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Internet Use, Leisure Activities, and Memory Performance Among 65+ Residents of Baltic States

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Abstract. Advances in the healthcare system and socioeconomic progress have led to longer life expectancy, resulting in an ageing population and societal challenges for policymakers. Active ageing, promoted by the United Nations Economic Commission for Europe through the Active Ageing Index, highlights Capacity and Enabling Environment for Active Ageing. Information and Communication Technology (ICT) use is crucial, enabling participation in social, economic, and cultural activities (UNECE, 2020).

Research indicates cognitive changes in ageing, especially memory deterioration, associating these changes with genetics, education, and professional and leisure activities (Stern, 2009). According to research, ICT positively affects cognition, enhancing memory (Almeida et al., 2012; Benge et al., 2023), but may also pose cognitive issues (Nagam, 2023). Prioritizing cognitive health among the elderly in social policies is vital, with ICT playing a key role.

The present study aimed to assess the links between Internet use and memory performance after controlling for demographic factors and leisure activities. Data from the Survey of Health, Ageing, and Retirement in Europe's 8th Wave (Börsch-Supan, 2022) included 2320 individuals aged 65–100 from Baltic countries. Memory was assessed using a modified Rey's Auditory Verbal Learning Test. Participation in leisure activities was assessed by asking respondents if they had taken part in any of the listed activities in the past year, and Internet use was assessed by asking about Internet use in the past 7 days.

Significant associations were found between memory, leisure activities, and Internet use. Internet use predicted memory capacity in older adults, remaining significant after controlling for demographics, health, and leisure activities. The current findings show that Internet use might be valuable in predicting memory functioning among older adults and can potentially contribute to the protection of cognitive function.

Keywords: Internet use, active ageing, memory, leisure activities, older adults, SHARE

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Vyresnio amžiaus asmenų naudojimasi internetu, laisvalaikio veiklų ir atminties gebėjimų lyginamoji analizė Baltijos šalyse

Santrauka. Socioekonominė pažanga bei medicinos pasiekimai lemia visuomenės senėjimą ir kelia iššūkių politikos formuotojams. Aktyvaus senėjimo indeksas pabrėžia gebėjimų ir aktyviam senėjimui palankios aplinkos svarbą, įtraukdamas ir informacinių technologijų naudojimą. Informacinių technologijų naudojimas gali teigiamai veikti pažintinius gebėjimus (Benge et al., 2023), tačiau gali sietis ir su pažintinėmis problemomis (Nagam, 2023). Šiuo tyrimu siekta įvertinti interneto naudojimo ir atminties gebėjimų sąsajas. Buvo analizuoti Europos 8-osios bangos sveikatos, senėjimo ir išėjimo į pensiją tyrimo (Börsch-Supan, 2022) duomenys, kurie apėmė 2320 65–100 metų asmenų iš Baltijos šalių. Rezultatai atskleidė, kad interneto naudojimas leidžia prognozuoti atminties gebėjimus, net ir kontroliuojant demografinius kintamuosius ir laisvalaikio veiklas. Naudojimasis internetu gali būti naudingas prognozuojant vyresnio amžiaus žmonių atminties gebėjimus ir prisidėti prie pažintinių gebėjimų saugojimo.

Pagrindiniai žodžiai: interneto naudojimas, aktyvus senėjimas, atmintis, laisvalaikio veiklos, vyresnio amžiaus asmenys, SHARE[1]

Introduction

As a result of recent positive advances in the health care system and socioeconomic progress, the global population has rapidly become an ageing one. This brought various challenges to modern society and currently requires actions from policymakers. Countries are exploring measures to increase employment rates among older workers and developing ways of providing services via the community and the concept of active ageing enables these actions. The United Nations Economic Commission for Europe (UNECE) has introduced the Active Ageing Index (AAI), which serves as a tool to assess the unrealized potential of older individuals in promoting active and healthy ageing across countries. It measures the level to which older people lead independent lives, engage in paid employment and social activities, and demonstrate the capability for active ageing. It includes 22 indicators grouped into four domains (independent, healthy and secure living; employment; participation in society and, the capacity and enabling environment for active ageing). The Capacity and Enabling Environment for Active Ageing domain is emphasized, where the use of Information and Communication Technology (ICT) plays a crucial role. According to UNECE it offers opportunities for learning, participating in social, economic, and cultural activities, therefore enhances the active ageing (Unece, 2020). Cognitive functioning holds a fundamental role across all domains of the Active Ageing Index, influencing aspects like employment, social interaction, independent living, and general well-being. As a result, enhancing cognitive health among older adults should be prioritized in social policies, with ICT potentially having a significant role in promoting cognitive functioning.

Memory issues have gained increasing significance (Cadar et al., 2017), as even minor memory impairments can affect independence, leading to daily challenges and a decline in overall quality of life. These issues can also burden family members and caregivers and indirectly impact a country's economy (Chaves et al., 2015; Hock et al., 2014). Memory comprises various systems, and not all are equally affected by ageing. Research

[1] SHARE – The Survey of Health, Ageing and Retirement in Europe

indicates that working memory and episodic memory systems are particularly sensitive to the effects of ageing (Nyberg et al., 2012). Memory decline is an individual process that may depend on several different factors. These changes are commonly associated with education, IQ, and professional activity (Stern, 2002; Stern, 2009). However, recent studies show that there are other significant factors related to memory performance in older adulthood, such as leisure activities (Clare et al., 2017; Arenaza-Urquijo et al., 2015; Scarmeas & Stern, 2003). Studies show that a variety of leisure activities, such as sewing, reading, playing a musical instrument, drawing and others, contribute to better cognition (Wang et al., 2012). Another important factor possibly contributing to cognitive performance is the use of ICT and the Internet (Klimova & Valis, 2018; Wilmer et al., 2017). However, results are scarce and contradictory.

The use of ICT helps to perform numerous tasks and is considered complex in terms of cognition, especially for older individuals. According to research, frequent computer use is associated with higher executive functions (Tun & Lachman, 2010) and is linked to reduced brain volume in regions essential for memory functioning (Silbert et al., 2016). According to Kurita and others (2021), computer use is associated with a less cognitive impairment, indicating that computer use has a significant protective effect on cognition. Other studies support these findings, indicating that increased digital device use is associated with reduced cognitive complaints (Benge et al., 2023) and higher cognitive capacities in older adults (Wu, Lewis & Rigaud, 2019). This is explained by the technological reserve hypothesis, suggesting that technology use has a protective effect on cognitive abilities due to its potential cognitive-stimulating properties and may reduce dementia risk (Scullin et al., 2021; Krell-Roesch et al., 2017; Wilson, Byrne, Rodgers, and Maden, 2022).

Other studies do not support these results. Existing data indicates that frequent use of modern technologies or social media is associated with increased subjective cognitive concerns among older adults (Sharifian and Zahodne, 2019). Similarly, Slegers, van Boxtel & Jolles (2009), found no cognitive benefits from intensive computer use among healthy older adults, with no observed improvements in various cognitive domains over time. They propose the digital distraction hypothesis, which posits that increased technological engagement can lead to negative cognitive consequences, including forgetfulness, slower information processing, and difficulties in organizing/performing tasks due to reliance on technologies that reduce the use of inherent memory systems. In line with this, Small et al. (2020) suggest that older adults who use technologies frequently are more likely to experience cognitive difficulties.

In recent decades, the Internet has become integral to daily life, which was particularly highlighted during the COVID-19 pandemic when physical distancing was recommended (Kim & Han, 2021; Kurita et al., 2021). Although, a substantial body of research has indicated a potential positive impact of computer use on increasing cognitive ability in older adults, the reliability of these findings remains somewhat uncertain (Calhoun & Lee, 2019). This increased the debate regarding the potential negative Internet effects on cognitive abilities (Schacter, 2022; Small et al., 2020). Some studies link modern technology and social media to subjective cognitive difficulties, while others suggest an inverse relationship (Benge et al., 2023). According to a Brazilian longitudinal study (de Rosso Krug, d'Orsi & Xavier, 2019), Internet use was associated with significant cognitive benefits and lower cognitive loss, implying that Internet engagement can be a protective factor against age-related cognitive changes.

In the current study, we aimed to examine the links between Internet use and memory performance among older adults after controlling for demographic factors, self-perceived health, and leisure activities. It was hyphotesized that memory capacity and Internet use will be significantly related. Involvement in leisure activities was expected to be related to a better memory capacity in older adulthood. Finally, it was hyphotesized that the use of Internet will allow for the prediction of memory capacity in older adulthood even after controlling for cognitively stimulating leisure activities, self-perceived health, and other demographic factors.

Methodology

Study design

This study was conducted using data from the Survey of Health, Ageing, and Retirement in Europe (SHARE), a biennial survey conducted since 2004. SHARE involves a vast cohort of over 140,000 individuals aged 50 and above, residing in 27 European countries and Israel (Bergmann et al., 2019a, 2019b). The survey employs a Computer Assisted Personal Interview (CAPI) supplemented by a paper questionnaire, administered in the respondents' homes and typically lasting around 90 minutes. The questions cover a range of socioeconomic, health-related, and psychological variables. Data collection procedures received approval from the internal review board of the University of Mannheim, Germany, until 2011, and from the Ethics Council of the Max Planck Society for the Advancement of Science from 2011 onwards.

Participants

Data for the present study has been drawn from the 8th wave of SHARE (Börsch-Supan, 2022; Börsch-Supan, 2013). Subjects with neurological diseases (Parkinson's and Alzheimer's disease) or comorbidities that may affect cognitive abilities (cancer, affective disorders, etc.) were excluded from the sample to increase the reliability of the results. In order to reduce the influence of cultural and sociopolitical factors, three historically, politically and culturally similar countries were selected. Therefore, the final analytic sample consisted of 2320 individuals from Latvia (N=340), Estonia (N=1454), and Lithuania (N=526). The age of the participants was 65 to 100 years, 34.1% were men and 65.9% were women.

Variables

Memory was selected as a dependent variable, which was assessed using two measures: immediate and delayed recall. The evaluation of memory involved a modified version of Rey's Auditory Verbal Learning Test (RAVLT), a test known for assessing both working memory and episodic memory (Dal Bianco, Garrouste and Paccagnella, 2013; Litwin, Schwartz, and Damri, 2017; Cheke and Clayton, 2013). In the modified version of the test, participants were presented with a list of ten words, which they were asked to remember. The words were read aloud by a researcher. After a delay of 5 to 10 minutes, the participants were asked to recall as many words as they could from the earlier list. Each participant's performance was scored on a scale of 0 to 10, based on the number of correctly recalled words. Participation in leisure activities was assessed by a categorical variable asking respondents if they had taken part in any of the following activities in the past year: voluntary or charity work; educational or training courses; sport, social, or other similar clubs; political or community-related organizations; word or number games (such as crossword puzzles/Sudoku); reading books, magazines, or newspapers; or playing card games or games such as chess. Responses were coded either 0 (for non-participation in a certain activity) or 1 (for participation in a certain activity). Internet use was measured by a single categorical variable asking respondents "During the past 7 days, have you used the Internet, for emailing, searching for information, making purchases, or for any other purpose at least once?". The study also considered other socio-demographic variables that may have been important in understanding the links between the use of the Internet, memory, and leisure activities. Age, years of education, place of residence by country were taken into account. Country variables were transformed into dummy variables by selecting Estonia as a reference country.

Data analysis

IBM SPSS Statistics 22 software was used for statistical data analysis. Descriptive statistics and Pearson's correlation coefficients were calculated, and hierarchical multiple regression models were constructed.

Results

The links between Internet use and memory were assessed first, and Pearson's correlation coefficients were calculated for this purpose. Memory showed statistically significant moderate correlations with Internet use in the past 7 days among older adults ($r = -0.362$, $p < 0.001$ for immediate recall and $r = -0.332$, $p < 0.001$ for delayed recall). The use of the Internet was associated with memory performance among older adults.

The relationship between cognitively stimulating leisure activities and memory in older adults was also examined, first by calculating Pearson's correlation coefficients (Table 1). Memory had statistically significant weak to moderate correlations with all leisure activities. The strongest statistically significant relationship was found with sport, social, or other similar clubs ($r = 0.23$, $p < 0.001$; $r = 0.19$, $p < 0.001$), reading books, magazines, or newspapers ($r = 0.25$, $p < 0.001$; $r = 0.19$, $p < 0.001$), and solving puzzles (such as crosswords or Sudoku puzzles) ($r = 0.31$, $p < 0.001$; $r = 0.26$, $p < 0.001$). Reading books, magazines, or newspapers, solving verbal or numerical puzzles, and participating in sport, social, or other similar clubs is associated with better immediate and delayed recall among older adults.

Table 1. **Pearson correlation coefficients between memory and leisure activities (N = 24,930)**

	1	2	3	4	5	6	7
Immediate recall	0.104**	0.174**	**0.230****	0.032	**0.246****	**0.314****	0.149**
Delayed recall	0.084**	0.165**	**0.194****	0.034	**0.192****	**0.264****	0.141**

Note. 1 = voluntary or charity work; 2 = educational or training courses; 3 = sport, social, or other similar clubs; 4 = political or community-related organizations; 5 = books, magazines, or newspapers; 6 = word or number games (such as crossword puzzles/Sudoku); and 7 = card games or games such as chess; ***p < 0.01; ***p < 0.001. The highest values are marked in bold.*

Finally, a three-step hierarchical linear regression analysis was applied to assess the prognostic value of Internet use on memory performance in older adulthood over and above the demographic (i.e. age, gender, country of residence, and years of education), self-perceived health, and leisure activity factors. In the first regression model (Table 2), immediate recall was selected as a dependent variable; and in the second (Table 3), delayed recall was chosen. Independent variables were included in three stages: 1) age, gender, country of residence (Estonia, Lithuania, and Latvia), self-perceived health and obtained education (expressed in years); 2) leisure activities; and 3) Internet use in past 7 days.

There were no outliers in the data (all Cook's distance values were < 1), and no multicollinearity problem was identified (all VIF values < 2). Based on the plotting of residuals, no problems of homoscedasticity were identified. The results of the hierarchical linear regression models are presented in Tables 3 and 4.

The first regression model – using age, gender, education, self-perceived health and country of residence as prognostic factors – explained 28% of the variance of immediate recall and 22% of delayed recall. This suggests that memory declines as the age of participants increases. And on the contrary, better memory performance is related to more years of education obtained. Results also show that better self-perceived health is related to better memory performance. Some differences are also seen depending on the country of residence. Results suggest that living in Lithuania compared to Estonia is related to worse memory performance. No significant difference has been seen between Estonia and Latvia.

The second regression model included leisure activities and explained 32% of the variance of immediate recall and 25% of delayed recall. R2 change = 0.04 and R2 change = 0.03 were statistically significant (F change = 20.17, p < 0.000; F change = 12,13 p < 0.000). This shows that the first and second regression models were statistically significantly different. The leisure activities variable, included in the regression equation along with the age, country of residence, gender, self-perceived health, and education, additionally explained 4% of the variance of immediate and 3% of delayed recall. In this equation, memory was most strongly predicted by the age variable, years of education, living in Lithuania, and leisure activities such as verbal and numerical games (crosswords or Sudoku puzzles).

The final regression model included the use of the Internet in the past 7 days and explained 32% of the variance of immediate recall and 26% of delayed recall. R2 change = 0.01 and R2 change = 0.01 were statistically significant (F change = 29.42, p < 0.001; F change = 28.72, p < 0.001). Therefore, the second and the final regression models also differ statistically significantly, which means that – even when controlling for leisure activities – use of the Internet improves the prediction of immediate and delayed recall by 1%.

Table 2. **Results of hierarchical multiple regression analysis with the results of immediate recall as a dependent variable (N = 2320)**

Prognostic factors	**Model**		
	Age, gender, self-perceived health, country and years of education	**Age, gender, self-perceived health, country, years of education, and leisure activities**	**Age, gender, self-perceived health, country, years of education, leisure activities, and use of Internet**
	Beta (β); B (confidence intervals, 95%)		
Gender	0.11***; 0.43 (0.30, 0.56)	0.08***; 0.30 (0.17, 0.43)	0.08***; 0.31 (0.18, 0.44)
Age	**-0.25*****; -0.06 (-0.07, 0.05)	**–0.23*****; -0.06 (-0.07, -0.05)	**–0.20*****; -0.05 (-0.06, -0.04)
Self-perceived health	-0.12***; -0.29 (-0.38, -0.20)	-0.09***; -0.21 (-0.28, -0.12)	-0.08***; -0.19 (-0.28, 0.10)
Years of education	**0.28*****; 0.14 (0.12, 0.15)	**0.22*****; 0.11 (0.09, 0.12)	**0.19*****; 0.09 (0.08, 0.12)
Country of residence (Estonia vs Lithuania)	**-0.22*****; -0.94 (-1.09, -0.78)	**-0.17*****; -0.73 (-0.89, -0.58)	**-0.17*****; -0.71 (-0.86, -0.56)
Country of residence (Estonia vs Latvia)	-0.09***; -0.46 (-0.64, -0.28)	-0.01; -0.07 (-0.26, 0.12)	-0.01; -0.07 (-0.26, 0.12)
ALY: done voluntary or charity work		-0.01; -0.08 (-0.33, 0.16)	-0.02; -0.13 (-0.37, 0.12)

ALY: attended an educational or training course		0.04**; 0.31 (0.05, 0.57)	0.03; 0.23 (-0.03, 0.49)
ALY: gone to a sport, social or other kind of club		0.08***; 0.42 (0.23, 0.60)	0.08***; 0.38 (0.19, 0.56)
ALY: taken part in a political or community-related organization		-0.03; -0.26 (-0.58, -0.07)	-0.03; -0.28 (-0.90, 0.05)
ALY: read books, magazines or newspapers		0.06***; 0.26 (-0.06, 0.57)	0.05***; 0.25 (-0.06, 0.56)
ALY: did word or number games (crossword puzzles/Sudoku...)		**0.14*****; 0.51 (0.37, 0.65)	**0.13*****; 0.48 (0.44, 0.61)
ALY: played cards or games such as chess		0.01; 0.05 (-0.14, 0.24)	0.00; 0.01 (-0.18, 0.19)
Use of Internet in past 7 days			**-0.11*****; -0.10 (-0.14, -0.06)
Constant	8.85	8.11	7.96
R^2	**0.28**	**0.32**	**0.33**

*Note. *p < 0.05; **p < 0.01; ***p < 0.001. All ANOVA values of the models are statistically significant. ALY = activities in last year.*

Table 3. **Results of hierarchical multiple regression analysis with the results of delayed recall as a dependent variable (N = 2320)**

Prognostic factors	**Model**		
	Age, gender, self-perceived health, country and years of education	**Age, gender, self-perceived health, country, years of education, and leisure activities**	**Age, gender, self-perceived health, country, years of education, leisure activities, and use of Internet**
	Beta (β)		
Gender	0.09***; 0.43 (0.26, 0.59)	0.07***; 0.30 (0.13, 0.46)	0.07***; 0.31 (0.15, 0.48)
Age	**-0.25*****; -0.08 (-0.09, -0.06)	**−0.23*****; -0.07 (-0.08, -0.06)	**−0.20*****; -0.06 (-0.07, -0.05)
Self-perceived health	-0.10***; -0.28 (-0.39, -0.17)	-0.07***; -0.20 (-0.31, -0.09)	-0.06**; -0.17 (-0.28, -0.06)
Years of education	**0.22*****; 0.13 (0.11, 0.15)	**0.17*****; 0.10 (0.08, 0.12)	**0.14*****; 0.09 (0.06, 0.11)

Country of residence (Estonia vs Lithuania)	**-0.21*****; -1.10 (-1.29, -0.90)	**-0.17*****; -0.90 (-1.10, -0.70)	**-0.17***** ; -0.87 (-1.07, -0.67)
Country of residence (Estonia vs Latvia)	-0.07***; -0.43 (-0.66, 0.20)	-0.01; -0.06 (-0.30, 0.19)	-0.01;-0.06 (-0.30, 0.19)
ALY: done voluntary or charity work		-0.02; -0.14 (-0.45,0.17)	-0.02; -0.20 (-0.51, 0.11)
ALY: attended an educational or training course		0.05**; 0.45 (0.12, 0.78)	0.04*; 0.35 (0.03, 0.68)
ALY: gone to a sport, social or other kind of club		0.07***; 0.40 (0.17, 0.63)	0.06**; 0.35 (0.12, 0.59)
ALY: taken part in a political or community-related organization		-0.01; -0.14 (-0.55, 0.28)	-0.02; -0.17 (-0.58, 0.25)
ALY: read books, magazines or newspapers		0.06**; 0.46 (0.06, 0.85)	0.08**; 0.45 (0.05, 0.84)
ALY: did word or number games (crossword puzzles/Sudoku...)		**0.13*****; 0.55 (0.37, 0.72)	**0.12*****; 0.50 (0.33, 0.68)
ALY: played cards or games such as chess		0.02; 0.14 (-0.10, 0.38)	0.01; 0.08 (-0.15, 0.32)
Use of Internet in past 7 days			**-0.12*****; -0.13 (-0.18, -0.08)
Constant	8.31	7.30	7.10
R^2	**0.22**	**0.25**	**0.26**

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. *All ANOVA values of the models are statistically significant. ALY = activities in last year.*

Discussion

In the present study, we aimed to assess the links between Internet use and memory performance after controlling for demographic factors, self-rated health, and leisure activities. Our results contribute to already existing knowledge about positive effect of leisure activities and Internet use on memory performance in older adulthood (Calhoun & Lee, 2019; Clare et al., 2017; Arenaza-Urquijo et al., 2015; Scarmeas & Stern, 2003; Klimova & Valis, 2018; Wilmer et al., 2017). While age and education remain primary predictors of memory in older adults, we also identified significant associations between country of residence, leisure activities, memory, and Internet use. Engaging in activities like reading and puzzles predicts memory capacity, and living in Lithuania, compared to Estonia, is associated with poorer memory. Importantly, Internet use is linked to improved memory performance.

Our results show that memory performance among older adults varies in Baltic countries. Living in Lithuania compared to Estonia is related to worse memory performance. Whereas no significant differences between Estonia and Latvia were documented. Although prior research directly comparing cognitive performance in Baltic countries is scarce, a study by Barbosa and colleagues (2020) examined cognitive performance in older adults across Europe using the SHARE database. They found notable differences in cognitive performance among countries, primarily attributed to socioeconomic factors like education levels and healthcare systems. The study highlighted the impact of factors such as years of education, BMI, self-perceived health, and physical inactivity on cognitive performance.

A Lithuanian study by Verkulevičiūtė-Kriukienė (2021) compared living standards in Baltic countries after integration in EU. Estonia had the highest living standards, surpassing Lithuania, which had previously been ahead of Latvia. Between 2004 and 2013, GDP per capita in the Baltics rose by an average of 46%, with Estonia leading in growth. Lithuanian workers had the lowest monthly wages (about 72.7% of the Estonian average), and Lithuanian pensioners received the lowest pensions. In terms of household consumption expenditure, Estonia had the highest standard of living, while Lithuania had the lowest in 2012. According to Barbosa et al. (2020), malnutrition independently influenced cognitive performance changes. Notably, obese or overweight individuals were less prone to cognitive impairment, while underweight individuals had nearly double the risk of cognitive impairment compared to those with normal BMI values, possibly due to undernutrition among the older population.

As expected, the results of the present study show that there are significant associations between leisure activities and memory. Specifically, playing verbal and numerical games (crosswords or Sudoku puzzles) was associated with better memory performance. Solving puzzles and playing verbal/numerical games can be considered as cognitively stimulating activities and there are several mechanisms by which such leisure activities might be related to better memory. These findings align with other studies. According to Shin and colleagues (2021), even after adjusting for covariates, it was found that engaging in activities such as reading books, using a computer, and playing cards/games/solving puzzles positively influenced cognitive functioning. Kim and others (2020) also show, that participating in cognitive leisure activities during the later stages of life is linked to enhanced cognitive function in older adults experiencing depressive symptoms. Furthermore, an increasing body of animal research indicates that cognitive stimulation may directly impact the brain structures that support cognition (La Rue, 2010). According to the cognitive reserve hypothesis (Stern, 2002, 2009), leisure activities, among other factors, might enable compensatory cognitive strategies at the onset of age-related cognitive decline, and ensure better memory capacity in later adulthood. According to

Valenzuela and colleagues (2008), the potential mechanism linking mental activity to reduced dementia rates and better cognition could involve the neuroprotection of the medial temporal lobe.

Finally, our study revealed that Internet use allows for the prediction of memory capacity in older adulthood even after controlling for cognitively stimulating leisure activities, demographic factors, and self-perceived health. These results diverged from some of the other studies (Voinea et al., 2020; Sharifian & Zahodne, 2019; Small et al., 2020). Nevertheless, our findings were in line with our hypothesis and supported some of the previous research. For example, Kim & Han (2022) showed, that transitioning into Internet use is associated with improved cognitive functioning and slower cognitive decline over time, indicating the Internet's positive cognitive stimulation for older adults. Choi and colleagues (2021) showed significant and lasting positive effects of technology use on memory and executive function, suggesting that ICT can stimulate cognitive processes, enhancing performance, as technology applications require a new learning process that episodic memory involves.

Calhoun & Lee (2019), noted a noticeable link between increased computer usage and enhanced cognitive abilities, even when accounting for age, gender, and education. In a cross-sectional functional MRI study (Small et al., 2009), it was demonstrated that Internet browsing engages brain regions associated with decision-making and complex reasoning, particularly in frequent Internet-using older adults, suggesting that repeated exposure to Internet search activities may engage a broader range of brain regions, contributing to greater cognitive diversity.

Longitudinal studies in Australia found that computer activities like email, games, and Internet use were associated with a reduced risk of dementia (Almeida et al., 2012). Xavier and others (2014) supported these findings by demonstrating that digital literacy (computer and Internet use) enhances brain and cognitive reserve (Valenzuela et al., 2008; Stern, 2002). This improvement in cognitive reserve can lead to the utilization of more efficient cognitive networks, thereby delaying cognitive decline. Consequently, digital literacy has the potential to enhance memory performance in older adulthood. This effect was observed even in groups considered to be at higher risk, such as individuals with lower cognitive function at baseline, whose cognitive trajectories were effectively captured by the percentage change measure. Internet use can also be considered a suitable mean of cognitive stimulation due to its ability to reduce socioeconomic limitations and enhance social interactions with other individuals and modern society in general (Ala-Mutka et al., 2008), therefore improving various cognitive functions, including memory. Another possible mechanism explaining the relationship between Internet use and memory is stress hypothesis, which views the Internet as a type of social interaction. In this perspective, the sense of belonging and the social networks formed through the activity stimulate brain evolution and functional development (Fratiglioni et al., 2004). Lastly, According to Wei and others (2022), the association between cognition and Internet use could also be explained by a larger globus pallidus volume, which was positively correlated with cognitive scores, suggesting that it might be a protective factor for cognitive decline.

This study has some limitations. Firstly, Internet use was assessed with a simple yes/no question, the use of a single binary statement may have increased measurement errors and prevented the capture of more subtle nuances of Internet use. The study might have also benefited from a more comprehensive exploration of Internet use, including factors such as duration of use, purposes of use, and engagement with social media. Currently, the use of a categorical variable may hinder the ability to draw generalized conclusions. More research is needed to uncover the possible mechanisms of Internet use in older adults' cognition. Secondly, the evaluation of leisure activities was limited, and a more detailed analysis of these activities, including their frequency and performance quality, could help to predict the individual cognitive differences in older adulthood. Additionally, considering other factors such as nutrition and financial condition could add valuable insights. Furthermore, this analysis only utilized the 8th wave of SHARE data and focused solely on Baltic countries. Including additional waves and European countries could offer more comprehensive data and reveal longitudinal changes in memory performance over time. In the future, it would also be important to conduct longitudinal research that would allow to see the cognitive changes over time and evaluate the importance of Internet use regarding cognitive changes.

Despite these limitations, the current study employs a large community-dwelling sample and sheds more light on the association between Internet use and memory performance among older adults. It contributes valuable data to existing research, highlighting the role of Internet use in understanding individual differences in memory capacity during ageing. Our study highlights the importance of Internet use in the context of active ageing, providing opportunities for social, economic, and cultural engagement. This knowledge might not only occupy the niche of lacking data but could also be useful for planning interventions for individuals with memory impairment. Interventions focusing on digital device usage can bridge the digital divide, increase access to resources and services, and potentially improve cognitive function, supporting independent living in older age (Wu, Lewis & Rigaud, 2019). Promoting social policies that encourage Internet use among older adults can have a positive impact on preserving and enhancing cognitive function, reducing the risk of cognitive impairments, and ultimately improving overall health and quality of life (de Rosso Krug, d'Orsi & Xavier, 2019).

In conclusion, there are significant associations between memory, leisure activities, and Internet use. Internet use allows for the prediction of memory capacity in older adulthood even after controlling for cognitively stimulating leisure activities, demographic factors, and self-perceived health. These associations might be explained by cognitive stimulation and cognitive reserve hypothesis. Identifying the relationship between Internet use and memory helps to better understand individual cognitive differences and age-related changes in cognition.

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References

Ala-Mutka K, Malanowski N, Punie Y, Cabrera Giraldez M. Active Ageing and the Potential of ICT for Learning . EUR 23414 EN. Luxembourg (Luxembourg): European Commission; 2008. JRC45209

Almeida, O. P., Yeap, B. B., Alfonso, H., Hankey, G. J., Flicker, L., & Norman, P. (2012). Older men who use computers have lower risk of dementia. *PLOS ONE*, *7*(8), e44239. https://doi.org/10.1371/journal.pone.0044239

Arenaza-Urquijo, E. M., Wirth, M., & Chételat, G. (2015). Cognitive reserve and lifestyle: moving towards preclinical Alzheimer’s disease. *Frontiers in Aging Neuroscience*, *7*. https://doi.org/10.3389/fnagi.2015.00134

Barbosa, R. M., Midão, L., Almada, M., & Costa, E. (2020). Cognitive performance in older adults across Europe based on the SHARE database. *Aging Neuropsychology and Cognition*, *28*(4), 584–599. https://doi.org/10.1080/13825585.2020.1799927

Benge, J. F., Kiselica, A. M., Aguirre, A., Hilsabeck, R. C., Douglas, M. P., Paydarfar, D., & Scullin, M. K. (2023). Technology use and subjective cognitive concerns in older adults. *Archives of Gerontology and Geriatrics*, *106*, 104877. https://doi.org/10.1016/j.archger.2022.104877

Bergmann, M., Kneip, T., De Luca, G., & Scherpenzeel, A. (2019). Survey participation in the Survey of Health, Ageing and Retirement in Europe (SHARE), Wave 1–7. Based on Release 7.0.0. SHARE Working Paper Series (41-2019). Munich Center for the Economics of Aging (MEA).

Bergmann, M., Scherpenzeel, A., & Börsch-Supan, A. (Eds.). (2019). SHARE Wave 7 methodology: Panel innovations and life histories. MEA, Max Planck Institute for Social Law and Social Policy.

Bianco, C., Garrouste, C., & Paccagnella, O. (2013). 18 Early-life circumstances and cognitive functioning dynamics in later life. In *De Gruyter eBooks* (pp. 209–224). https://doi.org/10.1515/9783110295467.209

Börsch-Supan, A. (2022). Survey of Health, Ageing and Retirement in Europe (SHARE) Wave 8. Release version: 8.0.0. SHARE-ERIC. Data set. DOI: 10.6103/SHARE.w8.800

Börsch-Supan, A., M. Brandt, C. Hunkler, T. Kneip, J. Korbmacher, F. Malter, B. Schaan, S. Stuck, S. Zuber (2013). Data Resource Profile: The Survey of Health, Ageing and Retirement in Europe (SHARE). International Journal of Epidemiology. DOI: 10.1093/ije/dyt088.

Cadar, D., Robitaille, A., Clouston, S., Hofer, S. M., Piccinin, A. M., & Muniz-Terrera, G. (2017). An international evaluation of cognitive reserve and memory changes in early old age in 10 European countries. *Neuroepidemiology*, *48*(1–2), 9–20. https://doi.org/10.1159/000452276

Calhoun, D., & Lee, S. (2019). Computer usage and cognitive capability of older adults: Analysis of data from the Health and Retirement Study. *Educational Gerontology*, *45*(1), 22–33. https://doi.org/10.1080/03601277.2019.1575026

Chaves, A. S., Santos, A. M. D., De Britto E Alves, M. T. S. S., & Filho, N. S. (2015). Associação entre declínio cognitivo e qualidade de vida de idosos hipertensos. *Revista Brasileira De Geriatria E Gerontologia*, *18*(3), 545–556. https://doi.org/10.1590/1809-9823.2015.14043

Cheke, L. G., & Clayton, N. S. (2013). Do different tests of episodic memory produce consistent results in human adults? *Learning & Memory*, *20*(9), 491–498. https://doi.org/10.1101/lm.030502.113

Choi, E. Y., Wisniewski, K. M., & Zelinski, E. M. (2021). Information and communication technology use in older adults: A unidirectional or Bi-directional association with cognitive function? *Computers in Human Behavior*, *121*, 106813. https://doi.org/10.1016/j.chb.2021.106813

Clare, L., Wu, Y., Teale, J. C., Macleod, C., Matthews, F. E., Brayne, C., Woods, B., & Team, C. S. (2017). Potentially modifiable lifestyle factors, cognitive reserve, and cognitive function in later life: A cross-sectional study. *PLOS Medicine*, *14*(3), e1002259. https://doi.org/10.1371/journal.pmed.1002259

De Rosso Krug, R., D'Orsi, E., & Xavier, A. J. (2019). Associação entre o uso de internet e a função cognitiva de idosos, estudo longitudinal populacional Epifloripa Idoso. *Revista Brasileira De Epidemiologia*, *22*. https://doi.org/10.1590/1980-549720190012

Fratiglioni, L., Paillard-Borg, S., & Winblad, B. (2004). An active and socially integrated lifestyle in late life might protect against dementia. Lancet Neurology, 3(6), 343–353. https://doi.org/10.1016/s1474-4422(04)00767-7

Hock, R. S., Lee, H., Bienvenu, O. J., Nestadt, G., Samuels, J., Parisi, J. M., Costa, P. T., & Spira, A. P. (2014). Personality and Cognitive Decline in the Baltimore Epidemiologic Catchment Area follow-up study. *American Journal of Geriatric Psychiatry*, *22*(9), 917–925. https://doi.org/10.1016/j.jagp.2012.12.217

Kim, M. J., Tsutsumimoto, K., Doi, T., Nakakubo, S., Kurita, S., Makizako, H., & Shimada, H. (2020). Relationships between cognitive leisure activities and cognitive function in older adults with depressive symptoms: a cross-sectional study. BMJ Open, 10(2), e032679. https://doi.org/10.1136/bmjopen-2019-032679

Kim, Y. K., & Han, S. H. (2021). Internet use and cognitive functioning in Later Life: Focus on asymmetric effects and contextual factors. *Gerontologist*, *62*(3), 425–435. https://doi.org/10.1093/geront/gnab149

Klímová, B., & Vališ, M. (2018). Smartphone applications can serve as effective cognitive training tools in healthy aging. *Frontiers in Aging Neuroscience*, *9*. https://doi.org/10.3389/fnagi.2017.00436

Krell-Roesch, J., Vemuri, P., Pink, A., Roberts, R. O., Stokin, G. B., Mielke, M. M., Christianson, T. J., Knopman, D. S., Petersen, R. C., Kremers, W. K., & Geda, Y. E. (2017). Association Between Mentally Stimulating Activities in Late Life and the Outcome of Incident Mild Cognitive Impairment, With an Analysis of the *APOE* ε4 Genotype. *JAMA Neurology*, *74*(3), 332. https://doi.org/10.1001/jamaneurol.2016.3822

Kriukienė, D. V. (2021). Change of living standards in Lithuania, Latvia and Estonia after joining the European Union. *Regional Formation and Development Studies*. https://doi.org/10.15181/rfds.v14i3.875

Kurita, S., Doi, T., Tsutsumimoto, K., Nakakubo, S., Ishii, H., & Shimada, H. (2021). Computer use and cognitive decline among Japanese older adults: A prospective cohort study. *Archives of Gerontology and Geriatrics*, *97*, 104488. https://doi.org/10.1016/j.archger.2021.104488

La Rue, A. (2010). Healthy brain aging: role of cognitive reserve, cognitive stimulation, and cognitive exercises. *Clinics in Geriatric Medicine*, *26*(1), 99–111. https://doi.org/10.1016/j.cger.2009.11.003

Litwin, H., Schwartz, E., & Damri, N. (2016). Cognitively stimulating leisure activity and subsequent cognitive function: a SHARE-based analysis. *Gerontologist*, gnw084. https://doi.org/10.1093/geront/gnw084

Nagam, V. M. (2023). Internet use, users, and cognition: on the cognitive relationships between Internet-based technology and Internet users. *BMC Psychology*, *11*(1). https://doi.org/10.1186/s40359-023-01041-5

Nyberg, L., Lövdén, M., Riklund, K., Lindenberger, U., & Bäckman, L. (2012). Memory aging and brain maintenance. *Trends in Cognitive Sciences*, *16*(5), 292–305. https://doi.org/10.1016/j.tics.2012.04.005

Scarmeas, N., & Stern, Y. (2003). Cognitive reserve and lifestyle. *Journal of Clinical and Experimental Neuropsychology*, *25*(5), 625–633. https://doi.org/10.1076/jcen.25.5.625.14576

Schacter, D. L. (2021). Media, technology, and the sins of memory. *Memory, Mind & Media*, *1*. https://doi.org/10.1017/mem.2021.3

Scullin, M. K., Jones, W., Phenis, R., Beevers, S., Rosen, S., Dinh, K. L., Kiselica, A. M., Keefe, F. J., & Benge, J. F. (2021). Using smartphone technology to improve prospective memory functioning: A randomized controlled trial. *Journal of the American Geriatrics Society*, *70*(2), 459–469. https://doi.org/10.1111/jgs.17551

Sharifian, N., & Zahodne, L. B. (2019). Social Media Bytes: daily associations between social media use and everyday memory failures across the adult life span. *The Journals of Gerontology: Series B*, *75*(3), 540–548. https://doi.org/10.1093/geronb/gbz005

Shin, S. H., Park, S., Wright, C., D'Astous, V., & Kim, G. (2020). The role of polygenic score and cognitive activity in cognitive functioning among older adults. The Gerontologist, 61(3), 319–329. https://doi.org/10.1093/geront/gnaa073

Silbert, L. C., Dodge, H. H., Lahna, D., Promjunyakul, N. O., Austin, D., Mattek, N., Erten-Lyons, D., & Kaye, J. (2016). Less Daily Computer Use is Related to Smaller Hippocampal Volumes in Cognitively Intact Elderly. *Journal of Alzheimer's Disease*, *52*(2), 713–717. https://doi.org/10.3233/jad-160079

Slegers, K., Van Boxtel, M., & Jolles, J. (2009). Effects of computer training and internet usage on cognitive abilities in older adults: a randomized controlled study. *Aging Clinical and Experimental Research*, *21*(1), 43–54. https://doi.org/10.1007/bf03324898

Small, G. W., Lee, J., Kaufman, A., Jalil, J., Siddarth, P., Gaddipati, H., Moody, T. D., & Bookheimer, S. Y. (2020). Brain health consequences of digital technology use. *Dialogues in Clinical Neuroscience*, *22*(2), 179–187. https://doi.org/10.31887/dcns.2020.22.2/gsmall

Small, G. W., Moody, T. D., Siddarth, P., & Bookheimer, S. Y. (2009). Your Brain on Google: Patterns of Cerebral Activation during Internet Searching. *American Journal of Geriatric Psychiatry*, *17*(2), 116–126. https://doi.org/10.1097/jgp.0b013e3181953a02

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*, *8*(3), 448–460. https://doi.org/10.1017/s1355617702813248

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, *47*(10), 2015–2028. https://doi.org/10.1016/j.neuropsychologia.2009.03.004

Tun, P. A., & Lachman, M. E. (2010). The association between computer use and cognition across adulthood: Use it so you won't lose it? *Psychology and Aging*, *25*(3), 560–568. https://doi.org/10.1037/a0019543

Unece. (2020). *2018 Active Ageing Index Analytical Report*. https://doi.org/10.18356/04cf7043-en

Valenzuela, M., Sachdev, P. S., Wang, W., Chen, X., & Brodaty, H. (2008). Lifespan mental activity predicts diminished rate of hippocampal atrophy. *PLOS ONE*, *3*(7), e2598. https://doi.org/10.1371/journal.pone.0002598

Voinea, C., Vică, C., Mihailov, E., & Savulescu, J. (2020). The internet as cognitive enhancement. Science and Engineering Ethics, 26(4), 2345–2362. https://doi.org/10.1007/s11948-020-00210-8

Wang, H., Jin, Y., Hendrie, H. C., Liang, C., Yang, L., Cheng, Y., Unverzagt, F. W., Ma, F., Hall, K., Murrell, J. R., Li, P., Bian, J., Pei, J. J., & Gao, S. (2012). Late life leisure activities and risk of cognitive decline. *The Journals of Gerontology*, *68*(2), 205–213. https://doi.org/10.1093/gerona/gls153

Wei, L., Yue, L., & Xiao, S. (2022). Association between internet use, cognitive function, and Globus pallidus volumes: a study among the elderly in Chinese communities. Frontiers in Public Health, 10. https://doi.org/10.3389/fpubh.2022.886974

Wilmer, H. H., Sherman, L. E., & Chein, J. (2017). Smartphones and Cognition: A Review of Research Exploring the Links between Mobile Technology Habits and Cognitive Functioning. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00605

Wilson, S., Byrne, P., Rodgers, S., & Maden, M. (2022). A systematic review of smartphone and tablet use by older adults with and without cognitive impairment. *Innovation in Aging*, *6*(2). https://doi.org/10.1093/geroni/igac002

Wu, Y., Lewis, M., & Rigaud, A. (2019). Cognitive function and digital device use in older adults attending a memory clinic. *Gerontology and Geriatric Medicine*, *5*, 233372141984488. https://doi.org/10.1177/2333721419844886

Xavier, A. J., D'Orsi, E., De Oliveira, C., Orrell, M., Demakakos, P., Biddulph, J., & Marmot, M. (2014). English Longitudinal Study of Aging: Can Internet/E-mail use Reduce Cognitive Decline? *The Journals of Gerontology*, *69*(9), 1117–1121. https://doi.org/10.1093/gerona/glu105