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USING FORMAL THEORIES IN PSYCHOLOGICAL EVALUATION: WHAT THEY ARE AND HOW THEY ARE APPLIED

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Abstract

This paper examines the integration of formal theories within psychological evaluation, focusing on evaluators' challenges when linking outcome measurements with comprehensive explanations of program success or failure. Traditional evaluation methods often fail to address the complexity of social and psychological contexts, but this study posits that formal theoretical frameworks enhance precision, validity, and explanatory power. The paper investigates various types of formal theories, their contextual adaptations, and their unique attributes. It underscores how formal theories improve empirical consistency and predictive accuracy through testable predictions and detailed insights into underlying mechanisms. Methods such as contribution analysis and agent-based modelling are discussed as tools to bridge the gap between theoretical concepts and practical applications. The study advocates for the broader adoption of formal theories, particularly in areas where verbal explanations have traditionally dominated. Implementing these frameworks promises to strengthen evaluation practices, support robust theoretical development, and solidify the scientific foundations of psychological research. Future research should explore applying formal theories across diverse, cross-cultural contexts to expand their effectiveness and applicability.

Keywords: Psychological evaluation, formal theories, theory-based evaluation, contribution analysis, agent-based modelling

INTRODUCTION

Evaluative practices in psychological research are essential for assessing the effectiveness of interventions. However, they often require more than outcome measurement to fully understand the factors contributing to their success or failure (Guenther et al., 2023). The significance of employing evaluation within complex psychological and social contexts presents challenges, as interventions often operate amid multifaceted variables that conventional evaluation methods may not sufficiently address (Leeuw & Vaessen, 2010). While outcome evaluations can measure efficiency and effectiveness, impact assessments offer crucial causal insights (Stern, 2023; Schwandt, 2015). Integrating formal theories—rigorously developed and empirically validated theoretical constructs—into psychological evaluations can enhance their precision and provide more profound, contextually relevant interpretations (Kupiec et al., 2023). The use of formal theories in psychological evaluation has been an ongoing debate. Early work by Chen and Rossi (1983) posited that theoretical frameworks help elucidate mechanisms behind program success or failure, thus enabling evaluators to anticipate and address challenges more effectively. This aligns with Lewin's assertion that robust theoretical foundations offer practical value by providing a structured, theory-based empirical approach (Bedeian, 2016). Pawson (2013) further emphasised that theories enrich evaluation practices by facilitating an understanding of the conditions under which interventions are effective, particularly in complex societal contexts. However, despite their benefits, the consistent integration of formal theories remains limited, leaving evaluators with insufficient tools for establishing causality and comprehensive explanations (Leeuw & Vaessen, 2010; Donaldson et al., 2009). The credibility of psychological evaluations relies on methodological rigour and the incorporation of theoretical knowledge relevant to the specific evaluation questions and the broader social landscape (Gullickson, 2020). While some scholars advocate for theory-based approaches to enhance evaluative insights, others, such as Scriven (1998), argue for focusing primarily on results rather than the underlying mechanisms. Understanding theoretical concepts equips evaluators to navigate complex challenges more effectively (Wanzer, 2021). Current research underscores the limited application of formal theories in practice, pointing to a gap in utilising social science knowledge in psychological evaluations (Linnell & Montrosse-Moorhead, 2024; Kupiec et al., 2023). Formal theories are pivotal in bridging these gaps by providing explicit frameworks that outline observable relationships and underlying mechanisms (Stern, 2023). However, empirical studies that showcase the application of formal theories, especially in areas like health and social behaviour interventions, are still sparse (Moore et al., 2019). The difficulty of adapting formal theories to diverse and intricate social contexts, as discussed by Vaessen and Leeuw (2010), presents additional challenges. Despite these challenges, advancements in theory-driven methodologies—such as contribution analysis and realist evaluation—highlight the potential of formal theories to enhance evaluation processes (Brousselle & Buregeya, 2018; Krueger & Wright, 2022). These approaches emphasise integrating formal theoretical components into existing models, significantly improving their predictive accuracy and explanatory power. By incorporating homeostatic feedback mechanisms, which represent physiological processes that regulate and return arousal levels to baseline, evaluations become more precise and reflective of complex real-world dynamics. Critiques dating back to Meehl (1978) remain relevant, noting that many evaluations still rely heavily on statistical tools like null hypothesis significance testing (NHST), which may lack theoretical robustness (Orben & Lakens, 2019). This reliance has contributed to "theoretical amnesia," where the strengths of well-established theories are overlooked (Oberauer & Lewandowsky, 2019; Borsboom, 2013). Moving towards theory-centric approaches prioritising predictive, testable propositions offers a firmer foundation for theory validation (Smaldino, 2019; Rodgers, 2010). Contemporary research emphasises the need for systematic frameworks for theory construction and iterative refinement to promote robust theoretical development (Borsboom et al., 2020; Haslbeck et al., 2019). Effective theory-building should address theoretical amnesia by focusing on clear objectives and equipping researchers with the necessary tools for theory refinement (Guenther et al., 2023; Muthukrishna & Henrich, 2019).

This study aims to explore the integration of formal theories in psychological evaluations and demonstrate how these frameworks can improve their precision, validity, and explanatory power, particularly in complex social and psychological contexts.

METHODOLOGICAL APPROACH, DATA, AND EMPIRICAL PHENOMENA

Investigating the integration of formal theories in psychological evaluation requires addressing key questions: the types of formal theories in use, variations in their application, and unique characteristics of these approaches. Coryn et al. (2011) emphasise the importance of theoretical grounding and methodological rigour, which guide this study's practitioner-focused approach. This framework prioritises actionable findings that reflect the inherent complexity of real-world evaluations. Ensuring transparency is critical for mitigating biases and enhancing evaluation credibility, as highlighted by Calderon Martinez et al. (2023). Anglin et al. (2022) argue that formal theories facilitate a deeper interpretation of social interactions, though their relevance may shift across cultural contexts. Although cultural aspects are not the central focus of this study, insights into applying formal theories across diverse settings are provided. Scientific discourse often portrays theories as direct explanations of data, but this view simplifies the nuanced relationship between theories and data. Theories explain empirical phenomena, stable and recurring patterns evidenced by data rather than the data itself (Woodward, 1989; Haig, 2014). For instance, theories in intelligence research explain the consistent positive correlations between IQ subtests—known as the “positive manifold”—not the raw test scores themselves (Spearman, 1904). This distinction frames theories as connectors between empirical data and broader phenomena (Oberauer & Lewandowsky, 2019).

Data are specific, context-bound observations or recorded results (Haig, 2014). In contrast, phenomena demonstrate generality and stability across studies, making them essential for constructing robust theories (Kessler et al., 2006; Bogen & Woodward, 1988). The consistent comorbidity between major depression and generalised anxiety disorder exemplifies a well-supported empirical phenomenon (Kessler et al., 2006). While data are mutable and context-specific, phenomena offer a reliable basis for broader theoretical development (Haig, 2014; Woodward, 1989). Explanatory theories aim to improve scientific understanding by offering frameworks that elucidate empirical phenomena through connected propositions (Haig, 2014). These theories often include general principles that provide comprehensive explanations. For example, the *g* factor in intelligence theory posits a general cognitive ability influencing task performance, explaining the positive correlations observed among cognitive tests across populations (Van der Maas et al., 2014; Spearman, 1904). Such principles illustrate the depth of well-constructed theories.

Theory construction involves analysing data to identify generalisable phenomena that guide model development (Fried & Flake, 2018; Haig, 2014). Patterns identified in data can lead to the abstraction of phenomena that inform explanatory models. The phenomenon of attitude polarisation, where individuals’ opinions intensify when they deliberate on a topic, has been consistently observed, demonstrating how data informs theory (Tesser & Conlee, 1975). This process emphasises that while data are specific, phenomena are foundational for theoretical advancement. Distinguishing between data and phenomena is crucial for scientific clarity and rigorous theory development. Flake et al. (2020) emphasise that this differentiation prevents methodological issues and strengthens research credibility. Oberauer and Lewandowsky (2019) warn that neglecting this distinction leads to “theoretical amnesia,” weakening the link between empirical data and theoretical understanding. Focusing theories on phenomena enhances their explanatory and predictive power (Haig, 2014). Formal theories, articulated through precise methodologies like mathematics and computational modelling, clarify the relationship between phenomena and theoretical constructs (Robinaugh et al., 2021; Lee et al., 2024). This formalisation refines theoretical propositions and supports empirical validation, which is essential for refining and confirming theoretical models (Haslbeck et al., 2019; Borsboom et al., 2020). Incorporating formal theories into evaluation practices advances psychological research by fostering transparency, enhancing consistency, and ensuring scientific rigour (Flake et al., 2020).

LITERATURE REVIEW

Conceptual framework

In psychological evaluation, formal theories serve as vital tools for defining and analysing concepts, which are cognitive symbols that delineate phenomena' features, attributes, or characteristics (Podsakoff et al., 2016). While terms like "concept" and "construct" are often used interchangeably, a construct refers explicitly to a concept designed for scientific investigation, such as psychological traits or leadership models. The emphasis on "concept" highlights its foundational role in developing formal theories that support psychological evaluations. From a philosophical perspective, conceptual analysis involves the detailed exploration of meanings and attributes, often through counterfactual reasoning, to establish necessary and sufficient conditions for defining a concept (Carnap, 1956; Jackson, 1998). However, such a priori precision is challenging outside physical sciences, as philosophical traditions acknowledge (Putnam, 1975; Quine, 1960; Wittgenstein, 1953).

The interpretation and applicability of a concept within formal theories depend on its level of abstraction, theoretical underpinnings, and the context in which it is used (Laurence & Margolis, 2003). For example, psychological constructs like "charisma" or "organisational citizenship behaviour" are often abstract and influenced by cultural and linguistic nuances (Bolegnesi & Steen, 2019; McDonough et al., 2012). Neuro-linguistic research supports that concrete concepts are typically rooted in perceptual experiences, whereas abstract ones evolve through social and linguistic interactions (Bolegnesi & Steen, 2019). Thus, concepts must adapt as language and socio-cultural dynamics change (Bentein, 2019; Haspelmath, 2009; Cook-Gumperz, 2006). Formal theories are essential for refining psychological concepts through structured frameworks that categorise and describe higher-order attributes (Goertz, 2006). For instance, integrating charisma into a role theory context repositions it within the "role play" category, altering its attributes through dramaturgical perspectives (Sharma & Grant, 2011; Gardner & Avolio, 1998). Given that multiple theories can apply to a single concept, maintaining adaptability in definitions is crucial, especially as empirical testing and theory refinement progress (Laurence & Margolis, 2003).

Approaches to defining concepts can be rationalist, empiricist, or constructionist. The rationalist view sees concepts as mediators between theory and empirical measurement, focusing on logical coherence and theoretical clarity (Bacharach, 1989; Giere, 1988; Van de Ven, 2007). For instance, charisma could be operationalised by peer or follower perceptions using attribution theory (Meindl et al., 1985). However, such approaches can result in divergent definitions that align with different theoretical views, leading to many interpretations (Cornelissen & Durand, 2014; Colquitt & Zapata-Phelan, 2007). In contrast, empiricist traditions focus on observable behaviours and activities, emphasising practical application and empirical classification (Roskam, 1989; Bridgman, 1959). In this context, charisma could be identified through specific leader behaviours such as emotional expressiveness, value-laden communication, and symbolic interaction (Antonakis et al., 2011). This approach prioritises empirical observability and often incorporates psychometric assessments to bolster predictive validity (Van Knippenberg & Sitkin, 2013; Bass & Avolio, 1990). The constructionist perspective suggests that concepts are socially constructed and defined by linguistic and cultural contexts (Gergen, 1999; Astley & Zammuto, 1992). According to this view, concepts evolve through collective understanding and are subject to change depending on the cultural lens through which they are viewed (Furnari, 2014; Cunliffe, 2008). For example, charisma might be redefined across cultures to stress heroic or routine elements, reflecting societal values and narratives (Khurana, 2002; Calas, 1993).

Formal theories provide a structured, transparent foundation for consistently developing and applying concepts in psychological evaluations. Unlike verbal theories, which can be ambiguous and proprietary, formal theories use standardised languages such as mathematics and computational programming, which allow for greater precision and shared understanding among researchers (Lee et al., 2023). Formalisation facilitates the comparison of theory-implied data models with empirical data, identifying inconsistencies and guiding theory refinement (Haslbeck et al., 2019). For example, applying formal mathematical models to the “maximise attraction” theory in social psychology has shown the importance of incorporating realistic social network structures to align theoretical predictions with real-world observations (Jia et al., 2015). Formal theories also meet the call for increased precision and transparency in psychological research (Flake & Fried, 2019; Fried & Flake, 2018). By clearly defining measurement functions and assumptions, formal theories ensure that theoretical models better reflect empirical data, thus enhancing reliability and validity (Kellen et al., 2020; Schuler et al., 2019). This transparency strengthens evaluations by providing a robust framework for explaining observed outcomes and facilitating iterative refinement that aligns theory with emerging data.

The dual role of scientific theories in psychological research

Scientific theories serve two essential functions: explanation and representation. These frameworks elucidate phenomena and capture the consistent, generalisable aspects of the world researchers aim to understand (Haig, 2014; Bogen & Woodward, 1988). Prominent examples in psychology include the Flynn Effect (Trahan et al., 2014), the matching phenomenon (Feingold, 1988), and the prevalence of panic attacks in specific populations (Kessler et al., 2006). Contemporary psychological research continues to focus on identifying such phenomena, with initiatives aimed at enhancing the rigour of the discipline by ensuring precise observation and measurement (Shrout & Rodgers, 2018; Munafò et al., 2017). Recognising and documenting these phenomena are fundamental for developing robust theoretical frameworks. Well-documented phenomena provide the empirical foundation upon which explanatory theories are constructed. Theories aim to elucidate the underlying elements of the environment that generate these phenomena, collectively referred to as the target system (Elliott-Graves, 2014). Conversely, the components and their interrelations within a theory constitute its structural framework. In the philosophy of science, the significance of representation in scientific endeavours has gained substantial recognition (Suárez & Pero, 2019; Bailer-Jones, 2009). Theories function as models that depict the target system, facilitating surrogate reasoning (Swoyer, 1991). This allows researchers to make informed predictions about the target system based on theoretical insights. Analogous to using a map for navigation, theories enable the interpretation, anticipation, and influence of real-world phenomena through logical reasoning derived from theoretical constructs. Achieving the core objectives of psychological science—namely explanation, prediction, and control—necessitates the development of theories that accurately represent the target system. Such precise representation enhances the validity of research findings and deepens the comprehension of complex human behaviours (Lawrie et al., 2024; Anglin et al., 2022).

Advancements in integrating formal theoretical models with empirical data have significantly improved predictive accuracy and explanatory power. Studies have demonstrated how computational models can simulate cognitive processes, providing deeper insights into mental disorders and behavioural patterns (Robinaugh et al., 2021). Incorporating machine learning techniques into theory testing has allowed for identifying nuanced patterns that traditional methods might overlook, thereby refining theoretical constructs (Synowiec et al., 2024). Moreover, an emphasis on interdisciplinary approaches has enriched theoretical development by incorporating diverse perspectives and methodologies. Collaborative efforts between psychology and fields such as neuroscience, data science, and sociology have led to more comprehensive models that account for multifaceted interactions within the human psyche and behaviour (Karvelis et al., 2023; Teixeira de Melo, 2023). These interdisciplinary theories not only enhance explanatory depth but also improve the practical applicability of psychological research in real-world settings.

Enhancing predictive precision through formal psychological theories

Surrogate reasoning relies on the ability to infer the behaviour of a target system based on its theoretical framework, such as forecasting the progression of its components over time. In soft psychology, numerous theories encounter challenges in generating precise predictions about system behaviour. This limitation is primarily due to the reliance on verbal articulation, which is susceptible to the inherent ambiguities of natural language (Calderon Martinez et al., 2023; Liu et al., 2022). Conversely, formal theories utilise more exact languages—such as mathematical models, formal logic, or computational programming languages—to define their structures. This formalisation permits researchers to derive exact predictions regarding the system's dynamics, thereby increasing the accuracy and reliability of their inferences (Chen et al., 2024; Reyna & Brainerd, 2023). Transitioning from verbal to formal theoretical frameworks can significantly enhance psychological science's empirical robustness and predictive power.

Formalising the vicious cycle theory of panic attacks for enhanced predictive accuracy

Panic attacks are characterised by sudden and intense episodes of arousal and perceived threats, often occurring unexpectedly (American Psychiatric Association, 2013). Clark's seminal verbal theory (1986) posits that initial bodily sensations associated with arousal, such as an elevated heart rate, are misinterpreted as threatening events (e.g., signalling a heart attack). This misinterpretation triggers further arousal, intensifying the perceived threat in a feedback loop that culminates in a panic attack. This verbal framework identifies two primary components—arousal and perceived threat—that mutually amplify each other, offering a conceptual explanation for the onset of panic attacks. However, verbal theories in psychology often suffer from imprecision due to the inherent ambiguities of natural language, which limits their predictive utility (Johnson, 2024). Formal theories address this limitation by employing precise languages like mathematics, formal logic, or computational programming, enabling exact deductions about system behaviour (Park et al., 2024). For instance, the vicious cycle theory can be translated into a mathematical model using differential equations to describe the dynamics of arousal (A) and perceived threat (T) over time:

$A_{\tau+1} = A_\tau + \alpha(vT_\tau - A_\tau)$

Here, α regulates the rate of change in arousal, and v quantifies the impact of perceived threat on arousal. Such formalisation precisely predicts how arousal and perceived threat interact and evolve, facilitating more accurate simulations of panic attack dynamics (Robinaugh et al., 2021). A comprehensive formal theory emerges by developing coupled differential equations that similarly define the evolution of perceived threat based on arousal. This formalisation enables the derivation of theory-implied behaviours, predicting the trajectories of arousal and perceived threat within individuals over time. For example, computational models implemented in programming languages like R can simulate various scenarios, illustrating how different formalisations of the vicious cycle theory yield distinct behavioural outcomes (Karvelis et al., 2023). Empirical studies indicate that formal models can more reliably replicate the spontaneous surges characteristic of panic attacks than verbal theories. One model might demonstrate sustained moderate arousal levels and perceived threat following an induced arousal event, while another could predict runaway positive feedback leading to acute panic episodes (Ren et al., 2024). These variations underscore the necessity of formalising verbal theories to achieve consistent and testable predictions. Additionally, formal theories facilitate the incorporation of regulatory mechanisms, such as homeostatic feedback, which can stabilise arousal levels and prevent excessive escalation of perceived threats. This enhancement improves the model's realism and ability to mirror actual physiological and psychological processes observed in panic attacks (Borba et al., 2023).

Figure 1 illustrates the development of four unique formal theories derived from the verbal "vicious cycle" framework of panic attacks. This process began by examining two essential questions: the specific effect of perceived threat (T) on arousal (A) and the distinct influence of arousal on perceived threat. The investigation focused on linear and sigmoidal interactions for each relationship type. Despite this limitation, the range of potential configurations remained extensive due to the diversity in parameter values defining these interactions. For illustrative purposes, a single set of parameter values was chosen for each interaction type—linear arousal-to-threat, sigmoidal arousal-to-threat, linear threat-to-arousal, and sigmoidal threat-to-arousal. This selection resulted in four formal theories encompassing all possible combinations of these effects. The half-saturation point parameter in the sigmoidal arousal-to-threat relationship was selected based on its recognised link to panic attack susceptibility from previous studies (Robinaugh et al., 2019).

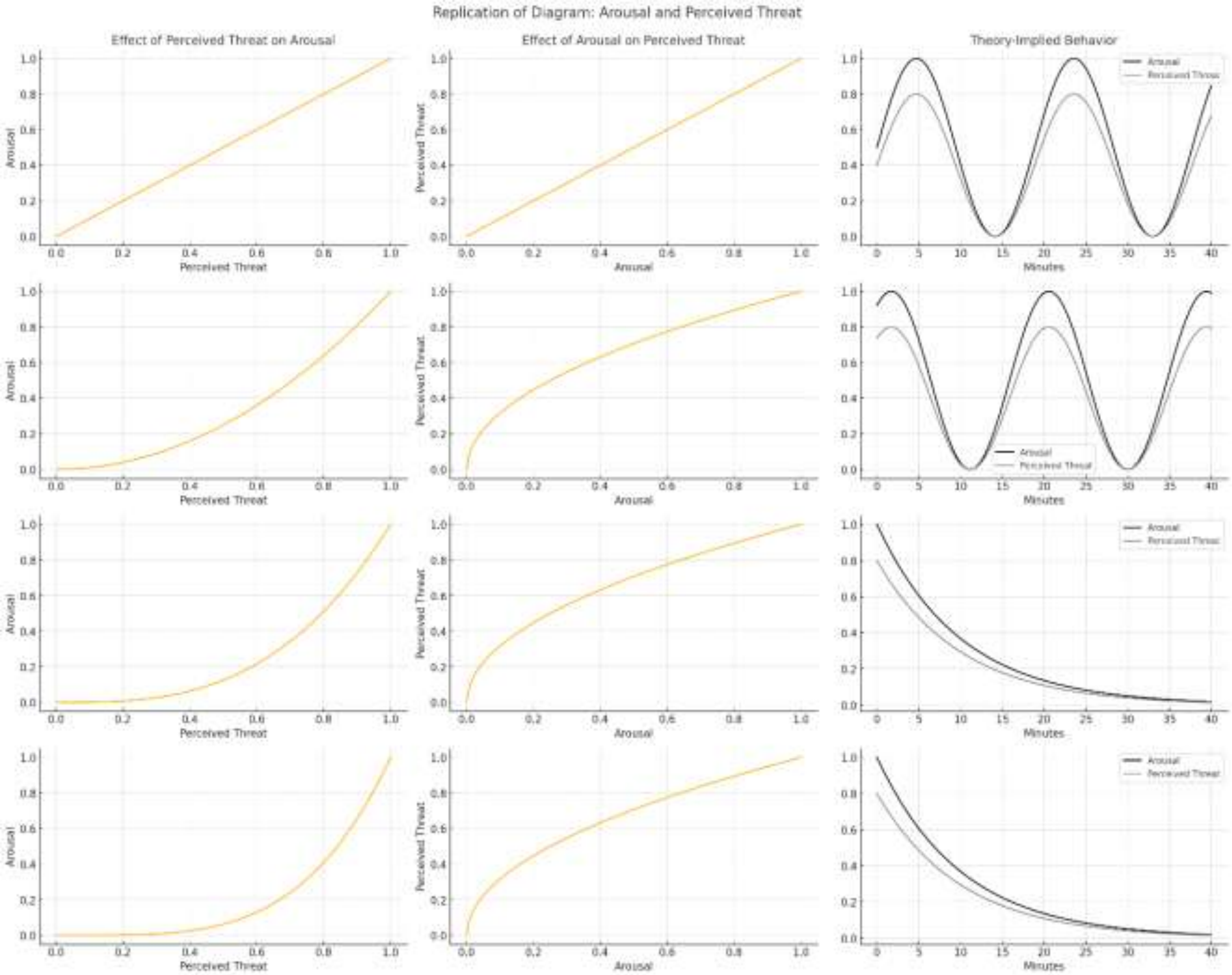

Figure 1. Dynamics between perceived threat and arousal over time

Integrating additional components into theoretical models can significantly improve their predictive accuracy and explanatory power (Lawrie et al., 2024; Calderon Martinez et al., 2023). This study incorporates a third element—homeostatic feedback (H)—into the existing feedback loop between arousal (A) and perceived threat (T). Homeostatic feedback represents the physiological mechanisms that regulate arousal levels, returning them to baseline after substantial increases (Borba et al., 2023). This negative feedback mechanism consistently influences arousal across all four formal theories, ensuring that variations in system behaviour result solely from the interactions between arousal and perceived threat. Following the mathematical formulations provided by Robinaugh et al. (2021), the formal theories were defined using different equations as follows:

I. Formal Theory A (Linear-Linear)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5(T_\tau - A_\tau) - 10H_\tau$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1(A_\tau - T_\tau)$$

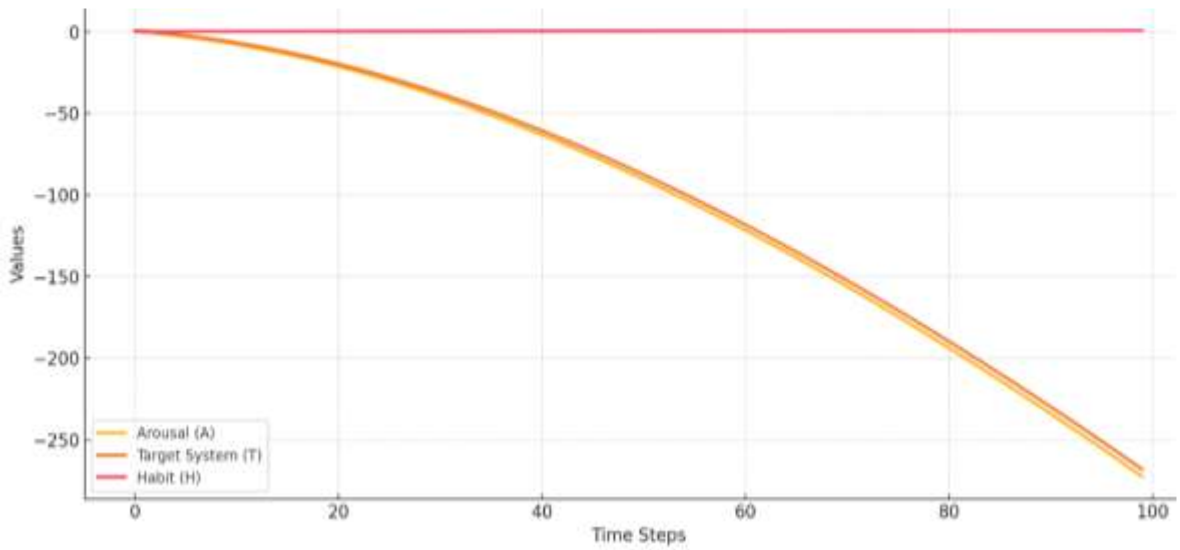

Figure 2. Simulation of theory A: Linear dynamics.

II. Formal Theory B (Linear - Sigmoidal)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5(T_\tau - A_\tau) - 10H_\tau$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1\left(\frac{A_\tau^5}{A_\tau^5 + 0.45} - T_\tau\right)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right)$$

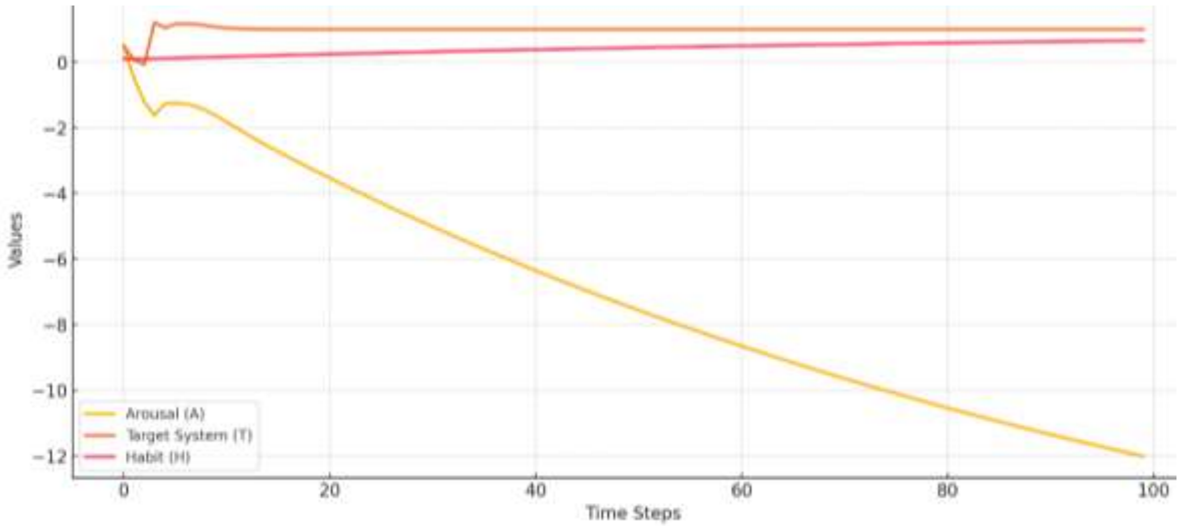

Figure 3. Simulation of theory B: Linear dynamics

III. Formal Theory C (Sigmoidal - Linear)

1. The equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5\left(\frac{T_\tau^5}{T_\tau^5 + 0.55} - A_\tau\right) - 10H_\tau$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1(A_\tau - T_\tau)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right)$$

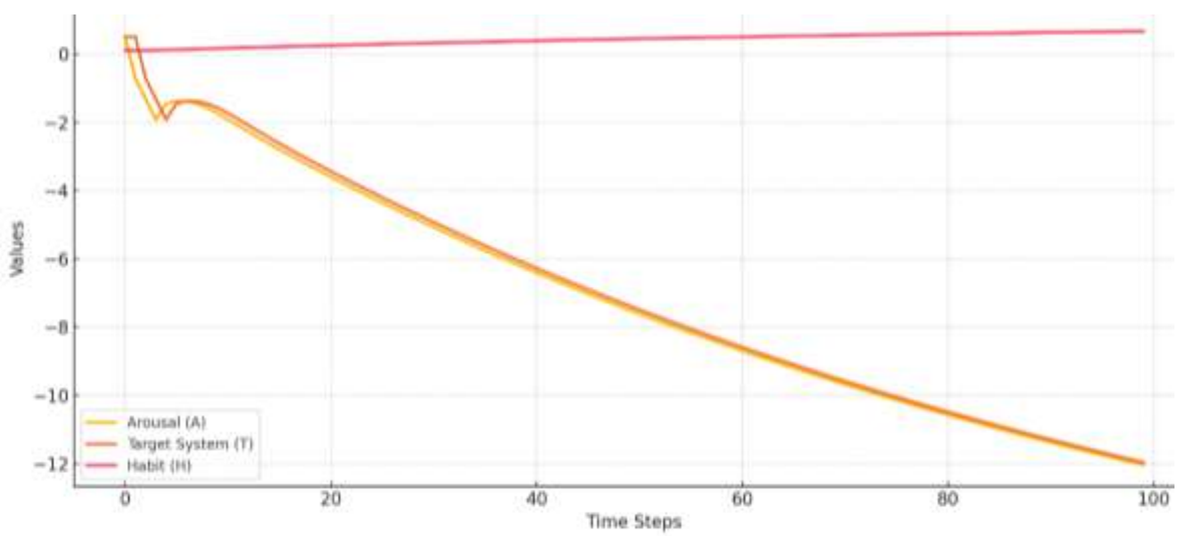

Figure 4. Simulation of theory C: Linear dynamics

IV. Formal Theory D (Sigmoidal - Sigmoidal)

1. The equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5\left(\frac{T_\tau^5}{T_\tau^5 + 0.55} - A_\tau\right) - 10H_\tau$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1\left(\frac{A_\tau^5}{A_\tau^5 + 0.45} - T_\tau\right)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right)$$

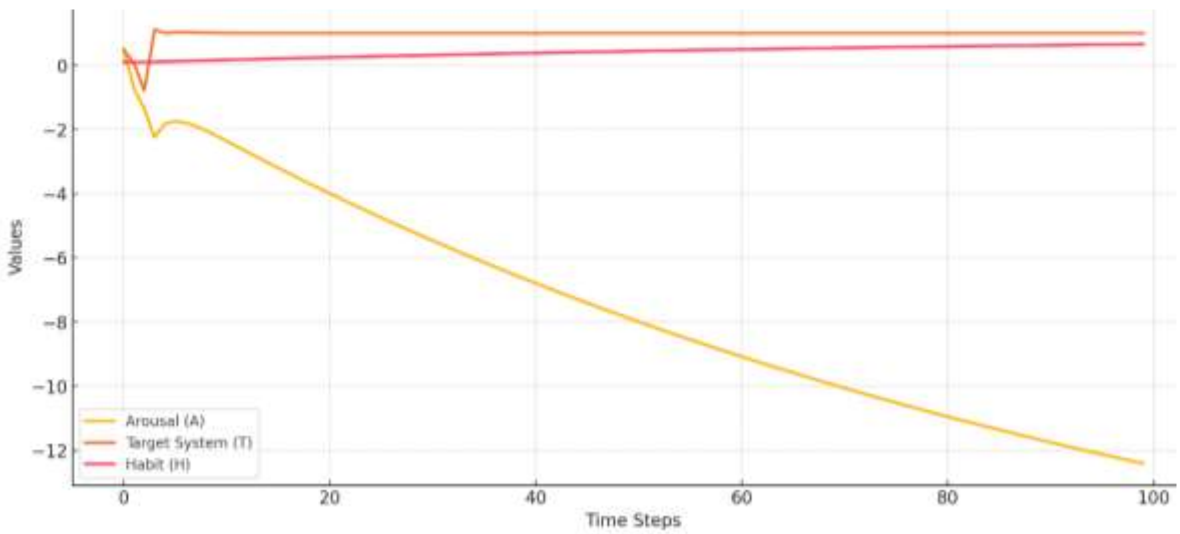

Figure 5. Simulation of theory D: Linear dynamics

The system's dynamic behaviour is modelled under different theoretical conditions, allowing for the analysis of interactions among variables such as arousal, target system behaviour, and habit over time. Formal theories were operationalised using distinct equations within the R programming environment (R Core Team, 2019) and evaluated under two simulation scenarios. Condition 1 introduced a specific arousal level (A = 0.5) to assess system responses to disturbances at the tenth time step. Condition 2 incorporated a red noise function (Van Nes & Scheffer, 2004) into the arousal equation to emulate natural fluctuations in arousal due to internal or external stimuli. Simulation results, depicted in Figure 1 of the main text, revealed distinct behavioural patterns across the four formal theories despite their common verbal origins. For example, Formal Theory A exhibited sustained moderate arousal levels and perceived threat following an induced arousal event. In contrast, Formal Theory B demonstrated a rapid escalation, leading to panic-like episodes. These differences highlight the critical importance of precise formalisation for accurately predicting system dynamics (Ren et al., 2024). The inclusion of homeostatic feedback uniformly regulated arousal levels across all models, underscoring the role of regulatory mechanisms in preventing excessive escalation of perceived threats (Borba et al., 2023). The observed variability in system behaviour among the formal theories underscores the limitations of verbal theories, which often lack the mathematical precision necessary for reliable outcome predictions without detailed formalisation (Johnson, 2024; Lee et al., 2023). The formalised equations used for the simulations of the different formal theories with added noise:

I. Formal Theory A (Linear-Linear)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5(T_\tau - A_\tau) - 10H_\tau + \text{Noise}(0, \sigma)$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1(A_\tau - T_\tau) + \text{Noise}(0, \sigma)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01 \left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau \right) + \text{Noise}(0, \sigma)$$

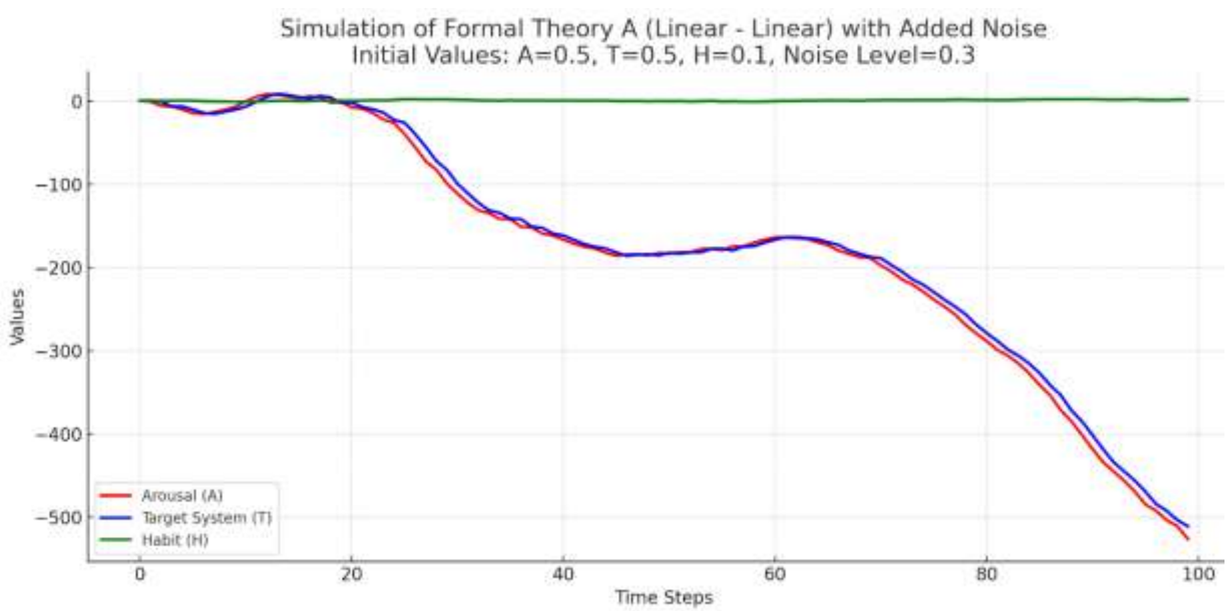

Figure 6. Simulation of theory A with noise effects

II. Formal Theory B (Linear - Sigmoidal)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5(T_\tau - A_\tau) - 10H_\tau + \text{Noise}(0, \sigma)$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1\left(\frac{A_\tau^5}{A_\tau^5 + 0.45} - T_\tau\right) + \text{Noise}(0, \sigma)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right) + \text{Noise}(0, \sigma)$$

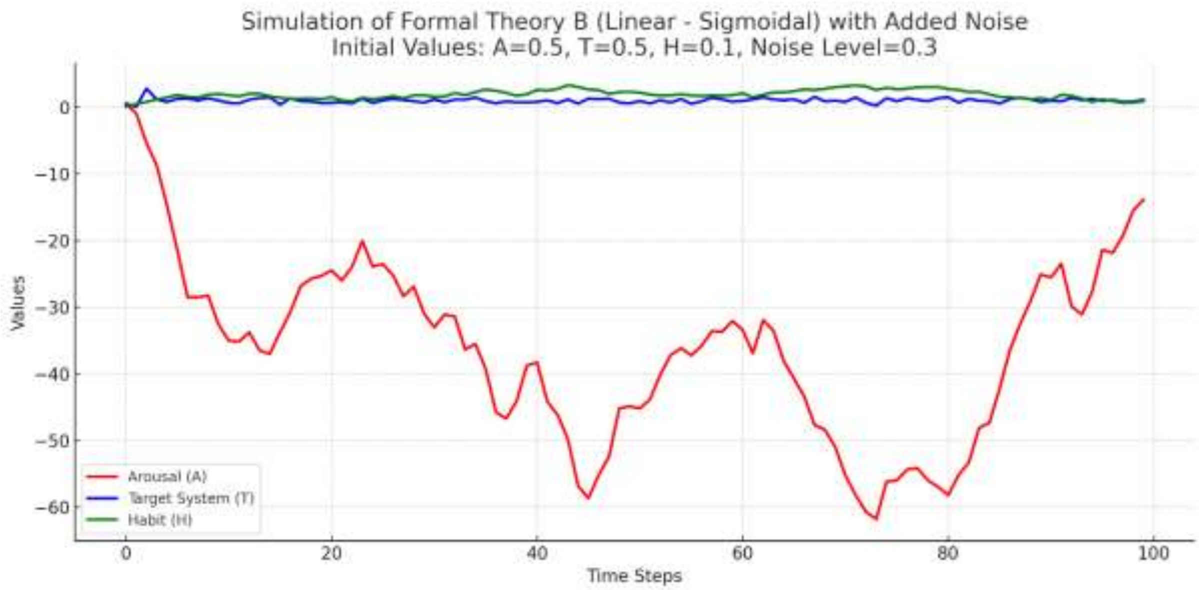

Figure 7. Simulation of theory B with noise effects

III. Formal Theory C (Sigmoidal - Linear)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5\left(\frac{T_\tau^5}{T_\tau^5 + 0.55} - A_\tau\right) - 10H_\tau + \text{Noise}(0, \sigma)$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1(A_\tau - T_\tau) + \text{Noise}(0, \sigma)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right) + \text{Noise}(0, \sigma)$$

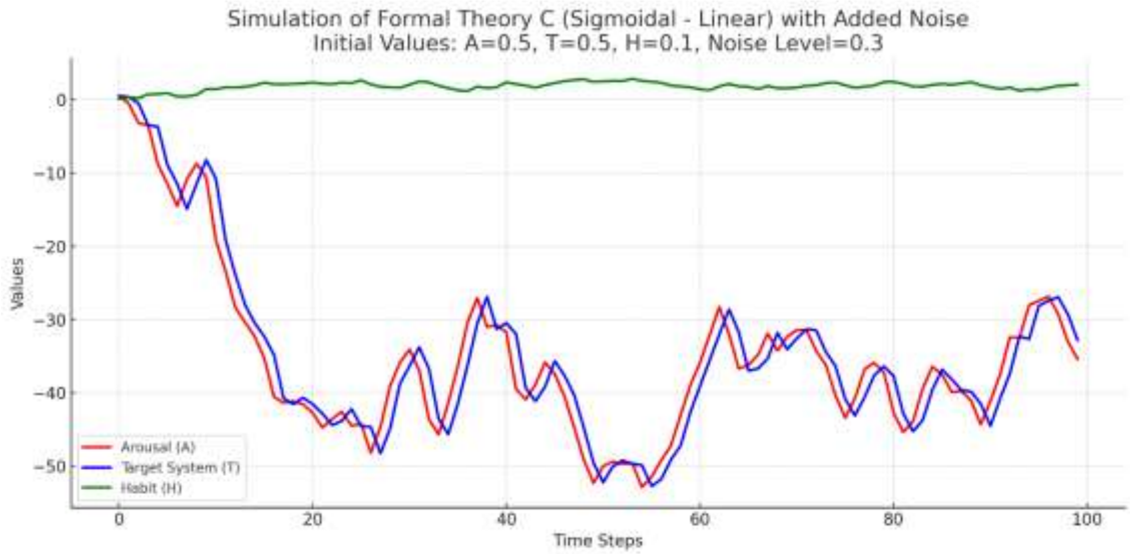

Figure 8. Simulation of theory C with noise effects

IV. Formal Theory D (Sigmoidal - Sigmoidal)

1. Equation for Arousal (A):

$$A_{\tau+1} = A_\tau + 0.5\left(\frac{T_\tau^5}{T_\tau^5 + 0.55} - A_\tau\right) - 10H_\tau + \text{Noise}(0, \sigma)$$

2. Equation for Target System (T):

$$T_{\tau+1} = T_\tau + 1\left(\frac{A_\tau^5}{A_\tau^5 + 0.45} - T_\tau\right) + \text{Noise}(0, \sigma)$$

3. Equation for Habit (H):

$$H_{\tau+1} = H_\tau + 0.01\left(\frac{A_\tau^8}{A_\tau^8 + 0.758} - H_\tau\right) + \text{Noise}(0, \sigma)$$

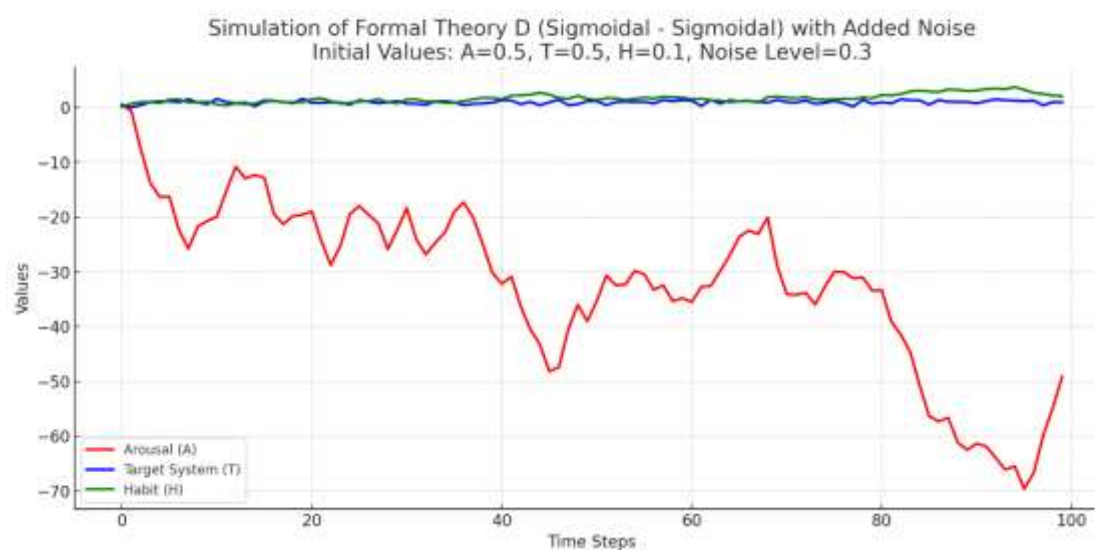

Figure 9. Simulation of theory D with noise

Formal theories facilitate the implementation of regulatory mechanisms, such as homeostatic feedback, thereby enhancing the models' realism and alignment with actual physiological and psychological processes observed in panic attacks (Borba et al., 2023). Each formal theory (A, B, C, and D) was depicted with added noise to illustrate the behaviour of the variables A (arousal), T (target system), and H (habit) over time. The Noise (0, σ) term represents a random noise function with a mean of 0 and a standard deviation σ, simulating real-world variability and perturbations. Each equation outlines the evolution of state variables, incorporating interactions and non-linear dynamics. These equations enable the implementation and analysis of dynamic simulations of theoretical models under conditions of external or internal noise. The development process involved examining the specific effects of perceived threat (T) on arousal (A) and the distinct influence of arousal on perceived threat. The investigation focused on linear and sigmoidal interactions for each relationship type. Despite this limitation, the diversity in parameter values allowed for a broad range of potential configurations. For illustrative purposes, a single set of parameter values was selected for each interaction type—linear arousal-to-threat, sigmoidal arousal-to-threat, linear threat-to-arousal, and sigmoidal threat-to-arousal—resulting in four formal theories encompassing all possible combinations of these effects. Notably, the half-saturation point parameter in the sigmoidal arousal-to-threat relationship was chosen based on its established link to panic attack susceptibility in prior research (Robinaugh et al., 2019).

Advancing psychological theories through agent-based modelling

Agent-based models present a formidable alternative to traditional difference equation methodologies in deriving theoretical predictions within psychological research (Wilensky & Rand, 2015). This approach is particularly pertinent in investigating the matching phenomenon, where romantic partners display congruence across physical attractiveness, intelligence, and personality traits (Feingold, 1988; Buss & Barnes, 1986). Two predominant theories elucidate this phenomenon: the maximise similarity and maximise attraction theories. The former posits that individuals intentionally select partners with traits mirroring their attractiveness, intelligence, or other desirable characteristics (Berscheid et al., 1971). Conversely, the latter theory suggests that the matching effect arises naturally as individuals seek the most attractive available partners, independent of a deliberate pursuit of similarity (Kalick & Hamilton, 1986; Burley, 1983). Conroy-Beam & colleagues (2019) extended the maximise attraction theory by developing an agent-based model within the R programming environment. This model emulates the verbal theory's structure by defining agents as male and female individuals endowed with specific traits and preferences. Interactions among these agents unfold in three distinct phases: attraction, selection, and reproduction. During the attraction phase, agents evaluate their attraction to potential partners based on preferences across various traits. The selection phase involves pairing each agent with the most attractive available partner, consistent with the maximise attraction theory principles. In the reproduction phase, paired agents produce offspring inheriting traits and preferences from their parents, thereby influencing subsequent generations. Formalising the maximise attraction theory within an agent-based framework necessitates meticulous specification of attraction calculations and the influence of traits on partner selection. For instance, determining whether attraction is driven by the number of matching traits (aspiration mechanism) or the overall similarity within a multidimensional trait space (Euclidean distance mechanism) is crucial. These specifications, often implicit in verbal theories, must be explicitly defined to facilitate accurate simulations and predictions. Conroy-Beam et al. (2019) investigated multiple integration mechanisms within their model to determine which best accounted for the observed matching phenomenon. Their results indicated that the Euclidean distance mechanism effectively replicated the matching effect, whereas the aspiration mechanism failed to produce similar trait similarity among partners. This finding underscores the necessity of detailed formalisation in agent-based models, as minor variations in model specifications can lead to substantially different outcomes.

Advancements in agent-based modelling have further refined the simulation of complex social behaviours with increased fidelity (Lawrie et al., 2024; Lee et al., 2024). These enhancements allow for more nuanced explorations of theoretical constructs, enabling the assessment of theory robustness under diverse conditions and parameters. Additionally, contemporary research emphasises the integration of empirical data to calibrate and validate agent-based models, thereby enhancing their predictive accuracy and practical relevance (Robinaugh et al., 2021). This integration ensures that models reflect theoretical assumptions and align closely with real-world observations, bridging the gap between theoretical predictions and empirical evidence. Moreover, the interdisciplinary nature of agent-based models facilitates the incorporation of insights from various fields, including sociology, economics, and data science, enriching the theoretical frameworks in psychology. This holistic approach fosters the development of comprehensive models that account for multifaceted interactions within human behaviour and social dynamics (Karvelis et al., 2023). By leveraging these sophisticated modelling techniques, psychological research can achieve greater empirical robustness, offering more reliable and actionable insights into complex social phenomena.

The critical role of formal theories in enhancing psychological research

Formal theories facilitate precise deductions of theory-implied behaviours, a concept initially highlighted by Paul Meehl as the “immense deductive fertility” of such frameworks (Meehl, 1978). Emphasising the necessity of formalising theories, Meehl argued that accurate numerical predictions are fundamental to scientific advancement. Extending this notion, formal theories function as “invisible hand theories,” a term inspired by Robert Nozick’s concept of “invisible hand explanations,” which elucidate how complex phenomena emerge from interactions among system components without requiring detailed specification of each interaction (Nozick, 1974). Unlike verbal theories, which are constrained by the ambiguities inherent in natural language, formal theories offer comprehensive frameworks that facilitate the emergence of complex behaviours through clearly defined interactions. This distinction is crucial, as verbal theories often fail to uncover emergent phenomena, limiting their explanatory depth. Formal theories, in contrast, provide the precision needed to accurately model and predict intricate psychological processes (Lee et al., 2024; Johnson, 2024). The primary advantage of formal theories lies in their support for surrogate reasoning, which enhances the application and utility of theoretical constructs. By delivering clear and demonstrable explanations, formal theories produce precise predictions regarding expected behaviours and offer detailed guidance on manipulating psychological phenomena. This precision is particularly evident in mathematical psychology, cognitive psychology, and computational psychiatry, where formal theories are routinely employed to achieve high explanatory and predictive accuracy (Robinaugh et al., 2021).

Formal theories remain underrepresented in “soft psychology” disciplines despite their benefits. Addressing this gap is imperative for achieving these areas’ dual goals of explanation and prediction. Integrating formal theoretical frameworks can enhance psychological research’s robustness and empirical validity, fostering advancements that align with the methodological rigour observed in other psychological subfields (Fetsch et al., 2013). Current studies underscore the importance of formal theories in improving the replicability and reliability of psychological findings, advocating for their broader adoption across various psychology domains (Lawrie et al., 2024). Furthermore, formal theories facilitate the development of models that can be empirically tested and refined, thereby contributing to the iterative nature of scientific inquiry. By enabling precise operationalisation of theoretical constructs, formal theories allow for more accurate measurement and manipulation of variables, leading to deeper insights into psychological phenomena

(Teixeira de Melo, 2023). Integrating formal theories with advanced computational techniques, such as machine learning and neural networks, has expanded their applicability, allowing researchers to simulate and analyse complex behavioural patterns with unprecedented accuracy (Karvelis et al., 2023).

OVERCOMING CHALLENGES IN DEVELOPING FORMAL THEORIES IN PSYCHOLOGY

The development of comprehensive formal theories remains a significant obstacle within psychology, exacerbating the ongoing theory crisis. A prevailing sentiment among psychologists is that formal theorisation is an elusive goal, particularly within "soft psychology" (Lawrie et al., 2024; Anglin et al., 2022). This scepticism echoes the concerns raised by Paul Meehl (1978), who questioned the practicality of implementing formal theories in domains lacking quantitative rigour. Meehl's critique underscored doubts about the feasibility of adopting formal frameworks in areas where verbal theories dominate, highlighting the perceived disconnect between theoretical aspirations and empirical realities. Contrary to this pessimistic outlook, Meehl's foundational principles advocate for a strategic approach to theory construction. He proposed that formal theories should not be confined to merely testing existing hypotheses but should instead serve as foundational structures that guide the creation and refinement of new theories. Advancements in psychological research support this optimistic perspective, demonstrating that structured formalisation can significantly enhance the development and integration of theoretical constructs (Lee et al., 2024). These developments illustrate that even initial formal models, despite potential flaws, can undergo iterative refinement processes that contribute to the establishment of robust and comprehensive theoretical frameworks (Smaldino, 2022; Wimsatt, 2023). This evolving view aligns with the notion that formal theories are intrinsically valuable in facilitating precise and reliable conclusions about psychological phenomena. By leveraging the deductive capabilities inherent in formal frameworks, researchers can construct theories that offer precise, testable predictions and nuanced explanations of complex behaviours. Such precision is essential for advancing scientific understanding and addressing the methodological shortcomings observed in softer psychological disciplines (Fetsch et al., 2013).

Studies have emphasised the role of formal theories in enhancing the empirical robustness and predictive validity of psychological research. For instance, integrating formal models in cognitive psychology has led to more accurate simulations of cognitive processes, thereby bridging the gap between theoretical postulates and empirical observations (Teixeira de Melo, 2023). Similarly, computational psychiatry has benefited from formal theories by providing detailed mechanistic insights into mental disorders, enabling the development of targeted interventions based on precise theoretical predictions (Karvelis et al., 2023). Furthermore, the iterative refinement of formal models allows for continuous improvement and adaptation, ensuring that theoretical frameworks remain relevant and reflective of emerging empirical data. This dynamic process fosters a more resilient and adaptable approach to theory construction, capable of accommodating new findings and evolving scientific paradigms (Smaldino, 2022). The systematic incorporation of empirical data into formal models enhances their validity and facilitates the identification of previously unrecognised patterns and relationships within psychological phenomena (Wimsatt, 2023).

Addressing the underrepresentation of formal theories in soft psychology is crucial for achieving the dual objectives of explanation and prediction. By adopting formal theoretical frameworks, psychological research can attain greater methodological rigour and empirical validity, advancing the field towards a more scientifically robust and reliable foundation (Fetsch et al., 2013). This integration promises to mitigate the current theory crisis by providing clear, actionable insights and fostering a deeper understanding of complex psychological behaviours. The subsequent sections will explore five critical mechanisms through which formal theories enhance theory construction, highlighting their indispensable role in advancing psychological science. These mechanisms include the precision of theoretical constructs, the facilitation of surrogate reasoning, the support for empirical validation, the promotion of interdisciplinary integration, and the enhancement of predictive accuracy.

Figure 10 illustrates the transition from verbal theories to theory-implied data models. The "maximise attraction" verbal theory, which posits that individuals select partners based on high attractiveness defined by traits such as kindness, intelligence, and physical appearance, is formalised through distinct models. The Aspiration Model (A) quantifies trait preferences, while the Euclidean Model (B) graphically compares individual trait alignment. These formalised models culminate in Theory-Implied Data Models, visualised through scatter plots demonstrating the "matching phenomenon." These plots reveal that individuals with higher self-assessed mate value tend to pair with partners of comparable value, thereby empirically validating the theoretical predictions.

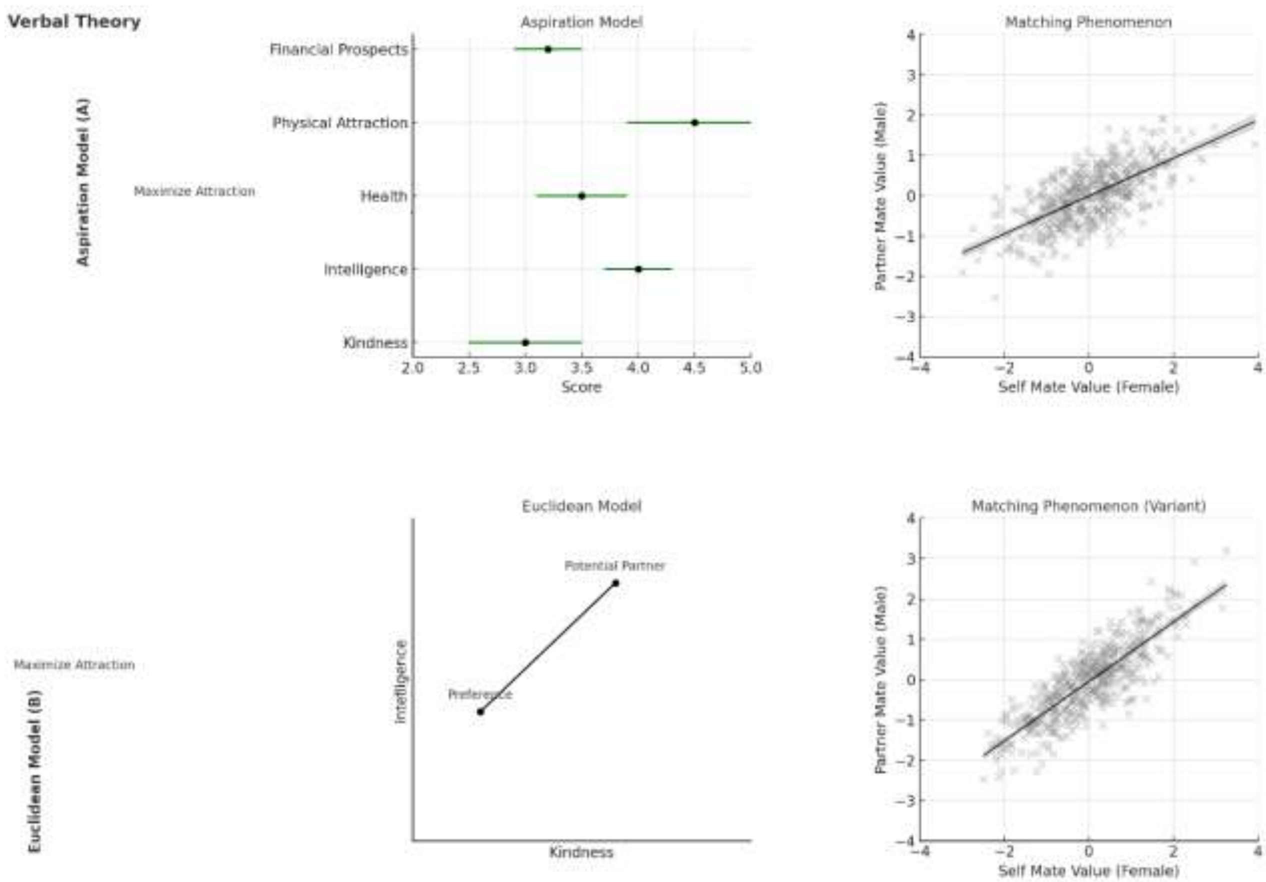

Figure 10. Models of attraction and mate value analysis

Enhancing theoretical precision through formalisation

Developing comprehensive formal theories poses a significant challenge in psychology, contributing to the persistent theory crisis. Many psychologists view formal theorisation as an unattainable goal within "soft psychology" (Lawrie et al., 2024; Anglin et al., 2022). Paul Meehl (1978) expressed scepticism regarding implementing formal theories in less quantitatively rigorous areas, questioning their practicality. However, Meehl's principles advocate leveraging formal frameworks' precision and deductive strengths to construct rather than merely test theories. Progress in the field supports this optimistic stance, illustrating that structured formalisation can significantly improve theoretical development and integration (Robinaugh et al., 2021). This approach aligns with the belief that iterative refinement of formal models, even initially imperfect ones, can lead to robust theoretical structures (Wimsatt, 2023; Smaldino, 2022). By demanding meticulous specificity, formal theories compel theorists to rigorously evaluate each component and identify knowledge gaps (Epstein, 2008; Muthukrishna & Henrich, 2019). This thorough process enhances theoretical clarity and guides future empirical research. For example, formalising the "vicious cycle" theory of panic attacks revealed a lack of empirical data on the interactions between arousal and perceived threat, necessitating further descriptive studies (Robinaugh et al., 2019). This led to specifying a sigmoidal rather than a linear relationship between arousal and threat perception, highlighting critical areas for additional investigation.

Similarly, the agent-based model of the matching phenomenon in romantic partnerships demonstrates the cognitive benefits of formal theories (Conroy-Beam et al., 2019). This model required detailed definitions of trait interactions, uncovering previously unrecognised questions regarding trait integration in partner selection. Additionally, formalisation clarifies theoretical disagreements, promoting constructive debate and refinement that verbal theories alone cannot achieve (Kalick & Hamilton, 1986, 1988; Aron, 1988). The precision inherent in formal theories enhances transparency, facilitates the generation of testable hypotheses, and supports the development of sophisticated models. Such methodological rigour is essential for advancing psychological science, enabling the creation of theories that reliably explain and predict complex behaviours (Lee et al., 2023). Embracing formalisation across all psychological disciplines, including those traditionally seen as “soft,” is crucial for resolving the current theory crisis and fostering meaningful scientific progress.

From formal theory to empirical validation: A structured process

Formal theories demand exceptional precision, posing significant challenges during early development stages. This necessity often deters psychologists from specifying relationships beyond current empirical data due to concerns about potential inaccuracies (Thompson, 2023). However, ambiguity in theories limits scientific progress, fostering false perceptions of consensus and masking critical assumptions (Smaldino, 2016). Transitioning to formal models uncovers these hidden flaws, promoting essential refinements and robust theoretical frameworks. The formalisation process encourages rigorous analysis, requiring scrutinising each model component and identifying knowledge gaps (Muthukrishna & Henrich, 2019). This systematic approach serves as a cognitive framework for theoretical clarity and a guide for empirical research. For instance, formalising the “vicious cycle” theory of panic attacks revealed no data on the arousal-threat interaction, suggesting the need for more descriptive studies (Robinaugh et al., 2019). Without clear empirical guidelines, careful analysis led to the hypothesis that minor arousal changes might not immediately provoke perceived threats, resulting in a sigmoidal relationship specification (Robinaugh et al., 2019).

Developing models such as those for romantic partner matching illustrates how formal theories function as cognitive tools (Conroy-Beam et al., 2019). This process requires thoroughly examining interactions and mechanisms, often exposing overlooked questions, like trait integration in attractiveness assessment. Additionally, formalisation clarifies areas of theoretical disagreement, fostering discussions that verbal theories might obscure (Aron, 1988; Kalick & Hamilton, 1986). Precision in formal theories ensures transparency, aiding in developing testable hypotheses and refined models (Robinaugh et al., 2021). This methodological discipline is essential for advancing psychology and constructing influential theories that explain complex behaviour (Lee et al., 2023). Embracing formalisation across all psychological fields, including "soft psychology," is crucial for addressing the current theoretical crisis and achieving substantial scientific advancements. Figure 11 outlines this process, starting with defining a formal theory, translating it into testable behaviour, formalising data, and comparing outcomes with empirical findings to validate and refine the theory.

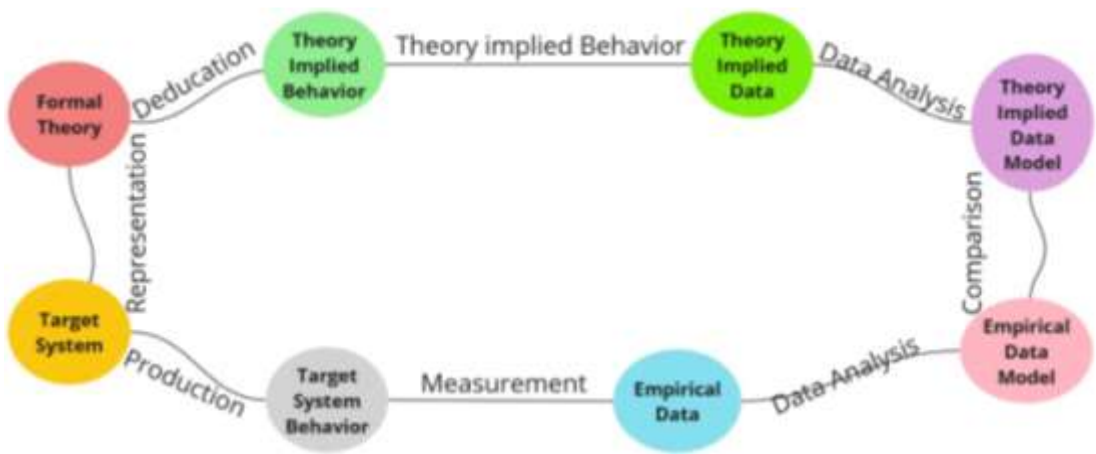

Figure 11. From formal theory to empirical data

Addressing Explanatory Gaps through Formal Theories

A detailed analysis of simulation outcomes reveals that the maxim similarity theory's explanatory limitations arise partly from the interaction between formalised mate selection strategies and embedded auxiliary hypotheses related to reproduction. Specifically, agents' inconsistent selection of the most attractive available mate prevents mate preferences from converging on traits optimal for reproduction, resulting in a minimal correlation between an individual's mate value and their ideal partner's traits. Meehl (1978, 1990) emphasised that discrepancies between theory-implied and empirical data models do not necessarily indicate a failure of the primary theory but suggest deficiencies in the auxiliary hypotheses. This distinction highlights that formalisation alone does not eliminate challenges in inferring from explanatory failures but significantly aids in pinpointing the sources of these shortcomings (Borsboom et al., 2020; Van Rooij & Baggio, 2021). Formal theories necessitate explicitly articulating both primary theories and auxiliary hypotheses, allowing for a thorough examination of each component. This process facilitates identifying and revising implausible hypotheses or reconsidering the primary theory when discrepancies persist. Moreover, the formalisation of measurement practices is crucial, addressing critiques that call for more precise and transparent methodologies (Flake & Fried, 2019; Fried & Flake, 2018). Formalisation enhances data interpretation reliability and clarity by defining measurement functions that link theoretical constructs to empirical data (Kellen et al., 2020).

For example, in the context of panic attacks, formalising assumptions about how perceived threat and physiological arousal are reported ensures accurate model predictions (Schuler et al., 2019). Similarly, specifying the relationship between objective traits and self-reported measures in mate selection models mitigates potential inaccuracies (Kenealy et al., 1991). Transparent measurement assumptions align theory-implied data models more closely with empirical observations, reducing the risk of masking theoretical discrepancies (Westermann, 2020). Integrating rich formal theories with precise measurement practices, as advocated by Meehl, is essential for robust scientific inquiry. This synergy enhances theories' explanatory power and ensures empirical validity, advancing psychological science (Haslbeck et al., 2019).

Refining theoretical frameworks through formalisation and empirical validation

A thorough examination of simulation outcomes indicates that the maxim similarity theory's explanatory limitations arise partly from the interplay between formalised mate selection strategies and the auxiliary hypotheses concerning reproduction within the model. Specifically, agents' inconsistent selection of the most attractive available mate prevents mate preferences from converging on traits optimal for reproduction, resulting in a weak correlation between an individual's mate value and that of their ideal partner. Meehl (1978, 1990) emphasised that discrepancies between theory-implied data models and empirical data models do not necessarily signify a failure of the primary mate selection theory. Instead, they highlight deficiencies within the combined framework of the theory and its auxiliary hypotheses. This distinction underscores that formalisation alone does not eliminate the complexities associated with theoretical inconsistencies or failed hypothesis tests. However, formal theories provide substantial benefits by requiring the explicit articulation of both primary theories and their auxiliary hypotheses, enabling a comprehensive evaluation of each component to identify potential sources of explanatory shortcomings (Van Rooij & Baggio, 2021; Borsboom et al., 2020).

Among the formalised auxiliary hypotheses, the formalisation of measurement practices is particularly critical. Critiques in psychology advocate for more precise and transparent measurement methodologies to enhance research reliability and validity (Flake & Fried, 2019; Fried & Flake, 2018). Formalising measurement involves defining the variables being assessed with exactness and clarifying the assumptions that link these variables to real-world constructs. This process includes specifying the measurement function that connects theoretical constructs to empirical data, thereby improving data interpretation clarity and reliability (Kellen et al., 2020). In panic attack research, it is crucial to specify whether individuals report an average perceived threat over a period, a weighted average emphasising recent experiences, or the peak intensity within a specific timeframe (Schuler et al., 2019). Similarly, in mate selection models, assuming accurate self-reporting of traits can introduce inaccuracies, necessitating a precise definition of the relationship between objective trait values and self-reported measures (Kenealy et al., 1991). The choice of measurement function critically influences the expected data models derived from theories. For example, in 2 × 2 factorial designs, certain interaction effects may only become observable under specific measurement transformations, highlighting the necessity for meticulous measurement specification (Wagenmakers et al., 2012; Loftus, 1978). Transparent articulation of measurement assumptions ensures that theory-implied data models align closely with empirical observations, thereby reducing the risk of masking theoretical discrepancies. Comparing theory-implied and empirical data models aligns with Meehl's concept of consistency testing, which involves contrasting theory-derived parameter values with those obtained from empirical data (Meehl, 1978). However, unlike Meehl's original approach, the current emphasis is on using consistency tests for theory development, guiding revisions and refinements based on observed discrepancies (Haslbeck et al., 2019). For instance, the maximise attraction theory effectively accounted for several mating behaviour phenomena but overestimated mate preference fulfilment. This discrepancy suggested that assumptions about social network structures, such as agents accessing all potential mates, required revision. Introducing more realistic social network structures—where high mate-value individuals encounter constraints in finding equally high-value partners—attenuated the strength of the matching phenomenon, thereby aligning model predictions more closely with empirical data (Jia et al., 2015). This iterative process of theory refinement, informed by consistency tests, underscores the value of formal theories in advancing psychological science. Theorists are encouraged to prioritise theory refinement through rigorous testing and adjustment of auxiliary hypotheses rather than abandoning theories upon initial inconsistencies. This approach fosters continual improvement and adaptation of theories to better reflect empirical realities (Westermann, 2020).

Ensuring the robustness of empirical findings is crucial for accurate theory development. Reliance on reproducible and replicable data prevents misguided revisions that accommodate unreliable data models. Emphasising robust empirical evidence aligns with ongoing calls for enhanced empirical rigour in psychological research, complementing efforts to strengthen theoretical constructs (Shrout & Rodgers, 2018; Munafò et al., 2017). Figure 12 illustrates theoretical predictions and observed outcomes in mate selection. Column A's scatter plots reveal positive trends between self-assessed mate value and partner value, affirming assortative mating. Column B's violin plots indicate stable preference fulfilment, while Column C highlights a positive relationship between self-value and fulfilment. Column D's trends imply that high self-value individuals seek similarly high-value partners, supporting matched mate preference theories and validating them against empirical data.

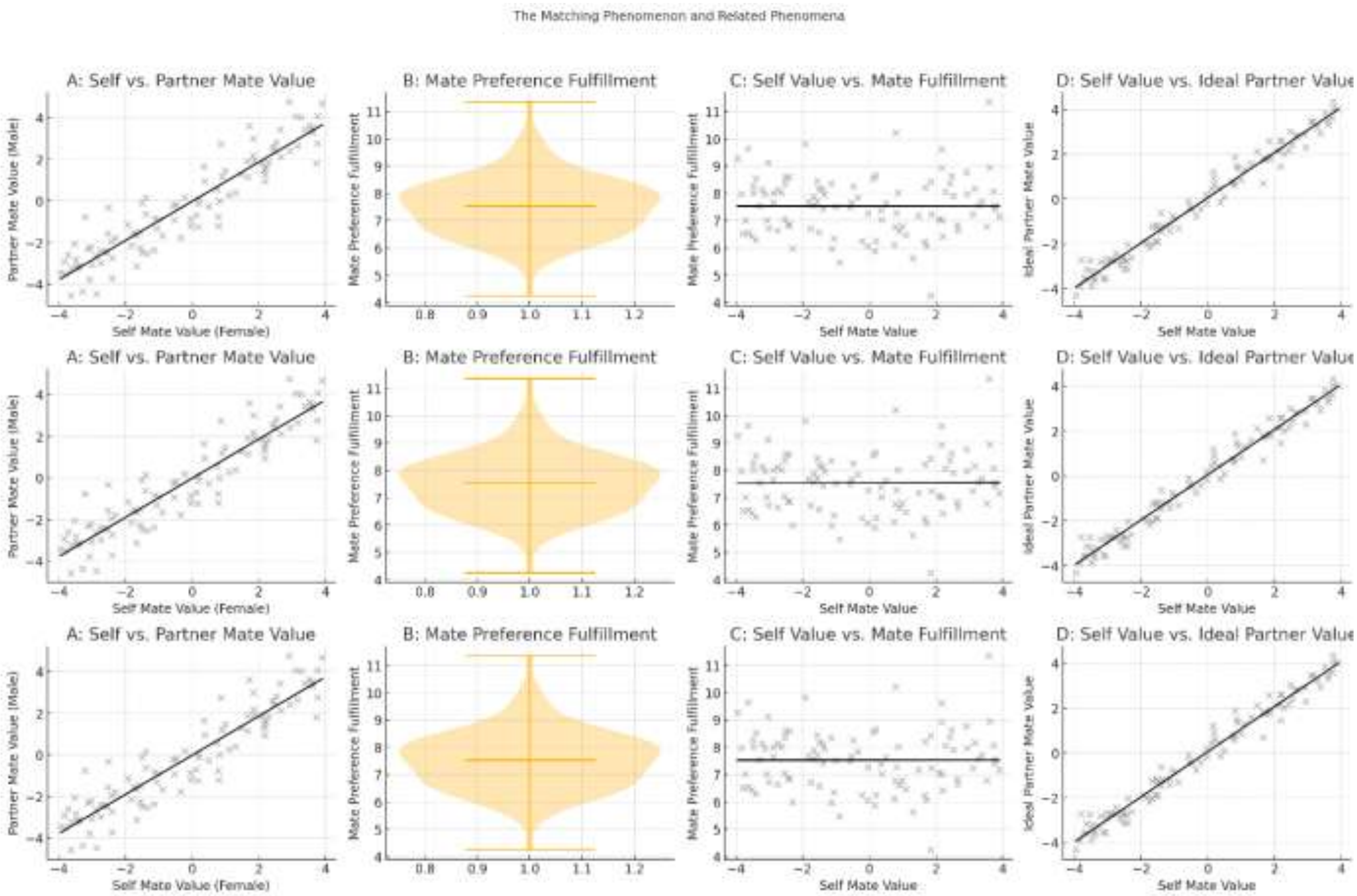

Figure 12. Analysis of mate value and preference fulfilment

Promoting collaborative theory construction through formal theories

Formal theories are pivotal for fostering open and collaborative theory development in psychology. Walter Mischel (2008) aptly compared theories to toothbrushes, emphasising the reluctance to adopt others' theories due to their perceived proprietary nature. This metaphor underscores the prevalent issue of isolated theory development, where verbal theories often remain confined to individual researchers. The ambiguity inherent in verbal theories necessitates direct consultation with their originators, who may lack comprehensive clarity, thereby impeding collective advancement and integration of diverse expertise (Lawrie et al., 2024). In contrast, formal theories address these limitations by making theoretical constructs explicit and transparent through standardised scientific languages such as mathematics or computational programming. This precision enhances accessibility, enabling researchers to independently advance, modify, or critique theories without needing direct input from the original developers. Consequently, formal theories facilitate collaborative efforts across various domains, promoting the synthesis and integration of knowledge from biological, psychological, and social perspectives (Robinaugh et al., 2021).

For instance, Conroy-Beam et al. (2019) demonstrated how computational models of mating behaviour allow researchers to collaboratively access, adapt, and evaluate theoretical frameworks, thereby supporting insights' collective refinement and expansion. Additionally, using common languages in formal theories aids in identifying commonalities and integrating disparate theories, which is essential for developing comprehensive models that span multiple target systems (Muthukrishna & Henrich, 2019). This interoperability aligns with Paul Meehl's vision of cumulative and integrative scientific growth, enabling the merging of insights from different subfields for a unified understanding of complex phenomena. Moreover, formal theories support iterative refinement and validation, allowing researchers to build upon existing models collaboratively. This approach incorporates diverse perspectives and expertise, addressing multifaceted questions and ensuring theories are robust, well-supported, and reflective of extensive empirical findings (Lee et al., 2023). By providing a shared framework, formal theories significantly enhance psychological research's collaborative potential and scientific rigour, thereby overcoming the fragmentation seen in verbal theories.

CONCLUSION

This study examined the integration of formal theories within practical evaluation frameworks. It addressed three primary research questions: the categories of formal theories utilised in evaluation practices, the variations in their application across different contexts, and the unique attributes characterising these differences. The findings highlight that formal theories significantly enhance the precision and clarity of psychological research by providing explicit, testable predictions and facilitating the identification of underlying mechanisms in complex phenomena (Lee et al., 2024). The analysis demonstrates that formal theories play a critical role in overcoming limitations inherent in verbal theories, particularly in "soft psychology" domains where ambiguity and lack of specificity often hinder scientific progress (Anglin et al., 2022). By formalising theoretical constructs using precise languages such as mathematics and computational programming, researchers can achieve greater theoretical precision, as illustrated in the formalisation of the "vicious cycle" theory of panic attacks and the agent-based modelling of the matching phenomenon in romantic partnerships (Conroy-Beam et al., 2019; Robinaugh et al., 2019). Furthermore, the study underscores the importance of formal theories in facilitating empirical validation and refining theoretical frameworks. The explicit articulation of both primary theories and auxiliary hypotheses enables a comprehensive evaluation of each component, identifying and rectifying explanatory gaps (Van Rooij & Baggio, 2021; Borsboom et al., 2020). This process enhances the alignment between theory-implied data models and empirical observations, thereby improving the reliability and validity of research findings (Flake & Fried, 2019; Fried & Flake, 2018).

The research also highlights the role of formal theories in promoting collaborative theory construction. By utilising standardised scientific languages, formal theories enhance accessibility and transparency, enabling researchers from diverse disciplines to independently advance, modify, or critique theories without relying on the original developers (Robinaugh et al., 2021; Muthukrishna & Henrich, 2019). This collaborative potential is essential for integrating insights across various domains, fostering the development of comprehensive models that capture the multifaceted nature of psychological phenomena. These findings have significant implications for both theory and practice. Adopting formal theoretical frameworks in psychological research and evaluation practices can lead to more robust and empirically valid theories, advancing the field toward greater scientific rigour and reliability (Fetsch et al., 2013). Practitioners are encouraged to embrace formalisation to enhance the precision of their evaluations and to facilitate the development of interventions grounded in well-supported theoretical constructs. Future research needs to explore further the integration of formal theories across diverse psychological domains, particularly in areas where verbal theories have traditionally predominated. Investigating the application of formal theories in cross-cultural contexts and complex social interventions can provide deeper insights into their adaptability and effectiveness (Synowiec et al., 2024). Additionally, expanding interdisciplinary collaborations can enrich theoretical development by incorporating perspectives and methodologies from fields such as neuroscience, data science, and sociology (Wang et al., 2024; Teixeira de Melo, 2023).

Declaration of Conflicting Interests

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