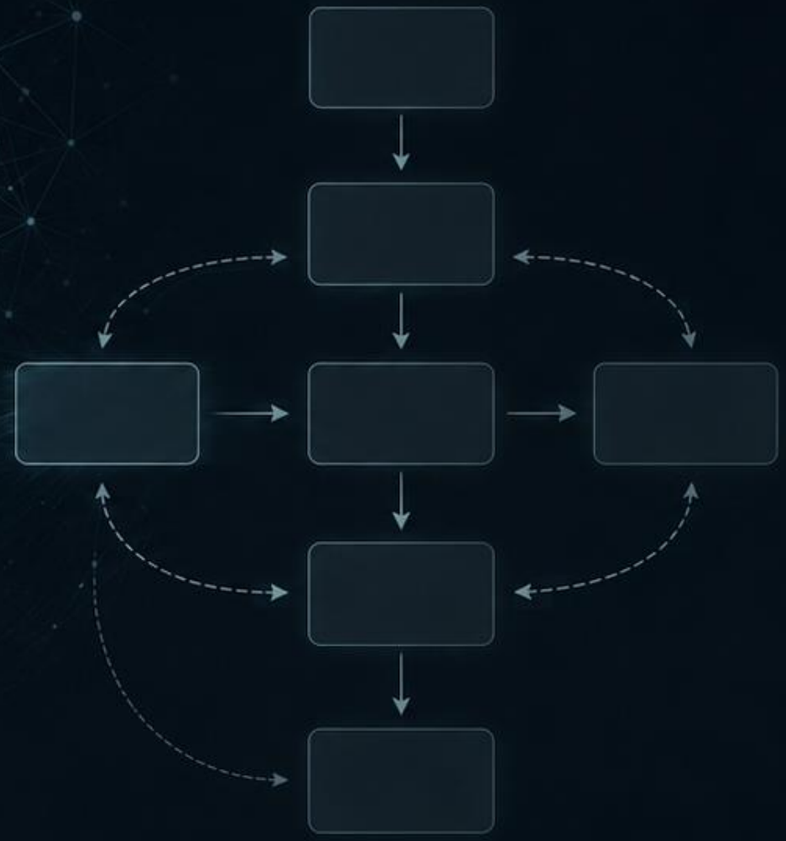
Enhancing Clinical Reasoning Using AI and Formulation Diagrams

Dr Chris Ludlow

Lecturer in Psychology
Deputy Clinic Director, Swinburne Psychology Clinic
Swinburne University of Technology



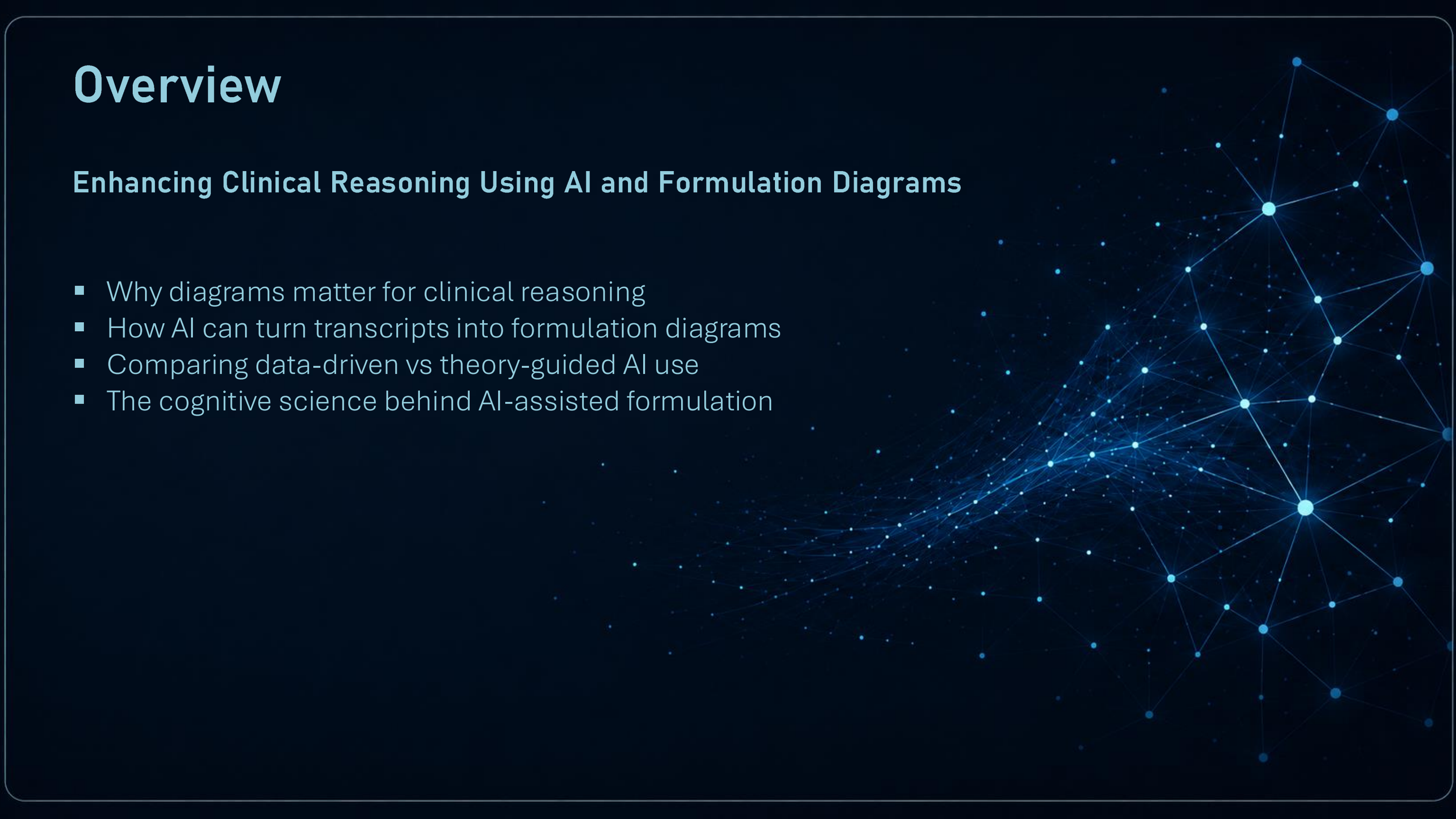
Acknowledgement of Country

I acknowledge the **Wurundjeri People of the Kulin Nation**, the Traditional Owners of the land from which I am presenting, and pay respects to Elders past and present. I also acknowledge the Traditional Owners of the lands from which others join today.

Overview

Enhancing Clinical Reasoning Using AI and Formulation Diagrams

- Why diagrams matter for clinical reasoning
- How AI can turn transcripts into formulation diagrams
- Comparing data-driven vs theory-guided AI use
- The cognitive science behind AI-assisted formulation

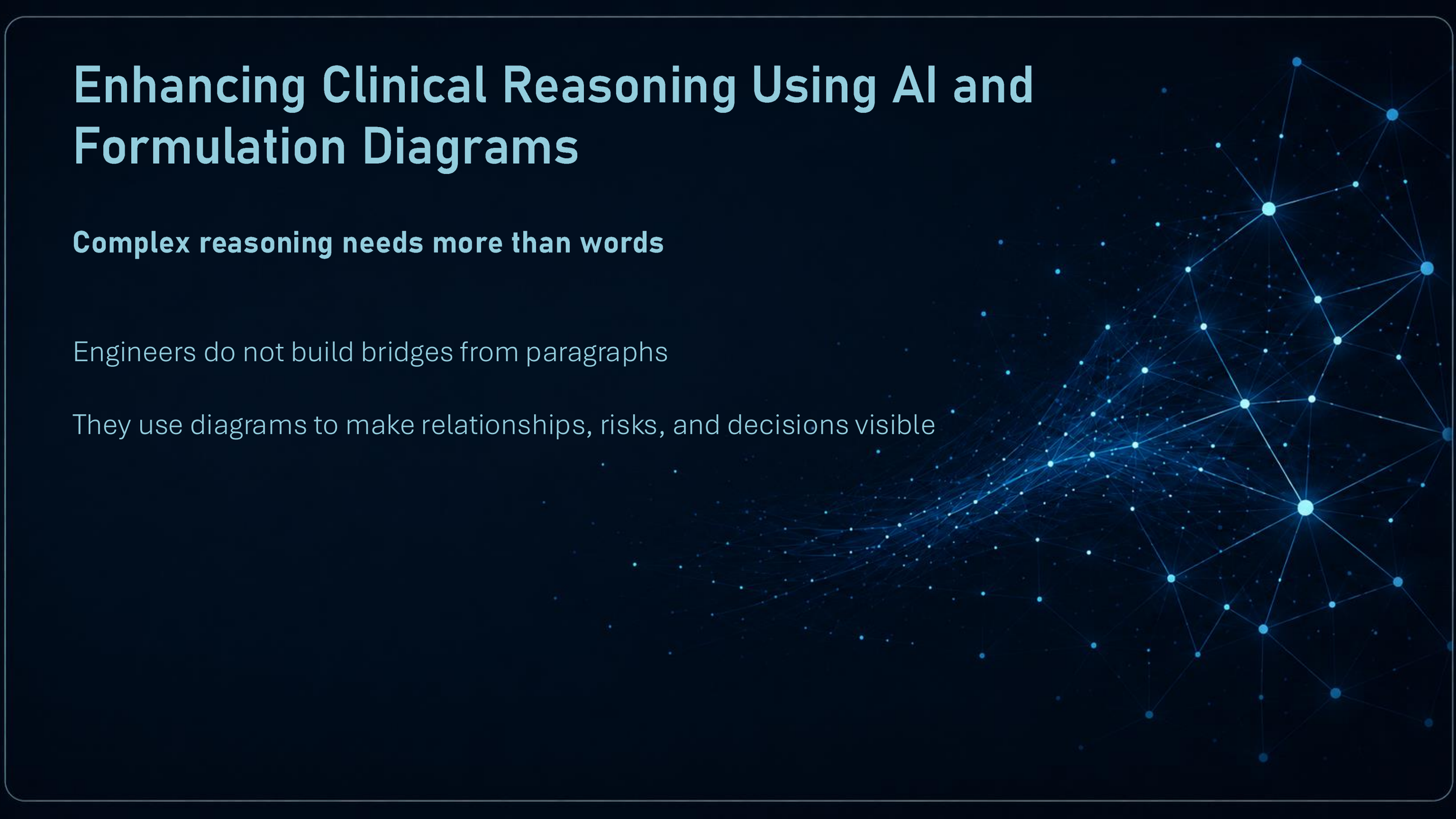


Enhancing Clinical Reasoning Using AI and Formulation Diagrams

Complex reasoning needs more than words

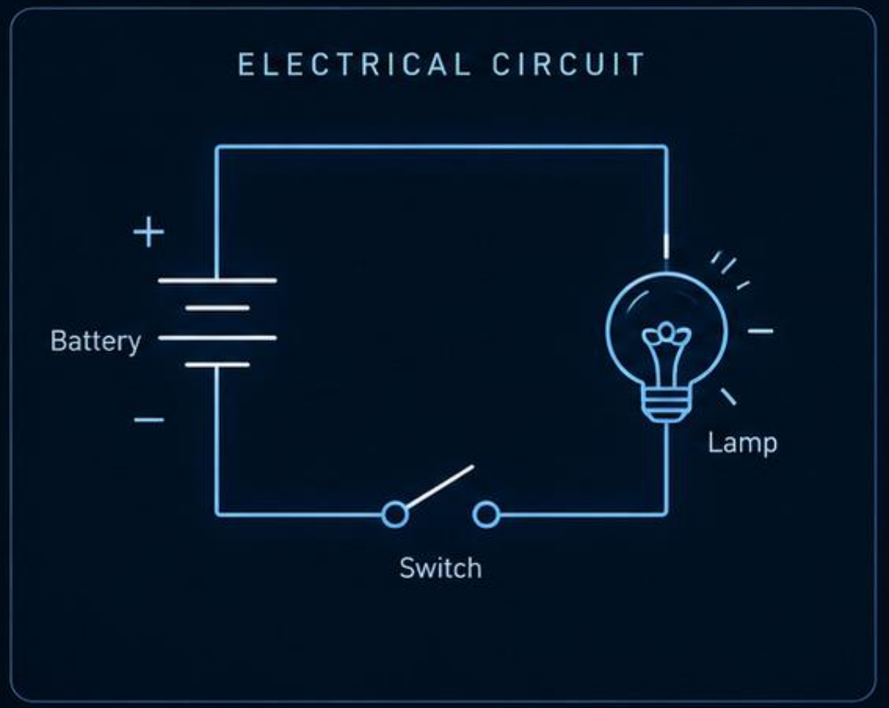
Engineers do not build bridges from paragraphs

They use diagrams to make relationships, risks, and decisions visible



Humans Reason Visually.
Diagrams Make Complexity Manageable.

Across domains, we rely on diagrams to understand **how things work**.



The same is true for **clinical reasoning**.
Formulation diagrams help us see relationships, not just facts.

Diagrams as cognitive tools

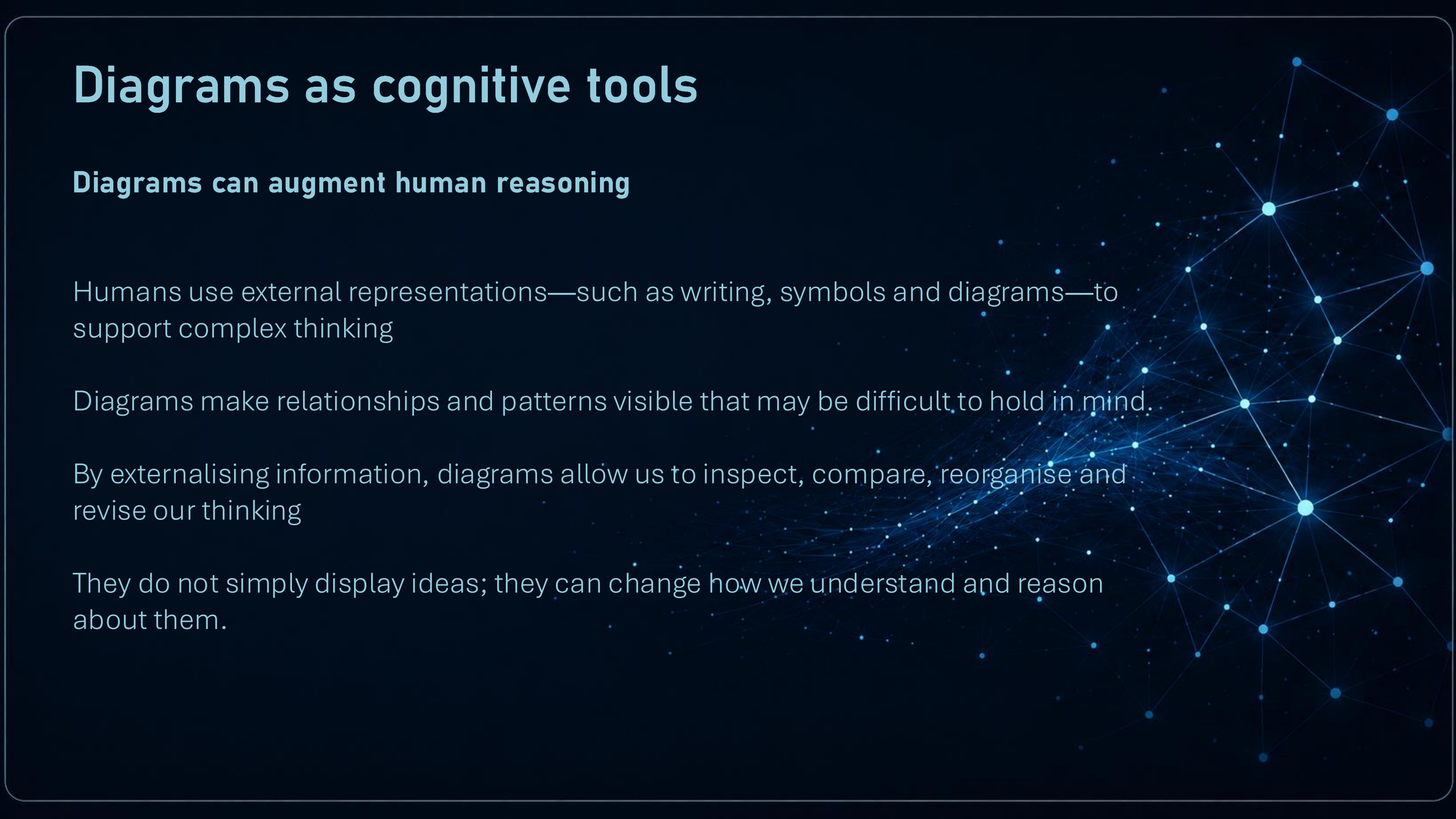
Diagrams can augment human reasoning

Humans use external representations—such as writing, symbols and diagrams—to support complex thinking

Diagrams make relationships and patterns visible that may be difficult to hold in mind.

By externalising information, diagrams allow us to inspect, compare, reorganise and revise our thinking

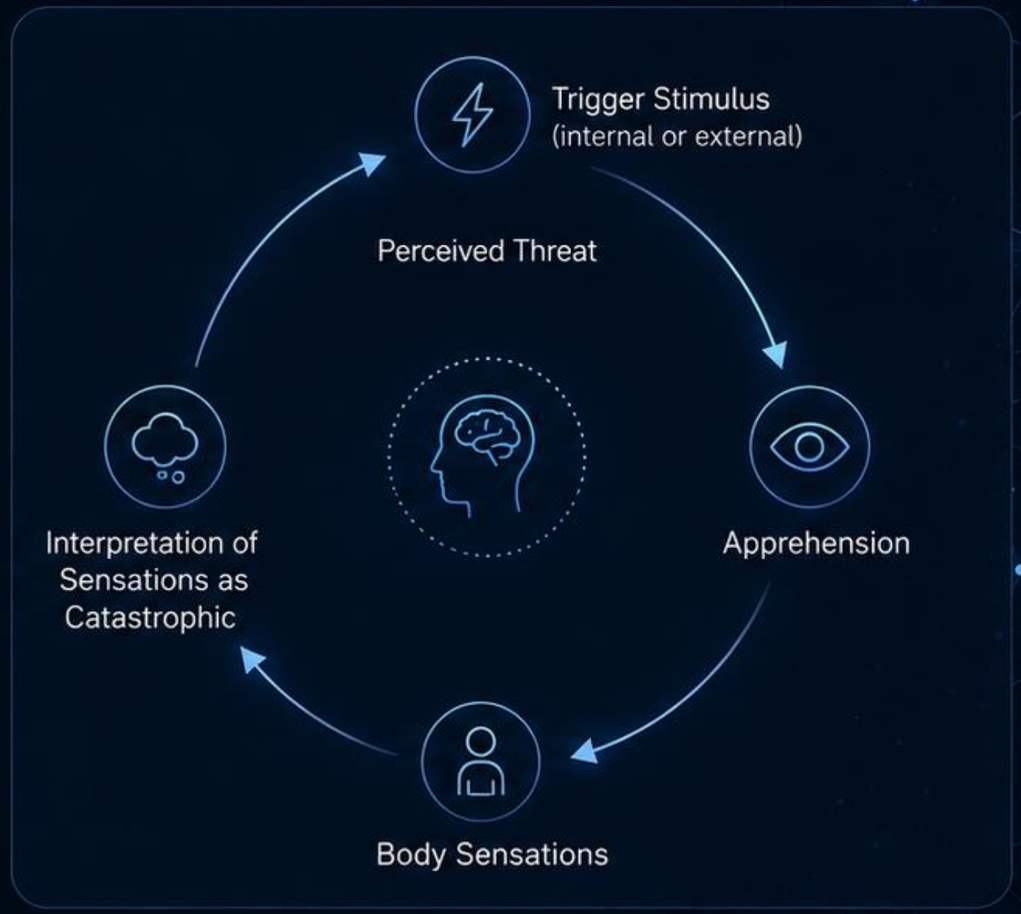
They do not simply display ideas; they can change how we understand and reason about them.



Psychologists already use diagrams extensively

COMPLEX REASONING NEEDS MORE THAN WORDS

- Cognitive behaviour therapy
- Chain analysis in dialectical behaviour therapy
- Cognitive Analytic Therapy
- Family therapy



Across approaches, diagrams help make relationships visible, support insight, and guide change.

Enhancing Clinical Reasoning Using AI and Formulation Diagrams

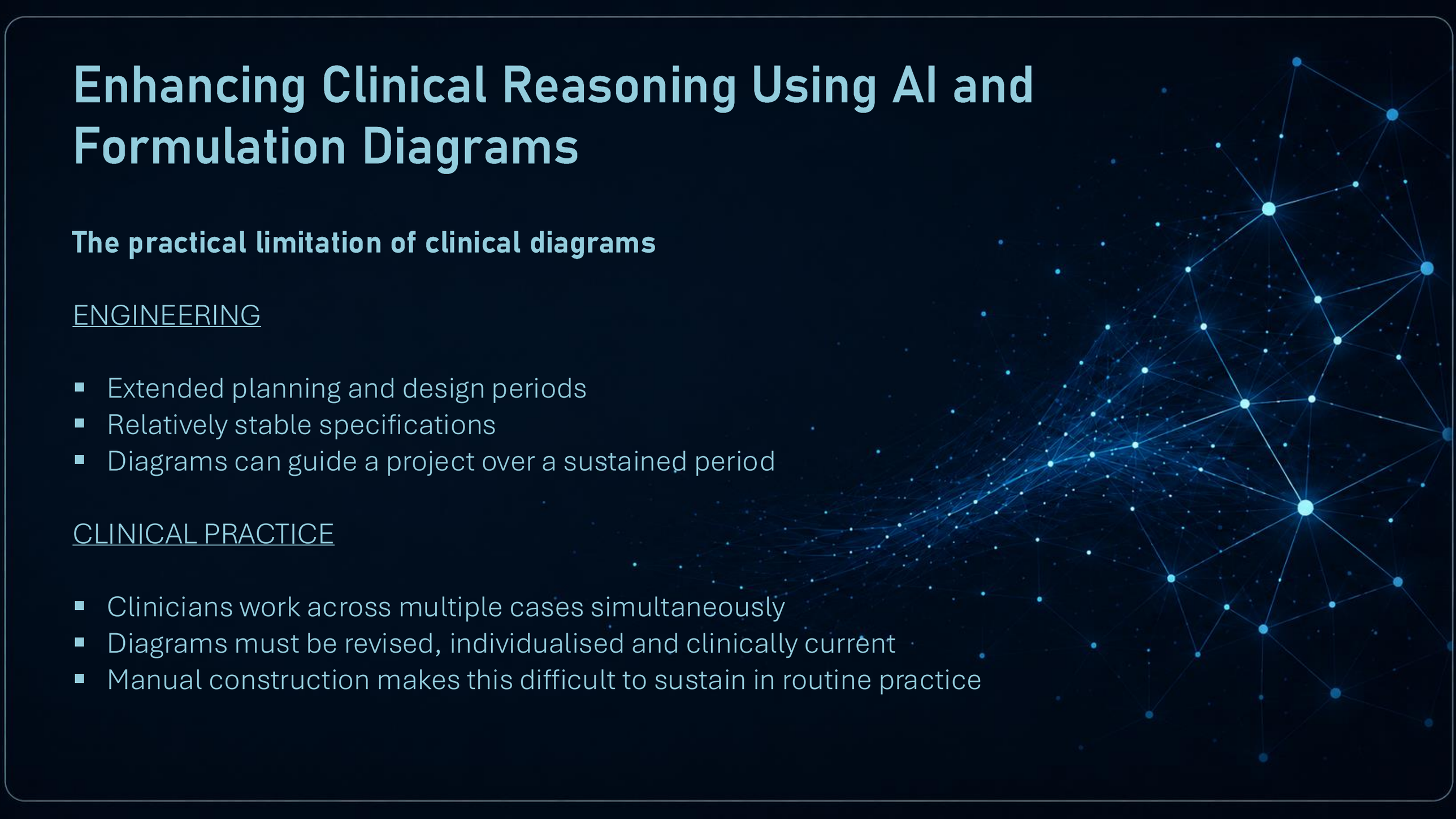
The practical limitation of clinical diagrams

ENGINEERING

- Extended planning and design periods
- Relatively stable specifications
- Diagrams can guide a project over a sustained period

CLINICAL PRACTICE

- Clinicians work across multiple cases simultaneously
- Diagrams must be revised, individualised and clinically current
- Manual construction makes this difficult to sustain in routine practice



Enhancing Clinical Reasoning Using AI and Formulation Diagrams

AI tools now can automatically convert AI-generated therapy transcripts into a diagram

Research is emerging in this area

PREPRINT

Investigating the Capability of Large Language Models to Identify Causal Relations in Psychiatric Case Studies: A Methodological Proof of Concept for the Analysis of Psychological Case Formulations

Ludlow C

1 Apr 2025 ◆ PsyArXiv ◆ arXiv: 2504.12721

PREPRINT

Towards a Computational Framework for Psychological Formulation: Conceptual Principles

Ludlow C, Zarnegar A

28 Jan 2026 ◆ PsyArXiv ◆ arXiv: 091XFG.v1

PREPRINT

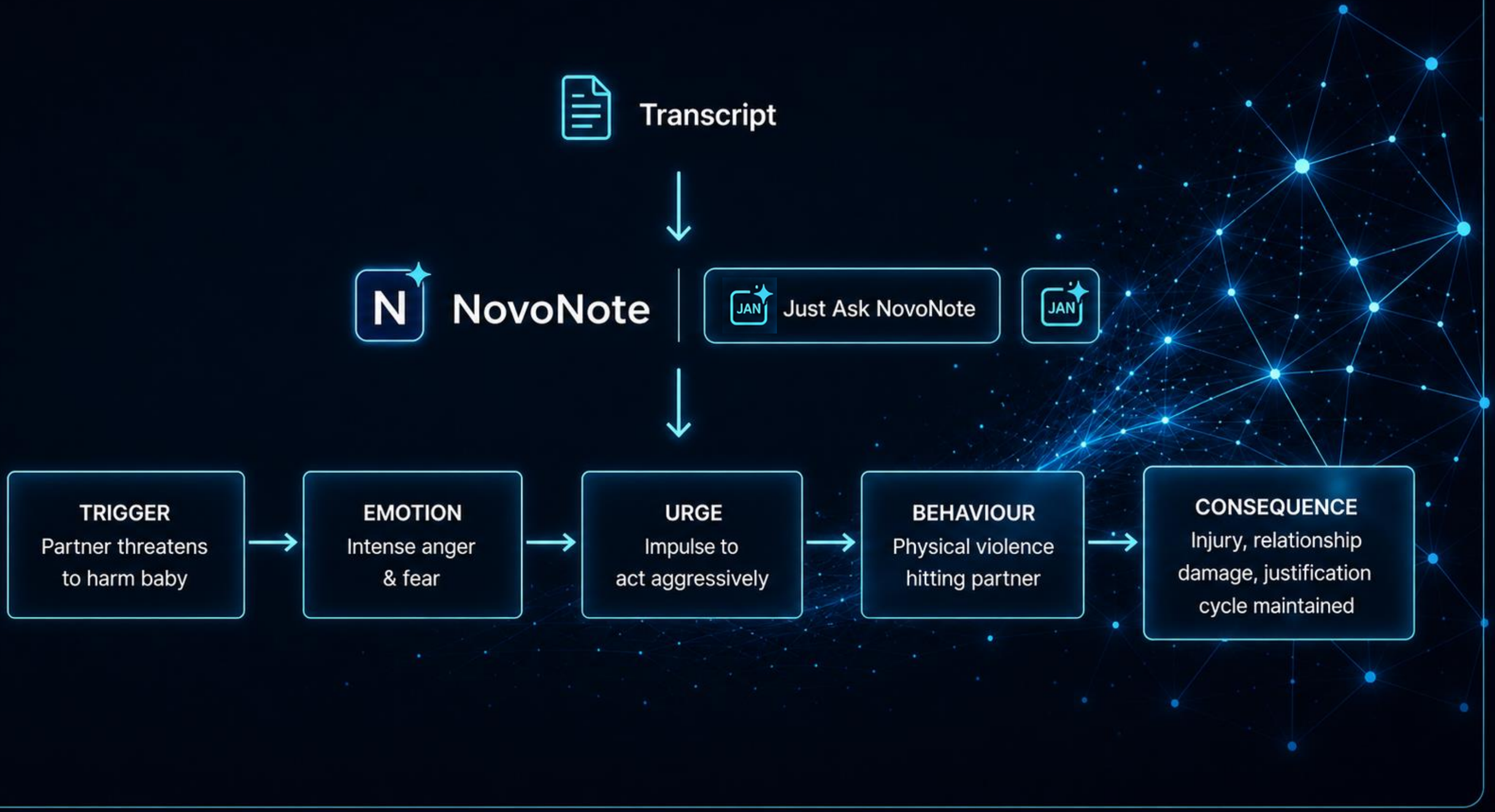
InsightFlow: LLM-Driven Synthesis of Patient Narratives for Mental Health into Causal Models

Gupta S, Adhikary PK, Dave B, Singh SM, Deroy A, Chakraborty T

14 Apr 2026 ◆ arXiv ◆ arXiv: 2604.12721

Early research suggests LLMs can extract, structure and map clinical information, supporting formulation development and clinical reasoning.


Dialectical Behavior Therapy (DBT) with Marsha Linehan Video
PsychotherapyNet
85.4k subscribers
Subscribe
1.3k
Share
Save
AI
TRIGGER
Partner threatens to harm baby
EMOTION
Intense anger & fear
URGE
Impulse to act aggressively
BEHAVIOUR
Physical violence hitting partner
CONSEQUENCE
Injury, relationship damage, justification cycle maintained


Transcript
NovoNote
Just Ask NovoNote
JAN
JAN
TRIGGER
Partner threatens to harm baby
EMOTION
Intense anger & fear
URGE
Impulse to act aggressively
BEHAVIOUR
Physical violence hitting partner
CONSEQUENCE
Injury, relationship damage, justification cycle maintained

Student Roleplay Transcript

AI

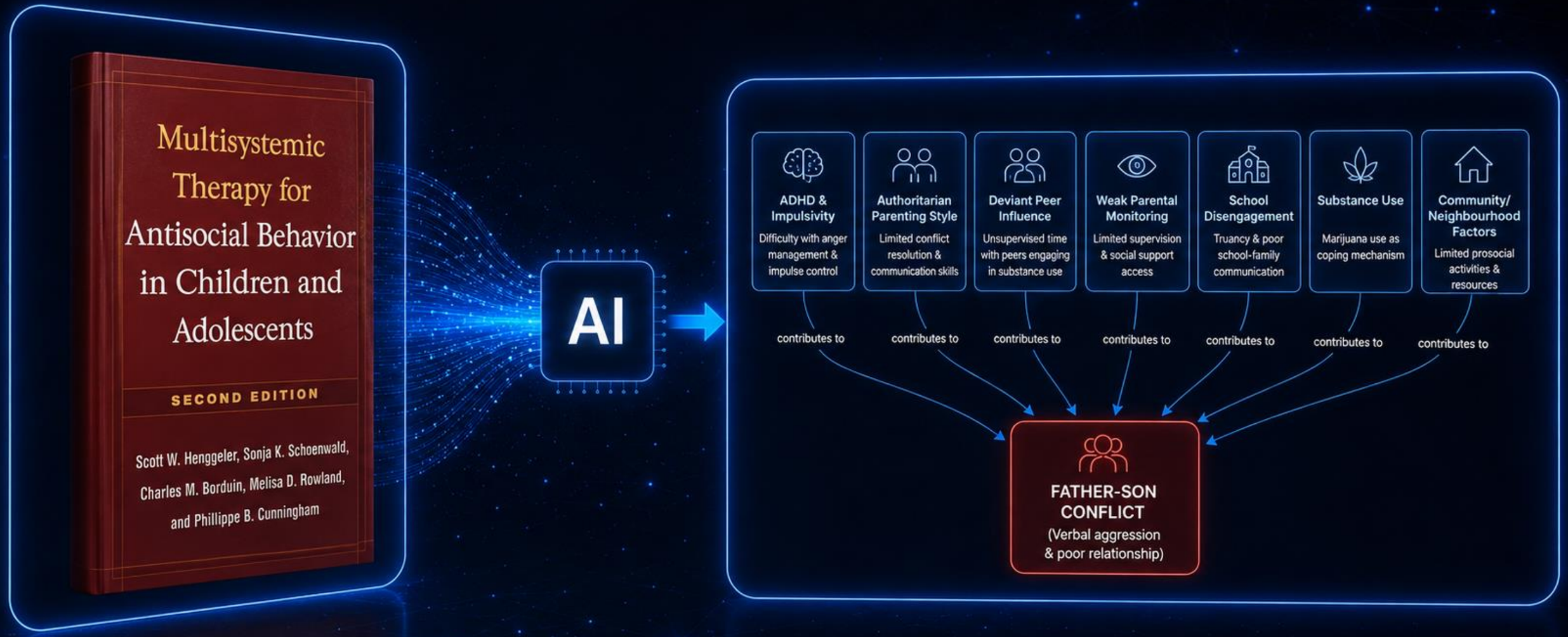
APPEARANCE CONCERN
Noticing balding

WORRY
People will judge me
It looks awkward

ANXIETY
Unease, tension,
sleep disruption

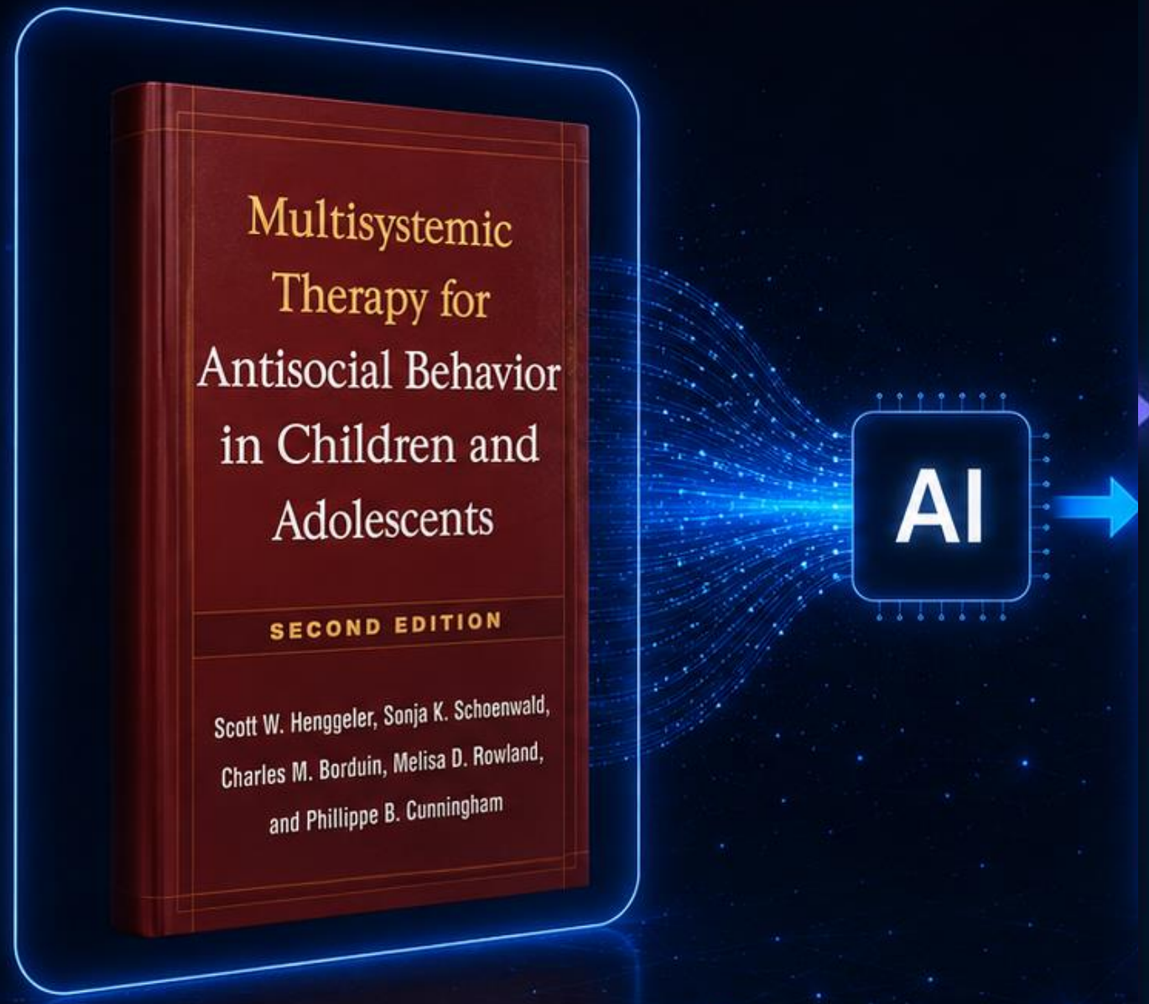
AVOIDANCE
Wear hat/hoodie
Avoid family dinners
Mirror checking

CYCLE MAINTAINS
Avoidance prevents
learning that others
don't judge as feared


Multisystemic Therapy for Antisocial Behavior in Children and Adolescents
SECOND EDITION
Scott W. Henggeler, Sonja K. Schoenwald, Charles M. Borduin, Melisa D. Rowland, and Phillippe B. Cunningham
AI
ADHD & Impulsivity
Difficulty with anger management & impulse control
Authoritarian Parenting Style
Limited conflict resolution & communication skills
Deviant Peer Influence
Unsupervised time with peers engaging in substance use
Weak Parental Monitoring
Limited supervision & social support access
School Disengagement
Truancy & poor school-family communication
Substance Use
Marijuana use as coping mechanism
Community/ Neighbourhood Factors
Limited prosocial activities & resources
contributes to
contributes to
contributes to
contributes to
contributes to
contributes to
contributes to
FATHER-SON CONFLICT
(Verbal aggression & poor relationship)

Comparison: MST Diagram vs AI-Generated Diagram

MST Diagram (Book)		AI Diagram	Similarity
Youth impulsivity and poor communication skills	→	ADHD & Impulsivity	★★★★★ Very high
Father uses inconsistent discipline	→	Authoritarian Parenting Style	★★★ Moderate
Family lacks mechanism for problem solving / conflict resolution	→	Authoritarian Parenting Style – limited conflict resolution & communication	★★★★ High
Youth's peers promote negative attitudes toward parents	→	Deviant Peer Influence	★★★★★ Very high
Neighbourhood provides models for aggression	→	Community / Neighbourhood Factors	★★★★ High
Youth more likely to fight when using marijuana	→	Substance Use	★★★★★ Very high
Youth angry at dad about mum's absence	→	Not explicitly represented	★★ Lower
Family members have different interpersonal styles due to cultural influences	→	Not explicitly represented	★★ Lower
Father–son conflict (target)	→	Father–son conflict (target)	★★★★★ Essentially identical



AI

Genogram (Context Map)

Paternal Grandmother
(deceased or not present)

Paternal Grandfather
(deceased or not present)

Paternal Uncle
(Lives nearby)
Involved in treatment
Resource for monitoring

close relationship

Nephew
(Lives nearby)
Potential support resource

Niece
(Lives nearby)
Potential support resource

Mr. Naaves
(Father)
Authoritarian parenting
Committed to Rick

involved in supervision

Rick Naaves
(16-year-old)
ADHD, impulsivity
Marijuana use, truancy
Fighting, verbal aggression

Sister
(13-year-old)
Lives with father & Rick

Deceased / Not present | Support / Resource | Key Family Members | Target Youth

Visualises relationships
& contextual influences

AI

TRIGGER
Thoughts about daughter discovering romantic relationship.

UNDERLYING BELIEF
I need external approval to be acceptable

THOUGHTS
I'm a bad mother
She'll reject me
I'm dishonest/hypocritical

EMOTIONS
Guilt, Anxiety, Shame

BEHAVIOURS
Avoidance & Deception
Withholding information

CONSEQUENCES
Increased distance
Unresolved conflict
Continued dishonesty

Data-Driven AI vs Theory-Guided AI

Two ways AI can support clinical formulation

DATA-DRIVEN AI

Starts with the session

Uses what you and the client actually said

Faithful summary

AI

THEORY-GUIDED AI

Adds clinical knowledge

Joins dots and suggests hypotheses

Possibilities to test

Clinician confirms what fits the client

Hypotheses support judgement, not replace it.

Theory-Guided AI

Recommending treatment targets from the formulation

Session transcript + CBT knowledge

AI

TRIGGER
Thoughts about daughter discovering romantic relationship.

CORE BELIEF
I need external approval to be acceptable

TARGET 3
Schema work self-acceptance

THOUGHTS
I'm a bad mother
She'll reject me
I'm dishonest/hypocritical

TARGET 1
Thought challenging

EMOTIONS
Guilt, Anxiety, Shame

TARGET 4
Emotion regulation self-compassion

BEHAVIOURS
Avoidance & Deception
Withholding information

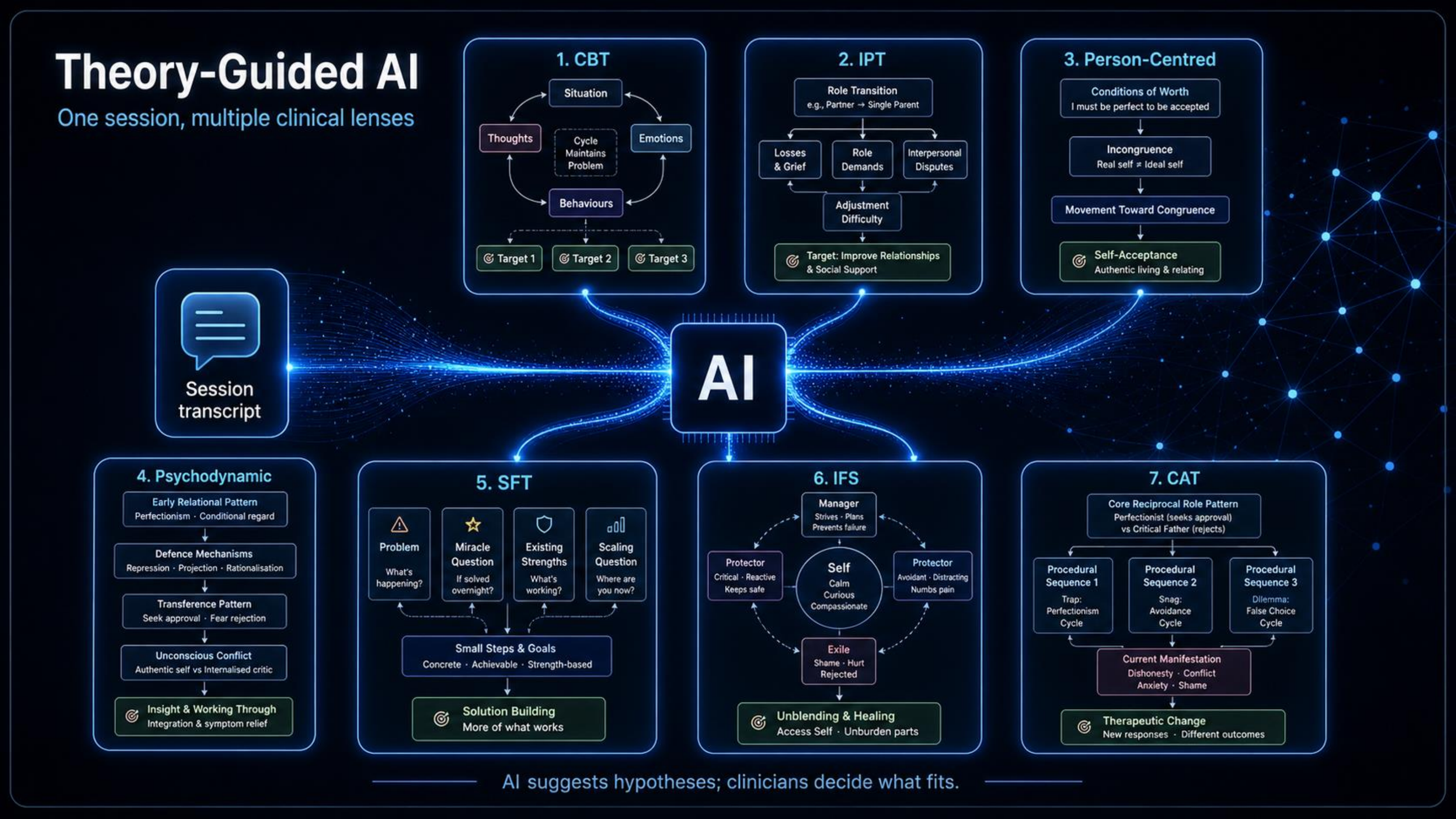
TARGET 2
Behavioural activation graded exposure to honesty

CONSEQUENCES
Increased distance
Unresolved conflict

Targets are hypotheses for clinician review.

Theory-Guided AI

One session, multiple clinical lenses



AI suggests hypotheses; clinicians decide what fits.

Exploring Differential Diagnosis with AI Diagrams

Same behaviours, different explanatory pathways

PRESENTING BEHAVIOUR
Refusal to get dressed
Insistence on routine order
Argues with adults
Blames others
Distress with transitions

DIFFERENTIAL FORMULATION

ASD PATHWAY

Core: Neurodevelopmental difference

ROOT CAUSE
Sensory sensitivity
Cognitive rigidity
Social communication difference

WHY BEHAVIOUR OCCURS
Clothing feels "wrong" = sensory discomfort
Routine order = need for predictability
Transitions = cognitive overwhelm
Argues = difficulty understanding others' perspectives

DISTINGUISHING FEATURES
- ✓ Lifelong rigid pattern
- ✓ Genuine preference for solitude
- ✓ Narrow interests (fascination)
- ✓ Reduced eye contact (social difference)
- ✓ Distress = overwhelm/frustration
- ✓ Normal language development

ODD PATHWAY

Core: Authority conflict & defiance

ROOT CAUSE
Oppositional stance to authority
Negative reinforcement cycle
Perceived unfairness

WHY BEHAVIOUR OCCURS
Clothing feels "wrong" = excuse to refuse
Routine order = control/power
Transitions = challenge to authority
Argues = oppositional stance to demands

DISTINGUISHING FEATURES
- ✓ Defiance primarily with authority
- ✓ Socially motivated (wants friends)
- ✓ Blames others for conflicts
- ✓ Eye contact variable/situational
- ✓ Distress = anger at perceived unfairness
- ✓ Negative reinforcement cycle

Formulating Educational & Neuropsychological Assessments

From cognitive results to developmental context and maintaining cycles

CURRENT CONTEXT

Medical Recovery Stabilised Health Status → Cognitive Assessment: IQ in Normal Limits No Deficits Identified

HISTORICAL CONTEXT

Age 7: Diagnosed with Acute Lymphoblastic Leukaemia → Normal Academic Development & Independence Pre-Illness (Average to Above-Average Achievement) → Engaged, Capable, Socially Well-Adjusted

MEDICAL TREATMENT PERIOD

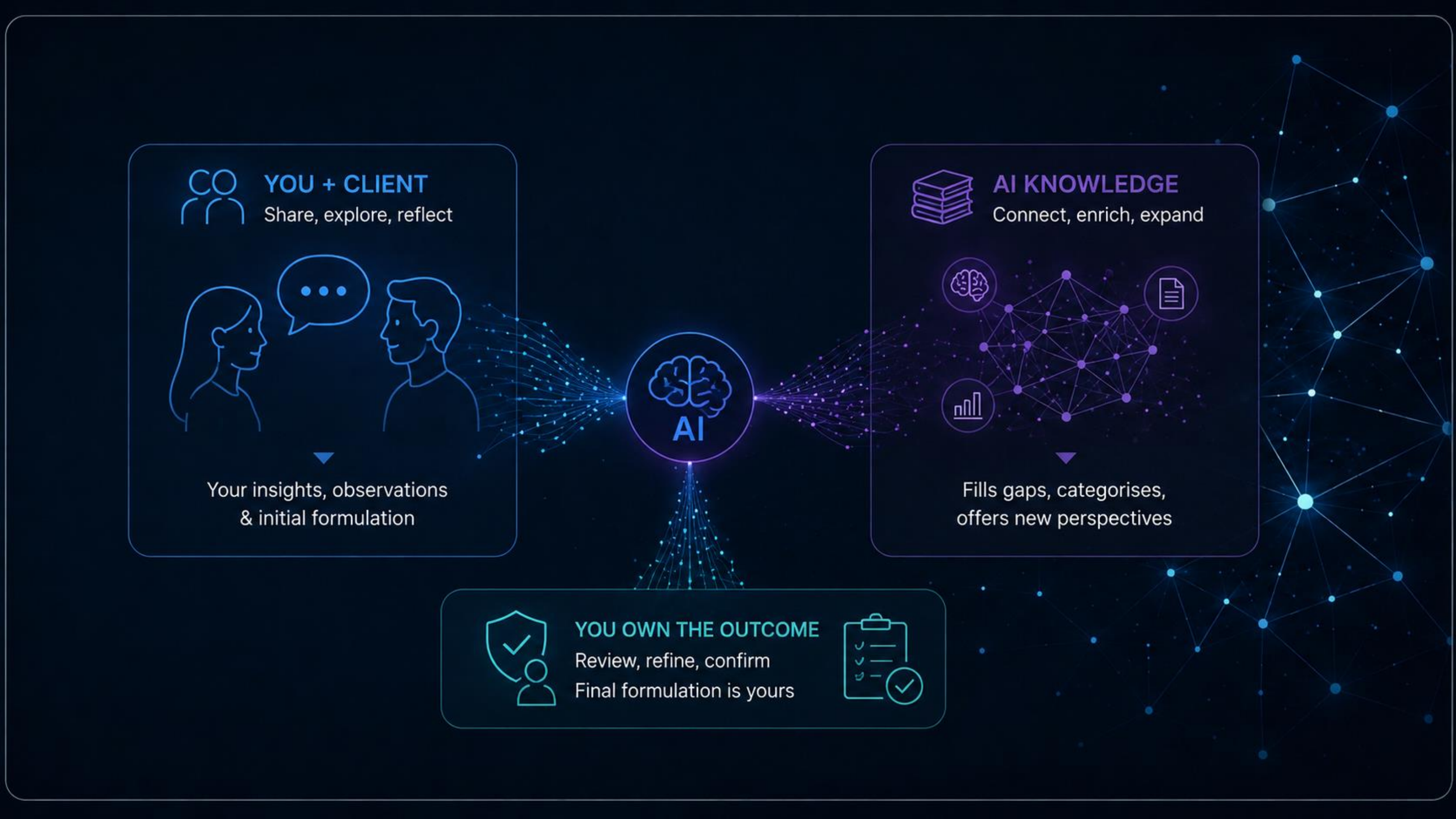
Lengthy Hospitalisation & Medical Treatment

- Significant School Disruption & Missed Curriculum
- Reduced Classroom Engagement with Peers
- Increased Family Accommodation & Support

MAINTAINING CYCLE OF LEARNED HELPLESSNESS

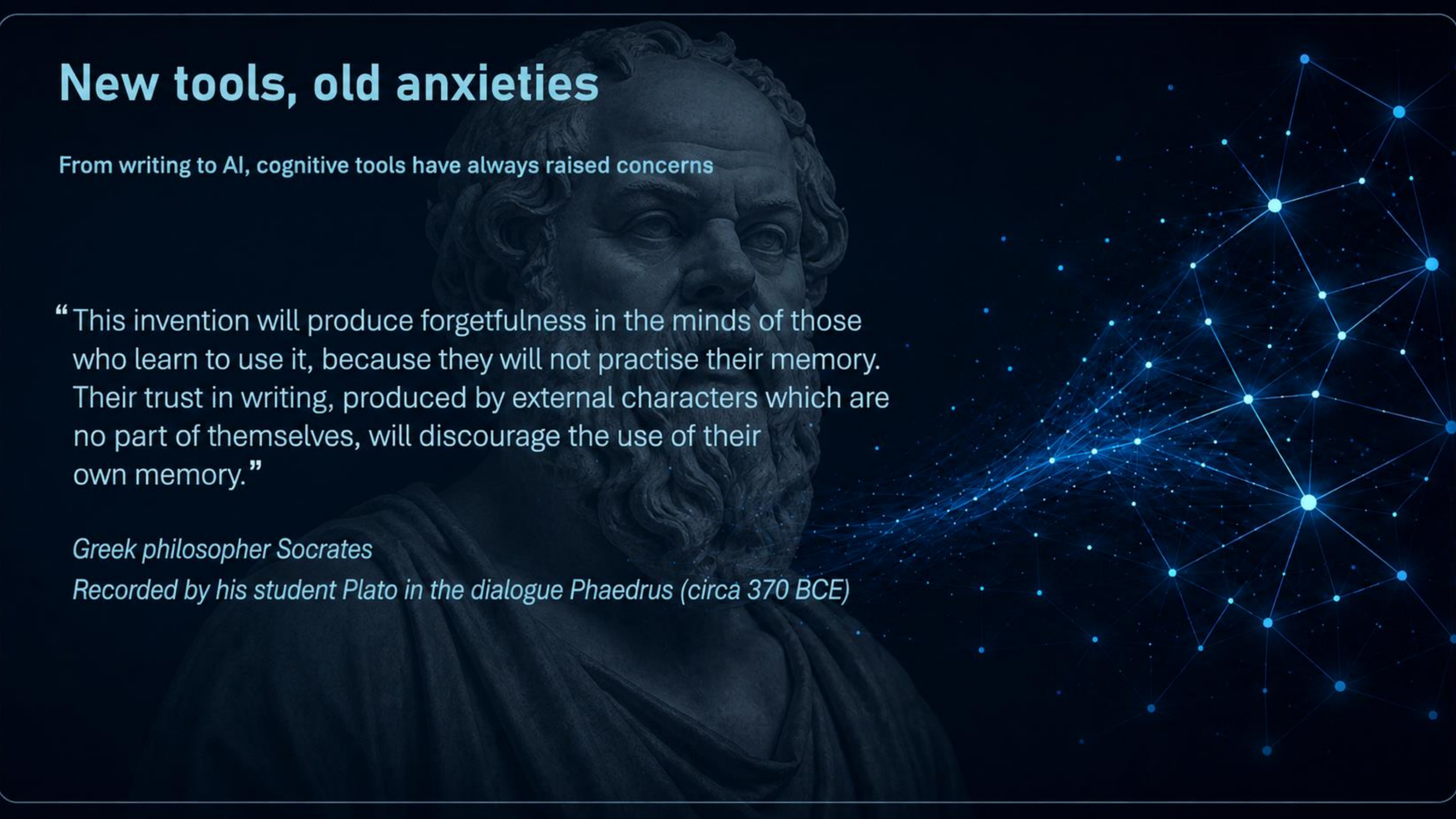
Residual Academic Skill Gaps → Genuine Difficulty Relative to Peers → Mistakes & Negative Feedback → Negative Self-Beliefs ("I'm stupid", "I can't do it") → Low Self-Efficacy & Anticipation of Failure → Avoidance of Challenge & Reluctance to Attempt Difficult Tasks → Reduced Practice & Learning Opportunities

Family Accommodation Continues (completing tasks, reassurance) → Reduced Independence & Skill Development → Avoidance of Challenge & Reluctance to Attempt Difficult Tasks


YOU + CLIENT
Share, explore, reflect
Your insights, observations
& initial formulation
AI
AI KNOWLEDGE
Connect, enrich, expand
Fills gaps, categorises,
offers new perspectives
YOU OWN THE OUTCOME
Review, refine, confirm
Final formulation is yours

New tools, old anxieties

From writing to AI, cognitive tools have always raised concerns



> "This invention will produce forgetfulness in the minds of those who learn to use it, because they will not practise their memory. Their trust in writing, produced by external characters which are no part of themselves, will discourage the use of their own memory."

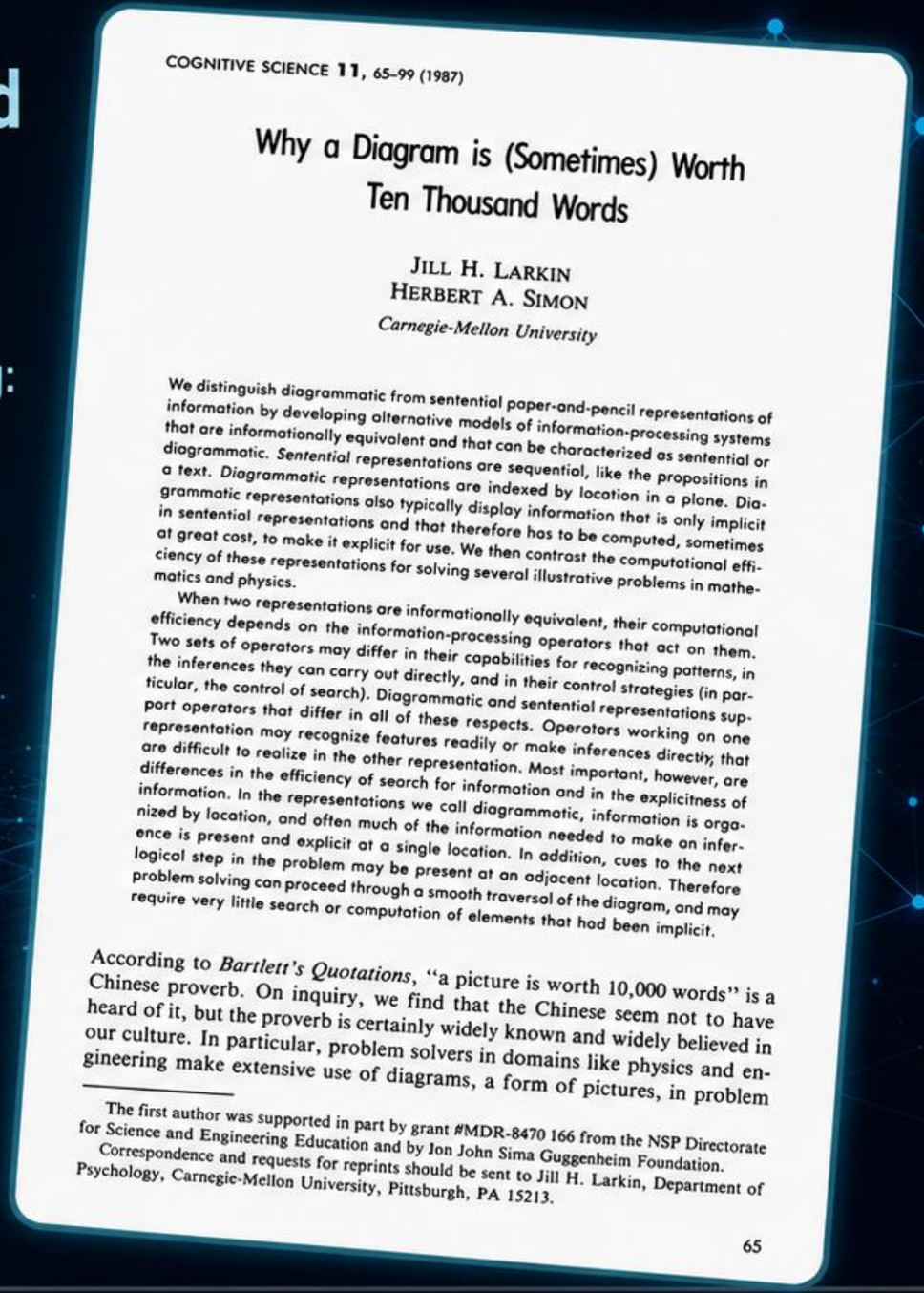
Greek philosopher Socrates

Recorded by his student Plato in the dialogue Phaedrus (circa 370 BCE)

The cognitive science behind AI-assisted formulation

Theoretically informed perspectives on AI and diagnostic reasoning:

- Enhanced communication
- Cognitive offloading
- Extended cognition
- Human-in-the-loop principles
- Representational redescription



COGNITIVE SCIENCE 11, 65–99 (1987)

Why a Diagram is (Sometimes) Worth Ten Thousand Words

JILL H. LARKIN
HERBERT A. SIMON
Carnegie-Mellon University

We distinguish diagrammatic from sentential paper-and-pencil representations of information by developing alternative models of information-processing systems that are informationally equivalent and that can be characterized as sentential or diagrammatic. *Sentential* representations are sequential, like the propositions in a text. *Diagrammatic* representations are indexed by location in a plane. Diagrammatic representations also typically display information that is only implicit in sentential representations and that therefore has to be computed, sometimes at great cost, to make it explicit for use. We then contrast the computational efficiency of these representations for solving several illustrative problems in mathematics and physics.

When two representations are informationally equivalent, their computational efficiency depends on the information-processing operators that act on them. Two sets of operators may differ in their capabilities for recognizing patterns, in the inferences they can carry out directly, and in their control strategies (in particular, the control of search). Diagrammatic and sentential representations support operators that differ in all of these respects. Operators working on one representation may recognize features readily or make inferences directly that are difficult to realize in the other representation. Most important, however, are differences in the efficiency of search for information and in the explicitness of information. In the representations we call diagrammatic, information is organized by location, and often much of the information needed to make an inference is present and explicit at a single location. In addition, cues to the next logical step in the problem may be present at an adjacent location. Therefore problem solving can proceed through a smooth traversal of the diagram, and may require very little search or computation of elements that had been implicit.

According to *Bartlett's Quotations*, "a picture is worth 10,000 words" is a Chinese proverb. On inquiry, we find that the Chinese seem not to have heard of it, but the proverb is certainly widely known and widely believed in our culture. In particular, problem solvers in domains like physics and engineering make extensive use of diagrams, a form of pictures, in problem

The first author was supported in part by grant #MDR-8470 166 from the NSP Directorate for Science and Engineering Education and by Jon John Sima Guggenheim Foundation.

Correspondence and requests for reprints should be sent to Jill H. Larkin, Department of Psychology, Carnegie-Mellon University, Pittsburgh, PA 15213.

Feedback to the Client

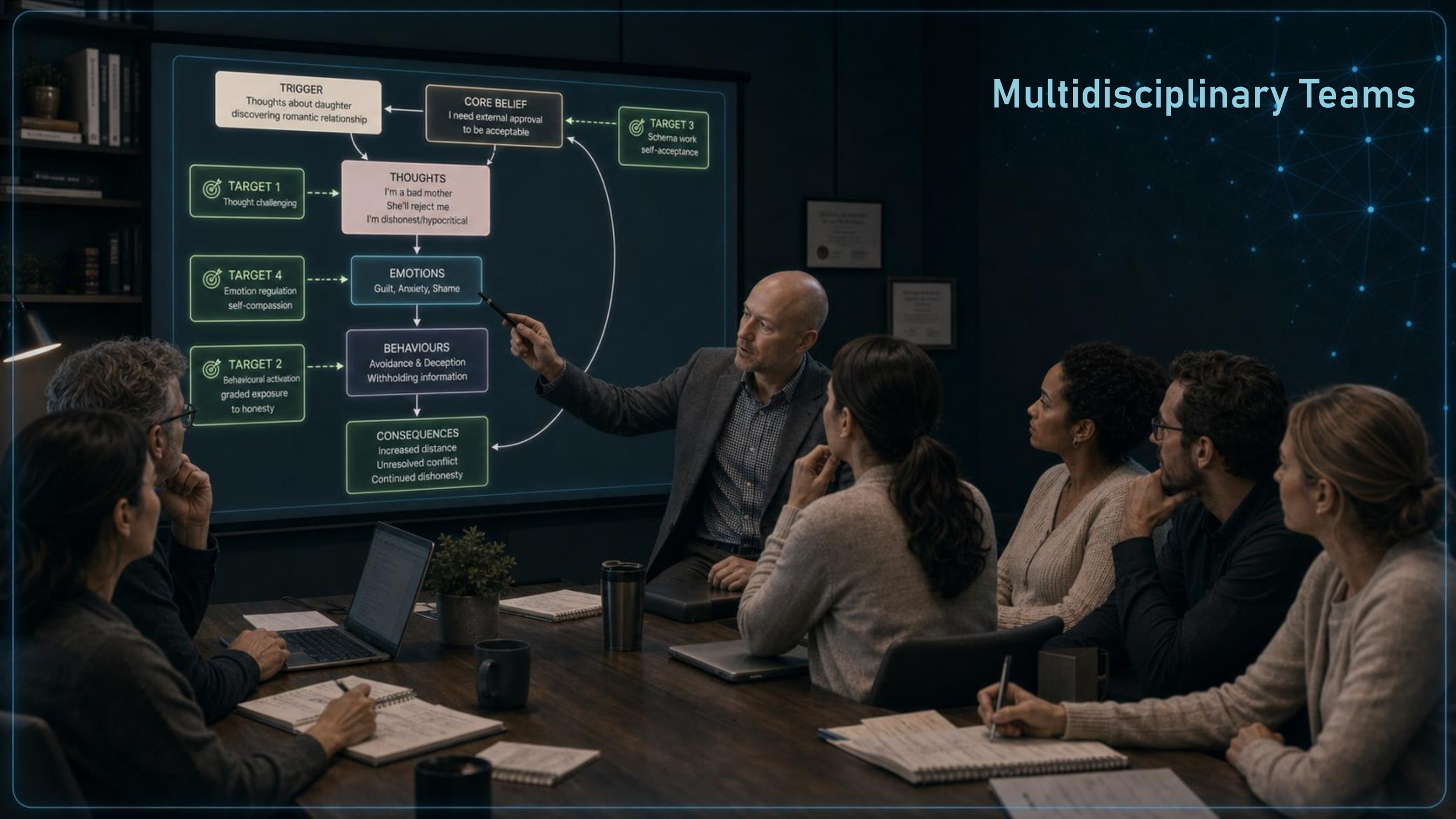
Sharing the formulation
invites reflection, collaboration
and guides next steps.

Multidisciplinary Collaboration

Supervision

Report Writing

Multidisciplinary Teams

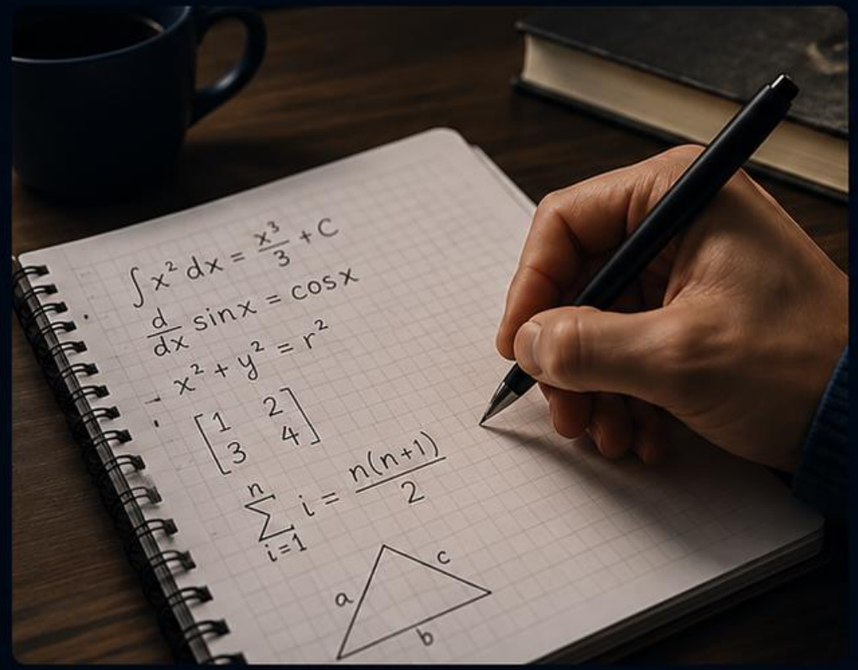


Different Ways to Use AI

How we can use AI to support rather than replace clinical reasoning

Cognitive offloading

Tool supports reasoning



Cognitive outsourcing

Tool replaces reasoning

Spatial reasoning
less active

Kirschner PA, Sweller J, Kirschner F, Zambrano R J. From Cognitive Load Theory to Collaborative Cognitive Load Theory.
Int J Comput Support Collab Learn. 2018;13(2):213-233. doi:10.1007/s11412-018-9277-y. Epub 2018 Apr 25. PMID: 30996713; PMCID: PMC6435105.

AI diagrams as thinking tools

1. Externalise cognitive load

frees space for critique, comparison,
refinement, empathy & hypothesis-testing

2. Think differently with the same material

multiple frames reveal new patterns,
assumptions & treatment targets

Enhancing Clinical Reasoning Using AI and Formulation Diagrams

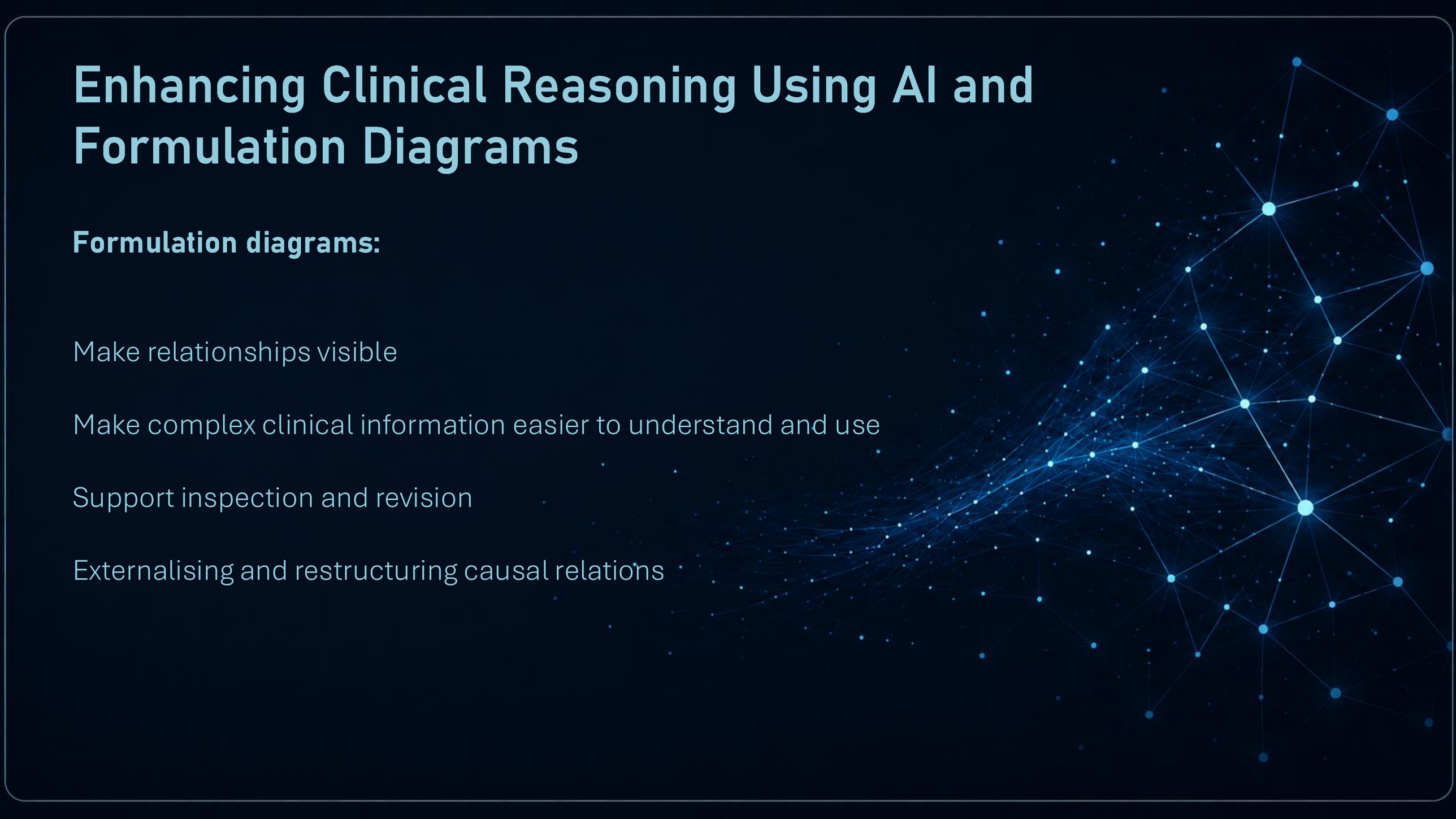
Formulation diagrams:

Make relationships visible

Make complex clinical information easier to understand and use

Support inspection and revision

Externalising and restructuring causal relations



EXTENDED COGNITION

THINKING IS DISTRIBUTED BETWEEN MIND AND WORLD

> *“ External tools are not just aids to thought; they are parts of the cognitive process itself. ”*
>
> — Andy Clark (1998)

Clark, A. (1998). *Magic Words: How Language Augments Human Computation.* In A. Clark & J. Toribio (Eds.), *Language and Meaning in Cognitive Science* (Vol. 4, pp. 162–183). Routledge.

Human in the Loop

AI generates. Clinicians verify. Understanding evolves.

Representational redescription: externalising and reshaping information changes understanding.

Representational Redescription

(Karmiloff-Smith, 1992)

Learning happens when we use **what we already understand** to make sense of **something new**.

Existing representation → Mapped onto a new domain → New understanding and mastery

Everyday analogy: learning chopsticks

1. You know how to eat with knife and fork.
2. You see someone using chopsticks and map it onto your 'model of eating'.
3. You adapt, refine and now you can use chopsticks with confidence.

A new skill built on an existing representation.

Clinical analogy: building causal models

1. You build a causal model for one case (e.g. panic).
2. The diagram helps you think externally and see patterns and relations more clearly.
3. You generalise this structure to new cases (e.g. psychosis and dissociation).

From one case to many: more mastery, better understanding.

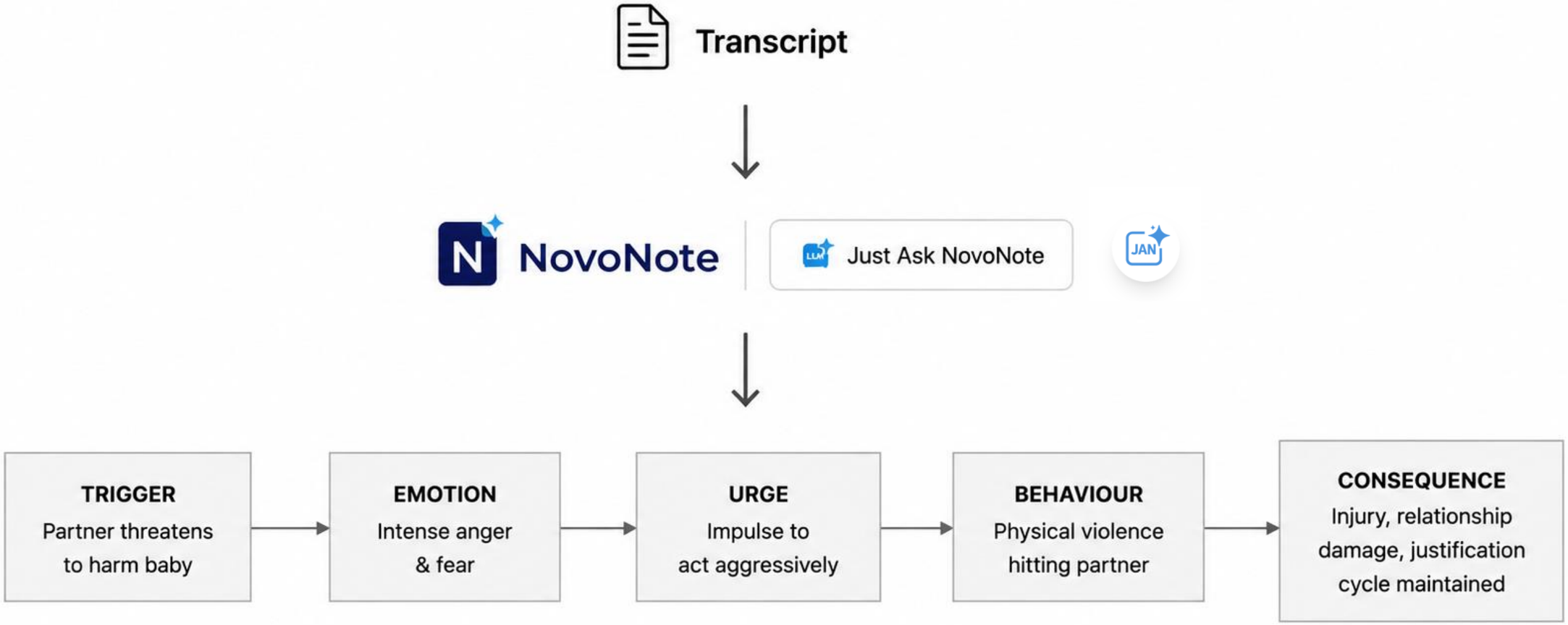
Key Takeaways

Enhancing Clinical Reasoning Using AI and Formulation Diagrams

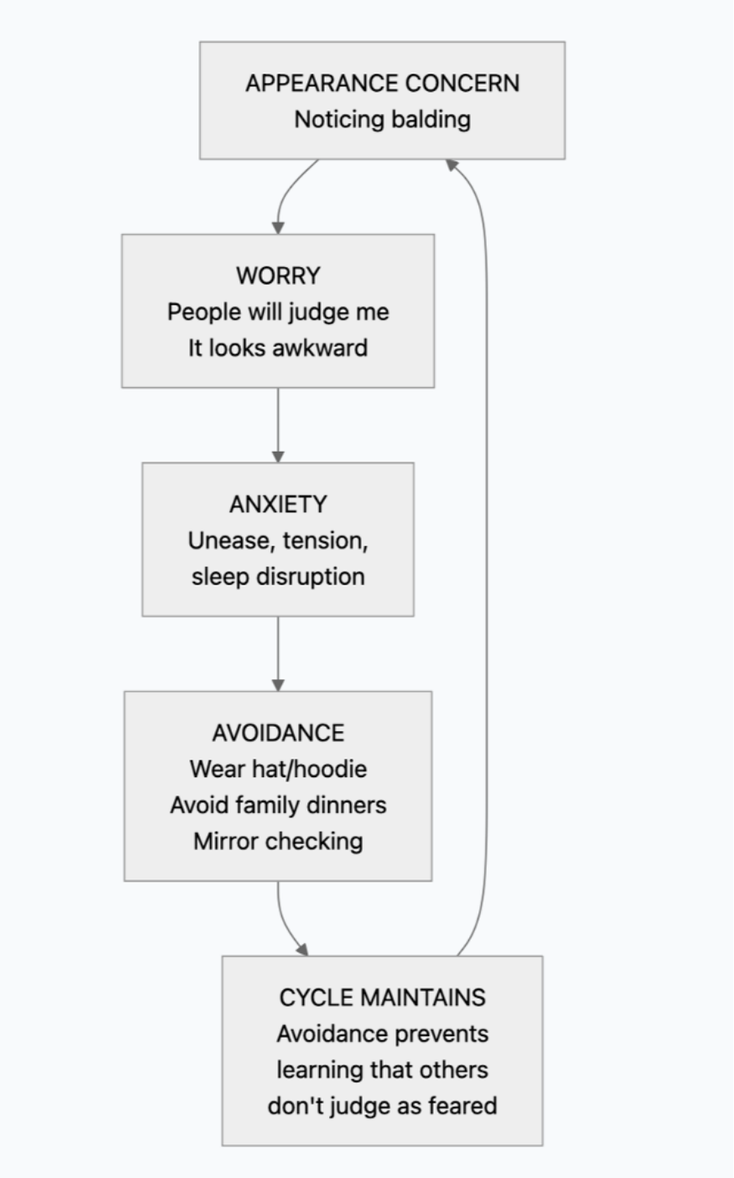
- Clinical formulations are not only communication tools—they are thinking tools
- Diagrams can act as external cognitive tools, reducing working memory demands and making complex clinical information easier to inspect
- AI can help clinicians generate and compare multiple representations of the same case
- By externalising formulation, clinicians can devote more attention to higher-order reasoning: critique, comparison, reflection, hypothesis testing, and treatment planning
- AI can rapidly transform transcripts into diagrams, making clinical reasoning more visible and easier to communicate
- The clinician remains responsible for interpretation, judgement, and determining clinical fit

APPENDIX: NovoNote Output

DBT Example: Transcript -> formulation

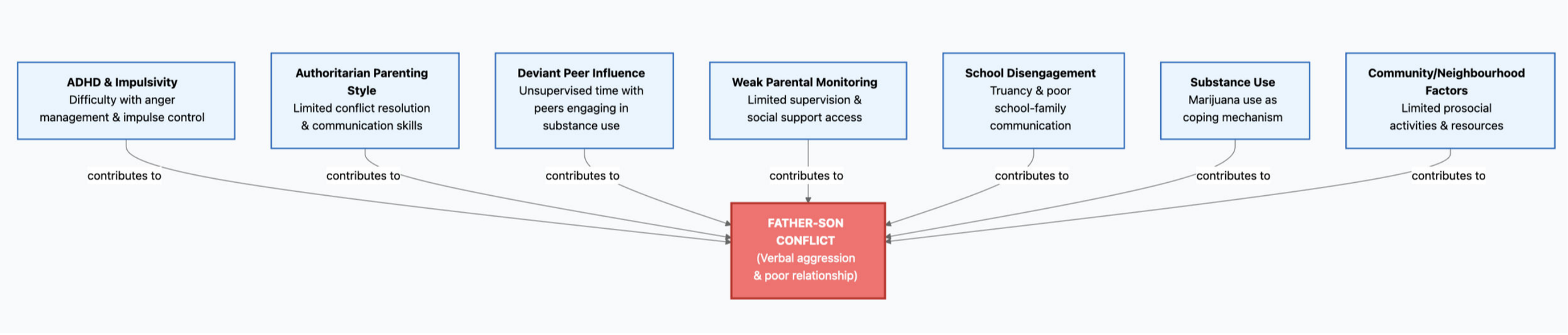


Student roleplay: Man with appearance concerns



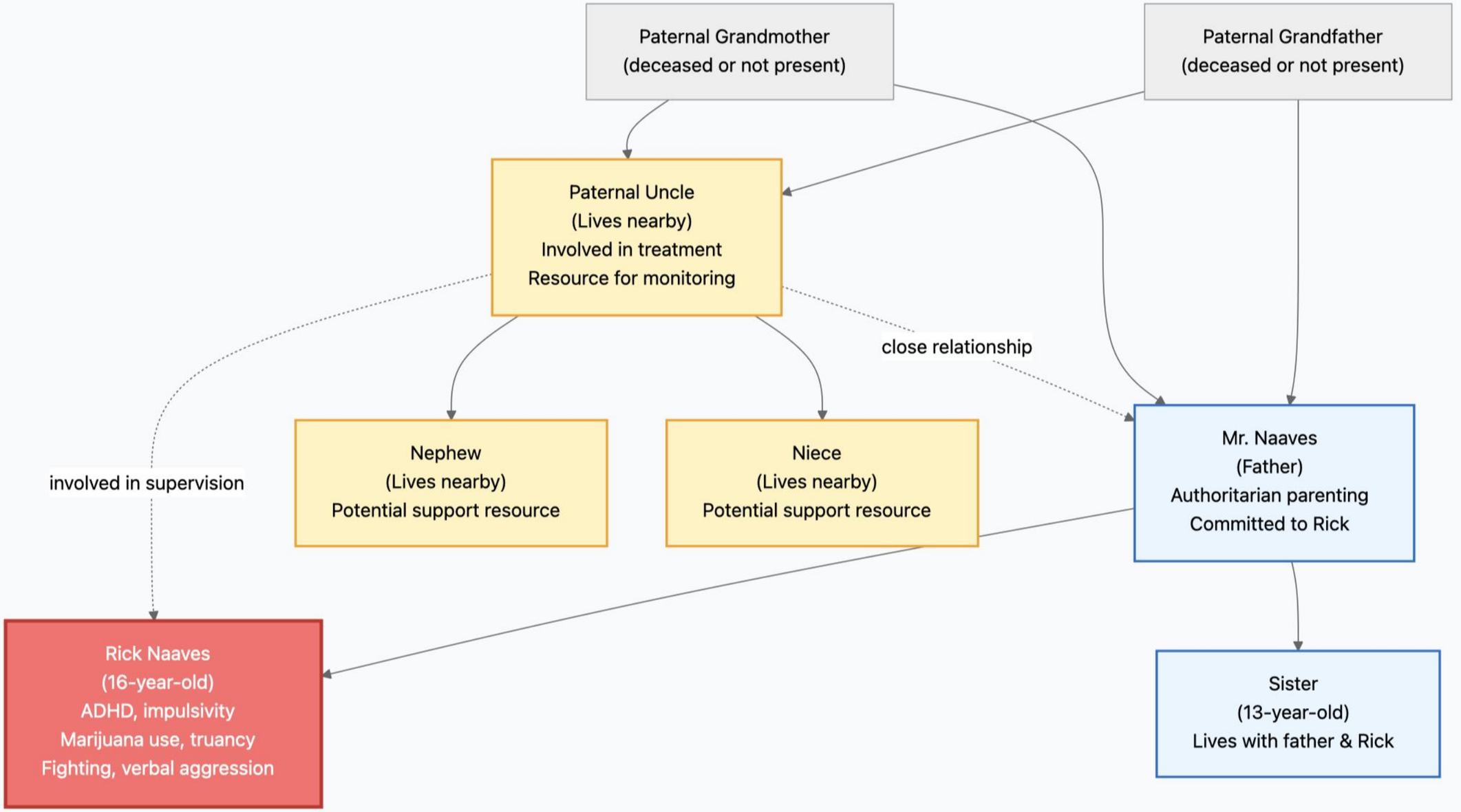
NovoNote Output

MST Example



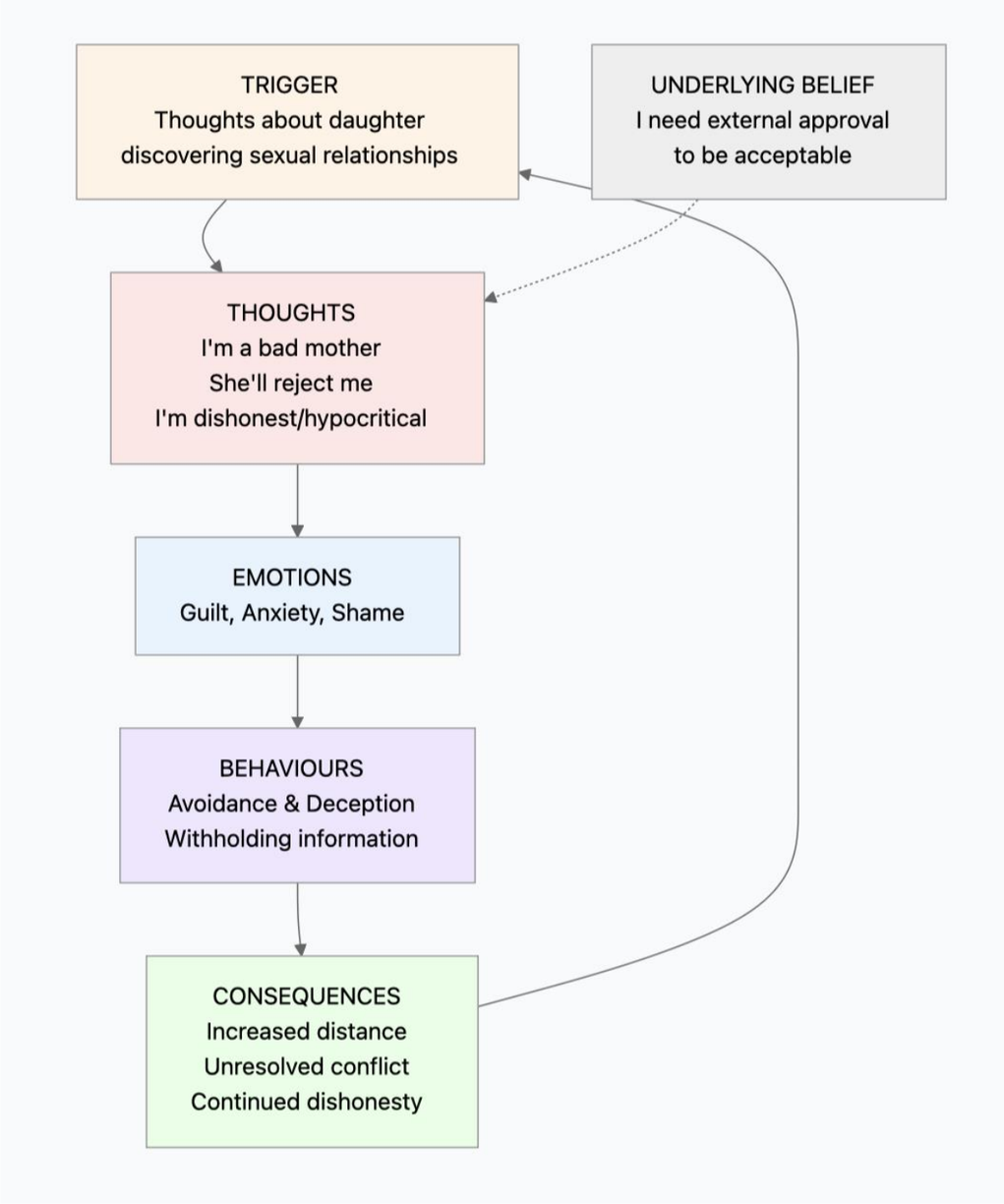
NovoNote Output

MST: Genogram



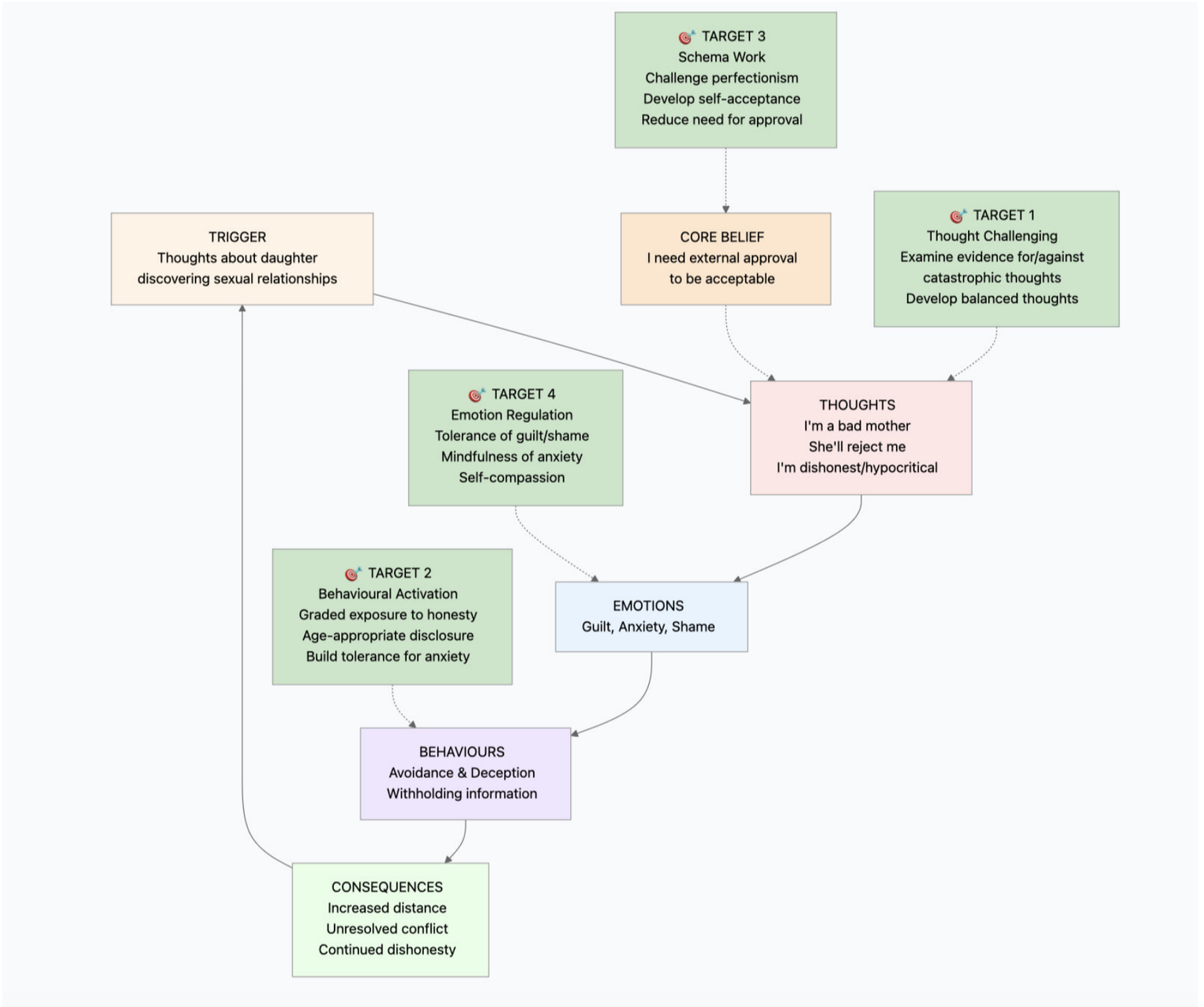
NovoNote Output

Gloria and Rogers: CBT



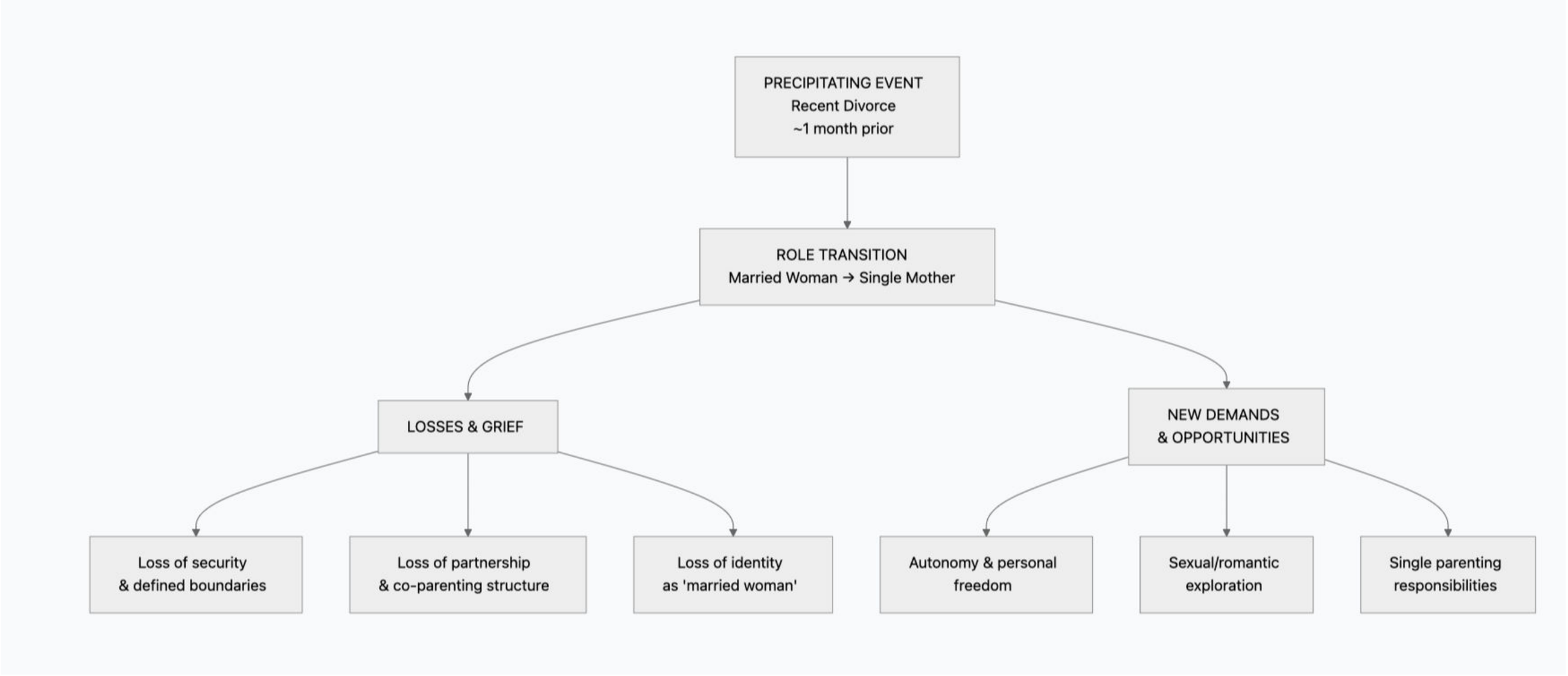
NovoNote Output

Gloria and Rogers: CBT with suggested treatment targets



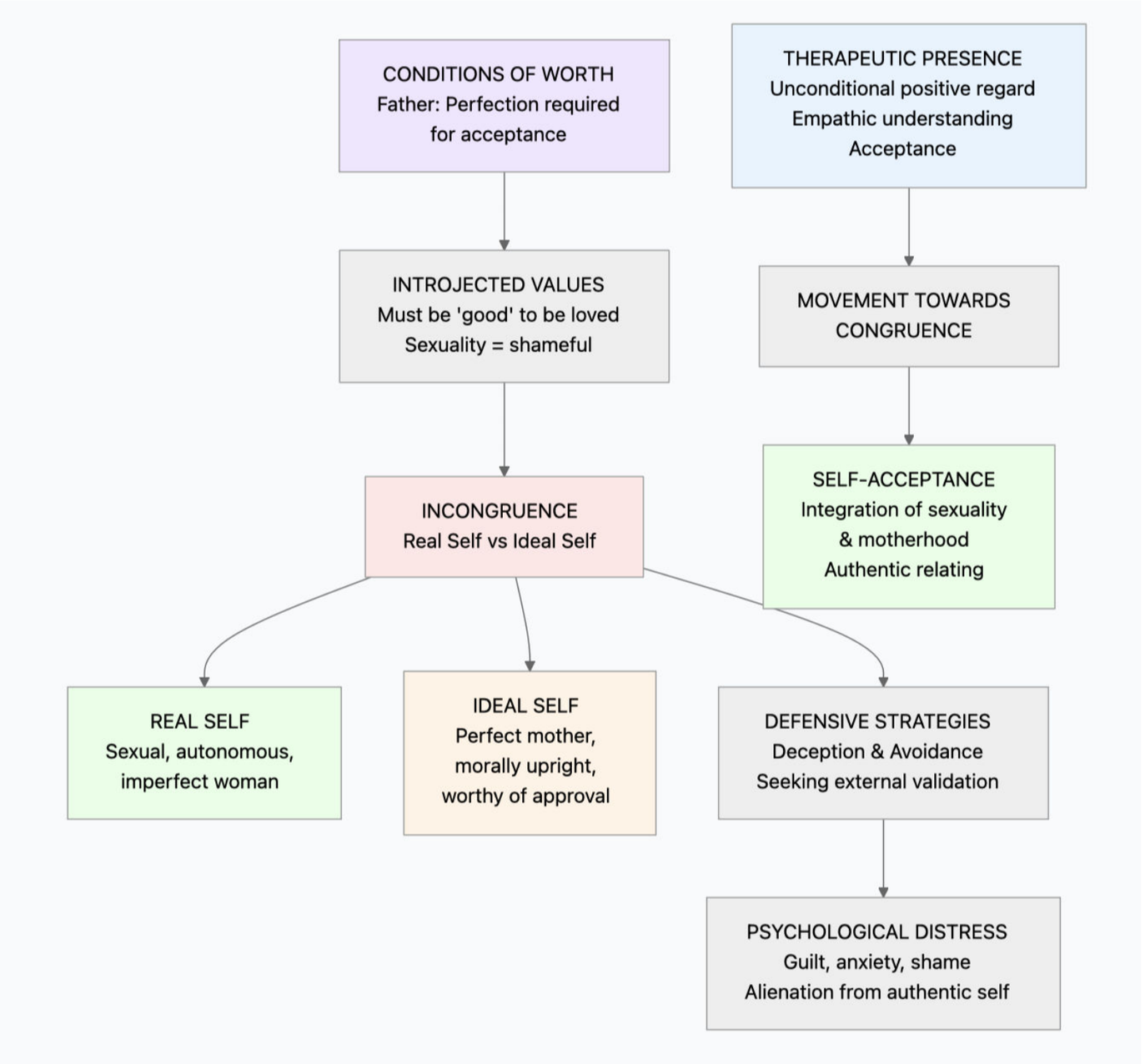
NovoNote Output

Gloria and Rogers: Interpersonal Therapy (IPT)



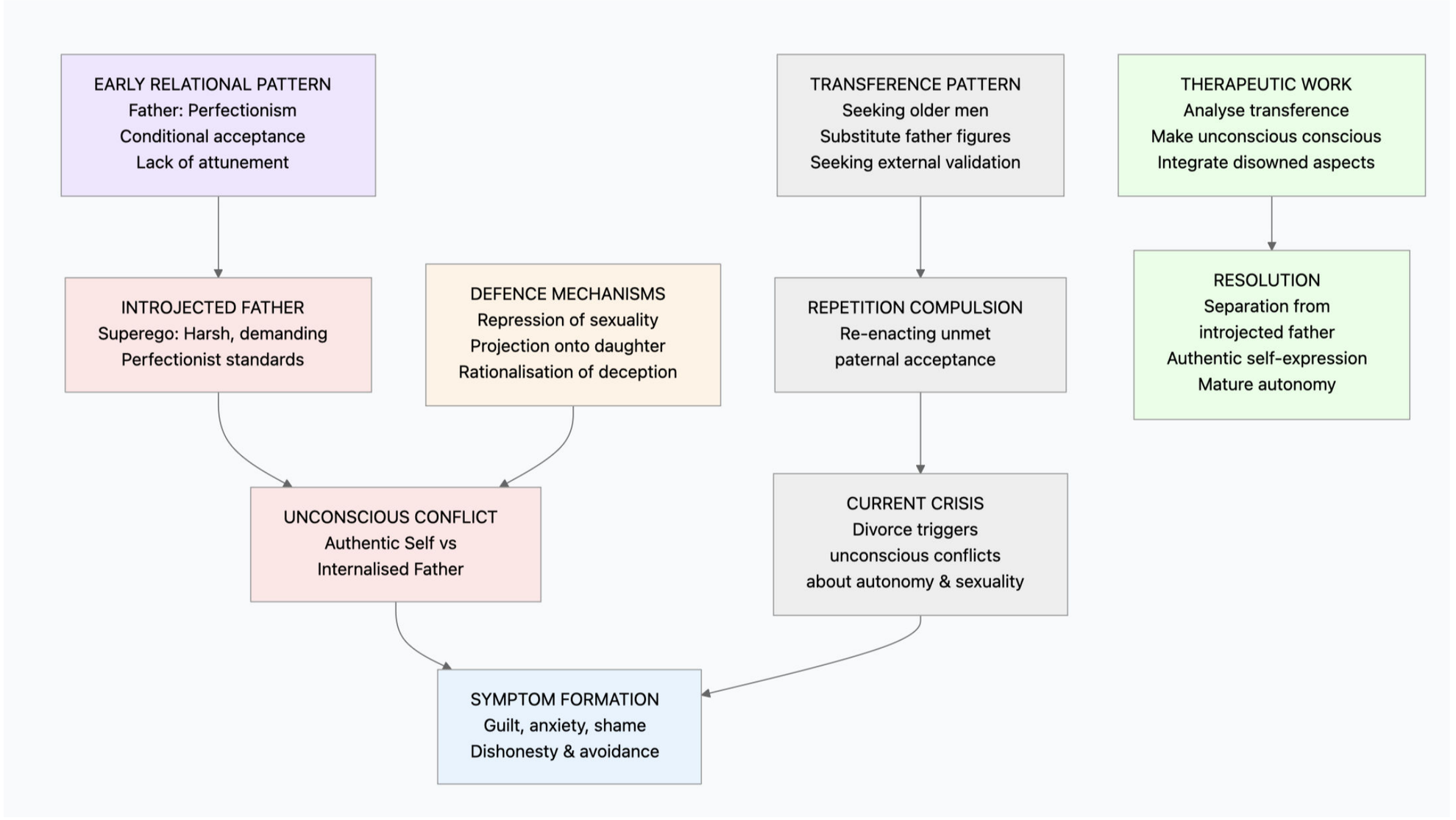
NovoNote Output

Gloria and Rogers: Person Centered Therapy



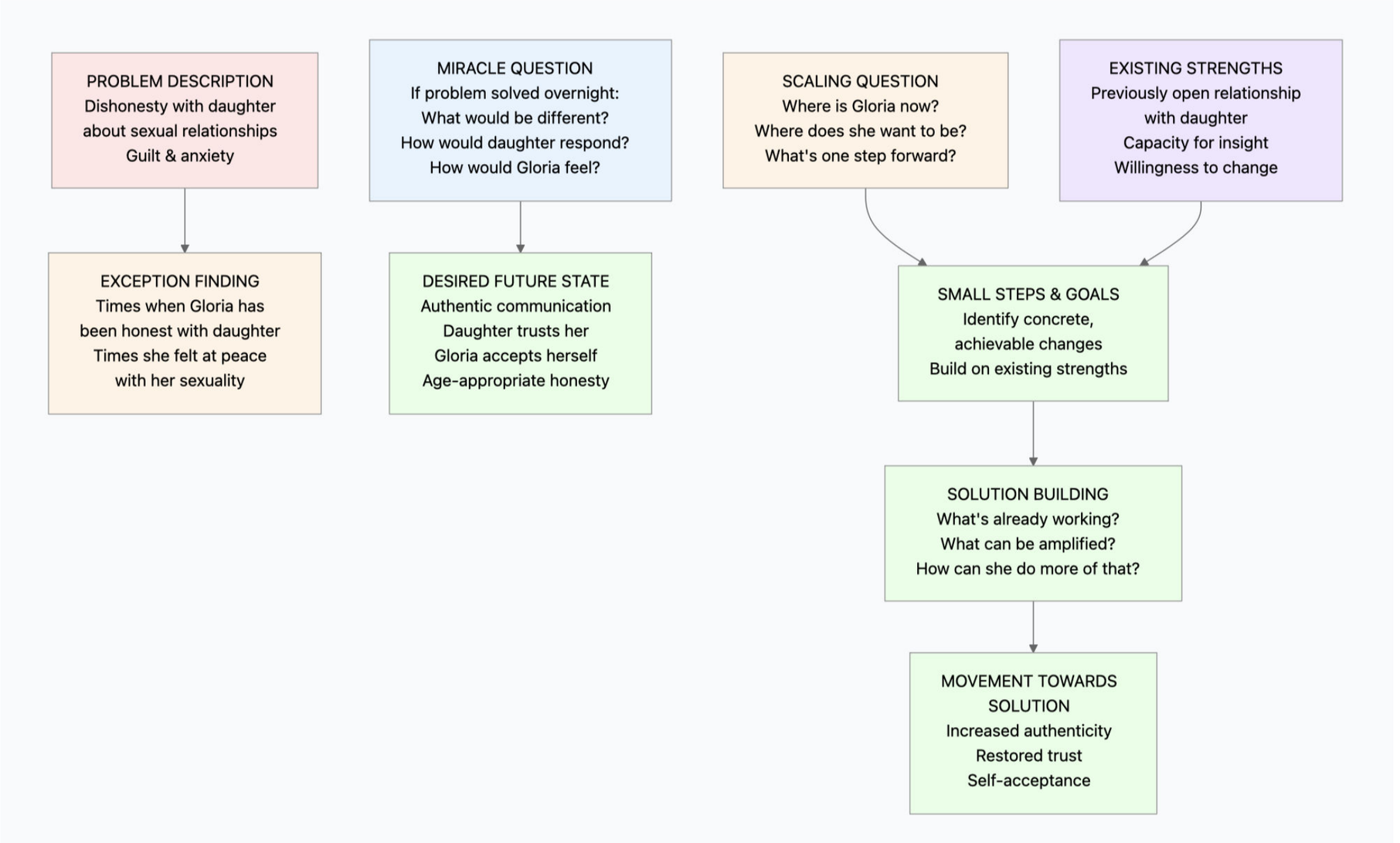
NovoNote Output

Gloria and Rogers: Psychodynamic Therapy



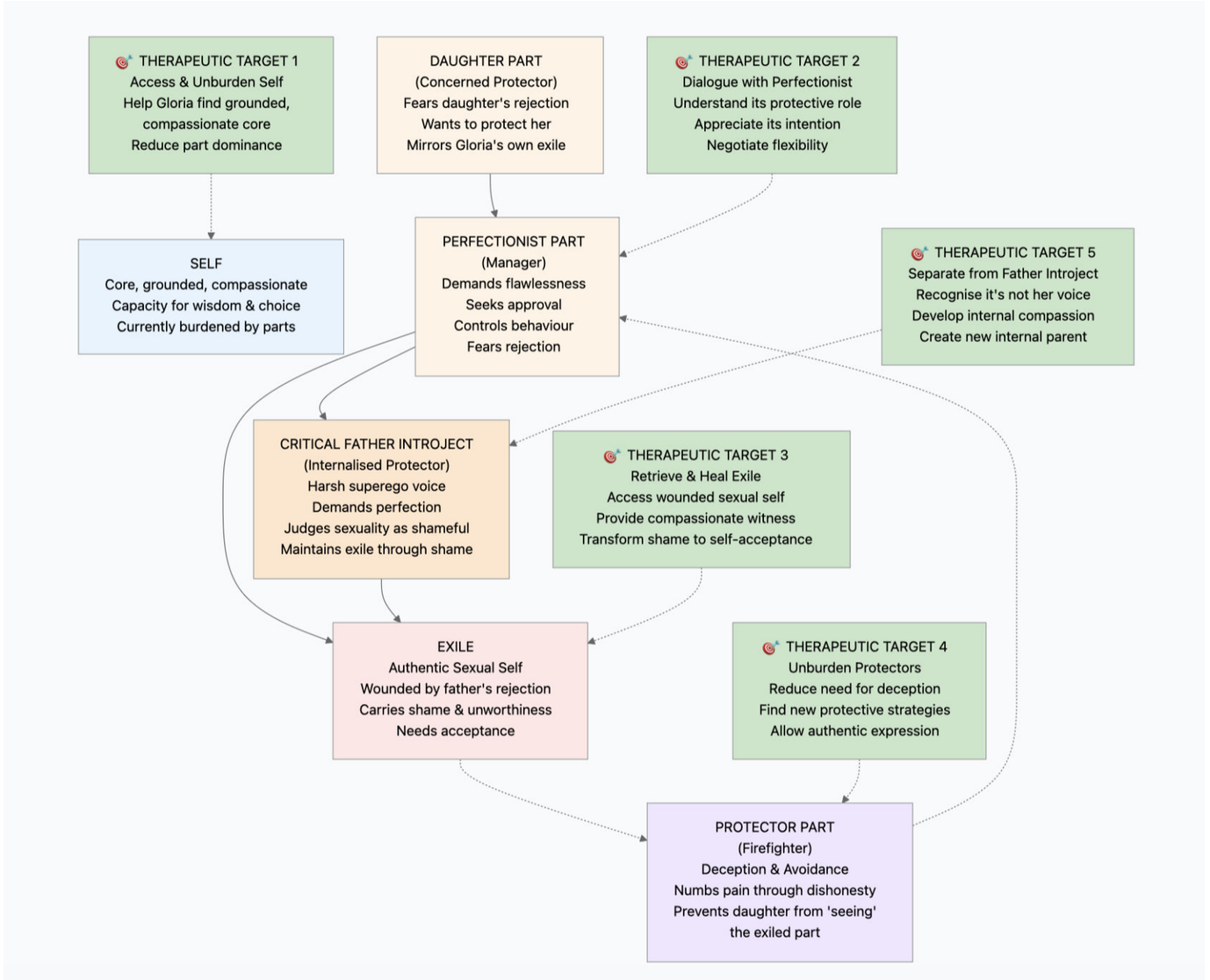
NovoNote Output

Gloria and Rogers: Solution Focused Therapy



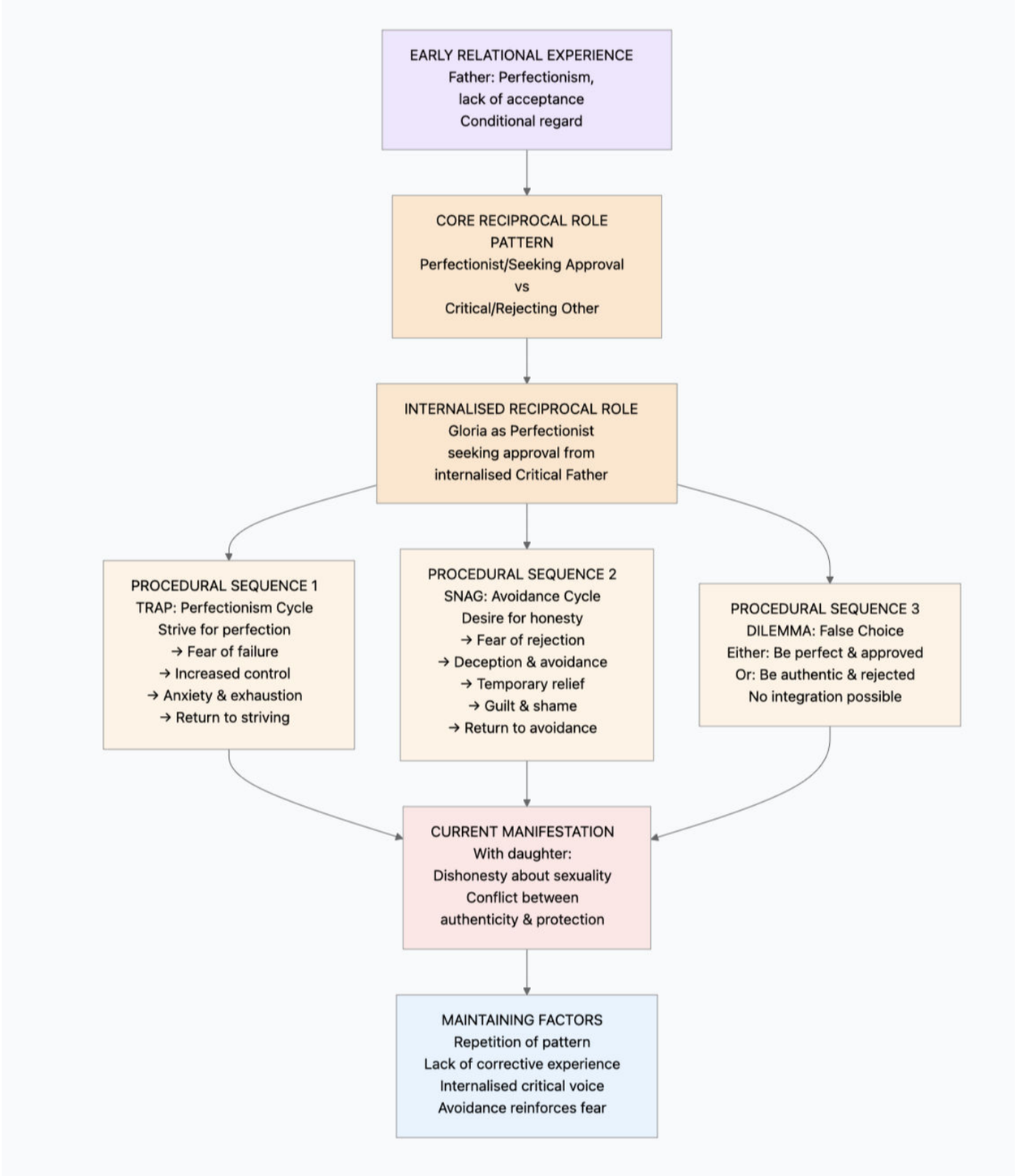
NovoNote Output

Gloria and Rogers: Internal Family Systems Therapy



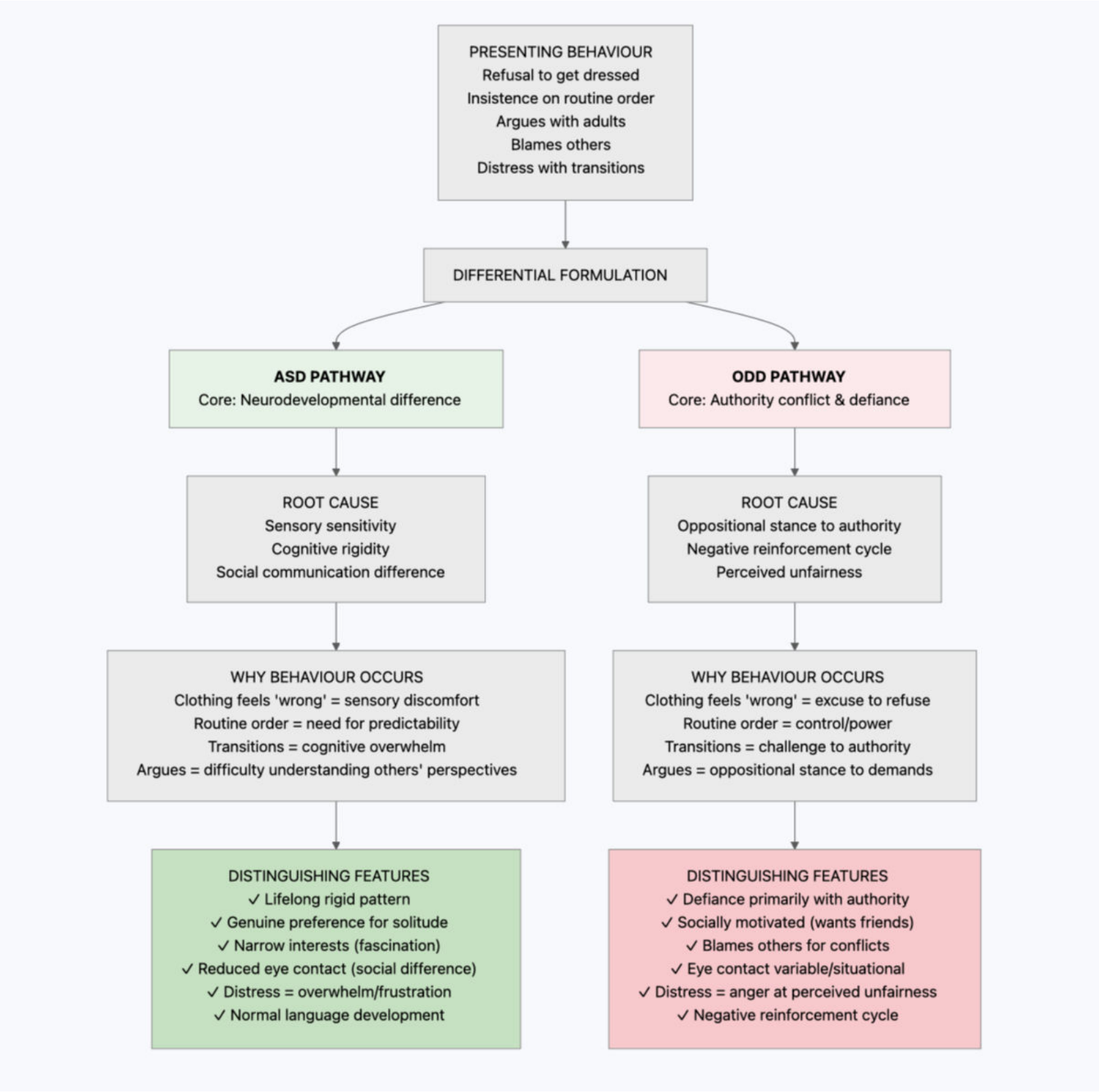
NovoNote Output

Gloria and Rogers: Cognitive Analytic Therapy (CAT)

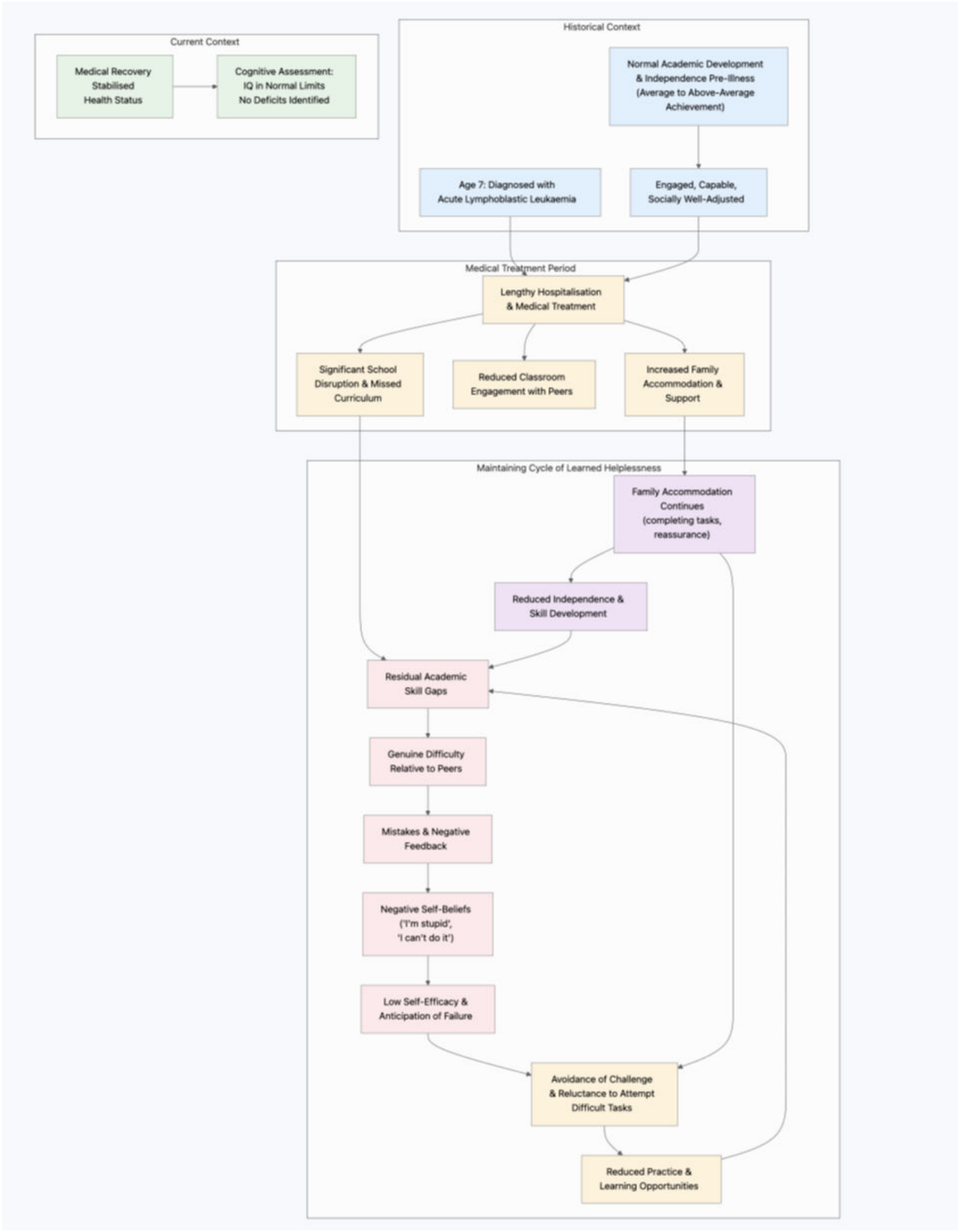


NovoNote Output

Differential diagnosis



Educational neuropsychological formulation



EXTENDED COGNITION

THINKING IS DISTRIBUTED BETWEEN MIND AND WORLD

EXTERNAL REPRESENTATION

Diagrams, symbols and writing make ideas visible and manipulable.

MANIPULATE & EXPLORE

We can inspect, compare, reorganise and test ideas outside the mind.

TRANSFORM THINKING

By working with external representations, we don't just offload thinking—we change and extend it.

INTERNAL REPRESENTATION

Mental models, memories and knowledge provide the foundation.

CONTINUOUS LOOP

Insight emerges through a dynamic loop between mind and world.

Clark, A. (1998).
Magic Words: How Language Augments Human Computation.
In A. Clark & J. Toribio (Eds.),
Language and Meaning in Cognitive Science
(Vol. 4, pp. 162–183). Routledge.

> *"External tools are not just aids to thought; they are parts of the cognitive process itself."*
>
> — Andy Clark (1998)

Human in the Loop

Formulation diagrams as a cognitive prosthetic

The clinician and AI form a cognitive system. Together they generate, test and refine formulations to understand what maintains difficulties and guide effective intervention.

1. INFORMATION IN

Narrative, observations, measures and context from the person.

2. AI AS REDESCRIPTION ENGINE

The AI externalises and restructures information into a causal formulation diagram.

LLM transforms tacit narrative knowledge into an explicit, inspectable structure.

3. CLINICIAN EVAUATES

Using their expertise and knowledge of the person, the clinician tests the hypothesis against the full picture.

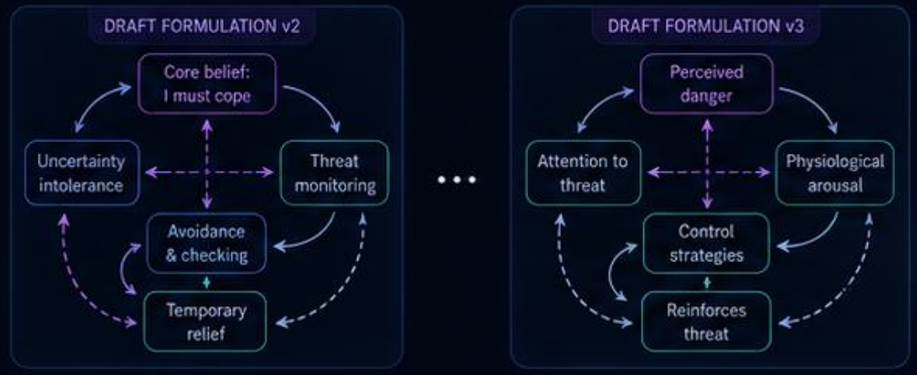
- Does this fit what I know about this person?
- What's missing or over-emphasised?
- What alternative explanation should I consider?
- What would be most useful to test in therapy?

CLINICIAN FEEDBACK (Recognition response)

The clinician's insight acts as an error signal—confirming, rejecting or refining the hypothesis.

4. ITERATE & REFINE

The AI generates a revised formulation, exploring alternatives suggested by the clinician.



5. WORKING FORMULATION

Through collaboration, a formulation emerges that is richer, more accurate and more useful for guiding treatment.

- Shared understanding
- Treatment targets
- Hypotheses to test
- Plan and monitor

Formulation diagrams are cognitive prosthetics—external structures that extend our thinking. They make the invisible visible, allow comparison of alternatives, support hypothesis testing and change how we understand.

Clark, A. (1998). *Magic Words: How Language Augments Human Computation.* In A. Clark & J. Toribio (Eds.), *Language and Meaning in Cognitive Science* (Vol. 4, pp. 162–183). Routledge.

Representational Redescription (Karmiloff-Smith, 1992)

Learning involves transforming existing representations into more explicit, flexible and generalisable forms that can be applied in new situations.

Start with what we already know → Redescribe and reorganise into a more powerful model → Apply and extend to new contexts

EVERYDAY ANALOGY: LEARNING CHOPSTICKS

1. Existing representation: 'eating with utensils'
2. New situation: chopsticks
3. Redescribed representation: 'using tools to eat'

You already understand the goal (eat) and the general structure (food to mouth using a tool).

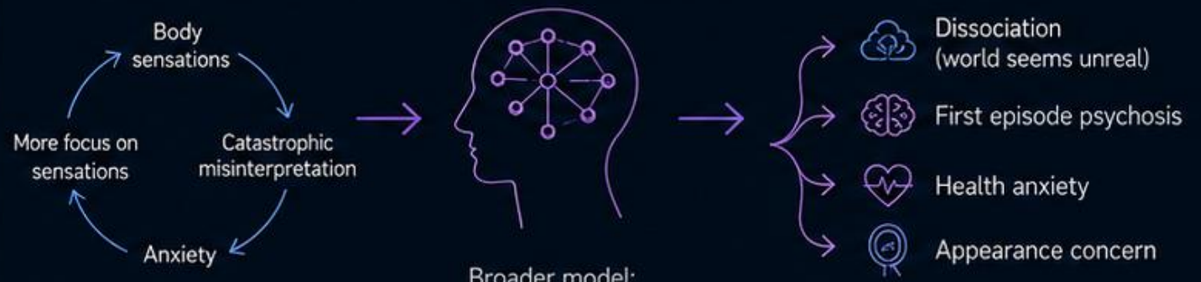
You map the new tool onto your existing model.

You redescribe your understanding so it now flexibly includes different tools and contexts.

From a specific experience to a more general, flexible representation.

CLINICAL ANALOGY: BUILDING CAUSAL MODELS

1. Learn a specific case (e.g. panic cycle)
2. Redescribe at a higher level (as a general causal loop)
3. Generalise to novel presentations



You build a diagram that explains how things maintain the difficulty.

Broader model: internal experience → threat interpretation → arousal → monitoring → amplification

The structure helps you recognise similar patterns in different presentations and new cases.

From one case to many: more mastery, better understanding.

AI-generated diagrams support representational redescription by externalising and structuring causal relations, helping clinicians connect ideas, generalise across cases and continue to learn.