Cognitive reserve and dementia
A scientometric review

Maria Helena Pestana¹, Margarida Sobral²

ABSTRACT. Research into cognitive reserve (CR) and dementia is advancing rapidly. This paper analyses the intellectual structure, emerging trends and relevant shifts in the development of available knowledge. Data collected from the Web-of-Science produced an expanded network of 564 articles and 12,504 citations in the 1998-2017 period. The co-citation network visualized was characterized by a scientometric review using CiteSpace. The results revealed that author Stern Y had the highest number of publications and citations. The network of journals, institutions and countries showed a central-peripheral structure with Neurology, Harvard University and the USA ranked first, respectively. While cognitive reserve remains the most prominent area of research in this field, studies related to functional ability, executive control, mortality data and reserve mechanisms have grown considerably. The identification of critical articles and the development of emerging trends highlights new insights in the area of research, better communicating key findings and facilitating the exploration of data.

Key words: cognitive reserve, dementia, intellectual structure, patterns, emerging trends, CiteSpace.

RESERVA COGNITIVA E DEMÊNCIA: UMA REVISÃO CIENTOMÉTRICA

Resumo. A pesquisa em reserva cognitiva e demência avança rapidamente. Este artigo analisa a estrutura intelectual, tendências emergentes e mudanças relevantes no desenvolvimento do conhecimento coletivo. Dados coletados do Web-of-Science, construíram uma rede expandida de 564 artigos e 12.504 citações, entre 1998-2017. A rede de cocitação visualizada foi caracterizada através de uma revisão cientométrica utilizando o CiteSpace. Os resultados revelam Stern Y com o maior número de publicações e citações. A rede de revistas científicas, instituições e países apresenta uma estrutura central-periférica, respetivamente com Neurologia, Universidade de Harvard e EUA em primeiro lugar. Enquanto a reserva cognitiva continua a ser a área de pesquisa mais proeminente neste campo, estudos relacionados à capacidade funcional, controle executivo, dados de mortalidade e mecanismos de reserva têm experimentado um crescimento considerável. A identificação de artigos críticos e o desenvolvimento de novas tendências emergentes destacam novos insights sobre a área de pesquisa, comunicando melhor as principais descobertas e facilitando a exploração de dados.

Palavras-chave: reserva cognitiva, demência, estrutura intelectual, padrões, tendências emergentes, CiteSpace.

Due to the progressive ageing of the population and life expectancy, increasing attention has been dedicated to the study of cognitive reserve (CR) and dementia. Dementia predominantly affects older people, and the risk of dementia rises with increasing age. Alzheimer's disease (AD) is the most common form of dementia in the elderly.¹ CR is a hypothetical model which reflects cognitive aging and describes the capacity of the adult brain to tolerate the effects of this neurodegenerative process,² while dementia is a syndrome in which there is deterioration in memory, thinking, orientation, comprehension, calculus, learning capacity, language, and judgement, thinking, behavior and the
Furthermore, no association was reported between occupational attainment and dementia in old age.11 Some studies have shown that the risk of developing AD is reduced in individuals with higher levels of education.2,3,5,7,12-16 Occupational attainment and participation in leisure activities2,5,14,17-21 are associated with a lower risk of dementia.2 Other studies found no association between education and incidence of dementia.13,2,19,20,22 Furthermore, no association was reported between occupational attainment and incident AD in several population-based longitudinal studies.1,22,23 CR interventions might be a key nonpharmacological approach to preventing this disease.24 Several studies on CR and dementia have used different methodologies, leading to disparate results.

CR and dementia research in several fields and disciplines such as clinical neuroscience, neurosciences, geriatrics, and gerontology. As research in these areas advances rapidly, it is critical to keep abreast of the rapid developments in the respective intellectual structure, emerging trends and relevant shifts in the development of available knowledge. Studies on CR and dementia have been published in a large number of journals by authors from all over the world. However, there is a need to gather systematic data on the research work being done on CR and dementia over the last twenty years. There is a need to gather systematic data on the research work being done on CR and dementia over the last twenty years. Moreover, innovative studies are required to make sense of the subfield of cognitive reserve and dementia.

BIBLIOGRAPHICAL LANDSCAPE

The global scientific outputs were generated from the Web-of-Science (WoS) database and analysed using CiteSpace (http://cluster.cis.drexel.edu/~cchen/citespace/) and VosViewer (http://www.vosviewer.com/). The dimensions used as a basis for selecting the articles on cognitive reserve and dementia were: keywords, journals and years of publication. Concerning keywords, given the focus on cognitive reserve and dementia, these two words were used to provide more scientific data on the information included in the database. Only those articles with the search terms in the title, abstract or keywords of the documents were extracted for further analysis25 from the WoS database. Regarding time horizon, the analysis spans twenty years, from 1998 to 2017. Many previous articles have adopted a similar time horizon, e.g. Ye et al.26 Finally, concerning the journals, the number of selected papers explicitly focused on cognitive reserve and dementia was taken into account. Only journals published in English were included in the sample. Using these three criteria (keywords, time horizon and journals), the total sample included 564 articles, representing 82.10% of all the documents, and 12,504 citations. Based on the assumption that the citing of an article makes it relevant to the topic, articles not cited by other studies and therefore disconnected, were eliminated. According to Obha et al.,27 findings on highly cited articles are useful to reveal the recognition of scientific advancement and give a historic perspective on scientific progress. Citation, as an association-of-ideas index, offers an approach to subject control of the literature of science.28 Some papers are not relevant for a specific research stream, they are not cited by other studies and therefore remain “disconnected”. Exclusion of disconnected articles from the overall sample, gave a final sample of 528 connected articles. These articles were distributed across 256 journals on the field of research, and 27 had no citations. The most-cited 85% with at least one citation are distributed into a network with reasonable quality (modularity 0.4295) and low density (0.0058), suggesting they are dominated by a small number of relevant journals. The top 10 journals in the WoS represent 37.25% of all CR and dementia journals and accounted for 29.94% of total publications. Neurology and Journal of Alzheimer Disease accounted for most of the research, totaling 51 documents (7.98%), followed by Journal of the International Neuropsychological Society, Dementia and Geriatric Cognitive Disorders, International Journal of Geriatric Psychiatry, International Psychogeriatrics, American Journal of Geriatric Psychiatry, Journal of the American Geriatric Society, and Neurology of Aging.

The network has 2365 keywords, where 285 had the minimum number of five occurrences, and the top ones are shown by time in Figure 1. The more recent key words are marked in red, such as diagnostic guidelines, human brain, lifelong bilingualism, life style, and prevention.

The structure of the network contains 1043 institutions and is dominated by a small number of them (very low density 0.0042). At the top, institutions with more than ten citations in our database include Harvard University, with 243 documents and 1504 citations, followed by Colombia University, with 26 documents and 4003 citations, and finally UCLA, with 23 documents and 653 citations. All these Institutions are in the USA.

The network generated 60 clusters (#). The pattern of our network is dominated by small clusters (low density 0.0058), with clear boundaries (silhouette >0.70), such that nodes within the same group are connected tighter than nodes between different groups (high modularity 0.9549). Only seven clusters have at least 10 members and are highly homogeneous (Table 1). Each cluster is labelled by noun phrases from titles of citing articles of the cluster,28 through three different algorithms: term frequency-inverse document frequency (TFidf), mutual information tests (MI), and log-likelihood ratio (LLR), where this last algorithm usually yields the best result in terms of uniqueness and coverage.29 The recentness of a cluster is indicated by the average year of publication. For example, cluster #2 has an average year of 2011 and is the most recently formed cluster, while clusters #6 and #8 have an average year of 1993, representing the oldest clusters, as well as the least representative cluster with only twelve references. The title of the top references that most cite the articles included in a cluster are marked in italics and
Cognitive reserve and dementia

Table 1. Major clusters of co-citation references.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Size</th>
<th>Silhouette</th>
<th>Label (TF-IDF)</th>
<th>Label (LLR)</th>
<th>Label (MI)</th>
<th>Avg. Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>0.642</td>
<td>underlying cognitive reserve</td>
<td>cognitive reserve</td>
<td>elderly adult</td>
<td>2004</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>0.739</td>
<td>mental status / preclinical alzheimers disease</td>
<td>functional ability</td>
<td>mrc cta</td>
<td>1999</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>0.988</td>
<td>information / history</td>
<td>executive control</td>
<td>poststroke aphasia</td>
<td>2011</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>0.777</td>
<td>sex difference / clinical severity</td>
<td>mortality data</td>
<td>mrc cta</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>0.623</td>
<td>japanese population / identification</td>
<td>reserve mechanism</td>
<td>ethnic variation</td>
<td>2002</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>0.949</td>
<td>neuropsychological assessment</td>
<td>Edinburgh cohort</td>
<td>cognitive reserve</td>
<td>1993</td>
</tr>
</tbody>
</table>

Source: authors (2019) from CiteSpace.

Figure 2 shows a timeline visualization of the network with distinct clusters, where some landmark articles are identified by first author. Cluster #2 has the highest number of references with a burst of citations in 2017, showing the relevance of executive control research to the current study of CR and dementia. Nevertheless, Stern from cluster #0 has the highest burst of citations in 2017 of all networks, showing its dominance for the current study of cognitive research.

The most cited papers have value in their revelation of advances in theory-building, and providing a historical perspective on the progress made within a discipline. They are usually regarded as landmarks because of their ground-breaking contributions. The five top-cited articles are distributed between two areas of research (#0 and #4) between 1998-2017 (Table 2). At the top, are Stern et al. and Katzman, both from cluster #0, respectively with 2570, 1776, 1242, and 1036 citations; and Fratiglioni et al. from cluster #4 with 1636 citations. Stern et al. develops a coherent theoretical background of reserve and CR, and focuses on the relevance of lifelong experiences to increasing CR, including educational and occupational attainment, and leisure activities in later life. Katzman focused on the effect of education on being diagnosed with dementia at an earlier point in time. Fratiglioni et al. focus on the importance of an active and socially integrated lifestyle in late life to protect against dementia and AD.

The most cited and betweenness centrality papers play an important role in different fields of CR and dementia research. Betweenness centrality articles indicate their importance in bridging different stages of field development. Stern Y is an author highly cited and belongs to three different clusters (#0, #1, #3), suggesting centrality in connecting these areas of research, can shed some light on the research done in that cluster. The largest cluster (#0) has 26 members, and is labelled cognitive reserve by LRR. The most active citer of #0 covering 19% of their references, is Pernecky et al., on “Cognitive reserve and its relevance for the prevention and diagnosis of dementia”. According to these authors, progressive brain damage is undoubtedly the main cause of clinical symptoms of dementia in neurodegenerative disorders such as AD. However, the association between brain damage and cognitive symptoms is not linear. Certain individual differences such as a good school education or a greater brain volume are associated with a higher resilience against brain damage, usually referred to as CR. In subjects suffering from progressive neurodegeneration, active mechanisms, mechanisms that are associated with the ability to maintain a certain level of cognitive performance in the face of progressive neurodegeneration, are thought to help compensate for brain damage. The article focuses on the positive association between CR and the active mechanisms that contribute to the adaptation of brain activity when task difficulty level is increased. Two articles account for 15% of cluster #0 references: Barttes-Faz and Are­naza-Urquijo, on “Structural and functional imaging correlates of cognitive and brain reserve hypotheses in healthy and pathological aging”, focuses on brain plasticity and on a complex correspondence between active and passive components of reserve; and Whalley et al., on “Cognitive reserve and the neurobiology of cognitive aging”, focuses on the association between CR and lifestyle style choices (early and mild), early education, lifelong dietary habit, leisure pursuits and the retention of late life mental ability.

The second largest cluster (#1) has 19 members and is labelled functional ability by LRR. The most active citer for this cluster are Roe et al., making up 26% of #1 references in “Alzheimer disease identification using amyloid imaging and reserve variables proof of concept”, focusing on the importance of the factors that influence AD pathology and dementia, to improve the predictive accuracy of amyloid imaging; and Geerlings et al., covering 21% of #1 references in “Cognitive reserve and mortality in dementia: the role of cognition, functional ability and depression”, focusing on the positive association between higher CR and mortality rates when clinical symptoms are more severe.

The third largest cluster (#2) has 18 members, is the newest cluster, with an average publication year of 2011, and is labeled by information by TF-IDF and executive control by LRR. The most active citer are Guzman-Velez and Tranel, in “Does bilingualism contribute to cognitive reserve? Cognitive and neural perspectives” and Perani and Abutaleb, in “Bilingualism, dementia, cognitive reserve and functional neuroanatomy”, both focusing on 53% of #2 references. These articles focus on the relationship between CR and bilingualism information.

The 4th largest cluster (#3) has 17 members and is labeled mortality data by LRR. The most active citer are Katzman, on “Epidemiology of Alzheimer’s disease and dementia: advances and challenges”, focusing on the age dependency of dementing disorders; and Qui et al., in “The influence of education on clinically diagnosed dementia incidence and mortality data from the lungholmen project”, focusing on aging of the population and on the positive association between level of education and AD or dementia. No effect was found between education and mortality. Both citer made up 35% of the references included in #3.

The 5th largest cluster (#4) has 16 members and is labeled reserve mechanism by LRR. The most active citer for this cluster are Borroni et al., in “Reserve mechanisms in neurodegenerative diseases: from bench to bedside and back again”, focusing on novel therapeutic targets in neurodegenerative diseases; Daffner in “Promoting successful cognitive aging: a comprehensive review”, exploring the positive association between CR and enhancing brain capacity; and Jones et al., in “Aging, brain disease, and reserve: implications for delirium”, centered on the prevention strategies for delirium and its role in aging and neuropsychiatric disease. All these citers together comprise 25% of #4 references.

Another major cluster corresponds to reversion, or metabolism syndrome (cluster #5). The most active citer are Kawanoto et al., covering 20% of #5 references in “Effects of educational background on verbal fluency task performance in older adults with Alzheimer’s disease and mild cognitive impairment”, investigating the importance of subjects’ educational background to analyze the effect of fluency task on the risk for developing AD; and Bruandet et al. accounting for 13% of #5 references in “Cognitive decline and survival in Alzheimer’s disease according to education level”, addressing the rate of cognition declines and survival in AD.

Finally, cluster #6 labelled neuropsychological assessment, or Edinburgh cohort; has an average publication year of 1993. The most active citers are Basso and Bornstein in “Estimated premorbid intelligence mediates neurobehavorial change in individuals infected with HIV across 12 months”, focusing on the hypothesis that estimated premorbid intelligence mediates decline in neuropsychological function in patients with stable HIV status, and Pereda et al., in “Factors associated with neuropsychological performance in HIV-seropositive subjects without aids”, on the effect of not being on zidovudine treatment, having lower reserve capacity and being of older age, to lower the threshold for neuropsychological abnormalities in cases of early HIV infection. All these citers cover 50% of #6 references.

The intellectual structure of CR and dementia

CiteSpace characterizes emerging trends and patterns of change in terms of visual attributes. Each node is depicted with a series of tree-rings across the time slices in which the citation burst occurs. Red indicates received. The color of the citations rings indicates the transformative potential of a scientific study, essential for the development of a knowledge domain. The thickness of the purple ring displays the degree of betweenness centrality, which measures the intellectual structure of CR and dementia research. Betweenness centrality articles play an important role in different fields of CR and dementia research. Betweenness centrality articles indicate their importance in bridging different stages of field development. Stern Y is an author highly cited and belongs to three different clusters (#0, #1, #3), suggesting centrality in connecting these areas of research,
contributing to the transformative improvement in CR and dementia research. Stern\textsuperscript{11} has the highest level of betweenness centrality (0.63). Another central article is Bialystok et al.,\textsuperscript{32} from cluster #2, connecting #2 (executive control) with #0 (cognitive reserve), currently highly cited, with a citation burst from 2013 to 2017 (Table 3). This article addressed the effect of lifelong bilingualism on dementia, which maintains cognitive functioning and delays the onset of symptoms of dementia in old age by about 4 years. Stern\textsuperscript{11} and Bialystok et al.,\textsuperscript{32} are also articles that have contributed to a structural change in the network, in 2002 and 2007, respectively (Figure 3).

Most active clusters and references

A citation burst can be used to detect the most active articles and areas of research. A citation burst provides evidence that a publication is associated with a surge in citations, attracting an extraordinary degree of attention from the scientific community.\textsuperscript{11} All clusters from #0 to #4 have bursts of citations, meaning they are representative of the diversity of interests in the field of research. Citation bursts provide a useful means of tracking the development of research areas. Cognitive reserve (#0) has the articles with strongest citation bursts, meaning that mainly after 2002, at the beginning of the burst, the major efforts of the research field concentrated in this area of research. Other research interests, mainly after 1999, involve functional ability (#1) and mortality data (#3) then, after 2003, on reserve mechanisms (#4); and after 2013 in executive control (#2). Table 3 shows the most active areas of research and articles, displayed by burst strength per cluster.

Emerging trends in the network of CR and dementia

The intellectual structure of the knowledge of co-cited references can be measured by modularity.\textsuperscript{11} Newly published articles may have little or no impact on the structure of the network, or may create a profound structural change, when deep changes occur in the modularity. Figure 3 shows the change in modularity during the 1998–2017 period. It is notable that modularity dipped mainly in 1999, 2002, 2007, and 2011. Therefore, we investigated potential emerging trends looking at publications with bursts of citations in these years, because we expected them to play an important role in changing the overall intellectual structure of CR and dementia. The top publications are marked with shading in Table 3, and include:

In 1999, Stern\textsuperscript{11} focuses on the effect of level of education and occupational attainment on memory in AD patients.

In 2002, Wilson et al.\textsuperscript{13} focuses on the effect of frequency of participation in cognitively stimulating activities on the risk of AD.

In 2007, the three relevant articles are: Fratiglioni & Wang\textsuperscript{14} focuses on the effects of education, adult-life occupational work complexity, mentally and social integrated lifestyle in late life, as factors to affect the onset of clinical dementia and AD; Bialystok et al.\textsuperscript{32} focuses on the effect of lifelong bilingualism on dementia in old age; and Valenzuela & Sachdev\textsuperscript{33} centers on LEQ as a tool for estimating brain reserve in older individuals.

In 2011, the three relevant articles are: Tucker & Stern\textsuperscript{1} focuses on the effect of executive functions task on CR; on the association between CR and neural efficiency, capacity, and ability; and on the fact that CR is not fixed but continues to evolve during the lifespan; Gollan et al.\textsuperscript{12} focuses on the effects of bilingualism on...
Cognitive reserve and dementia
Pestana and Sobral
Cognitive reserve and dementia

CR and suggested an upper limit on the extent to which reserve can delay dementia; and Jones et al. 16,17 focuses on approaches for quantifying reserve using latent variable models, with an emphasis on their application in the field of cognitive rehabilitation.

CONCLUSION

This bibliometric study carried out during the 1998-2017 period has allowed a number of conclusions to be drawn in line with the objective established in the introductory section of this paper. The exploration of the literature on CR and dementia from WoS databases has outlined the evolutionary trajectory of the collective knowledge over the past twenty years and highlighted the areas of active pursuit and future research. Based on the network visualization and document co-citation analysis using CiteSpace and VosViewer, this study evaluated emerging trends and patterns of publications, citations, journals, institutions, and areas of research in the literature. The top clusters covered a range of themes, reflecting the interdisciplinary nature of CR and dementia. They are foundational to the field of research.

To the best of our knowledge, this study represents the first attempt to apply CiteSpace and visualize CR and dementia knowledge. It is one of only a few investigations that have focused on co-citations as a marker of development of this domain from different perspectives. The findings of the present investigation demonstrate the potential of bibliometric visualization techniques for studying the scientific literature.

First, by visualizing the relational analysis of top authors and articles, the study provides insights into the evolution of this field and visualizes CR and dementia knowledge. It is one of only a few investigations that have focused on co-citations as a marker of development of this domain from different perspectives. The findings of the present investigation demonstrate the potential of bibliometric visualization techniques for studying the scientific literature.

Secondly, despite the relevance of the WoS database as the main bibliographic tool in this kind of study, relevant conferences or books published in other databases could have been included within other databases. Nevertheless, it is evident that bibliometric analysis has helped to characterize, both qualitatively and quantitatively, the CR and dementia research field in terms of its development, trends of investigation and collaboration networks. As a result, researchers have been equipped with new tools of exploration.

The results help further understanding on the intellectual structure of this field through an innovative methodological approach, using co-citation analyses to understand the development of CR and dementia from different perspectives. The study findings demonstrate the potential of bibliometric visualization techniques to investigate the scientific literature.

Authors contributions

All authors contributed significantly to, and approved, the content of this manuscript.