may have developed negative, and possibly realistic, perceptions of ageing. The papers in this thesis have attempted to control for this potential confound by covarying for baseline health status including chronic conditions, medication use, cardiovascular disease and mental health. Additionally, the analyses have controlled for change in health status between the two waves of data. The effect of negative perceptions of ageing on walking speed and cognition longitudinally is therefore independent of whether, for example, participants had a heart attack, developed diabetes or increased their medications between waves. Consistent with this, previous work has shown that negative perceptions of ageing are relatively stable across life and remain consistent even in the face of ill health [81]. In addition, Becca Levy found that older adults who had negative stereotypes about ageing in mid-life were more likely to have had a cardiovascular event up to 38 year later [55]. Of course this is still self-reported data and there may be a reporting bias associated with negative perceptions of ageing. It is also possible that confounding remains in our studies using

objective measures. It will be necessary to explore this pathway in future waves of the TILDA data which will include repeated measures of all outcome variables including, crucially, the Aging Perceptions Questionnaire.

There are a number of other limitations to this work which must be highlighted. Due to both the unreliability of the grip strength and physical activity measures between waves, and as height and weight were self-reported rather than measured in wave 2, I was unable to measure frailty in wave 2 [238, 239]. In paper 2 I used the TUG measure as a proxy of frailty as previous work from TILDA has found that this may be appropriate [240]. The unreliability of the frailty measure in wave 2 also pertains to wave 1 as it is possible that unreliability in the measures at baseline also lowered the sensitivity and specificity of our frailty measure at baseline. The unreliability of measures such as grip strength, however, is a problem faced by all longitudinal studies and is not unique to TILDA. Future waves of TILDA data will include objective measures of physical activity through the use of accelerometers, objective measures of weight loss through BMI and will potentially have greater reliability in the measures between waves 1 and 3 as the measures will have been conducted by the same trained nurses, rather than interviewers, at both time points.

The issue of reliability across all measures is one that is common to many measures in all longitudinal studies. As the same measures are repeated over waves of data it is possible that either measurement error or practice effects may cause fluctuations in scores which would confound the associations investigated through longitudinal analyses. There is, however, a statistical solution to this if the test-retest reliability of a measure is known as it is possible to correct regression estimates for bias due to measurement error [172, 252]. Papers 2 and 3 of this thesis include longitudinal analyses of change in physical and cognitive measures which may be prone to measurement error and practice effects [172]. I therefore included known measurement error and test-retest reliability estimates of the measures to regression analyses to control for potential residual confounding. These analyses did not change the findings suggesting that measurement error does not account for the change in cognitive and physical scores observed over two years.

With regards to follow-up, we only had a number of cognitive measures which were repeated in wave 2. This meant that I did not have access to repeated

measures of attention, processing speed or executive function aside from verbal fluency. Verbal fluency is, however, a well-established, normally distributed measure of executive function and we will have additional measures in future waves. Finally, in relation to repeated measures, the APQ was only taken at wave 1 and not repeated at wave 2 which proved a disadvantage to this study as it would have been interesting to assess change in the APQ against change in outcome measures. Again, this is something which can be analysed in future waves of data.

Another limitation to the longitudinal studies in this thesis is, as is common to all longitudinal studies, attrition. Attrition can bias results as the oldest and sickest members of the population are less likely to be included in follow-up leading to an unrepresentative sample. As our sample at baseline excluded participants with dementia, or any illness which would prevent them from participating in a long interview and health assessment, our sample was already relatively young and healthy at baseline and thus attrition rates mean longitudinal analyses are conducted on an even healthier subsample. We did, however, achieve a relatively low rate of attrition in TILDA between waves 1 and 2 of just 14%, many of whom have indicated that they will return for the health assessment in wave 3. Furthermore, the use of attrition weights in papers 2, 3 and 5 did not change the results of our analyses leading me to be more confident that attrition was not biasing the findings.

An additional note in considering the results of this thesis is that the effects are small. Paper 1 showed a difference in cognitive function between robust and frail participants but the difference between them was approximately half a standard deviation in most cases which is likely not clinically meaningful. Similarly, paper 2 and 3 illustrated the influence of perceptions of ageing on walking speed and cognitive function 2 years later but again the results were small with a difference of around 1 second in TUG time between those who did not have negative perceptions of ageing and those who did, and a difference of 2 animals named between those who had negative perceptions of ageing and those who did not. Again, the relative risk of change in social and cognitive behaviours at follow-up were minimal. Although these changes are small, however, they are over a short follow-up period of 2 years and it may be of interest that there is any such difference in a community dwelling sample of relatively young older adults. It will, of course, be necessary to follow these

participants in future waves of the data to determine whether perceptions of ageing continue to influence change in physical, cognitive and social functions as people age.

This thesis has shown that a psychological variable – perceptions of ageing – influences outcomes in a population representative sample of older adults both cross-sectionally and longitudinally. Considering that other psychological factors also affect health outcomes in later life, it is important to consider whether perceptions of ageing overlaps with other psychological constructs or if it is a distinct factor of the psychology of ageing. Perhaps the most obvious to begin with is depression. A large body of evidence has shown that depressed mood in later life is associated with declines in physical and cognitive function [254, 281]. One criticism of this work may therefore be that the ageing perceptions questionnaire is picking up on depressed mood which is already known to be associated with the same outcomes. However, the correlations between the five domains of perceptions of ageing and depression are low to moderate (Timeline: rho = 0.22, Positive Control: rho = -0.05, Negative Control and Consequences: rho = 0.24, Positive Consequences: rho = -0.08; Emotional Representations: rho = 0.32). Furthermore, the effect of perceptions of ageing on decline in cognitive and physical function was independent of the effect of depressed mood when it was included as a covariate in analyses. This suggests that the perceptions of ageing measure is not merely a proxy for depressed mood.

A second criticism may be that negative perceptions of ageing reflect the reality of participants' lives rather than their psychological state. For example, participants who truly are socially isolated or lonely will report worse perceptions of ageing, as will those who perceive their health to be poor. As noted I controlled for a large number of objective health measures but I also controlled for perceived health status, or self-rated health, as this may reflect a psychological belief outside of actual health. However, the correlations between the domains of perceptions of ageing and self-rated health (Timeline: rho = 0.25, Positive Control: rho = -0.12, Negative Control and Consequences: rho = 0.29, Positive Consequences: rho = -0.08; Emotional Representations: rho = 0.24) were low. In addition, the correlations between perceived loneliness and the domains of perceptions of ageing were low to moderate (Timeline: rho = 0.12, Positive Control: rho = -0.02, Negative Control and Consequences: rho = 0.16, Positive Consequences: rho = -0.03; Emotional Representations: rho =

0.21) suggesting that the perceptions of ageing measure is distinct from self-rated health and loneliness. Furthermore, the effect of perceptions of ageing did not change when these factors were also included as covariates in the analyses. It thus appears that perceptions of ageing have an effect on cognitive function, physical function and social engagement independent of actual health, perceived health and other psychological factors.

This thesis has thus shown that a distinct psychological construct – perceptions of ageing – has a longitudinal effect on cognitive and physical function in older adults. In addition, it illustrates that perceptions of ageing may influence engagement with some of the social and cognitive activities which are known to build cognitive reserve and delay the onset of dementia. It also suggests that older adults with negative perceptions of ageing may be more likely to enter into a cycle of decline in which both cognitive and physical functions are impaired. These findings have important implications not only for future research but also for practice on an individual and a societal level.

Implications

Interventions

These findings illustrate that perceptions of ageing have an independent effect on decreased physical, mental and social function, all of which are significant risk factors for dementia (e.g. [120, 167, 265, 282]). As there is no current effective treatment for dementia, and no immediate prospect for finding one, then the only viable approach to dementia is one of prevention. One promising contribution to slowing down the development of dementia may be to try to change self-perceptions of ageing which I and others have shown to have such a detrimental effect on accelerating known risk factors. If we could find ways to do this on a mass scale – which is theoretically possible given modern digital media and communication technologies – then we may be able to delay the onset of cognitive decline in some older adults.

Two previous studies used change in attitudes towards ageing to increase levels of physical activity with some success [118, 119]. Fascinatingly, however, a very recent intervention study has shown that older adults' objectively measured physical function can be increased over 8 weeks purely by an implicit positive stereotype intervention [278]. Becca Levy and colleagues developed an

intervention whereby older adults were implicitly primed with words relating to positive stereotypes about ageing once per week over four weeks while a control group were primed with neutral words. Throughout the course of the experiment their beliefs in stereotypes about ageing, their self-perceptions of ageing and their physical function were measured. Following the intervention and for 3 weeks afterwards participants in the intervention group had statistically significantly more positive stereotypes about ageing, positive self-perceptions and an improvement in physical function that was comparable to the results of a previous 6-month exercise intervention in similar participants [278]. There was no improvement in the control group in any measures. Furthermore, structural equation modelling revealed that the pathway in improvement most likely resulted from improved stereotypes which improved self-perceptions which, in turn, improved physical function. It is fascinating that these results lasted for 3 weeks after the end of the intervention and suggests that there may be the potential for long-lasting interventions to improve older adults' physical function based purely on implicit positive perceptions of ageing. In addition, the successful intervention simply involved presenting older adults with words related to positive stereotypes about ageing outside of their consciousness suggesting that widespread interventions may be possible through social media, television and film as well as individual interventions. There are no similar studies exploring cognitive function or physiological measurements, although these will no doubt be the basis for future research.

Anti-Ageism Campaigns

A large number of anti-ageism campaigns are carried out every year in Ireland and worldwide which aim to prevent younger members of the population from holding stereotypical ageist views about older adults. While ageism is an important issue to target, my findings suggest that self-perceptions of ageing are an important predictor of health and thus these campaigns may need to consider targeting older adults' self-ageist views as much as, or perhaps even more, than younger adults' attitudes. Previous work in this field has found that self-ageist beliefs can be primed with worryingly simple messages such as stereotypical words about ageing and false information that the majority of older adults suffer from dementia (e.g. [40]). This suggests that campaigns may need to carefully consider how they market anti-ageism campaigns which use age-related stereotypes as they may be priming older adults with negative self-

perceptions of ageing. However, this is still conjectural and experiments will be necessary to test whether modification of these campaigns influences perceptions and, in turn, frailty or cognitive function at a population level.

The "White Coat" Effect

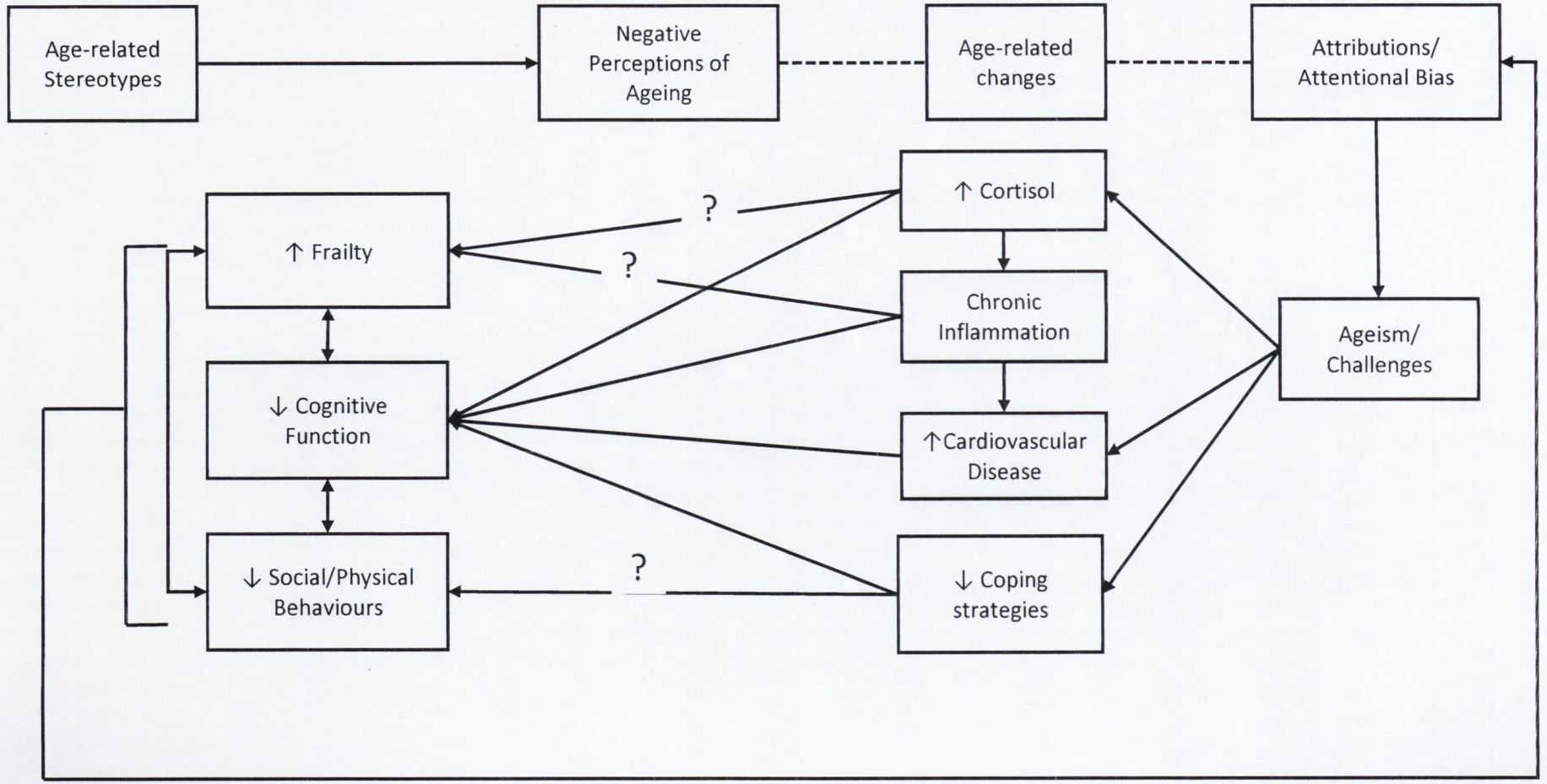
The "white coat" effect is well recognised in medical practise as an effect in which blood pressure readings can often be inaccurate and falsely high when taken by a medical practitioner [283]. This is as a result of patients' anxiety or stress when faced with a doctor who may give them bad news and second readings may need to be taken when one is abnormally high. Previous research in the field of ageing attitudes has found that older adults given negative information about ageing or primed with negative age-related stereotypes show immediate declines in cognitive function when tested and the findings from this thesis illustrate that negative perceptions about ageing may have long-term effects on cognition. As noted above, simple primes can affect self-perceptions and I thus suggest that medical and psychological professionals may need to be aware of a "white coat"-type effect when conducting neuropsychological assessments in older adults. For example, many people unconsciously speak to older adults in infant speak without regard for their actual physical and cognitive status [124]. This likely impacts on older adults' self-perceptions of ageing. Similarly, the information given in a neuropsychological, medical or any testing setting that imply that cognitive decline is to be expected or normal with age may influence how older adults view age-related changes and affect the efforts they make to address any changes which can be prevented. These unconscious factors in the way medical and psychological professionals speak to older adults may not only be giving inaccurate results in a clinical setting but potentially also contributing to longer lasting adverse changes.

Conclusion

Negative perceptions of ageing are a risk factor for decline in cognitive function, physical function and social behaviours. This is the first body of work to show that perceptions of ageing are longitudinally associated with objective decline in cognitive, physical and social function in a population representative sample of older adults. Importantly, perceptions of ageing may be modifiable and, crucially, an intervention improving perceptions of ageing has shown a direct

improvement in physical function over 2 months. Of course, it is not yet clear whether change in perceptions through interventions such as these are sustainable over a longer period of time and this will need to be validated in large scale intervention trials. Future research will also be needed to test whether these interventions can impact change in cognitive function and social behaviours. For now we can suggest that perceptions of ageing may provide the key to novel methods of inexpensive, effective healthcare to prevent or delay the onset of two debilitation conditions in later life.

Figure 20. Hypothetical Model of the Pathway Between Negative Perceptions of Ageing, Frailty, Cognitive Function and Social Behaviours.



? = pathways that are speculated but not confirmed. Model based on data analysed as part of this thesis and hypotheses formed based on previous research.

Appendix

Brief Aging Perceptions Questionnaire (B-APQ)

We are interested in your own personal views and experiences about getting older. Please indicate your views on the following statements (strongly disagree, disagree, neither agree nor disagree, agree, or strongly agree).

Please tick one box per line which best shows how you feel about each statement	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I always classify myself as old	☐	☐	☐	☐	☐
I am always aware of the fact that I am getting older	☐	☐	☐	☐	☐
I feel my age in everything that I do	☐	☐	☐	☐	☐
As I get older I get wiser	☐	☐	☐	☐	☐
As I get older I continue to grow as a person	☐	☐	☐	☐	☐
As I get older I appreciate things more	☐	☐	☐	☐	☐
I get depressed when I think about how ageing might affect the things that I can do	☐	☐	☐	☐	☐
The quality of my social life in later years depends on me	☐	☐	☐	☐	☐
The quality of my relationships with others in later life depends on me	☐	☐	☐	☐	☐
Whether I continue living life to the full depends on me	☐	☐	☐	☐	☐
Getting older makes me less independent	☐	☐		☐	☐
As I get older I can take part in fewer activities	☐	☐	☐	☐	☐
As I get older I do not cope as well with problems that arise	☐	☐	☐	☐	☐
Slowing down with age is not something I can control	☐	☐	☐	☐	☐

I have no control over the effects which getting older has on my social life	☐	☐	☐	☐	☐
I worry about the effects that getting older may have on my relationships with others	☐	☐	☐	☐	☐
I feel angry when I think about getting older	☐	☐	☐	☐	☐

Centre for Epidemiologic Studies – Depression Scale (CES-D)

INSTRUCTIONS FOR QUESTIONS: Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week. HAND CARD A.

Rarely or None of the Time (Less than 1 Day)
Some or a Little of the Time (1-2 Days)
Occasionally or a Moderate Amount of Time (3-4 Days)
Most or All of the Time (5-7 Days)

During the past week:

I was bother by things that usually don't bother me.
I did not feel like eating; my appetite was poor.
I felt that I could not shake off the blues even with help from my family or friends.
I felt that I was just as good as other people.
I had trouble keeping my mind on what I was doing.
I felt depressed.
I felt that everything I did was an effort.
I felt hopeful about the future.
I thought my life had been a failure.
I felt fearful.
My sleep was restless.
I was happy.
I talked less than usual.
I felt lonely.
People were unfriendly.
I enjoyed life.
I had crying spells.
I felt sad.
I felt that people dislike me.
I could not get 'going'.

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