

Exploring Mathematical Psychology: A Systematic Review with Special Reference to Neurodiversity



Irtiza Javeed¹, Azhar Mushtaq Shalla²

1: (Student, Department of Psychology, University of Kashmir)

2: (Research Scholar, Department of Psychology, University of Kashmir)

Abstract

Mathematical psychology uses formal mathematical and computational models to study cognitive phenomena such as perceptual processes, decision making, memory, learning. The present systematic review is based on 47 peer-reviewed pertaining to the period 1950 to 2026 and extracted from PsycINFO, PubMed, Web of Science, Scopus and Google Scholar databases, according to the PRISMA 2020 guidelines. The review combines two complementary streams of literature: (1) classical and contemporary mathematical psychology frameworks such as sequential sampling models, probabilistic graphical models, Bayesian inference, signal detection theory, and computational cognitive models; and

(2) an emerging literature of mathematical and computational models of neurodiversity, including autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), dyslexia, dyscalculia, and dyspraxia. Results show that fundamental cognitive processes like evidence accumulation, perceptual differentiation and memory retrieval can be consistently and formally described as differential equations, stochastic processes, and network-based processes. There are mechanistic, testable models of autism, ADHD, dyslexia and dyscalculia within predictive coding frameworks, connectome-based predictive modelling and dynamic systems approaches. These models together imply that mathematical psychology provides a principled and experimentally tractable route towards an understanding of typical and atypical cognition that is personalised on the basis of the strengths involved.

Key Words: mathematical psychology, neurodiversity, autism spectrum disorder, ADHD, dyslexia, dyscalculia, predictive coding, sequential sampling models.

Correspondence:

Azhar Mushtaq Shalla
Azharmushtaq.shalla@gmail.com



© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third-party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

Introduction

Mathematical psychology is a subfield which applies mathematical modeling and statistical procedures in the assessment and prediction of psychological phenomenon like thinking, conduct and reasoning. It strives to make use of solid mathematics to be able to quantify theoretical psychology ideas, and to bring structure and order to research findings.

The aim of this systematic review is to map and synthesize the key theoretical frameworks, empirical findings and computational approaches that have characterized mathematical psychology from 1950 to 2026 and extend this review to the field of neurodiversity by examining how mathematical and computational approaches have been applied in understanding autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), dyslexia, dyscalculia, dyspraxia and other neurodivergent conditions.

Through the lens of methods, cognition theory and meta-theoretical reflection, the history of these developments testifies to the profound intellectual tradition of our field, along with the continuous pursuit for methodological precision (Oeser, 1990; Turner, 1990; Winn, 1990). Applications are also expanding into the educational, decision making, tourism behavior and social systems domains through quantitative and multi-criteria frameworks (Jin & Park, 2019; Hinloopen & Nijkamp, 1990).

In the realm of theoretical contributions, formal modelling is emphasized as essential for advancing theory construction and directing empirical research (Navarro, 2021) while changes to preregistration procedures improve clarity and replicability across multiple contexts (Cruwell & Evans, 2021). Stabilities in individual characteristics of neurocognitive processes using evidence accumulation frameworks have been demonstrated, offering insight into transdiagnostic psychopathology vulnerabilities (Weigard & Sripada, 2020; Sripada & Weigard, 2021). Such framework has been supplemented with neurocognitive psychometric evidence that connects attentional control with its underlying neural mechanisms (Schuber et al., 2021).

The current theories are not solely within the classical framework as emerging fields of study extend from quantum and beyond-quantum models in describing complex cognitive phenomena such as question order effects and response replication ability (Sassoli de Bianchi, 2018; 2025). The empirical and theoretical studies on perception and cognition, which includes the areas of visual discrimination and perceptual learning, exemplify the confluence of both discrete and continuous models (Hughes et al., 1990; Zohary et al., 1990).

The recent developments in the field include the applications in learning processes modeled with stochastic functional equations and fixed-point methods to guarantee existence and uniqueness of psychological theoretical solutions (Turab, Ali, & Park, 2022) as well as application in applied fields such as military research via improved methodology and analytical frameworks (Biggs, 2022). In cognition measurement issues related to response latency variations (post-error slowing) and response

bias are addressed (Derrfuss et al., 2021).

Method

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The full search was conducted on several electronic databases, such as PsycINFO, PubMed, Web of Science, Scopus and Google Scholar, ranging from 1950 to 2026. The search terms were designed to reflect the essence of mathematical psychology, computational modelling, sequential sampling models, Bayesian inference, neurodevelopmental conditions such as ASD and ADHD, dyslexia, dyscalculia, dyspraxia (developmental coordination disorder) and related conditions. Titles and abstracts were screened by two independent reviewers for pre-defined inclusion criteria: English-language, peer-reviewed empirical and/or theoretical studies involving mathematical, computational or formal models, which are relevant to psychological processes or neurodivergent cognitive profiles. Studies were not included if they lacked a formal model, were not fully accessible or were duplicates. Forty-six studies were included, and summarized below in Table 1. Data were collected with a structured template that includes the author(s), year, title, method, measures and key interpretations. A complete PRISMA flow diagram, showing the number of records identified, screened, assessed for eligibility, and included can be obtained from the corresponding author by request.

Result Table 1

Synthesis of Theoretical Frameworks, Empirical Findings, Computational Methods and Neurodiversity Applications in Mathematical Psychology

<i>S.no</i>	<i>Author(s) & Year</i>	<i>Title</i>	<i>Method & Measures</i>	<i>Interpretations</i>
<i>1</i>	Ali Turab, Wajahat Ali & Choonkil Park (2022)	<i>A unified fixed-point approach to study the existence and uniqueness of solutions to the generalized stochastic functional equation emerging in the psychological theory of learning</i>	<i>In the realm of psychological learning theory, this study delved into existence and uniqueness of solutions for a particular kind of generalized stochastic functional equation. The researchers utilized a unified fixed- point approach to address these questions</i>	<i>The research successfully outlined the criteria necessary for solutions to both exist and be singular.</i>

2.	Adam T. Biggs (2022)	<i>How to enhance military research using mathematical psychology</i>	<i>The study focused on enhancing military research through the application of mathematical psychology.</i>	<i>The study explored how math-psych improves the accuracy of lethal-force decision research.</i>
3.	Jan Derrfuss, Claudia Danielmeier, Tilmann A. Klein, Adrian G. Fischer, Markus Ullsperger (2021)	<i>Unbiased post-error slowing in interference tasks: A confound and a simple solution</i>	<i>The study investigated post-error slowing in interference tasks</i>	<i>The researchers uncovered a potential issue in how this slowing is typically measured and corrected a common measurement bias in post-error slowing data</i>
4.	Sophia Crüwell, Nathan J. Evans (2021)	<i>Preregistration in diverse contexts: a preregistration template for the application of cognitive models</i>	<i>The study presented a preregistration template intended to facilitate the application of cognitive models in diverse research contexts.</i>	<i>It provides a systematic way to boost openness, & established a standard protocol for transparency in cognitive modeling.</i>
5.	Conrad Heilmann, Stefan Wintein (2021)	<i>No Envy</i>	<i>The study explored the concept of envy. It explored the concept of Axiomatic social choice theory.</i>	<i>The paper refined the math required for fair, "envy-free" resource allocation.</i>

6.	Jan Tinbergen, Conrad Heilmann, Stefan Wintein, Ruth Hinz & Erwin Dekker (2021)	<i>Mathematical Psychology</i>	<i>The study focused on mathematical psychology. It focused on mathematical psychology and discussed its theoretical aspects and applications.</i>	<i>The research paper defined the transition from logic-based to process-based psychology.</i>
7.	Danielle J. Navarro (2021)	<i>If Mathematical Psychology Did Not Exist We Might Need to Invent It: A Comment on Theory Building in Psychology</i>	<i>This paper offers a theoretical perspective and commentary, delving into conceptual discussions rather than presenting empirical findings.</i>	<i>It highlights the crucial role of formal models in sharpening our understanding of underlying assumptions, argued formal models are essential to make psychological theory falsifiable.</i>
8.	Alexander Samuel Weigard, Chandra Sripada (2020)	<i>Task-general efficiency of evidence accumulation as a computationally-defined neurocognitive trait: Implications for clinical neuroscience</i>	<i>Human participants engaged in a series of cognitive tasks by using Drift Diffusion Modeling</i>	<i>Findings indicated efficiency of evidence accumulation is a stable, task-general neurocognitive trait.</i>
9.	Anna-Lena Schuber, Christoph Löffler & Dirk Hagemann (2021)	<i>A Neurocognitive Psychometrics Account of Individual Differences in Attentional Control</i>	<i>The study involved human subjects, through their specific number and demographic details were not provided.</i>	<i>Individual differences in attentional control, a key cognitive function linked to by connecting observable cognitive performance with the brain process that support it.</i>

10.	Chandra Sripada & Alexander Weigard (2021)	<i>Impaired Evidence Accumulation as a Transdiagnostic Vulnerability Factor in Psychopathology</i>	<i>The study involved human subjects, through their specific number and demographic details were not provided. They engaged in a series of cognitive tasks by using Hierarchical DDM</i>	<i>Difficulty in gathering evidence accumulation is a cognitive trait that spans multiple psychiatric disorders</i>
11.	Mario Ferraro (1984)	<i>Characterization of discrete and continuous modes of visual pattern discrimination</i>	<i>Experimental study on visual pattern discrimination, examining discrete and continuous modes.</i>	<i>This research explored the ways people distinguish visual patterns, looking at both distinct and flowing methods of processing.</i>
12.	Massimiliano Sassoli de Bianchi (2018)	<i>Heisenberg uncertainty principle and the strange physics of spaghetti</i>	<i>The study is theoretical. It demonstrates how the Heisenberg uncertainty principle can be applied to macroscopic systems, such as spaghetti, revealing counterintuitive and “strange” physical behaviors.</i>	<i>Quantum principles, when viewed through the right lens, can actually shed light on the things we experience everyday.</i>
14.	Yanchun Jin & Yoonseo Park (2019)	<i>An Integrated Approach to Determining Rural Tourist Satisfaction Factors Using the IPA and Conjoint Analysis</i>	<i>The study used quantitative data and employed two analytical techniques, Importance-Performance Analysis (IPA) and conjoint analysis to identify factors influencing rural tourist satisfaction.</i>	<i>The key findings indicate which attributes most strongly affect among rural tourists and these methods can guide targeted improvements in rural tourism services.</i>

15.	Cumming, G., Self, J. (1990)	<i>Intelligent educational systems: identifying and decoupling the conversational levels</i>	<i>The theoretical background research exploring intelligent educational systems by analyzing and decoupling conversational levels.</i>	<i>The key interpretation is that understanding these levels can enhance the design and effectiveness of educational systems.</i>
16.	David Sloan Wilson (1990)	<i>Species of thought: A comment on evolutionary epistemology</i>	<i>This research paper offers the theoretical perspective and commentary on evolutionary epistemology, discussing how different "species" of thought can be understood from an evolutionary perspective.</i>	<i>The key interpretation is that cognitive processes and knowledge structures can be analyzed through evolutionary principles to better understand human reasoning.</i>
17.	Erhard Oeser (1990)	<i>The evolution of scientific methods</i>	<i>This theoretical research study discusses the development and evolution of scientific methods over time</i>	<i>The historical progression of scientific methodologies can inform the design and improvement of current research practices.</i>
18.	Chandler, M. (1990)	<i>Attitudes, leprechauns and neutrinos: The ontology of behavioral science</i>	<i>This theoretical research paper explores the ontology of behavioral science, examining the conceptual foundations of attitudes and phenomena in psychology.</i>	<i>It involved careful analysis of underlying assumptions is essential for coherent and rigorous behavioral science research.</i>

19.	Markl, P. (1990)	<i>Evolutionary epistemology, realism and analytical chemistry</i>	<i>This paper revolves on theoretical perspective delving evolutionary epistemology and its relation to realism in the context of analytical chemistry.</i>	<i>The application of evolutionary epistemology can enhance better understanding and development of scientific knowledge in chemistry.</i>
20.	Winn, W. (1990)	<i>Some implications of cognitive theory for instructional design</i>	<i>The theoretical study discussing implications of cognitive theory for instructional design.</i>	<i>The key findings provided insights from cognitive theory can guide the development of more effective instructional strategies and learning environments.</i>
21.	Hinloopen, E., Nijkamp, P. (1990)	<i>Qualitative multiple-criteria choice analysis</i>	<i>The qualitative research represents a multiple-criteria choice analysis framework.</i>	<i>This approach viewed decision-making by systematically evaluating options across multiple qualitative criteria.</i>
22.	Kuehn, P.A., Stallings, W.M. & Holland, C.L. (1990)	<i>Teacher licensure test job analysis response by gender, race, and age: Secondary science and mathematics</i>	<i>The numerical study analyzing job analysis responses for teacher licensure tests across gender, race, and age groups in secondary science and mathematics.</i>	<i>The research findings suggested unique responses based on these demographic variables, and such differences ensured fairness and validity in licensure testing.</i>

23.	Turner, J.H. (1990)	<i>The misuse and use of metatheory.</i>	<i>The theoretical research study discusses the proper and improper uses of metatheory in sociology.</i>	<i>When employing metatheory, it's crucial to wield it as a tool for sharpening, unifying, and propelling theoretical understanding forward.</i>
24.	Griffiths, M.D. (1990)	<i>The cognitive psychology of gambling</i>	<i>The theoretical research study involves cognitive processes involved in gambling behavior.</i>	<i>The key findings suggested gamblers' beliefs, biases, and cognitive distortions play a central role in gambling behavior and problem gambling.</i>
25.	Hughes, B., Epstein, W., Schneider, S. et al. (1990)	<i>An asymmetry in trans-modal perceptual learning</i>	<i>The study used numerical data by examining trans-modal perceptual learning and identified an asymmetry in learning across sensory modalities.</i>	<i>It suggested that learning does not transfer equally between different perceptual modalities, suggesting modality-specific constraints on perceptual learning.</i>
26.	Marini, M.M. (1990)	<i>Sex and gender: What do we know?</i>	<i>The research study based on theoretical background pin-pointing reviews and discusses knowledge about sex and gender.</i>	<i>The key findings suggested that sex and gender are distinct concepts with complex social, biological, and psychological dimensions that must be carefully differentiated in sociological research.</i>

27.	Zohary, E., Hillman, P. & Hochstein, S. (1990)	<i>Time course of perceptual discrimination and single neuron reliability</i>	<i>The study used quantitative data. It examined the time course of perceptual discrimination in relation to the reliability of single neuron responses.</i>	<i>The research indicate a relationship between neuronal reliability and perceptual performance, and the interpretation is that Single-neuron response reliability constrains the speed of perceptual choice.</i>
28.	Menn, S. (1990)	<i>Descartes and some predecessors on the divine conservation of motion</i>	<i>The study is theoretical. It analyzes Descartes' and earlier philosophers' views on the divine conservation of motion.</i>	<i>The interpretation of early modern accounts of motion were deeply connected to theological assumptions about divine action in the natural world.</i>
29.	Dill, M., Fahle, M. (1998)	<i>Limited translation invariance of human visual pattern recognition</i>	<i>The study used quantitative data. It examined visual pattern recognition</i>	<i>The research findings involved visual recognition is not fully position-invariant but rather limited translation invariance and is constrained by spatial location.</i>
30.	Ruffell, M., Mason, J. & Allen, B. (1998)	<i>Studying attitude to mathematics.</i>	<i>The study used quantitative data. It examined attitudes toward mathematics and how they can be studied and measured.</i>	<i>Findings revealed that students' attitudes toward mathematics are an important factor influencing engagement and learning in mathematics education.</i>

31.	Levy, S. (1998)	<i>A Typology of Partial-Order: The Case of Drug Use in Israel</i>	<i>The study used qualitative data. It developed a typology of partial-order relationships to analyze patterns of drug use in Israel.</i>	<i>partial-order methods can reveal structured patterns in complex social behaviors such as drug use.</i>
32.	Barrouillet, P., Fayol, M. (1998)	<i>From algorithmic computing to direct retrieval: Evidence from number and alphabetic arithmetic in children and adults.</i>	<i>The study used quantitative data. It examined number and alphabetic arithmetic in children and adults and found a shift from algorithmic computation to direct memory retrieval with development and expertise.</i>	<i>The cognitive processing in arithmetic becomes faster and more automatic as knowledge is consolidated.</i>
33.	Hartman, H.J. (1998)	<i>Metacognition in teaching and learning: An introduction.</i>	<i>The study is theoretical. It introduces the concept of metacognition in teaching and learning.</i>	<i>The awareness and regulation of one's own thinking processes are essential for effective learning and instruction.</i>
34.	Walliser, B. (1998)	<i>A spectrum of equilibration processes in game theory.</i>	<i>The study is theoretical. It analyzes different equilibration processes in game theory.</i>	<i>The multiple dynamic paths can lead to equilibrium, and understanding these processes is crucial for modelling strategic behavior.</i>

35.	Breckir, N.J. (1950)	<i>Hospital orientation and training program for group psychotherapy of schizophrenic patients.</i>	<i>The study used qualitative data. It described and evaluated a hospital orientation and training program designed for group psychotherapy with schizophrenic patients.</i>	<i>The structured orientation and training can support the effective implementation of group psychotherapy in hospital settings.</i>
36.	Cottle, W.C. (1950)	<i>A factorial study of the multiphasic, strong, kuder, and bell inventories using a population of adult males</i>	<i>The study used quantitative data. It conducted a factorial analysis of several psychological inventories in a population of adult males.</i>	<i>The underlying factor structures across the inventories, and the interpretation is that these instruments measure overlapping psychological dimensions.</i>
37.	Thomas, A.K. (2023)	<i>Memory and cognition: shifting approaches to how we do science.</i>	<i>The study is theoretical. It discusses changing approaches in memory and cognition research.</i>	<i>The key interpretation is that the field is moving toward more open, integrative, and methodologically diverse scientific practices.</i>
38.	Garg, M. (2023)	<i>Mental Health Analysis in Social Media Posts: A Survey.</i>	<i>The study is theoretical. It surveys methods for analyzing mental health through social media posts.</i>	<i>The key interpretation is that computational techniques can provide insights into mental health trends and patterns from online data.</i>

39.	Adamou, Kehagias & Antoniou (2026)	<i>A multi-scale mathematical framework for modelling the dynamic nature of autism spectrum disorder symptoms: integrating predictive coding, information theory, and network principles</i>	<i>Theoretically derived algebraic and differential equations modelling seven core ASD symptom domains using predictive coding, information theory, and network neuroscience. No empirical data collected; parameter ranges derived from existing literature.</i>	<i>ASD symptoms are reframed as adaptive neurobiological responses. Dynamic equations generate testable predictions and identify individualised intervention targets, advancing beyond static DSM-5 descriptions.</i>
40.	Adamou, Kehagias & Antoniou (2026)	<i>A mathematical framework for modelling the dynamic nature of ADHD symptoms</i>	<i>Theory-driven algebraic equations modelling inattention as exponential decay, hyperactivity as a sinusoidal oscillatory function, and impulsivity via hyperbolic delay discounting with a softmax choice rule.</i>	<i>Dynamic, context-dependent models capture ADHD symptom variability beyond static diagnostic criteria, providing parameter-level intervention targets and supporting neurodiversity-affirming clinical formulation.</i>
41.	Maiella et al. (2025)	<i>A statistical learning-based clustering model with feature selection to identify dyslexia in school-aged children</i>	<i>Model-based clustering using finite mixtures of contaminated Gaussian distributions applied to cognitive profile data of 122 Polish children (51 with dyslexia), with integrated variable selection to identify clinically relevant cognitive skills.</i>	<i>Probabilistic multi-deficit modelling outperforms traditional univariate methods, capturing the heterogeneous cognitive profile of dyslexia and enabling more accurate, data-driven identification of children who require support.</i>
42.	Lanillos et al. (2019)	<i>A review on neural network models of schizophrenia and autism spectrum disorder</i>	<i>Systematic review of artificial neural network and computational models (predictive coding, Bayesian, reinforcement learning) applied to ASD and schizophrenia; evaluates model architectures and their neurobiological plausibility.</i>	<i>Mathematical neural network models successfully capture key features of ASD symptomatology; Bayesian and predictive coding architectures provide the most mechanistically coherent accounts, supporting theory-driven computational psychiatry.</i>

43.	Noel & Angelaki (2023)	<i>A theory of autism bringing across levels of description</i>	<i>Multi-level theoretical framework integrating computational, algorithmic, and implementational levels of description (after Marr) to provide a unified account of autism across sensory, motor, social, and cognitive domains.</i>	<i>Applying Marr's three-level framework to autism creates a principled, testable theoretical architecture; the computational level reframes autistic traits as arising from altered priors rather than deficits, directly consonant with neurodiversity principles.</i>
44.	Wertheimer & Hart (2024)	<i>Autism spectrum disorder variation as a computational trade-off via dynamic range of neuronal population responses</i>	<i>Mathematical modelling of neuronal population dynamic range as a computational trade-off axis; shows that ASD variation emerges from altered signal-to-noise ratios in neural population responses, quantified via information-theoretic and dynamical systems frameworks.</i>	<i>ASD traits are reframed as mathematically quantifiable computational trade-offs in neural coding efficiency; this directly supports a neurodiversity-affirming view in which autistic variation reflects an alternative optimisation strategy rather than a deficit.</i>
45.	Keyesers, Silani & Gazzola (2024)	<i>Predictive coding for the actions and emotions of others and its deficits in autism spectrum disorders</i>	<i>Theoretical review applying predictive coding mathematics to social cognition; models how precision-weighted prediction errors for others' actions and emotions are aberrant in ASD, integrating mirror neuron system evidence.</i>	<i>Predictive coding mathematically explains social-emotional atypicalities in ASD via aberrant precision-weighting; social differences are reframed as arising from altered generative models rather than empathy deficits, aligning with neurodiversity perspectives.</i>

46.	Khan & Chourasiya (2025)	<i>NAPIFASD: Design of an iterative neuroadaptive multimodal framework for predictive modelling, subtype discovery, and intervention simulation in autism spectrum disorders</i>	<i>Iterative neuroadaptive computational framework integrating predictive modelling, unsupervised subtype discovery, and simulation of intervention outcomes across multimodal ASD data sources.</i>	<i>The framework advances ASD modelling by combining predictive, subtyping, and simulation capabilities; mathematical personalisation of intervention pathways supports neurodiversity-affirming, data-driven clinical decision-making.</i>
-----	-------------------------------------	--	--	---

As per Table 1, integrating the theories and models of mathematical psychology such as the probabilistic modeling approach, sequential sampling models, the framework of memory and the various theories of perception, provide a coherent view of how the brain perceives, makes decisions and remembers when facing uncertainties, time limits, or structures information in a certain order. The conclusions from these models suggest that perception, memory and decision-making can all be described mathematically and then tested empirically.

Keeping the mathematical approach to psychology, Adamou, Kehagias, and Antoniou (2026) turn to the field of neurodiversity directly, with the two complementary papers of mathematical models of ASD both proposing a multi-scale framework for mathematical models of ASD, using predictive coding, information theory, and network neuroscience, and proposing a complementary framework for mathematical models of ADHD, where inattention is modelled as an exponential decay function, hyperactivity as a sinusoidal oscillatory function, and impulsivity as a hyperbolic delay discounting function, each generating testable, parameter-level predictions, rather than static categorical descriptions. Maiella et al. (2025) apply this modelling logic to dyslexia by introducing a probabilistic model-based clustering technique based on contaminated Gaussian mixture distributions, which yields better results than the traditional univariate diagnostic techniques in representing the cognitive profile of dyslexic children as a mixture of different profiles. Lanillos et al. (2019) systematically review neural network and Bayesian computational models of ASD, demonstrating that predictive coding and active inference models are among the most plausible formal models of autistic cognition, given their neurobiological plausibility. In contrast, Noel and Angelaki (2023) adopt a distinctly theoretical approach, and using Marr's three-level computational framework for autism, they argue that the autism traits are not due to impaired mechanisms per se, but rather to altered priors and generative models, a position that is more in keeping with a neurodiversity-affirming interpretation. In their paper published in Nature Neuroscience, Wertheimer and Hart (2024) formalise ASD variation as a mathematically defined computational trade-off in the dynamic range of neuronal population responses, and

demonstrate that autistic neural coding is an alternative optimisation strategy. Keyzers, Silani, and Gazzola (2024) use precision-weighted predictive coding to introduce a new perspective on social cognition, viewing social-emotional differences in ASD as differences in generative models, not differences in empathy. Last, Khan and Chourasiya (2025) introduce an iterative neuroadaptive multimodal framework, NAPIFASD, that combines predictive modelling, unsupervised subtype discovery and intervention simulation to illustrate the use of mathematical personalisation to aid the clinical process of neurodiversity-affirming clinical decisions.

Analyzing the sequential sampling models and especially the Diffusion Decision Model (DDM) developed by Ratcliff (1978) and Ratcliff & McKoon (2008), one can see that decisions are not instantaneous but a process in which the organism accumulates noisy evidences through time to reach the decision criterion. This explains why both RT and accuracy vary in the case of two choices. Extensions of the DDM like the linear ballistic accumulator (LBA) model (Brown & Heathcote, 2008) which offers a deterministic description, or the leaky competing accumulator (LCA) model (Usher & McClelland, 2001) which includes the competition and decaying process and thus more biological plausibility are further indications that decision-making is dynamic, probabilistic and sensitive to some extent to the subject and the task.

On a more global scale, probabilistic graphical models (Koller & Friedman, 2009; Baum et al., 2011) offer a framework in which perception and decision-making is viewed as Bayesian inference over latent variables given observations. Here the organism attempts to learn some underlying structure based on the data it observes, and is represented as a probability computation system, constantly updating its beliefs about the latent state of the world based on past knowledge and present observations. In this sense, accumulation of evidence in the sequential sampling models can be understood as the organism's ability to make probability computations when updating beliefs under some certain criteria. Therefore, decision-making and perception, unlike separated processing units, are not separate abilities but are closely integrated with the probability modeling approach.

The framework of memory further supports this integration. Baddeley & Hitch's (1974) model of working memory emphasizes parallel processing in the phonological loop and visuo-spatial sketchpad. Such architecture can be linked to simultaneous processing in many units when making a decision as stated by other models above, which increase efficiency. Meanwhile, associative memory organization developed by Mandler (1972) shows that in memory, information is stored in networks based on serial, systematic and semantic relationships. The structures generated can influence the speed of recall and consequently improve performance when acquiring the stimuli or utilizing existing knowledge for decision-making.

Empirical research on organizational and mnemonic strategies also lends credence to the notion. Memory techniques like the method of hierarchy (Bower et al., 1969), first-letter mnemonic (Herrmann et al., 2002) and narrative method all demonstrated better memory performances by imposing a more

systematic way in learning materials. From the mathematical psychology view, they represent mechanisms that increase the drift rate, reduce the noise of information in the sequential sampling models, and thus speed up the decision process. It further implies that memory mechanisms might directly impact decision-making processes by improving the quality of the evidences available to the accumulator.

Theories of perception are also amenable to mathematical treatment. Pandemonium model of perception by Selfridge (1959) suggests that perception is achieved through hierarchical features detection and different features are detected simultaneously. This is parallel to the parallel processing theory and is also similar to current computational methods including neural network models. For example, the Moon Illusion study by Kaufman & Kaufman (2000) and Ross & Plug (2002) suggests that humans are able to infer the distance information from context which can lead to decision-making about the apparent size of the moon, based on computational processes integrating sensory information with external clues. Bregman's Auditory Scene Analysis (ASA) (1990) suggests that even in the sound world, auditory signals with similarities and proximities can be grouped together into different streams through different grouping principles like similarity and proximity and this grouping principle could be explained in a probability modeling sense as some clustering algorithm or dynamic system in probability.

Discussion:

The debate about analytical and synthetic thinking (Bartlett, 2001) can be understood in one more level. Analytical thinking is characterized by decomposing complex systems into simpler components, a parallel process with mathematical breakdown of the cognition process into variables such as drift rate, threshold and noise. Synthetical thinking, however emphasizes on synthesis and understanding the whole picture by the interaction among components, the behavior of the system which is modelled by system-level approach. Both two kinds of thinking are crucial in mathematical psychology as they can contribute to balance the rigor with the nature of cognition.

Several general themes are evident from the above discussion: 1. Cognitive processes are probabilistic; individuals often make judgments and decisions in the absence of full knowledge. 2. Cognitive processes are dynamic and context-dependent in time, as shown in sequential sampling and auditory processing systems. 3. Cognition processes are hierarchical, organized from bottom-up with hierarchy structure, association memories, and parallelism at different levels of processing or different subsystems. 4. Cognition domains are highly interconnected. Decision-making depends on memory and perception, and vice versa.

The findings from the neurodiversity studies, which are summarised in Table 1, significantly add to the discussion in a number of ways. First, they show that the tools of mathematical psychology, such as differential equations, stochastic processes, Bayesian inference, and network-theoretic measures, are not limited to neurotypical cognition, but are equally rigorous to apply to neurodivergent profiles. The

predictive coding and active inference models applied to ASD by Arthur et al. (2023) and Keyzers et al. (2024) share the same basic principles of Bayesian inference that have been adopted in the study of perceptual decision making. The principles of Bayesian inference that are applied to ASD by Arthur et al. (2023) and Keyzers et al. (2024) are the same ones that are applied in the study of typical perceptual decision making, indicating a close theoretical connection between the study of typical cognition and neurodevelopmental variation. Secondly, the studies collectively raise the question of the deficit nature of mathematical formalisation. In all three treatments of ASD variation as a computational trade-off (Wertheimer & Hart, 2024), Marrian reframing of autistic priors (Noel & Angelaki, 2023). The mathematical framework here is conceptually similar to the perspective of signal detection theory, which treats perceptual errors as reasonable responses to a criterion, rather than as mistakes. Finally, these results have practical implications: the parameters of the sequential sampling model, which correspond to drift rate and boundary separation, are individual targets for cognitive interventions, while the

parameters of the neurodiversity-focused models, which are precision-weighting coefficients, excitation–inhibition ratios and network connectivity indices, are individual targets for support or accommodation. Mathematical psychology is therefore not just a science of average cognition but a structure which can also respect the whole range of human cognitive diversity. There are implications from models of cognitive integration to behavior. Different models parameters such as drift rate or threshold can be applied to model variability in decision-making, and these parameters might be associated with attention, memory, or context. In perceptual system, the occurrence of illusions or biases can be viewed as a rational process that assumes underlying probabilistic nature of perceptual system given certain environmental factors

Conclusion:

Mathematical psychology allows for a deep exploration of human cognition by synthesizing theoretical frameworks with real-world data. Sequential sampling models explain cognition at a dynamic level, capturing how decision processes unfold over time, while probabilistic graphical models explore the complex realm of uncertainty and reasoning. Furthermore, detailed cognitive models such as the theory of working memory, the nature of associative organization, and models of visual processing illustrate how knowledge is represented and manipulated. Together, these efforts provide strong evidence against the view that cognition depends solely on pure intuition. Instead, they demonstrate how our decisions, perceptions, and memories follow structured, calculable processes.

As evidenced by the Diffusion Decision Model, probabilistic inference, Baddeley's working memory model, and Marr's theory of vision, cognition is best understood as a multi-level system that is inherently probabilistic, dynamic, and interactive. This knowledge is not only vital for the advancement

of cognitive theory but also offers significant promise for the future of artificial intelligence, neuroscience, and human-computer interaction. In the end, cognition may be viewed as a sophisticated information-processing system. Its operations are simple enough to allow for the simulation of complex processes like memory and perception, yet deep enough to provide the essential foundation for human intelligence and the resilient architecture of the soul.

Future Directions:

When we look at the history of mathematical psychology from 1950 to 2025, we see a brilliant "Invisible Architecture" that has been built largely within the quiet, controlled walls of laboratories. However, a significant research gap appears when we try to apply these elegant formulas to the loud, chaotic reality of everyday life. We have a deep understanding of how the mind processes information in a vacuum, but we lack evidence of how these "calculable processes" hold up when a young person is navigating the weight of "hustle culture" or the moral gray areas of modern society. The math tells us how the gears of the mind turn ($dX_i = vdt + \sigma dW_i$), but it remains silent on the human weight of those turns. We do not yet fully understand how a youth's internal decision-making is reshaped by the constant pressure to perform or the digital noise of their social landscape.

To move forward, future directions in this field must strive to bridge the distance between abstract equations and the actual lived experience. First, we must stop looking at youth as static data points and instead follow their journey over time. By applying our models to the lives of young people as they grow, we can see how their ability to gather evidence and make choices stabilizes or changes during the most important milestones of their lives. Second, we must use our growing knowledge of Artificial Intelligence not just to simulate thoughts, but to protect them. Future research should explore how social media environments interact with our "hierarchical" brain processes, helping us design digital spaces that support, rather than overwhelm, the human spirit. By expanding our research to include these diverse, real-world stories, we ensure that our mathematical models serve as a true reflection of the "Invisible Architecture" of the soul.

References:

- Adamou M, Kehagias A and Antoniou G (2026) A multi-scale mathematical framework for modelling the dynamic nature of autism spectrum disorder symptoms: integrating predictive coding, information theory, and network principles. *Front. Psychiatry* 17:1787120. <https://doi.org/10.3389/fpsyt.2026.1787120>
- Adamou M, Kehagias A and Antoniou G (2026) A mathematical framework for modelling the dynamic nature of ADHD symptoms. *Front. Psychiatry* 16:1671764. <https://doi.org/10.3389/fpsyt.2025.1671764>
- Aerts, D., Arguëlles, J. A., Beltran, L., Geriente, S., Sassoli de Bianchi, M., Sozzo, S., & Tomasini, I. (2018). Beyond-quantum modeling of question order effects and response replicability in

- psychological measurements. *Journal of Mathematical Psychology*, 82, 135–147.
<https://doi.org/10.1016/j.jmp.2017.11.002>
- Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 47–89). Academic Press.
- Barrouillet, P., & Fayol, M. (1998). From algorithmic computing to direct retrieval: Evidence from number and alphabetic arithmetic in children and adults. *Memory & Cognition*, 26(2), 355–368.
<https://doi.org/10.3758/BF03201146>
- Biggs, A. T. (2022). How to enhance military research using mathematical psychology. *Journal of Mathematical Psychology*, 106, 102619. <https://doi.org/10.1016/j.jmp.2021.102619>
- Breckir, N.J. Hospital orientation and training program for group psychotherapy of schizophrenic patients. *Psych Quar* 24, 131–143 (1950).
<https://doi.org/10.1007/BF01813028>
- Bregman, A. S. (1990). *Auditory scene analysis: The perceptual organization of sound*. MIT Press.
- Chandler, M. Attitudes, leprechauns and neutrinos: The ontology of behavioral science. *Philosophical Studies* 60, 5–17 (1990). <https://doi.org/10.1007/BF00370972>
- Cottle, W.C. A factorial study of the multiphasic, strong, kuder, and bell inventories using a population of adult males. *Psychometrika* 15, 25–47 (1950). <https://doi.org/10.1007/BF02289176>
- Crüwell, S., & Evans, N. J. (2021). Preregistration in diverse contexts: A preregistration template for the application of cognitive models. *Royal Society Open Science*, 8(10), 210155.
<https://doi.org/10.1098/rsos.210155>
- Cumming, G., & Self, J. (1990). Intelligent educational systems: Identifying and decoupling the conversational levels. *Instructional Science*, 19(1), 11–27.
<https://doi.org/10.1007/BF00377983>
- Derrfuss, J., Danielmeier, C., Klein, T. A., Fischer, A. G., & Ullsperger, M. (2021). Unbiased post-error slowing in interference tasks: A confound and a simple solution. *Behavior Research Methods*.
<https://doi.org/10.3758/s13428-021-01673-8>
- De Bianchi, M. S. (2018). Heisenberg uncertainty principle and the strange physics of spaghetti. *AutoRicerca*, 19, 135–193.
- Dill, M., & Fahle, M. (1998). Limited translation invariance of human visual pattern recognition. *Perception & Psychophysics*, 60(1), 65–81.
<https://doi.org/10.3758/BF03211918>
- Ferraro, M., Foster, D.H. Characterization of discrete and continuous modes of visual pattern discrimination. *Biol. Cybern.* 50, 9–13 (1984). <https://doi.org/10.1007/BF00317935>
- Garg, M. Mental Health Analysis in Social Media Posts: A Survey. *Arch Computat Methods Eng* 30, 1819–1842 (2023). <https://doi.org/10.1007/s11831-022-09863-z>

- Griffiths, M. D. (1990). The cognitive psychology of gambling. *Journal of Gambling Studies*, 6, 31–42.
<https://doi.org/10.1007/BF01015747>
- Hartman, H. J. (1998). Metacognition in teaching and learning: An introduction. *Instructional Science*, 26, 1–3. <https://doi.org/10.1023/A:1003023628307>
- Heilmann, C., & Wintein, S. (2021). No envy. *Erasmus Journal for Philosophy and Economics*, 14(1), 1–13. <https://doi.org/10.23941/ejpe.v14i1.610>
- Hinloopen, E., & Nijkamp, P. (1990). Qualitative multiple-criteria choice analysis. *Quality & Quantity*, 24, 37–56. <https://doi.org/10.1007/BF00221383>
- Hughes, B., Epstein, W., & Schneider, S. (1990). An asymmetry in transmodal perceptual learning. *Perception & Psychophysics*, 48, 143–150.
<https://doi.org/10.3758/BF03207081>
- Jin, Y., & Park, Y. (2019). An Integrated Approach to Determining Rural Tourist Satisfaction Factors Using the IPA and Conjoint Analysis. *International Journal of Environmental Research and Public Health*, 16(20), 3848. <https://doi.org/10.3390/ijerph16203848>
- Keyzers, C., Silani, G., & Gazzola, V. (2024). Predictive coding for the actions and emotions of others and its deficits in autism spectrum disorders.. *Neuroscience and biobehavioral reviews*, 105877 .
<https://doi.org/10.1016/j.neubiorev.2024.105877>.
- Khan, S., & Chourasiya, A. (2025). NAPIFASD: Design of an Iterative Neuroadaptive Multimodal Framework for Predictive Modeling, Subtype Discovery, and Intervention Simulation in Autism Spectrum Disorders. *International Journal of Latest Technology in Engineering Management & Applied Science*.
<https://doi.org/10.51583/ijltemas.2025.1409000074>.
- Koller, D., & Friedman, N. (2009). *Probabilistic graphical models: Principles and techniques*. MIT Press.
- Kuehn, P.A., Stallings, W.M. & Holland, C.L. (1990). Teacher licensure test job analysis response by gender, race, and age: Secondary science and mathematics. *J Pers Eval Educ* 3, 151–167.
<https://doi.org/10.1007/BF00125253>
- Lanillos, P., Oliva, D., Philippsen, A., Yamashita, Y., Nagai, Y., & Cheng, G. (2019). A Review on Neural Network Models of Schizophrenia and Autism Spectrum Disorder. *Neural networks : the official journal of the International Neural Network Society*, 122, 338-363 .
<https://doi.org/10.1016/j.neunet.2019.10.014>.
- Levy, S. (1998). A typology of partial-order: The case of drug use in Israel. *Quality & Quantity*, 32, 1–13. <https://doi.org/10.1023/A:1004229124947>
- Maiella, M., M.Benedetti, P.Alaimo Di Loro, and A.Maruotti. 2025. “A Statistical Learning-Based Clustering Model With Features Selection to Identify Dyslexia in School-Aged Children.”

- Dyslexia31, no. 4: e70013. <https://doi.org/10.1002/dys.70013>
- Marini, M. M. (1990). Sex and Gender: What Do We Know? *Sociological Forum*, 5(1), 95–120. <http://www.jstor.org/stable/684583>
- Markl, P. Evolutionary epistemology, realism and analytical chemistry. *Fresenius J Anal Chem* 337, 168–171 (1990). <https://doi.org/10.1007/BF00322391>
- Menn, S. Descartes and some predecessors on the divine conservation of motion. *Synthese* 83, 215–238 (1990). <https://doi.org/10.1007/BF00413758>
- Navarro, D. J. (2021). If mathematical psychology did not exist we might need to invent it: A comment on theory building in psychology. *Perspectives on Psychological Science*, 16(4), 707–730. <https://doi.org/10.1177/1745691620974769>
- Noel, J., & Angelaki, D. (2023). A theory of autism bringing across levels of description.. *Trends in cognitive sciences*. <https://doi.org/10.1016/j.tics.2023.04.010>
- Oeser, E. (1990) The evolution of scientific methods. *Fresenius J Anal Chem* 337, 150–154. <https://doi.org/10.1007/BF00322387>
- Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review*, 85(2), 59–108. <https://doi.org/10.1037/0033-295X.85.2.59>
- Ratcliff, R., & McKoon, G. (2008). The diffusion decision model: Theory and data for two-choice decision tasks. *Neural Computation*, 20(4), 873–922. <https://doi.org/10.1162/neco.2008.12-06-420>
- Ruffell, M., Mason, J., & Allen, B. (1998). Studying attitude to mathematics. *Educational studies in Mathematics*, 35, 1–18. <https://doi.org/10.1023/A:1003019020131>
- Schuber, A.-L., Löffler, C., & Hagemann, D. (2021). A neurocognitive psychometrics account of individual differences in attentional control. *PsyArXiv*. <https://doi.org/10.31234/osf.io/vj7eb>
- Sripada, C., & Weigard, A. (2021). Impaired evidence accumulation as a transdiagnostic vulnerability factor in psychopathology. *Frontiers in Psychiatry*, 12, 627179. <https://doi.org/10.3389/fpsy.2021.627179>
- Thomas, A. K. (2023). Memory and cognition: Shifting approaches to how we do science. *Memory & Cognition*, 51, 1–3. <https://doi.org/10.3758/s13421-023-01395-6>
- Tinbergen, J., Heilmann, C., Wintein, S., Hinz, R., & Dekker, E. (2021). Mathematical psychology. *Erasmus Journal for Philosophy and Economics*, 14(1), 226–243. <https://doi.org/10.23941/ejpe.v14i1.607>
- Turab, A., Ali, W., & Park, C. (2022). A unified fixed-point approach to study the existence and uniqueness of solutions to the generalized stochastic functional equation emerging in shie psychological theory of learning. *AIMS Mathematics*, 7(4), 5291–5304.

<https://doi.org/10.3934/math.2022294>

- Turner, J. H. (1990). The Misuse and Use of Metatheory. *Sociological Forum*, 5(1), 37–53.
<http://www.jstor.org/stable/684580>
- Walliser, B. (1998). A spectrum of equilibration processes in game theory. *Journal of Evolutionary Economics*, 8, 67–87. <https://doi.org/10.1007/s001910050056>
- Weigard, A. S., & Sripada, C. (2020). Task-general efficiency of evidence accumulation as a computationally-defined neurocognitive trait: Implications for clinical neuroscience. *PsyArXiv*.
<https://doi.org/10.31234/osf.io/q9hge>
- Wertheimer, O., & Hart, Y. (2024). Autism spectrum disorder variation as a computational trade-off via dynamic range of neuronal population responses. *Nature Neuroscience*, 27, 2476 - 2486.
<https://doi.org/10.1038/s41593-024-01800-6>.
- Wilson, D.S. Species of thought: A comment on evolutionary epistemology. *Biol Philos* 5, 37–62 (1990). <https://doi.org/10.1007/BF02423832>
- Winn, W. (1990). Some implications of cognitive theory for instructional design. *Instructional Science*, 19, 53–69. <https://doi.org/10.1007/BF00377985>
- Zohary, E., Hillman, P., & Hochstein, S. (1990). Time course of perceptual discrimination and single neuron reliability. *Biological Cybernetics*, 62, 475–486. <https://doi.org/10.1007/BF00205109>