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Developmental Timing in Human Neuropsychology: A Systematic Review of Recent Evidence and an Integrative Framework

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ADMINISTRATIVE INFORMATION

Support - No support.

Review Stage at time of this submission - The review has not yet started.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 3 September 2026 and was last updated on 3 September 2026.

INTRODUCTION

Review question / Objective To what extent does contemporary empirical evidence support developmental timing as a fundamental determinant of human neuropsychological development, and how are its principal temporal dimensions operationalized across typical development and neurodevelopmental disorders?

Rationale The temporal organization of development is fundamental to human neurodevelopment, yet the mechanisms governing developmental timing remain among the least systematically studied aspects of developmental neuroscience and neuropsychology. Although the timing of developmental events influences brain maturation, cognitive development, behavioral adaptation, and vulnerability to neurodevelopmental disorders, there is currently no comprehensive synthesis of the contemporary empirical literature examining developmental timing as a unifying principle of human neuropsychological development.

Development is characterized not only by changes in neural, cognitive, and behavioral function but also by the timing with which these changes occur. While substantial advances have been made in developmental neuroscience and neuropsychology, comparatively little attention has been devoted to developmental timing itself as a fundamental organizing principle of development. Existing research has largely focused on specific developmental processes, individual neurodevelopmental disorders, or isolated biological mechanisms, whereas evidence concerning developmental rate, developmental sequence, developmental synchrony and asynchrony, developmental duration, sensitive and critical periods, and developmental prediction remains dispersed across multiple disciplines.

Recent advances in developmental neuropsychology, neuroimaging, electrophysiology,

developmental neuroscience, developmental genetics, and computational modeling have generated a rapidly expanding body of empirical evidence relevant to developmental timing. However, this literature has not been systematically synthesized within a unified conceptual framework. Consequently, it remains unclear whether common developmental timing principles can be identified across neuropsychological domains, developmental stages, and neurodevelopmental conditions, or whether these principles can contribute to a more predictive understanding of human development.

This systematic review will address this gap by synthesizing contemporary empirical evidence published from January 2021 onward to evaluate developmental timing as a multidimensional construct in human neuropsychology. Using a structured narrative synthesis, the review will examine evidence across typical development and major neurodevelopmental disorders and will evaluate the extent to which the empirical literature supports, refines, or challenges an integrative developmental timing framework.

By identifying common temporal principles across neuropsychological domains, this review seeks to provide a contemporary evidence base for understanding developmental timing and to establish an evidence-informed framework capable of informing developmental theory, neuropsychological assessment, developmental prediction, and the timing of preventive and therapeutic interventions.

Condition being studied Developmental timing in human neuropsychology, including the temporal organization of brain, cognitive, behavioral, and neuropsychological development across the prenatal period through young adulthood. The review will examine six principal developmental timing constructs, developmental rate, developmental sequence, developmental synchrony and asynchrony, developmental duration, sensitive and critical periods, and developmental prediction, and their relationships to typical neurodevelopment and major neurodevelopmental disorders, including autism spectrum disorder, attention-deficit/hyperactivity disorder, developmental language disorder, developmental coordination disorder, dyslexia, dyscalculia, and other specific learning disorders.

METHODS

Search strategy A comprehensive, prospectively developed search strategy will be employed to identify empirical studies examining developmental timing in human neuropsychology. Electronic searches will be conducted in PubMed/MEDLINE, PsycINFO, Scopus, and Web of Science Core Collection. The search strategy has been designed in accordance with the recommendations of PRISMA 2020 and PRISMA-S and will be adapted to the indexing system and syntax of each database.

Searches will combine three principal conceptual domains using Boolean operators (AND/OR):

1. Developmental timing constructs, including developmental timing, developmental trajectories, maturational trajectories, developmental rate, developmental sequence, developmental synchrony, developmental asynchrony, developmental duration, developmental progression, developmental delay, brain maturation, cortical maturation, neural maturation, white matter maturation, network maturation, sensitive periods, critical periods, developmental plasticity, developmental windows, and related concepts.
2. Developmental populations, including prenatal, fetal, neonatal, infant, toddler, child, adolescent, pediatric, and young adult populations.
3. Neuropsychological outcomes, including neuropsychology, neurodevelopment, cognition, executive functioning, attention, memory, language, learning, reading, mathematics, motor development, motor coordination, social cognition, social communication, adaptive functioning, autism spectrum disorder, attention-deficit/hyperactivity disorder, developmental language disorder, developmental coordination disorder, dyslexia, dyscalculia, and specific learning disorders.

Searches will be limited to peer-reviewed empirical studies involving human participants, published in English between January 1, 2021, and the date of the final literature search.

Controlled vocabulary (e.g., MeSH in PubMed and thesaurus terms in PsycINFO) will be combined with free-text title and abstract searches to maximize retrieval. Database-specific syntax, truncation symbols, field restrictions, and proximity operators will be adapted while maintaining conceptual equivalence across databases.

To minimize the risk of missing relevant studies, supplementary search procedures will include backward reference searching, forward citation tracking, and related-article searches. The search strategy will be validated using sentinel

publications identified a priori, and any necessary refinements will be documented transparently before the formal review commences. Complete database-specific search strategies will be provided as supplementary material to ensure reproducibility.

Participant or population The review will include empirical studies involving human participants from the prenatal period through young adulthood, including both typically developing individuals and individuals with neurodevelopmental disorders. Eligible populations include fetuses, neonates, infants, toddlers, children, adolescents, and young adults.

Clinical populations may include, but are not be limited to, individuals with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), developmental language disorder (DLD), developmental coordination disorder (DCD), dyslexia, dyscalculia, specific learning disorders (SLDs), and related neurodevelopmental conditions. Studies involving healthy comparison groups will also be included where relevant.

Studies must investigate one or more aspects of developmental timing in relation to neuropsychological, cognitive, behavioral, motor, language, social, neurophysiological, or neuroimaging outcomes.

Intervention No intervention will be evaluated in this systematic review.

The review will examine empirical evidence concerning developmental timing as a multidimensional construct in human neuropsychology. Specifically, it will evaluate studies investigating developmental rate, developmental sequence, developmental synchrony and asynchrony, developmental duration, sensitive and critical periods, and developmental prediction in relation to brain, cognitive, behavioral, and neuropsychological development. The review is observational in nature and will synthesize evidence across both typical development and neurodevelopmental disorders rather than assessing the effectiveness of therapeutic, educational, pharmacological, or behavioral interventions.

Comparator No predefined intervention comparator is applicable.

Eligible studies may compare developmental timing characteristics across different participant groups, developmental stages, neuropsychological domains, or neurodevelopmental conditions. Comparators may include, where appropriate:

Typically developing participants versus individuals with neurodevelopmental disorders.
Different developmental stages (e.g., infancy, childhood, adolescence).
Earlier versus later maturational trajectories.
Synchronous versus asynchronous developmental profiles.
Participants with differing neuropsychological, cognitive, behavioral, or developmental outcomes.
Longitudinal within-subject comparisons across developmental time.

Studies without explicit comparison groups will also be eligible, provided they investigate one or more predefined developmental timing constructs relevant to the objectives of the review.

Study designs to be included The review will include peer-reviewed empirical observational studies investigating developmental timing in human neuropsychology.eer-reviewed empirical observational studies involving human participants will be included, including prospective and retrospective longitudinal studies, birth cohort and cohort studies, case-control studies, analytical cross-sectional studies, developmental neuropsychological, neuroimaging, electrophysiological, developmental genetic, and multimodal observational studies. Studies must investigate one or more developmental timing constructs in relation to neuropsych.

Eligibility criteria Studies will be eligible if they: (1) report original empirical data from human participants spanning the prenatal period through young adulthood; (2) investigate one or more developmental timing constructs (developmental rate, developmental sequence, developmental synchrony/asynchrony, developmental duration, sensitive or critical periods, or developmental prediction); (3) examine neuropsychological, cognitive, behavioral, motor, language, social, neurophysiological, neuroimaging, or developmental outcomes; (4) are published in peer-reviewed journals in English; and (5) were published between January 1, 2021, and the date of the final literature search.

Eligible study designs include longitudinal, cohort, case-control, analytical cross-sectional, developmental neuropsychological, neuroimaging, electrophysiological, developmental genetic, and other observational studies.

The review will exclude animal studies, in vitro studies, intervention trials in which developmental timing is not an outcome of interest, narrative reviews, systematic reviews, meta-analyses, editorials, commentaries, letters, conference abstracts, dissertations, book chapters, protocol papers, unpublished reports, and studies not directly addressing developmental timing.

Information sources Electronic searches will be conducted in PubMed/MEDLINE, PsycINFO, Scopus, and Web of Science Core Collection. Additional studies will be identified through backward reference searching of eligible articles, forward citation tracking, and related-article searches. Only peer-reviewed studies published in English between January 1, 2021, and the date of the final literature search will be considered. Supplementary materials associated with eligible publications will be reviewed where relevant.

Main outcome(s) The primary outcomes will be empirical evidence describing developmental timing in human neuropsychology, including developmental rate, developmental sequence, developmental synchrony/asynchrony, developmental duration, sensitive and critical periods, and developmental prediction. Outcomes will include neuropsychological, cognitive, behavioral, motor, language, social, neurophysiological, and neuroimaging measures that characterize developmental trajectories in typical development and neurodevelopmental disorders.

Additional outcome(s) Additional outcomes will include participant characteristics, developmental stage, neurodevelopmental diagnosis, study design, methodological quality, neuroimaging and electrophysiological findings, genetic and biological markers where reported, developmental predictors, and evidence relevant to neuropsychological assessment, developmental trajectory prediction, timing of intervention, and the proposed integrative developmental timing framework.

Data management All retrieved records will be imported into EndNote 21 for reference management and duplicate removal before being transferred to Rayyan for title/abstract and full-text screening. Data extraction will be performed using standardized electronic extraction forms, and the final reconciled dataset will be maintained in Microsoft Excel with version control and secure electronic backup. All review materials, including search strategies, extraction templates, coding manuals, evidence tables, and protocol amendments, will be archived. Reviewer-generated materials will be made publicly available through the Open Science Framework (OSF) upon publication of the review, where appropriate.

Quality assessment / Risk of bias analysis Methodological quality and risk of bias will be assessed independently by two reviewers using study design-appropriate critical appraisal instruments. The Newcastle-Ottawa Scale (NOS) will be used for cohort and case-control studies, the Joanna Briggs Institute (JBI) Critical Appraisal Checklists for analytical cross-sectional and other applicable observational studies, and the National Heart, Lung, and Blood Institute (NHLBI) Quality Assessment Tool where appropriate. Studies will be evaluated for participant selection, measurement validity, confounding, outcome assessment, missing data, and statistical methodology. Disagreements will be resolved through discussion or adjudication by a third reviewer. Quality assessments will inform interpretation of the evidence but will not be used as grounds for excluding otherwise eligible studies.

Strategy of data synthesis A structured narrative synthesis will be conducted in accordance with PRISMA 2020 guidance. Quantitative meta-analysis is not planned because substantial heterogeneity is anticipated in study designs, participant populations, developmental stages, methodologies, developmental timing constructs, and outcome measures.

The synthesis will proceed in sequential stages. First, included studies will be summarized descriptively according to study design, participant characteristics, developmental stage, neuropsychological domain, and methodological approach. Second, evidence will be synthesized within major neuropsychological domains, including brain maturation, executive functioning, attention, memory, language, learning, motor development, social cognition, adaptive functioning, and neurodevelopmental disorders. Third, findings within each domain will be analyzed according to the predefined developmental timing constructs (developmental rate, developmental sequence, developmental synchrony/asynchrony, developmental duration, sensitive and critical periods, and developmental prediction). Fourth, evidence will be integrated across domains to identify recurring developmental timing principles, methodological convergence, and knowledge gaps. Finally, the cumulative evidence will be synthesized into an evidence-informed developmental timing framework, with

methodological quality incorporated into interpretation throughout the review.
Sensitivity analyses will examine the consistency of findings across study design, developmental stage, participant population, neuropsychological domain, and methodological quality. Conclusions will be based on the consistency, quality, and convergence of the available empirical evidence.

Subgroup analysis Where sufficient evidence is available, subgroup analyses will be conducted descriptively according to developmental stage (prenatal, neonatal, infancy, childhood, adolescence, and young adulthood), participant population (typically developing individuals versus specific neurodevelopmental disorders), neuropsychological domain (e.g., executive functioning, language, motor development, social cognition), study design (longitudinal, cohort, case-control, cross-sectional), methodological approach (behavioral, neuropsychological, neuroimaging, electrophysiological, genetic, or multimodal), and developmental timing construct (developmental rate, developmental sequence, developmental synchrony/asynchrony, developmental duration, sensitive and critical periods, and developmental prediction). These analyses will be used to identify patterns of convergence, divergence, and context-specific developmental timing principles rather than to perform formal statistical comparisons.

Sensitivity analysis Formal statistical sensitivity analyses are not planned because quantitative meta-analysis is not anticipated. The robustness of the findings will be evaluated qualitatively by examining the consistency of conclusions across study designs, developmental stages, participant populations, neuropsychological domains, methodological quality, and developmental timing constructs. Particular attention will be given to whether the principal conclusions remain consistent after consideration of studies at higher versus lower risk of bias and across independent methodologies.

Language restriction Only studies published in English will be included. This restriction was adopted to ensure consistent application of the eligibility criteria, data extraction procedures, and quality assessment across all included studies.

Country(ies) involved Israel and Canada.

Other relevant information This review has been prospectively registered before commencement of the literature search and will be conducted in accordance with PRISMA 2020 and PRISMA-S reporting guidelines. The protocol specifies all major methodological procedures, including eligibility criteria, search strategy, screening, data extraction, quality assessment, and evidence synthesis, prior to review initiation.

Unlike previous reviews focusing on individual neurodevelopmental disorders or isolated developmental processes, this review adopts a cross-domain, theory-informed approach to evaluate developmental timing as a multidimensional organizing principle of human neuropsychological development. The synthesis is designed to determine whether common developmental timing principles emerge across neuropsychological domains, developmental stages, and neurodevelopmental conditions and to develop an evidence-informed integrative framework grounded in the empirical literature.

All reviewer-generated materials, including database search strategies, coding manuals, extraction templates, methodological documentation, and evidence tables, will be archived and made publicly available where appropriate to facilitate transparency, reproducibility, and future research.

Keywords Developmental timing; Neuropsychology; Neurodevelopment; Developmental neuroscience; Developmental trajectories; Brain maturation; Developmental synchrony; Sensitive periods; Neurodevelopmental disorders; Systematic review.

Dissemination plans The completed systematic review will be submitted for publication in a peer-reviewed international journal specializing in neuropsychology or developmental neuroscience. Findings will also be disseminated through presentations at national and international scientific conferences and incorporated into invited lectures and academic seminars where appropriate. The preregistered protocol, reviewer-generated methodological materials, and supplementary documentation will be made publicly available through an open-access repository to promote transparency, reproducibility, and future research. Subject to journal copyright policies, supporting materials including search strategies, coding manuals, and evidence tables will be shared to facilitate replication and secondary analyses.

Contributions of each author
Author 1 - Gerry Leisman - Conceived the review, developed the theoretical framework, designed the methodology, prepared the protocol, search strategy, data extraction and synthesis plans, will

conduct the literature review, quality assessment, evidence synthesis, manuscript preparation, and serve as guarantor for the review.
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Author 2 - Raymond Roy - Contributed to the conceptual development of the review, refinement of the research questions and methodology, critical review of the protocol, interpretation of the evidence, and will participate in manuscript revision and approval of the final publication.
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