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Review article

Can neurodevelopmental disorders influence the course of neurodegenerative diseases? A scoping review

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ABSTRACT

This scoping review aims at giving an overview of the possible influence of neurodevelopmental disorders (NDDs) on cognitive-behavioral neurodegenerative diseases (CBNDs). Based on the PRISMA-ScR checklist, it details the methods of NDDs screening, the identified NDDs-CBNDs associations, as well as the criteria and types of association. The last literature search was performed in June 2023. In the final study, 32 articles were included. Analysis first showed that NDDs were mainly detected through medical records screening. Second, the association of specific learning disorders and major or mild neurocognitive disorder due to Alzheimer's disease was the most investigated. Third, associations were mostly based on prevalence comparisons. Finally, 66 % of studies reported a positive association between NDDs and CBNDs. Notably, up to 67 % of positive associations were observed with atypical forms of certain CBNDs. Authors' interpretations suggest that NDDs could constitute a risk factor for CBNDs. However, the influence of NDDs on CBNDs still lacks evidence and biological support, possibly due to the heterogeneity of methods and criteria employed. Developing validated assessment tools for all NDDs and conducting cohort studies could be beneficial for research, and clinical practice. Indeed, this review also underlines the importance of adopting a life-span approach regarding CBNDs.

1. Introduction

Neurocognitive disorders, as defined in the DSM-5 (American Psychiatric Association, 2013), are characterized by an acquired cognitive impairment. Their diagnosis thus depends on the comparison between current and previous levels of functioning (American Psychiatric Association, 2013; Gale et al., 2018). However, both can be affected by neurodevelopmental disorders (NDDs), as they influence dynamics of lifelong neurocognitive trajectories. Indeed, while cognitive and behavioral symptoms of atypical brain development reveal themselves in childhood, they frequently persist into adulthood (Faraone et al., 2015; Geurts and Jansen, 2012; Nergård-Nilssen and Hulme, 2014; Whitehouse et al., 2009). Therefore, without thorough retrospective

clinical screening, atypical features caused by NDDs may sometimes be mistaken for symptoms of cognitive and behavioral neurodegenerative diseases (CBNDs) (Callahan, 2017; Colvin and Sherman, 2020).

Recent literature reflects the growing interest in the link between NDDs and CBNDs (Ouellette and Lacoste, 2021; Paternicó et al., 2015). Delving beyond the possible concomitance and resemblance of symptoms, a collection of publications even suggests that NDDs could influence the emergence, and sometimes the course of CBNDs. Accordingly, several reviews focusing on the potential association between certain CBNDs and specific NDDs were released (Becker et al., 2023; Callahan, 2017). For instance, they aimed at evaluating the risk of neurodegenerative disease or dementia in adults with attention-deficit/hyperactivity disorder (Becker et al., 2023) (ADHD), or at outlining hypothetical

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ways in which ADHD and mild cognitive impairment (MCI) might relate to each other (Callahan, 2017). Moreover, points of view were also given on possible interactions between these two groups of syndromes (Magnin, 2021). Nevertheless, the range of syndromes studied and the type of methodology used to identify syndromes and their associations make it arduous to obtain a comprehensive understanding of the issue.

The present scoping review aims at giving an up-to-date overview of the question. Its focus is not only on the pairs of NDDs and CBNDs that have been studied, but also on the methods employed to do so. Additionally, it sums up interpretations found in the literature regarding the interactions between NDDs and CBNDs. More precisely, the five questions addressed in this scoping review are: (1) What methods are used to detect a history of neurodevelopmental disorder? (2) What pairs of neurodevelopmental disorders and neurodegenerative diseases have been studied in the literature? (3) What are the criteria used by the authors to determine whether associations between neurodevelopmental disorders and neurodegenerative diseases exist? (4) What type of associations are these? (5) How are they interpreted by the authors? This study should provide insights for future research and clinical practice, by helping identifying questions for future experimentation and by suggesting ways of addressing them.

2. Methods

This scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco et al., 2018).

2.1. Data sources

A systematic search of publications listed in the PubMed, Embase and Web of Science databases was conducted on December 20, 2022 using 3 equations specifically tailored to each database. Appendix A contains the full search strategies from each database. Example search terms included «neurodevelopmental disorder» and «neurodegenerative disease». There was no date restriction. We applied «English language» and «human» filters. The search was updated on June 26, 2023. Additional relevant publications were identified by scrutinizing references of the studies found through the database searches.

2.2. Study selection

Articles were selected if they were peer-reviewed primary studies that addressed the following question: What is the influence of neurodevelopmental disorders on cognitive and behavioral neurodegenerative diseases? We adopted the NDD definition provided by the DSM-5 (American Psychiatric Association, 2013), which includes attention deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), Intellectual Developmental Disorder (IDD) (except genetic syndromes such as Rett syndrome, Fragile X syndrome, Down syndrome), communication disorders, specific learning disorders, and motor disorders. Regarding neurodegenerative diseases, we focused on those characterized by a primary impairment in cognition and/or behavior that are not attributable to an acquired brain injury/event. This is why we excluded predominantly motor neurodegenerative diseases such as Parkinson's disease as well as cerebrovascular disorders and chronic traumatic encephalopathy, respectively.² Furthermore, in addition to editorials, reviews and position papers, interventional research, methodology papers and validation studies were excluded. Similarly, studies focusing on non-human animals, cells, organoids and *in silico* models

² Movement disorders, cerebrovascular disorders and chronic traumatic encephalopathy were excluded to limit the heterogeneity in classification of neurocognitive disorders, definition of types of association and methods of investigation, in order to facilitate interpretation of the findings.

were also excluded.

All citations outside the scope of this review were initially excluded by one author (PS) on the basis of their title. Following this, two authors (PS and JP) examined the abstracts of the remaining citations. If these met the eligibility criteria, they underwent a full-text review by PS and JP. Decisions involving two reviewers were blinded. In case of disagreement, consensus was reached through discussion.

2.3. Data extraction

In accordance with the PRISMA Extension for Scoping Reviews guidelines (Tricco et al., 2018), we used a flowchart to outline the study selection process (Fig. 1). Where reported, the following data were extracted from each article: title, authors, year of publication, article type, group size, method for determining NDD history, investigated NDD and CBND pairs, association criteria, type of association and author interpretation (Table 1).

2.4. Data analysis

To address the five research questions, variables of interest collected in each reviewed study were categorized as follows.

2.4.1. Methods of investigation of the history of NDDs

The methods used to identify NDDs history were classified into 7 categories, and all methods used were listed. Articles that reviewed subjects' medical records, or recruited participants from specialized databases were classified as «Medical Record Screening». The term «Anamnesis» was chosen to describe questions such as «Do you have a history of a learning disability?» and, more generally, the clinical interview during which subjects could report a history of NDDs. The label «Questionnaires» encompassed both personal surveys and self-administered questionnaires that were completed by the patient or the caregiver alone. A «cognitive assessment», in this context, referred to evaluating a cognitive domain to identify potential neurodevelopmental deficits. «Genetic proxies» are genome-wide significant variants the presence of which is associated with NDDs, regardless of familial history. Studies using adapted «Diagnosis criteria» aimed to identify NDDs in adult patients following clinical criteria. Lastly, «Informant» referred to a method that involved gathering the perspective of study partners or caregivers on the subject's history of NDDs through a questionnaire or interview, in addition to the subject's own responses.

2.4.2. Pairs of NDDs & CBNDs

A «pair» refers to a set comprising a category of NDDs and a category of CBNDs that has been studied in the literature. The DSM-5 (American Psychiatric Association, 2013) provides the categories under which the various terms used to describe NDDs and CBNDs in the reviewed studies were classified.

The classification of NDDs is detailed in Table 2. It should be noted that the terms «learning disorders» (according to the ICD10) (Weltgesundheitsorganisation, 2009) and «mental retardation» were grouped under the heading «Intellectual Disability»/«Intellectual Developmental Disorder». So were «dyslexia» and «reading disorder», corresponding to the subcategory «Specific Learning Disorders with impairment in reading» (315.00), but also «language learning disability» fitting the «Specific Learning Disorders with impairment in reading» (315.00) or the «Specific Learning Disorders with impairment in written expression» (315.2) categories. Additionally, «speech disorder» is an exact subcategory (315.39) of «Communication disorders» of the DSM-5 (American Psychiatric Association, 2013). Likewise, «Attention Deficit Hyperactivity Disorder» and «Autism Spectrum Disorder» are listed as such (codes 314.01 and 299.00 respectively).

Regarding the classification of CBNDs, details can be found in Table 3. Again, it should be noted that the term «cognitive disorders» (including delirium, dementia, amnesia, other cognitive disorders)

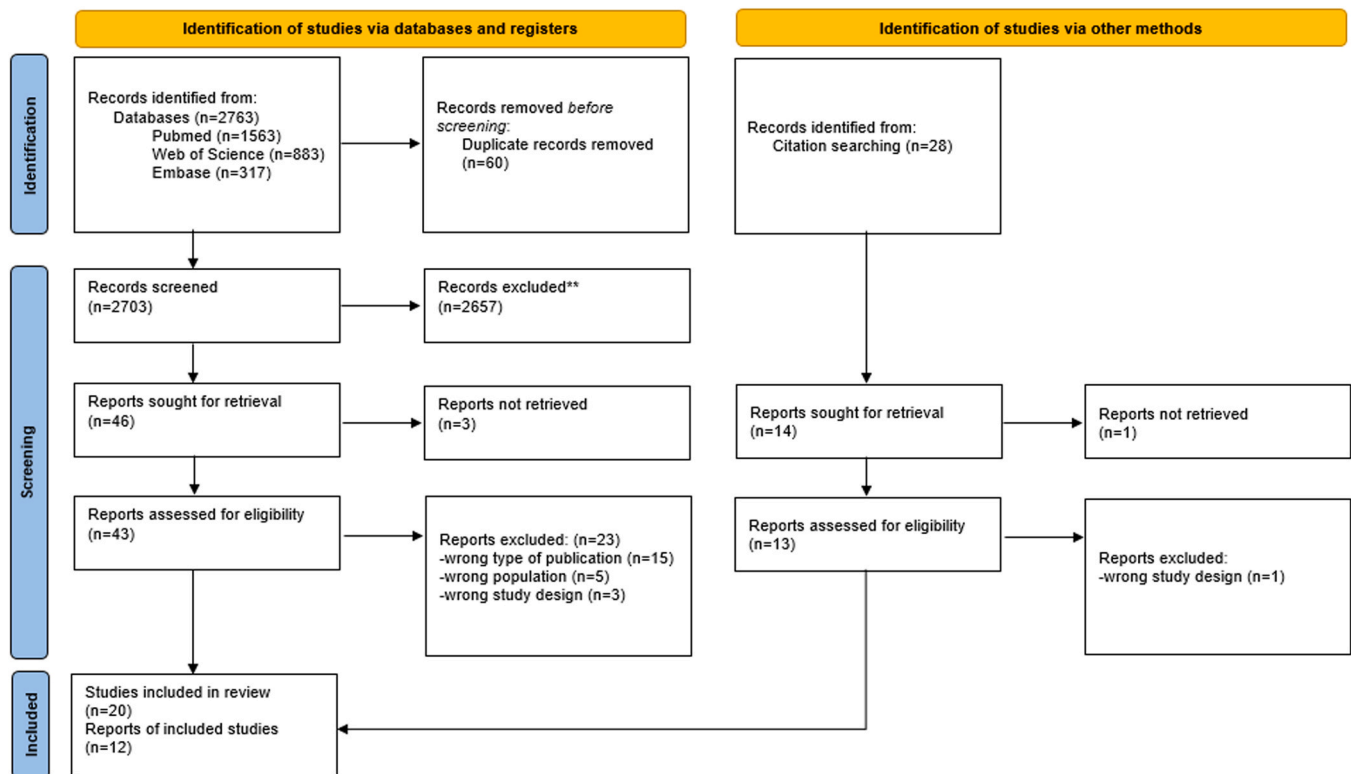


Fig. 1. Flow diagram for the scoping review process with Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews guidelines.

found in one study based on the ICD10 (Weltgesundheitsorganisation, 2009) corresponds to the broad category «Neurocognitive Disorders» (591) of the DSM-5 (American Psychiatric Association, 2013). The articles reporting «dementia (including Alzheimer's disease (AD), vascular dementia (VaD), and other dementias)», «dementia including AD», «AD and other dementias», «early-onset AD and other dementias», «pre-senile dementia», «Mild cognitive impairment» (MCI) and «cognitive decline» were classified as treating «Major and Mild Neurocognitive Disorders» (602). The labels «Alzheimer-type neuropathology», «AD», «logopenic variant Primary Progressive Aphasia» (lvPPA), «Posterior cortical atrophy» (PCA) and «dysexecutive AD» were part of «Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease» (611). «Frontotemporal dementia» (FTD), «semantic variant Primary Progressive Aphasia» (svPPA) and «non fluent variant Primary Progressive Aphasia» (nfvPPA) described «Major or Mild Frontotemporal Neurocognitive Disorder» (614). Finally, «Lewy Body Disease» (LBD) referred to «Major or Mild Neurocognitive Disorder with Lewy Bodies» (618). We tallied the frequency with which each pair was investigated, considering that several may have been examined in the same article. If a NDD was studied in relation to two CBNDs, then we counted the former as studied twice, in two separate pairs. The same rule was applied to a CBND that would be associated with two NDDs. Moreover, atypical CBNDs were identified, grouping together the following syndromes: primary progressive aphasia (PPA), posterior cortical atrophy (PCA), behavioral Alzheimer's disease (AD) and early-onset CBNDs. Pairs of NDDs and atypical CBNDs were explicitly analyzed.

2.4.3. Criterion of association

The criterion of association is the result upon which the conclusion of the association between a NDD and a CBND is based. Seven criteria have been identified. Firstly, the outcome may be the severity of «cognitive impairment» assessed by neuropsychological testing in patients with a history of NDDs compared with patients without a history of NDDs. A second criterion is «concurrent cerebral modifications», which refers to the

presence of features typical of NDDs in cerebral regions affected by neurodegeneration. A third is the estimate derived from «Mendelian randomization», which uses genetic variation to address causal questions about how modifiable exposures such as NDDs influence different outcomes, in this case, the development of a CBND. Another is the «prevalence» of NDDs in individuals with a CBND compared to the prevalence of NDDs in a control group, or the prevalence of CBNDs in individuals with NDDs compared to that in a sample of individuals without NDD. Finally, the association criterion can be a «hazard ratio» (HR), comparing two risks: the likelihood of developing a CBND in an individual with a NDD versus the likelihood of developing it in an individual without. The same principle applies to the «Odds Ratio» (OR) and the «Incidence Rate Ratio» (IRR). In these cases, instead of comparing risks, odds and incidence rates are compared, respectively.

2.4.4. Type of association

For each pair, we recorded the number of times the association between a NDD and a CBND was classified as «positive», «negative», or «undetected». The association was considered «positive» if the NDD appeared to favor the presence of the CBND or the modification of its clinical expression. Conversely, the connection was classified as «negative» if the opposite was observed. We labeled a lack of association as «undetected», indicating that the NDD did not appear to affect the CBND. The type of association was based on the criterion of association. When no statistical analysis was available, it was based on the conclusion provided by the article.

2.4.5. Authors' interpretation

The final issue examined in this review pertains to how the authors of the articles in question interpreted the associations between NDDs and CBNDs. To address this, we closely examined their discussions. It must be noted that we collected all interpretations and hypotheses, not only the ones focusing on the pairs specifically investigated in each article. Using thematic analysis techniques (Vaismoradi et al., 2016) in an

Table 1
Summary of reviewed studies.

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|------------------------------------|-----------------|---|---|--|--|--|---|---|--|---|
| 1 Reid and Aungie, (1974) | Cross-sectional | 155 "mentally defective" Age \geq 44 | Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Prevalence | Prevalence of dementia: age \geq 45: 11/155 age \geq 65: 3/22 Prevalences superior to the ones reported in samples of age \geq 65. | Intellectual Developmental Disorder / Major and Mild Neurocognitive Disorders | NI | No |
| 2 Tait, (1983) | Cross-sectional | 81 "mental defectives" Age \geq 65 | Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Prevalence | Prevalence of senile dementia: between 10 % and 17 %. Prevalence comparable to the normal and to the "handicapped" population. | None | NI | No |
| 3 Barcikowska et al., (1989) | Cross-sectional | 70 "mentally retarded people" Age \geq 65 | Intellectual Developmental Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Non described | Prevalence | 22/70 (31,4 %) brains had neuropathology consistent with a diagnosis of AD. Prevalence consistent with the "non-retarded population". | None | NI | No |
| 4 Popovitch et al., (1990) | Cross-sectional | 385 brains of "mentally retarded adults " Age at time of death: 23–44 years (n=51) 45–64 years (n=172) 65–90 years (n=162) | Intellectual Developmental Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Medical record screening | Prevalence | Frequency of individuals with neurofibrillary tangles and/or neuritic plaques: 33 % in the age group <45, 56.8 % in the middle age group, and 78 % in the age group >65. These values are within the range of those reported in non-retarded, non-demented individuals at comparable ages. Positive diagnoses of AD (histological definition): 9.5 % of cases <50 yo, 54.2 % of cases 50–65 yo, 76 % of cases 66–75 yo, and 87 % of cases >75 yo. No given comparison. | Intellectual Developmental Disorder / Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | NI | No |
| 5 Silverman et al., (1993) | Cross-sectional | 303 "mentally retarded adults" (same sample in Popovitch et al., 1990) | Intellectual Developmental Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Medical record screening | Prevalence | AD diagnosed in 9.5 % of cases <50 yo, 54.2 % in those 50–65 yo, 76 % in those 66–75 yo, 87 % in the >75 yo. These values are within the range of those reported in a number of | None | NI | No |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|------------------------------|------------------|--|-------------------------------------|--|---|----------------------------------|---|---|--|---|
| 6 Sansom et al., (1994) | Cross-sectional | 124 individuals w/ a "learning disorder": 32 mild 56 moderate 36 severe LD NB: 4 had Down's syndrome Age range: 60–94 | Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening & Diagnosis criteria | Prevalence | studies of non-retarded, non-demented individuals at comparable ages. Sixteen (12.9%) subjects showed evidence of a dementing condition (including one with Down's syndrome). Prevalence comparable with that in the general population over the age of 65. | None | NI | No |
| 7 Cooper, (1997) | Cross-sectional | 134 people with "learning disorder" Age range: 65–94 (73,2; 6,48 years) | Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Prevalence | Dementia in 21±6% (CI99,9% [9,9%; 33,4%]) Higher than the general population rate. | Intellectual Developmental Disorder / Major and Mild Neurocognitive Disorders | NI | No |
| 8 Zigman et al., (2004) | Cross-sequential | 117 adults with "mental retardation without Down syndrome" Comparison sample from the National Health Interview Survey 1996 Age: ≥65 | Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Prevalence | For adults 65 and 75 years of age and older, respectively: Possible/definite dementia: .042 (95% CI [.012,.104]) and .056 (95% CI [.012,.154]) Possible/definite dementia or "uncertain with complications": .090 (95% CI [.042,.164]) and .121 (95% CI [.050,.233]). Prevalence rates of AD based upon physician diagnosis: .027 (95% CI [.006,.076]) and .041 (95% CI [.008,.114]). Rates comparable to consensus prevalence estimates for AD for the general population without mental retardation. | None | NI | No |
| 9 Rogalski et al., (2008) | Case-control | 353 controls Age at first visit: 69.4 (8.2) 154 w/ typical amnesic AD Age at onset: 71.2 (9.5) 84 w/ bvFTD Age at onset: 60.3 (9.2) | Specific Learning Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal | Anamnesis & Medical record screening | Prevalence | Pearson chi2 for individual history, 33.15; p<.001; Pearson chi2 for first-degree family members, 41.57; p<.001 | Specific Learning Disorder / Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal | Yes | No |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|-------------------------------------|-----------------|---|--|--|--|----------------------------------|---|---|--|---|
| 10 Metzler-Baddeley et al., 2008 | Cross-sectional | 108 w/ PPA Age at onset: 62.9 (8.3) 195 older adults Age: 77 (8) | Specific Learning Disorder with impairment in reading | Neurocognitive Disorder Major and Mild Neurocognitive Disorders | Questionnaire | Prevalence | 10% of patient sample received a positive score suggestive of dyslexia, consistent with estimates of prevalence in the general population. | Neurocognitive Disorder None | NI | No |
| 11 Golimstok et al., (2010) | Case-control | 109 patients with early mild to moderate probable Dementia Lewy Body Age: 75.1 (7.4) 251 patients with early probable AD Type Age: 74.2 (7.1) 149 controls Age: 74.1 (8) | Attention Deficit Hyperactivity Disorder | Major or Mild Neurocognitive Disorder With Lewy Bodies | Questionnaire & Diagnosis criteria & Informant | Odds ratio | Prevalence of ADHD symptoms in DLB cases was significantly higher when compared with the control group ($p < 0.001$, OR 5.1, 95%CI 2.7–9.6) and also when compared with AD Type ($p < 0.001$, OR 4.9, 95%CI 2.8–8.4) | Attention Deficit Hyperactivity Disorder / Major or Mild Neurocognitive Disorder With Lewy Bodies | NI | No |
| 12 Ivanchak et al., (2011) | Cross-sectional | 310 elderly participants: 297 ADHD negative Age: 77.9 (7.5) 13 ADHD positive Age: 74.3 (7.4) | Attention Deficit Hyperactivity Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Questionnaire & Informant | Prevalence | Cognitive status (Normal: Cognitively impaired) ($p=0.90$) ADHD positive: 10:3 ADHD negative: 233:64 | None | NI | No |
| 13 Miller et al., (2013) | Case-control | 48 individuals w/ lvPPA Age: 64 (9) 51 individuals w/ nvfPPA Age: 68 (7) 90 individuals w/ svPPA Age: 63 (7) | Specific Learning Disorder with impairment in reading and/or with impairment in written expression | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder | Medical record screening | Prevalence | Among the PPA subtypes, history of learning disability was significantly greater in the logopenic variant ($n=12/48$, 25%; 10/12 were dyslexic) relative to semantic variant PPA [$n=3/90$ 3%; $P < 0.001$] and non-fluent variant PPA cohort [$n=1/51$ 2%; $P \leq 0.001$] | Specific Learning Disorder with impairment in reading and/or with impairment in written expression / Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Yes | Yes |
| 14 Kats et al., (2013) | Cross-sectional | Sample from 2009 to 2010: 438 w/ ASD & IDD (27% mild, 37% moderate, 36% severe IDD) Age: 42 (8) 4551 w/ IDD only (47% mild, 33% moderate, 19% severe) Age: 45 (8) Sample from 2010 to 2011: 298 w/ ASD and IDD (31% mild, 34% moderate, 36% severe IDD) | Autism Spectrum Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Prevalence | ASD group versus IDD-only group: 2009–2010 prevalence ratio (PR)=1.01, IC95 (1.00, 1.03) 2010–2011: PR=0.99 95%CI(0.99, 1.00) | None | NI | No |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|-------------------------------|-----------------|---|---|--|--|----------------------------------|--|---|--|---|
| 15 Rogalski et al., (2014) | Cross-sectional | Age: 41 (8) 3963 w/ IDD-only (47 % mild, 35 % moderate or 18 % severe IDD) Age: 44 (8) 58 patients w/ PPA: 29 w/ personal or family history of LD Age: 60.4 (8.3) 29 w/o personal or family history of LD: Age: 62.0 (8.2) NB: 20 patients are also part of the sample in Rogalski et al., (2008). | Specific Learning Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder | Anamnesis & Informant & Medical record screening | Prevalence | 50 % of the cases (29 of 58 patients with PPA) had either a personal or family history of LD. | Specific Learning Disorder / Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder | Yes | No |
| 16 Seifan et al., (2015) | Case-control | 68 individuals w/ Typical AD Age: 70.1 (6.7) 17 individuals w/ Atypical AD (11 lvPPA, 3 PCA, 3 Dysexecutive AD) Age: 67.1 (8.0) | Specific Learning Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Questionnaire | Odds ratio | Patients with Probable LD vs patients with Possible or Absent LD, were significantly more likely to be diagnosed with Atypical Dementia vs. Typical AD (OR 13.1, 95 %CI [1.3; 128.4]) | Specific Learning Disorder / Atypical Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Yes | No |
| 17 Croen et al., (2015) | Case-control | 1507 w/ ASD [(37.2 % autistic disorder, 29.7 % Asperger's syndrome, 30.7 % PDD-NOS, 2.3 % undetermined; 19.2 % also had a diagnosis of IDD (12.8 % mild, 3.1 % moderate, 6.2 % severe, 77.9 % level not specified)] 15,070 Controls Age of the study population: 29 (12) (52 % between 18 and 24 y, 9.5 % ≥ 50 y) | Autism Spectrum Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Odds ratio | Dementia OR (99 %CI): 4.40 [2.50; 7.71] | Autism Spectrum Disorder / Major and Mild Neurocognitive Disorders | NI | No |
| 18 Lebowitz et al., (2016) | Case-control | 163 individuals w/ Suspected Reading Disorder Age: 62 (9) 1641 Normal readers Age: 62 (9) | Specific Learning Disorder with impairment in reading | Major and Mild Neurocognitive Disorders | Cognitive evaluation | Odds ratio | Individuals who met criteria for Suspected Reading Disorder were significantly more likely to meet the psychometric definition of MCI on Paired Associates delayed recall (OR = 3.36, [2.13; 5.31] p < 0.001) and Visual Reproduction delayed recall (OR = 1.93, [1.14; 3.28] p < 0.05). | Specific Learning Disorder with impairment in reading / Major and Mild Neurocognitive Disorders | NI | No |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|-----------------------------------|----------------------|---|--|--|---|-----------------------------------|---|---|--|---|
| 19 Fluegge and Fluegge, (2017) | Retrospective cohort | 162 individuals w/ AD 162 individuals w/ LBD Age: Non described | Attention Deficit Hyperactivity Disorder | Major or Mild Neurocognitive Disorder With Lewy Bodies Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Medical record screening | Incidence rate ratio | Severe ADHD phenotype increases hospitalization risk for an all-listed Lewy Body Dementia diagnosis (IRR: 1.21, 95 %CI [1.08; 1.35]) and Alzheimer's disease (AD) discharge diagnosis (IRR: 1.15, 95 %CI [1.05; 1.27]) | Attention Deficit Hyperactivity Disorder / Major or Mild Neurocognitive Disorder With Lewy Bodies Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | NI | No |
| 20 Tzeng et al., (2017) | Retrospective cohort | 675 participants with ADHD 2025 matched control group without ADHD Total of 2700 enrolled patients Age: 78,07 % aged 18–54; 21,93 % aged ≥ 55 | Attention Deficit Hyperactivity Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Hazard ratio | Incidence of dementia was higher in the ADHD groups than in the non ADHD control cohort (5.48 % vs. 4.0 %). Adjusted HR: 4.008 (95 % CI = [2.526; 6.361], p<.001). | Attention Deficit Hyperactivity Disorder / Major and Mild Neurocognitive Disorders | NI | Yes |
| 21 Miller et al., (2018) | Case-control | 95 individuals w/ PCA Age at first visit: 61.9 (7.0) 84 individuals w/ lvPPA (including 48 previously described in Miller et al., 2013) Age at first visit: 65.1 (8.7) 100 individuals w/ amnesic AD Age at first visit: 64.0 (12.6) | Specific Learning Disorder with impairment in reading, in written expression, in mathematics | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Medical record screening | Prevalence | For all Specific LDs: Compared with a 10.0 % estimated general population rate of LDs, individuals with PCA and lvPPA had a significantly elevated prevalence of LDs (p=.007 and p<.001, respectively). Non-language LD: The PCA cohort had an elevated prevalence of mathematical LDs compared with the general population (13 observed vs 6 expected, p=.003). | Specific Learning Disorder (all) / atypical Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Specific Learning Disorder with impairment in mathematics / atypical Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Yes | No |
| 22 Miller et al., (2019) | Case series | 3 patients w/ lvPPA and dyslexia Age: Case 1: 47 Case 2: 54 Case 3: 53 | Specific Learning Disorder with impairment in reading | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Anamnesis | Concurrent cerebral modifications | Cerebrocortical microdysgenesis, reminiscent of focal cortical dysplasia was observed in all patients. The same perisylvian regions showed the highest extent of AD-dependent neurodegeneration. | Specific Learning Disorder with impairment in reading / atypical Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Yes | No |
| 23 Rhodus et al., (2020) | Cross-sectional | 142 older persons with cognitive impairment All participants: 79.84 (8.39) ASD Unlikely: 80.41 (8.00) | Autism Spectrum Disorder | Major and Mild Neurocognitive Disorders Major or Mild Neurocognitive Disorder Due to | Questionnaire | Cognitive impairment | Participants with high autism index ratings (Autism 'Possible/Very Likely', n=23) reported significantly younger age at onset of cognitive | Autism Spectrum Disorder / Major and Mild Neurocognitive Disorders Major or Mild | NI | Yes |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|-------------------------------------|----------------------|--|--|---|---|----------------------------------|--|--|--|---|
| | | ASD Possible/Likely: 76.96 (9.87) | | Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder Major or Mild Neurocognitive Disorder With Lewy Bodies | | | impairment than those who scored in the Autism 'Unlikely' range (n=119): 71.14±10.9 vs. 76.65 ±8.25 (p=0.034) | Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder Major or Mild Neurocognitive Disorder With Lewy Bodies | | |
| 24 Hand et al., (2020) | Case-control | 4685 autistic older adults Matched population comparison (N=46,850) Age: ≥65 | Autism Spectrum Disorder | Neurocognitive Disorders | Medical record screening | Odds ratio | OR: 8.4 95 %CI [7.7; 9.1] | Autism Spectrum Disorder /Neurocognitive Disorders | NI | No |
| 25 Zhang et al., (2021) | Retrospective cohort | 4246,182 index person-parent pairs, 7548,861 index person-grandparent pairs, 1838,520 index person-uncle/aunt pairs Median ages (Inter Quartile Ranges): Index persons: 23 (18–28) Parents: 53 (47–59) Grand-parents: 82 (72–91) Uncles/aunts: 53 (47–60) | Attention Deficit Hyperactivity Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Hazard ratio | Parents of index persons with ADHD had an increased risk of AD compared to the parents of index persons without ADHD (HR 1.55, 95 %CI [1.26; 1.89]. The association with AD in grandparents attenuated (1.11, 1.08;1.13), and the association in uncles/aunts was similar to grandparents but not statistically significant (1.15, 0.85;1.56). A similar pattern was observed for any dementia with an increased risk in parents (1.34, 1.11;1.63) and grandparents (1.10, 1.08;1.12), and a nonsignificant association in uncles/aunts (1.04, 0.79;1.39). | Attention Deficit Hyperactivity Disorder /early onset Major and Mild Neurocognitive Disorders | NI | Yes |
| 26 Dobrosavljevic et al., (2021) | Retrospective cohort | Total cohort (N=3591,689 individuals) 3582,157 individuals w/o ADHD Median age at end at follow up (Inter Quartile Range): 63 (56–70) 9532 individuals w/ ADHD 63 (56–70) | Attention Deficit Hyperactivity Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Hazard ratio | Hazard ratio was 2.92 (95 %CI [2.40; 3.57]) for dementia, and 6.21 ([5.25; 7.35]) for MCI. | Attention Deficit Hyperactivity Disorder / Major and Mild Neurocognitive Disorders | NI | No |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|-------------------------------|-------------------------|---|--|--|---|----------------------------------|---|--|--|---|
| 27 Vivanti et al., (2021) | Retrospective cohort | ASD only (n=12,648) IDD w/o ASD (n=406,570) ASD w/ IDD (n=26,168) Neither ASD nor IDD diagnoses (n=798,828) Age at enrollment of total sample: 30–64 | Autism Spectrum Disorder & Intellectual Developmental Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Hazard ratio | Dementia was found to occur more frequently in individuals with ASD only (adjusted HR, 1.96; 95 % CI [1.69; 2.28]), as well as individuals with ASD and co-occurring IDD (2.89; [2.62; 3.17]) and IDD only (3.01; [2.87; 3.15]). | Autism Spectrum Disorder and Intellectual Developmental Disorder / early onset Major and Mild Neurocognitive Disorders | Yes | No |
| 28 Pagoni et al., (2022) | Mendelian randomization | ADHD: 20,183 cases; 35,191 controls ASD: 18,381 cases; 27,969 controls AD: 24,087 cases; 55,058 controls | Autism Spectrum Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease | Genetic proxies | Mendelian Randomization | Weak evidence of a causal effect of genetic liability: to ADHD on AD (OR=1.00, 95 %CI [0.98; 1.02], p=0.39) to AD on ADHD (OR=1.12, 95 %CI [0.86; 1.44], p=0.37) to ASD on AD (OR =0.99, 95 %CI [0.97; 1.01], p=0.70) to AD on ASD (OR=1.19, 95 %CI [0.94; 1.51], p=0.14). | None | NI | No |
| 29 dos Reis et al., (2022) | Cross-sectional | 16 controls w/ AD Age: 79.9 (9.0) 20 individuals w/ PPA (age: 68.1 (7.7)): 8 svPPA, Age: 65.0 (8.5) 7 nfvPPA Age: 72.4 (5.9) 3 lvPPA Age: 67.0 (9.6) 2 non-classifiable Age: 67.0 (2.8) | Specific Learning Disorder | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder | Questionnaire & Informant | Prevalence | Regarding the comparison between patients with PPA and AD, and their children, no significant differences were observed regarding the occurrence of: a report of learning difficulties in childhood; take it longer than children the same age to learn to read and write; history of diagnosis of any learning disability; need for tutoring or addition classes due to learning difficulties; school dropout; repetition of any school grade. | None | No | No |
| 30 Klein et al., (2023) | Case-control | 210 autistic middle and older age adults 14,453 population based non autistic participants Age of total sample: 55.63 (9.44), range 42–81 | Autism Spectrum Disorder | Major and Mild Neurocognitive Disorders | Medical record screening | Cognitive impairment | Higher autistic trait ratings were found for autistic adults screening positive compared to those screening negative using a cutoff of ≥ 1 (p=0.05, d=-0.23), and a higher-threshold cutoff | Autism Spectrum Disorder / Major and Mild Neurocognitive Disorders | NI | Yes |

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Table 1 (continued)

| Reference | Study design | Participants Age (in years) | Studied NDD | Studied CBND | Method of Investigation of the history of NDD | Type of criterion of association | Criterion of association | Positively associated pairs | Positive association of an atypical CBND | CBND earlier onset in post-hoc analysis |
|---|-------------------------|---|---|--|--|--|--|--|--|---|
| 31 Leffa et al., 2023 | Prospective cohort | 212 cognitively unimpaired individuals (age: 73.1 (5.9)): A β -negative (N=137): 72.2 (5.7) A β -positive (N=75): 74.8 (5.9) Age: | Attention Deficit Hyperactivity Disorder | Major and Mild Neurocognitive Disorders | Genetic proxies | Cognitive impairment | of ≥ 2 ($p=0.001$, $d=-0.47$) on the Ascertain Dementia Questionnaire-8 (AD8). Higher ADHD-Polygenic Risk Score (PRS) was associated with a higher decline in general cognitive performance over 6 years (ADHD-PRS x time; $\beta = -0.10$, 95 %CI [-0.16; -0.03], $p=0.003$). Higher ADHD-PRS was related to a progressive decline in memory function (ADHD-PRS x time; $\beta = -0.01$, 95 %CI [-0.02; -0.002], $p=0.01$). | Attention Deficit Hyperactivity Disorder / Major and Mild Neurocognitive Disorders | NI | No |
| 32 Nassan et al., (2023) | Mendelian randomization | svPPA (308 cases/616 controls) nfvPPA (269 cases/538 controls) lvPPA (324 cases/3444 controls) | Specific Learning Disorder with impairment in reading and/or with impairment in written expression and Communication Disorder (speech disorder) | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease Major or Mild Frontotemporal Neurocognitive Disorder | Genetic proxies | Mendelian Randomization | Using the Inverse Variance-Weighted MR method, dyslexia and developmental speech disorders were not associated with any PPA subtype ($p>0.05$). | None | No | No |

Note: When given in the studies, mean ages and standard deviations were reported as follows: mean (standard deviation). Earlier-onset dementia ($n=1$) was classified as an atypical CBND. However, typical CBNDs found to have an earlier onset in post-hoc analysis were not classified as atypical. Such cases are reported in the column "CBND earlier onset in post-hoc analysis". AD: Alzheimer's disease, ADHD: attention deficit/hyperactivity disorder, ASD: autism spectrum disorder, DLB: dementia with Lewy Bodies, FTD: Frontotemporal dementia, HR: hazard ratio, IDD: intellectual developmental disorder, IRR: incidence rate ratio, LD: learning disorder, lvPPA: logopenic variant of primary progressive aphasia, MCI: Mild cognitive impairment, MR: mendelian randomization, nfvPPA: non-fluent variant of primary progressive aphasia, NI: not investigated, OR: odds ratio, PCA: Posterior cortical atrophy, svPPA: semantic variant of primary progressive aphasia, VaD: Vascular dementia.

Table 2
Classification of neurodevelopmental disorders.

| Labels found in the reviewed papers | Corresponding categories of the DSM-5 |
|--|--|
| Mental retardation Intellectual disability Learning disorder* | Intellectual Disability (Intellectual Developmental Disorder) |
| Autism Spectrum Disorder Attention Deficit Hyperactivity Disorder | Autism Spectrum Disorder (299.00) Attention Deficit Hyperactivity Disorder (314.01) |
| Learning disorder Learning disability Dyslexia Suspected reading disorder Language learning disability Language learning disability | Specific Learning Disorder with impairment in reading (315.00) with impairment in written expression (315.2) |
| Dyscalculia, difficulties in mathematical and/or visuospatial functioning Speech disorder | with impairment in mathematics (315.1) Communication Disorder Speech disorder (315.39) |

Note: *Based on the ICD10

Table 3
Classification of cognitive and behavioral neurodegenerative diseases.

| Labels found in the reviewed papers | Corresponding categories of the DSM-5 |
|--|---|
| Cognitive disorders (delirium, dementia, amnesia, other cognitive disorders)* | Neurocognitive Disorders (591) |
| Dementia (AD, VaD, and other dementias) Dementia including AD AD and other dementias Early-onset AD and other dementias Pre-senile dementia MCI Cognitive decline Alzheimer-type neuropathology AD lvPPA PCA dysexecutive AD FTD svPPA nfvPPA Lewy Body Disease | Major and Mild Neurocognitive Disorders (602) Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease (611) Major or Mild Frontotemporal Neurocognitive Disorder (614) Major or Mild Neurocognitive Disorder With Lewy Bodies (618) |

Note: AD: Alzheimer's disease, FTD: Frontotemporal dementia, ICD10: International Classification of Diseases 10th revision, lvPPA: logopenic variant of primary progressive aphasia, MCI: Mild cognitive impairment, nfvPPA: non-fluent variant of primary progressive aphasia, PCA: Posterior cortical atrophy, svPPA: semantic variant of primary progressive aphasia, VaD: Vascular dementia. *Based on the ICD10

inductive semantic approach, we identified the themes described in the Results section.

3. Results

In June 2023, a total of 2763 articles were found in the PubMed, Embase, and Web of Science databases (Fig. 1). After removing 60 duplicates, 2703 articles were screened based on their title and abstract. Out of these, 46 met the inclusion and exclusion criteria. Three records could not be retrieved resulting in a total of 43 articles that were reviewed in full-text. Twenty of these were included in the study. In addition, we identified 28 articles through citation searching, 12 of which were part of our final analysis. Ultimately, the scoping review focuses on 32 records.

3.1. Methods of investigation of the history of neurodevelopmental disorders

The most common approach used to detect a potential history of NDDs was the medical record screening, employed in 50 % of the studies (n=19). Questionnaires were the second most frequent method, found in 6 articles (16 %) (Table 4). Informants were consulted in 4 studies (10 %), whereas anamnesis and genetic proxies were used 3 times (8 %) each. Two studies (5 %) adapted diagnosis criteria and one (3 %) conducted a cognitive evaluation. In 78 % of cases (n=25), the method was utilized alone, but in 6 studies (22 %), it was combined with other methods. The combinations were as follows: Informant/Questionnaire/Diagnosis criteria, Informant/Anamnesis/Medical record screening, Medical record screening & Diagnosis criteria, Anamnesis & Medical Record Screening, Informant & Questionnaire (combination used twice). Thus, the help of the Informant and the Diagnosis criteria were used exclusively in combination. One study did not specify any method.

3.2. Pairs of NDD & CBND

On the one hand, the most studied NDDs were Specific Learning Disorders (n=15 articles, 34 % of associations), either unspecified (n=7, 16 %) or with impairment in reading and/or in written expression (n=4, 9 %), solely in reading (n=3, 7 %), or in reading, written expression and/or mathematics (n=1, 2 %). ASD was reported 10 times (23 %), and was followed by IDD (n=9, 20 %) and ADHD (n=8, 18 %). Communication disorders were mentioned twice (5 %).

On the other hand, regarding CBNDs, 16 reports examined Major and Mild Neurocognitive Disorders (39 % of associations). Other studies targeted Major or Mild Neurocognitive Disorder due to Alzheimer's Disease (n=15, 37 %), due to Frontotemporal Neurocognitive Disorder (n=6, 15 %), or else with Lewy Bodies (n=3, 7 %). One article was dedicated to the broader category of Neurocognitive Disorders (2 %).

Regarding pairs of NDDs and CBNDs, 15 were studied in the literature (regardless of the type of association). These pairs are described in Fig. 2. The most frequently studied was Specific Learning Disorders in relation with Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease (n=8).

3.3. Criterion of association

In 50 % of the studies (n=16), an association was determined by comparing prevalence. Hazard and odds ratios were utilized four (13 %) and five times (16 %) respectively, representing about 28 % of the criteria collectively. Cognitive impairment evaluation was selected in 9 % of the studies (n=3), while estimates from mendelian randomization were implemented in two studies (6 %). Concurrent cerebral modifications and Incidence Rate Ratio were reported once (3 %) each.

3.4. Type of association

An association between NDDs and CBNDs was found to be positive in 66 % of the studies (n=21) (Fig. 2), while 34 % of the records did not detect any (n=11). None of the studies reported a negative association.

Notably, some positive associations were found between NDDs and atypical presentations of CBNDs (Table 1). Indeed, atypical variants of CBNDs concerned 17 % (n=2/12) of the positive associations of Major and Mild Neurocognitive Disorders, 67 % (n=6/9) of that of Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease and 67 % (n=2/3) of that of Major or Mild Frontotemporal Neurocognitive Disorder. Besides, four studies (13 %) reported an earlier onset of CBNDs in post-hoc analyses.

Table 4
Description of the questionnaires used to investigate NDDs.

| Reference of the study | Studied NDD | Description of the questionnaire | Source of the questionnaire |
|-------------------------------|---|--|---|
| Metzler-Baddeley et al., 2008 | Specific Learning Disorder with impairment in reading | - 10 yes/no items relating to cognitive problems associated with dyslexia - Cut-off: 5 points - Not fully validated | McLoughlin et al., (1994) |
| Golimstok et al., (2010) | Attention Deficit Hyperactivity Disorder | - Spanish Wender Utah Rating Scale - Uses 25 characteristics of ADHD - Likert-type scale from 0 (not at all/ slightly) to 4 (very much) - Cut-off: 36 or above - Validated | Rodríguez-Jiménez et al., (2001) |
| Ivanchak et al., (2011) | Attention Deficit Hyperactivity Disorder | - Wender-Utah ADHD scale - Uses 25 characteristics of ADHD - Likert-type scale from 0 (not at all/ slightly) to 4 (very much). - Cut-off: 36 or above - Validated | Ward et al., (1993) |
| Seifan et al., (2015) | Specific Learning Disorder (language related or non-language related) | - Consensus review of the Social & Developmental History - LD categorized as: Probable, Possible or Absent - Non validated scale but many items are included in the Colorado Learning Difficulties Questionnaire | Patrick et al., (2013) |
| Rhodus et al., (2020) | Autism Spectrum Disorder | - Gilliam Autism Rating Scale-Second Edition (GARS-2), filled by partners and caregivers - 42 objective statements of characteristic ASD behaviors based on observable frequency - Item ranked on an ordinal scale from 0 to 3 - 3 subscales: behaviors, communication, social interaction - Autism Index Score (AIS): 'Autism Possible/Very Likely' (AIS ≥ 70) and 'Autism Unlikely' (AIS < 70) - Lack of validation in older adults | Montgomery et al., (2008) |
| dos Reis et al., (2022) | Specific Learning Disorder | - Structured heteroquestionnaire prepared by the researchers - Applied in person or by telephone - Non-validated | https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2022.703729/full#SM1 |

Note: Six of the included studies used questionnaires to investigate the presence or the history of NDDs. For each of these studies, the NDD targeted, a description of the questionnaire and its reference are provided. Unless otherwise stated, questionnaires are auto-questionnaires. NDD: neurodevelopmental disorder.

3.5. Authors' interpretation

When considering the articles' discussions, we found that the idea that NDDs could be considered as a risk factor (Cooper, 1997; Dobrosavljevic et al., 2021; Fluegge and Fluegge, 2017; Golimstok et al., 2010; Hand et al., 2020; Klein et al., 2023; Lebowitz et al., 2016; Leffa et al., 2023; Metzler-Baddeley et al., 2008; Miller et al., 2019; Popovitch et al., 1990; Rogalski et al., 2008, 2014; Tzeng et al., 2017; Vivanti et al., 2021; Zhang et al., 2021) for CBNDs was expressed in 50 % of them (n=16 articles). Some examples include designating NDDs as «an apparent predisposition» (Popovitch et al., 1990) or a «susceptibility marker» (Rogalski et al., 2014) for CBNDs, and describing individuals with a history of NDDs as «more likely to be diagnosed with» (Hand et al., 2020) or as having «an increased risk of developing» (Zhang et al., 2021) CBNDs. Numerous authors hypothesized that the association between NDDs and CBNDs could be explained by lower cognitive reserve (Cooper, 1997; Croen et al., 2015; Dobrosavljevic et al., 2021; Popovitch et al., 1990; Rhodus et al., 2020; Tzeng et al., 2017; Vivanti et al., 2021; Zhang et al., 2021) (25 % of articles, n=8). Indeed, NDDs might constitute an «earlier behavioral burden» that «may lower the threshold for onset» of CBNDs (Zhang et al., 2021), potentially via «co-morbid features that are frequently observed» in NDDs (Vivanti et al., 2021) or via «lifestyle» and «barriers» to satisfying «service need» (Vivanti et al., 2021). Another hypothesis (25 % of articles, n=8) suggests a

pathophysiological overlap (Fluegge and Fluegge, 2017; Golimstok et al., 2010; Miller et al., 2019, 2018, 2013; Rhodus et al., 2020; Rogalski et al., 2008; Seifan et al., 2015) between NDDs and CBNDs that would constitute a «susceptibility of the same neural network» (Miller et al., 2013) or a «selective vulnerability» (Seifan et al., 2015) of specific cerebral structures. This overlap may also present as «a common neurotransmitter pathway dysfunction» (Golimstok et al., 2010). Sixteen percent of articles (n=5) also mentioned genetics (Cooper, 1997; Croen et al., 2015; Leffa et al., 2023; Rogalski et al., 2008; Zhang et al., 2021) as a potential factor influencing the associations of pairs, considering «genetic liability» for a NDD «as a relevant factor influencing [a CBND] progression» (Leffa et al., 2023) or even that NDDs and CBNDs «may share similar genetic factors» (Croen et al., 2015). Finally, 19 % of discussions (n=6) underlined that the association between NDDs and CBNDs has consequences on healthcare (Cooper, 1997; Lebowitz et al., 2016; Metzler-Baddeley et al., 2008; Rhodus et al., 2020; Tait, 1983; Vivanti et al., 2021), not only because patients with a NDD «are likely to require additional support» (Cooper, 1997), but also because «learning disorder history may increase the likelihood of misdiagnosis» (Lebowitz et al., 2016) by producing «similar behavioral features» (Rhodus et al., 2020) as CBNDs, notably.

| | Major and Mild Neurocognitive Disorders (602) | Major or Mild Neurocognitive Disorder Due to Alzheimer's Disease (611) | Major or Mild Frontotemporal Neurocognitive Disorder (614) | Major or Mild Neurocognitive Disorder With Lewy Bodies (618) | Neurocognitive Disorders (591) |
|---|---|--|--|--|--------------------------------|
| Specific Learning Disorder | 18 10 | 9 15 21 29 13 16 22 32 | 9 13 29 15 32 | | |
| Autism Spectrum Disorder (299.00) | 27 23 14 17 30 | 23 28 | 23 | 23 | 24 |
| Intellectual Developmental Disorder | 27 1 6 7 2 8 | 4 5 3 | | | |
| Attention Deficit Hyperactivity Disorder (314.01) | 20 26 25 31 | 19 12 | | 11 19 | |
| Communication Disorder (speech disorder, 315.39) | | 32 | 32 | | |

Fig. 2. : Studied pairs and types of association of neurodevelopmental disorders and cognitive-behavioral neurodegenerative diseases. Note: Each rectangular icon represents an article studying a pair of NDDs and CBNDs. The numbers inside icons are references to the articles in Table 1. The colored filling indicates when a positive association was shown. Stripes indicate when the positive association referred to an atypical variant of CBNDs.

4. Discussion

This scoping review aimed to compile the evidence on the association between NDDs and CBNDs. The interest in this question dates back decades, with the oldest included article published in 1974. However, to the best of our knowledge, comprehensive contributions addressing this issue while considering the wide range of NDDs are scarce.

4.1. Methods of investigation of the history of NDD

Seven types of methods of investigation of the history of NDDs were distinguished, and none appears flawless. Indeed, NDDs constitute a rather recent diagnostic category: “Developmental disorders” first appeared in the DSM-III in 1980 (American Psychiatric Association, 1980; Morris-Rosendahl and Crocq, 2020). They were thus rarely detected in the generations nowadays affected with CBNDs and medical records might consequently contain incomplete information. They may also be biased by modifications of diagnostic labels and criteria over time (Barcikowska et al., 1989; Leffa et al., 2023). Structured questionnaires, as opposed to medical records, permit a standardized collection of data (dos Reis et al., 2022). However, few retrospective questionnaires exist and only part of them are validated in adult populations (Rhodus et al., 2022). Similarly, some questionnaires lack specificity (e.g., items such as “Do you often confuse left and right?” to screen for dyslexia) or the cut-off above which to consider the existence of a history of NDDs is sometimes chosen arbitrarily (Metzler-Baddeley et al., 2008). Thus, some authors chose to interrogate patients by asking open questions during the anamnesis. Of course, even if long term memory is usually spared in CBNDs, patients may not be able to remember their childhood properly, or may wrongly attribute to their childhood, symptoms resulting from a CBND (Ivanchak et al., 2011). Patients can also be confused by NDDs labels and not identify to any of them, or report no formal diagnosis of NDDs whereas they actually experienced associated symptoms. For these reasons and to avoid misclassification, the screening of NDDs should rely on symptomatology rather than on self-reported diagnosis (Colvin and Sherman, 2020). Besides, this dimensional approach of NDDs would also be more robust to changes in diagnostic criteria over time. While informants can be

consulted in order to increase confidence in the retrospective search, this might be challenging because patients’ caregivers are typically their spouses or children, who generally do not know the patients since childhood. A few other studies used raw scores of cognitive performance tests in patients with a CBND as a reflection of developmental difficulties. If, unlike the WRAT-III (Wide Range Achievement Test: Word Reading subtest, 3rd Edition) (Snelbaker et al., 2001) or the National adult reading test (NART) (Nelson and Willison, 1991), these tests are not validated (Lebowitz et al., 2016), this method can be particularly unreliable. All in all, the retrospective investigation of NDDs remains uncertain. In that context, using genetic mutations as proxies of NDDs may appear as a suitable solution. Nonetheless, genetics can only account for a small number of cases of NDDs and mutations associated with NDDs alone are not entirely causative of their phenotype. Indeed, pleiotropic pathways could be at stake (Davies et al., 2018; Pagoni et al., 2022) and the genetic risk for NDDs might carry part of the genetic risk for CBNDs (Leffa et al., 2023). Thus, the results highlight the lack of tools to screen NDDs in the elderly population with cognitive impairments. If such a screening should be done, however, literature shows that the following combination should be preferred: a screening of symptoms evoking NDDs with a questionnaire investigating childhood and adulthood, filled by the patient with the help of a caregiver (siblings, long-standing friend or spouse); a description of personal, social, academic and professional trajectories; an exploration of familial history of NDDs; a proper diagnosis in light of all previous elements, according to validated criteria (American Psychiatric Association, 2013).

4.2. Pairs of NDDs & CBNDs

Over time, classification and diagnostic criteria have evolved and NDDs labels might have been very heterogeneous, especially in older studies. In order to reduce potential biases in pairs of NDDs and CBNDs, a systematic classification according to the DSM-5 (American Psychiatric Association, 2013) was applied. This led to five categories of NDDs, the most studied of which were specific learning disorders, first mentioned in 2008. This might reflect the growing interest following a study suggesting a positive association between NDDs and atypical presentations of CBNDs (Rogalski et al., 2008). On the contrary, the

communication disorders category was only reported twice and represented by speech disorder only. Likewise, the Motor Disorders category of the DSM-5 (American Psychiatric Association, 2013) was not reported, perhaps because the consensus on these disorders is more recent than that on learning disorders, or because they are less relevant in the context of CBNDs than they would be in the context of primary motor neurodegenerative disorders. Regarding CBNDs, most articles fell in the Major and Mild Neurocognitive Disorders category. In other words, no diagnosis more precise than “dementia” was provided. When it was, however, the most frequent was AD, probably because it is the most prevalent and the best characterized.

Unsurprisingly because they were the most frequently studied of NDDs and CBNDs, the most investigated pair was specific learning disorders/AD. Another frequently studied pair was Intellectual Disability/Major or Mild Neurocognitive Disorder. It has been the main focus in articles published before 2008, probably because Down’s syndrome—causing similar symptoms to IDD—and its link with AD had been long proven (Karlinsky, 1986). It is worth noting that whereas we excluded articles on Down’s syndrome (DS), one article focusing on IDD included a few individuals with DS in its sample (4/124 subjects) (Sansom et al., 1994). This low proportion is nonetheless unlikely to bias results.

4.3. Criterion of association

The association between NDDs and CBNDs was based on seven diverse types of criteria. The most frequent was the prevalence, but it was often employed in the absence of a control group and thus compared to rates found in previous publications (Barcikowska et al., 1989; Reid and Aung, 1974; Tait, 1983). This resulted in the comparison of unmatched groups and methods that could be an important source of bias. Besides, the prevalence used in some studies was that of CBNDs in individuals with a history of NDDs. The accuracy of this prevalence depends on the diagnosis of CBNDs, which can also be uncertain. For example, to reveal Alzheimer-type physiopathology, a team used a staining method described as “very sensitive compared to other methods” (Barcikowska et al., 1989). Thus, the number of individuals with Alzheimer-type physiopathology could have been overestimated.

A more precise criterion, relying on control groups and providing confidence intervals, is the use of hazard, odds, and incidence rate ratios. However, their interpretation depends on the control of confounders. For instance, taking diabetes into account removed a significant association found between antecedent ADHD and risk of AD (Fluegge and Fluegge, 2017). This would equally apply to other criteria, such as the study of cognitive impairment. For instance, studies showed that the presence of indicators of NDDs was associated with a greater (i. e. broader and more severe) cognitive impairment (Leffa et al., 2023; Rhodus et al., 2020) and that individuals scoring positive on a dementia screener had more features of autism (Klein et al., 2023). This shows that NDDs seem to aggravate symptoms of CBNDs, but one should keep in mind that a greater cognitive impairment would also increase the likelihood of expressing features resembling that of NDDs. Overcoming confounding is the main strength of mendelian randomization (MR) (Davies et al., 2018). This implies the correct choice of instruments, as weak ones might lower the causal effect of mutations associated with NDDs. Plus, MR precludes the study of the impact of rare genetic variants, argued to have a higher penetrance and thus to contribute more to genetic susceptibility to NDDs than common ones (Pagoni et al., 2022). Finally, one article relies on the concurrence of cerebral modifications associated with Alzheimer-type pathology and dyslexia. While this criterion would give neurobiological evidence to a potential link between NDDs and CBNDs, it supposes that these cerebral modifications are reliable indicators of these syndromes. However, the authors themselves qualified the indicator of dyslexia as “controversial” and underlined that the late stage of the CBND “may have caused histological distortions” that resembled the features of the NDD (Miller et al., 2019).

Literature offers a wide range of criteria to determine if a link

between NDDs and CBNDs exists, but shows a great heterogeneity and underlines the paucity of reliable methods to answer this question.

4.4. Type of association

The majority of the studies showed a significant and positive association between NDDs and CBNDs. According to them, a history of the former might favor the development, or modify the clinical expression of the latter. Since this distinction was not systematically investigated, the term “positive” was indeed chosen to encompass for both cases. Yet, this difference appears critical in the understanding of the link between the two groups of syndromes, and should thus be addressed in future works. Moreover, this majority of positive associations could be the consequence of a bias in publication, positive results being more reported than negative ones. Likewise, a bias of recruitment could lead to the inflation of the proportion of CBNDs in people with NDDs, since they are more prone to be in contact with medical services, and thus to be diagnosed (Cooper, 1997; Vivanti et al., 2021). This greater medical attention could also lead to dementia being recognized sooner, thus partially explaining why an earlier onset of dementia was sometimes observed in the NDD groups (Vivanti et al., 2021). However, the contrary could be advocated: persisting gaps in access to healthcare in patients with NDDs might lead to an underestimation of the true occurrence of CBNDs in this population (Malik-Soni et al., 2022). Some have argued that “excess mortality associated with ADHD and ASD” could be another factor that “might bias any associations between the two conditions and Alzheimer’s” (Pagoni et al., 2022) even if according to others, there is no evidence supporting this assumption (Oberman and Pascual-Leone, 2014).

It is worth noting that despite the hypothesis that hyperplasticity in ASD would confer protection from AD (Oberman and Pascual-Leone, 2014), no included study reported negative associations. This shows that the idea that a NDD could protect against a CBND is still speculative or explored on non-human models (Santos et al., 2015). On the contrary, some positive associations were found between NDDs and atypical variants of CBND: out of the eleven times atypical CBNDs were studied, they were positively associated with a NDD ten times. In particular, ASD and IDD were linked to early-onset AD and other dementias once, and learning disabilities were linked to PPA or atypical AD four times. More specifically, four other studies showed a link between language learning disorder and language based CBNDs, and between mathematical and visuospatial learning disorders and CBNDs characterized by visuo-spatial symptoms. In other words, alterations associated with NDDs and atypical CBNDs could share a common phenotype (Miller et al., 2018). It is plausible that an inflation of LDs is observed in individuals with atypical diagnoses such as PPA for “they may be more inclined to explore their family history for similar disorders” (Rogalski et al., 2008) than others. In addition, the association between language learning disorders and PPA may not be that straightforward, and could depend on the underlying physiopathology (Miller et al., 2013; Rogalski et al., 2014). Despite these elements, it seems that NDDs could influence the course of CBNDs and favor the development of atypical presentations of the latter. However, based on the small amount of evidence and the lack of subcategorization of CBNDs—that can include a wide range of symptoms and physiopathologies—in numerous studies, no formal conclusion can be drawn regarding this question yet. The idea that NDDs would increase the likelihood of developing CBNDs is not definite either: in spite of the small number of studies, contradictory findings exist. For example, the pair IDD/Major or Mild Neurocognitive Disorder was investigated six times, and an association was found in 50 % of the cases. Similarly, it is still unclear whether there are causal effects between genetic liability to ADHD and AD’s (Zhang et al., 2021), or not (Pagoni et al., 2022).

4.5. Authors' interpretation

From this review and based on the interpretation found in the studies, emerged the idea that NDDs could predispose to the development of CBNDs. However, evidence supporting this hypothesis remains scarce and several authors underline the risk of interpreting NDDs as associated with CBNDs, when they could in fact be mistaken because of symptoms overlap (Callahan, 2017; Ivanchak et al., 2012). This emphasizes the necessity to consider histories of NDDs to define a proper cognitive “baseline” in patients with cognitive complaints, and thus to avoid falsely interpreting a pathological cognitive decline (Colvin and Sherman, 2020). Besides, in addition to core symptoms, the higher prevalence of comorbid psychiatric disorders in patients with NDDs could contribute to cognitive impairment likely to meet diagnostic criteria for CBNDs (Ivanchak et al., 2012).

Nevertheless, this argument is not incompatible with the hypothesis of a higher cognitive burden, that would remain compensated during much of adulthood, but that would weaken the abilities of coping with the onset of CBNDs. In particular, it has been proposed that this early vulnerability would target specific neural networks, explaining why a shared phenotype between NDDs and CBNDs can sometimes be observed (Miller et al., 2013; Rogalski et al., 2008). A similar phenomenon was described in two patients with PPA and a background of mild left hemispheric hypoplasia (Alberca et al., 2004) illustrating this possibility of a “locus of least resistance”. It should be noted that these are individual cases that must be interpreted with caution. However, as demonstrated by studies showing a positive association between NDDs and atypical CBNDs, personal factors could indeed help explaining why, in certain cases, CBNDs present with unusual features. A decade ago, the concept of nexopathies even offered a neuropathological framework for this hypothesis. According to this concept, network disintegration could interfere with the propagation of pathogenic proteins, hence possibly explaining focal alterations found in atypical CBNDs, such as in PPA (Miller et al., 2013; Warren et al., 2013).

More generally, the potential link between NDDs and CBNDs could partially be unraveled with genetics. For example, several genes of brain growth would be involved in ASD and dementia (Opris and Casanova, 2014) and activity-dependent neuroprotective protein (ADNP) mutations associated with autism and intellectual disability were found in brains of patients with AD (Ivashko-Pachima et al., 2021). However, perhaps links between NDDs and CBNDs rely on less specific biological pathways, since older adults with a history of NDD—more precisely ASD—seem more at risk than the general older adult population to be diagnosed with a wide variety of physical and mental health conditions (Hand et al., 2020). Besides, in this study, results were controlled for sex, which appears as a factor of influence regarding the association between NDDs and CBNDs. Indeed, a stronger association of ADHD and dementia was found in men compared to women (Dobrosavljevic et al., 2021), and a greater proportion of women than men developed dementia among a group with IDD (Cooper, 1997). Other factors, such as language spoken or educational attainment for example, could also be of importance (dos Reis et al., 2022). Based on the available evidence, it might be too soon to consider a history of NDDs as a real risk factor for typical or atypical CBNDs, but it seems relevant that such confounding factors should be controlled in future studies of this issue.

4.6. Limitations

Several limitations were identified in this scoping review. First, grey literature was not searched and only a small number of articles were analyzed. It cannot be excluded that some relevant articles, listed in other databases for example, were omitted.

Other limitations come from included studies themselves. Indeed, many can be considered exploratory: analyses were often performed on small samples and some studies even focused on the same individuals (Popovitch et al., 1990; Silverman et al., 1993). This can lead to a lack of

power and reproducibility. Some studies also showed a poor control of confounders that are likely to bias the results, such as duration and age of onset of the CBNDs, metabolic dysregulations and mental health conditions. In other studies, the presence of mental health conditions was a non-inclusion criterion. As psychiatric comorbidity in individuals with NDDs are “the rule rather than the exception” (Leffa et al., 2023), this choice limits the external validity of the results. Similarly, few studies investigated the frequent comorbidity of NDDs in their samples, let alone the effect of this comorbidity on CBNDs (Kats et al., 2013; Croen et al., 2015; Vivanti et al., 2021). Analogously, comorbidity of several CBNDs was not reported nor discussed in the included studies, possibly biasing outcomes (Spina et al., 2021). These questions should be addressed in future research. The generalizability and external validity of the results can be criticized, too. For example, the great majority of studies were conducted exclusively on Caucasian individuals. This is problematic considering the influence culture has on diagnoses of NDDs, CBNDs, and by extension on the interpretation of their link. As a matter of fact, since no biological markers of NDDs are available, their diagnosis is based on behavioral criteria that are largely influenced by cultural values. This could partly explain the great disparity of incidence of ASD or specific language impairments worldwide, for instance (for a review, see Norbury and Sparks, 2013). Similarly, Cipriani and Borin (2015) highlighted how symptoms evocative of dementia are differentially interpreted in ethnically diverse groups, and how this alters its diagnosis and its management. Educational level also affects diagnosis and expression of both kinds of syndromes. On the one hand, it can reflect individuals' history and thus inform on potential difficulties linked with NDDs, but it can be confounding and lead to an erroneous conclusion too, because it is influenced by external factors (psychosocial context, physical health, etc.) (American Psychiatry Association, 2013). On the other hand, NDDs are associated with a lower academic achievement (references on ADHD and LDs include Faraone et al., 2021; Stevens et al., 2022). However, the number of years of education is a common proxy of cognitive reserve and a higher level of education is associated with a lower risk of MCI and dementia (for a review, see Pettigrew and Soldan, 2019). Culture and education are thus two sociodemographic factors highly relevant in the question of the association between NDDs and CBNDs, and should thus be considered in future works. Consequently, despite being exhaustive, this review is limited in the conclusions it can draw.

4.7. Perspectives & Recommendations

This scoping review underlined the relative paucity of reliable evidence regarding the influence of NDDs and CBNDs, and consequently, the need for further exploration (Table 5).

On the one hand, future studies could tackle the lack of power that previous research suffered from, by collaborating and pooling data between investigation centers. In a nearer future, it also seems reasonable to improve the screening of NDDs in older individuals with the validation of new tools: diagnostic criteria for NDDs tailored to adult populations and retrospective methods to specifically assess NDDs. Such tools would be highly beneficial to clinical practice and personalized medicine. As a matter of fact, NDDs can contribute to the impairments objectivized in tests scores and falsely lead to the identification of a cognitive decline (Lebowitz et al., 2016). Plus, certain features of NDDs can mimic symptoms of atypical variants of CBNDs, leading to a misidentification of these diseases (Callahan, 2017; Ivanchak et al., 2012). By avoiding this, systematically taking a history of NDDs into account would lead to more precise diagnosis of CBNDs. It could also help identifying cognitive domains potentially rendered vulnerable to CBNDs by NDDs, thus enabling to target them with accurate therapeutic interventions improving prognosis (Colvin and Sherman, 2020; Metzler-Baddeley et al., 2008). To go further, if individuals with NDDs are one day identified as truly having a greater risk of developing CBNDs, it seems of utter importance to be able to identify them early and to provide preventive interventions to them (Seifan et al., 2015).

Table 5
Summary of preliminary findings and recommendations.

| Questions | Summary | Recommendations |
|--|---|---|
| (1) What methods are used to detect a history of neurodevelopmental disorder? | Medical records screening, anamnesis, questionnaires, cognitive assessments, genetic proxies, diagnosis criteria, and the assistance of informants are used. Retrospective and genetic methods of detection of NDDs are, nevertheless, imperfect. | Conducting longitudinal life-span studies and developing new screening tools. If needed, detecting NDDs with the following combination: a screening of symptoms evoking NDDs with a questionnaire investigating childhood and adulthood, filled by the patient with the help of a caregiver (siblings, long-standing friend or spouse); a description of personal, social, academic and professional trajectories; an exploration of familial history of NDDs; a proper diagnosis based on validated criteria in light of all previous elements (American Psychiatric Association, 2013). |
| (2) What pairs of neurodevelopmental disorders and neurodegenerative diseases have been studied in the literature? | The most investigated pair was specific learning disorders/ major or mild neurocognitive disorder due to Alzheimer's disease. However, diagnoses categories were heterogeneous. | Addressing comorbidities of both NDDs and CBNDs and characterizing CBNDs physiopathologies to increase reliability of diagnoses. |
| (3) What are the criteria used by the authors to determine whether associations between NDDs and CBNDs exist? | Prevalence comparison, hazard and odds ratios, cognitive evaluation, mendelian randomization, cerebral modifications, incidence rate ratios. | Comparing matched samples, controlling confounders (education, comorbidities...), reporting size effects and confidence intervals in order to tackle methodological limitations. |
| (4) What type of associations are these? | 11 studies did not find any association between NDDs and CBNDs. 21 reported a positive one, some with atypical variants of CBNDs. | Formulating and testing hypotheses on the processes underlying these associations based on biomarkers, neuroimaging and genetics. Distinguishing between the influence of NDDs on the emergence of CBNDs and on modifications in the clinical expression of CBNDs. |
| (5) How are they interpreted by the authors? | Authors argued NDDs could be a risk factor for CBNDs, potentially through a lessened cognitive reserve, genetic factors or physiopathological overlaps. They also discussed healthcare's impact on and implications in NDDs and CBNDs links. | Interpreting findings based solely on robust methods, and clearly stating limitations of studies' designs. |

Deciphering the link between NDDs and CBNDs would also impact clinical research. Indeed, targeting a dysfunction evolving since childhood or for a couple of decades probably has different implications (Geschwind et al., 2001). Nonetheless, if this dysfunction is located on a particular neural network or neurotransmitter pathway that is shared between specific NDDs and CBNDs, common therapeutic solutions could exist. This has already been investigated in a small sample of adults with memory complaints, in which methylphenidate improved certain cognitive and physical symptoms (Ben-Itzhak et al., 2008). Likewise, a recent study showed that adults with ADHD who received psychostimulant medication, in contrary to those who did not, had no clear increase in the risk of dementia (Levine et al., 2023). However, it has also been found that risk for dementia was not decreased with ADHD medications (Tzeng et al., 2017). Hypothetically, these shared therapeutic solutions could target mechanisms such as mitochondrial dysfunction, as it has been linked with ASD and premature ageing diseases, notably (Fei Fang et al., 2016; Wang et al., 2021). More generally, non-medical interventions —such as language and speech therapy— could target cognitive impairments shared by NDDs and CBNDs. To sum up, considering NDDs could influence the treatment of CBNDs in two ways. First, in helping to identify the accurate CBND and thus the appropriate therapeutic; second, in helping to identify new therapeutic pathways, that may be common to certain NDDs and CBNDs.

On the other hand, in order to investigate the link between NDDs and dementias, neuroimaging and autopsies could be informative (Callahan, 2017). Indeed, they could help outlining neuropathological changes associated with NDDs and studying their spatial and temporal relationships with CBNDs' neuropathological features. However, to this day, no markers of NDDs are available and such studies would require a clear *a priori* of the changes and structures to scrutinize. It thus appears that longitudinal studies, following cohorts from childhood to older age, remain the most powerful tool to decipher this link. The significance of such studies in comprehending risk factors is exemplified by the Framingham cohort, which was fundamental in the understanding of heart diseases. Admittedly, there are methodological limitations to conducting such long-term experiments, which may explain their current unavailability.

To finish, another way of better understanding the link between NDDs and CBNDs would be to study the neurodevelopment of individuals with CBNDs causal mutations. This has two advantages: younger individuals have less comorbidities than older ones, and non-carrier siblings would enable to control for other genetic environmental effects (Geschwind et al., 2001). Previous studies already showed a developmental influence of mutations associated with frontotemporal dementia and amyotrophic lateral sclerosis, for example. A higher probability of ASD in family members of C9orf72 carriers was found (Devenney et al., 2018) and specific frontotemporal dementia-causing genetic mutations were associated with potential advantageous neurodevelopmental consequences (Finger et al., 2022). Other conditions, including fragile X-associated tremor/ataxia syndrome (FXTAS), illustrate the genetic relationship between some NDDs and neurocognitive disorders, and could thus be relevant in this field (Bourgeois et al., 2006). Indeed, FXTAS is seen in individuals with a premutation of the FRM1 gene, which is responsible for the fragile X syndrome, a major cause of inherited IDD.

Hence, after accumulating evidence of NDDs being declinations of the same spectrum, we might be on the way to consider NDDs and CBNDs as two chapters of the same story.

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CRedit authorship contribution statement

PS: Conceptualization, methodology, formal analysis, and writing—original draft; **JP, MJ:** Conceptualization, methodology, project administration and writing—review and editing; **AD:** methodology, writing—review and editing; **EB, YC, MP, MR, MW, and FG:** writing—review and editing. All authors certify that they have participated sufficiently in the work to take public responsibility for the content.

Declaration of Competing Interest

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Data availability statement

The data is available on request from the corresponding author.

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Appendix A

Scoping Review Search Strategies

Search developed by Perrine SIGUIER and Jérémie PARENTE

PubMed (PubMed.gov) – 1563 references retrieved on June 26, 2023

Single-line search run in the “New PubMed” interface. «English language» and «human» filters were applied with the interface.

(((((«Neurodevelopmental Disorders/analysis»[Majr] OR «Neurodevelopmental Disorders/classification»[Majr] OR «Neurodevelopmental Disorders/diagnosis»[Majr] OR «Neurodevelopmental Disorders/diagnostic imaging»[Majr] OR «Neurodevelopmental Disorders/genetics»[Majr] OR «Neurodevelopmental Disorders/physiology»[Majr] OR «Neurodevelopmental Disorders/physiopathology»[Majr] NOT «Anxiety, Separation»[Mesh]) NOT «Conduct Disorder»[Mesh]) NOT «Sluggish Cognitive Tempo»[Mesh]) NOT «Mutism»[Mesh]) NOT «Reactive Attachment Disorder»[Mesh]) NOT «Schizophrenia, Childhood»[Mesh]) AND (((((((((((«Neurocognitive Disorders»[Majr] OR posterior cortical atrophy[Majr] OR apraxia of speech[Majr] NOT «AIDS Dementia Complex»[Mesh]) NOT «Dementia, Vascular»[Mesh]) NOT «Diffuse Neurofibrillary Tangles with Calcification»[Mesh]) NOT «Huntington Disease»[Mesh]) NOT «Kluver-Bucy Syndrome»[Mesh]) NOT («Anxiety, Separation»[TIAB]) NOT «Conduct Disorder»[TIAB]) NOT «Sluggish Cognitive Tempo»[TIAB]) NOT «Mutism»[TIAB]) NOT «Reactive Attachment Disorder»[TIAB]) NOT «Schizophrenia, Childhood»[TIAB])

Embase (Embase.com) – 317 references retrieved on June 26, 2023
Single-line search run in Results tab of Embase.com interface:

(«primary progressive aphasia»/mj OR «posterior cortex atrophy» OR «apraxia of speech»/mj OR «lewy body disease»/mj OR «alzheimer disease»/mj OR «frontotemporal dementia»/mj OR «creutzfeldt jakob disease»/mj) AND («autism»/mj OR «learning disorder»/mj OR «mental deficiency»/mj OR «attention deficit hyperactivity disorder»/mj OR «developmental coordination disorder»/mj OR «tic»/mj OR «communication disorder»/mj OR «developmental delay»/mj) AND [humans]/lim AND [english]/lim

Web of Science (clarivate.com/products/web-of-science) – 883 references retrieved on June 26, 2023

Single-line search run in Results tab of Embase.com interface. An «English language» filter was applied with the interface.

(ALL=(neurodevelopment* dis*)) AND (ALL=(neurodegenerative dis*))

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