ROMANIAN JOURNAL OF PSYCHOLOGICAL STUDIES

HYPERION UNIVERSITY
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WHEN INTERNAL TIME FAILS: A THEORETICAL FRAMEWORK FOR TIMING-BASED MARKERS OF IMPULSIVITY

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Abstract

Impulsivity is commonly explained through inhibitory failure, reward-driven choice, or executive dysfunction. Although well supported, these models may not fully explain why some individuals respond prematurely in situations requiring pacing and self-regulation over time. This theoretical paper reviews evidence linking impulsive behavior with disturbances in time perception and proposes that deficits in the behavioral use of internal time may represent an underrecognized pathway to impulsive behavior. The construct of Temporal Decision Control is introduced, defined as the capacity to use internally represented temporal information to regulate behavior adaptively under changing demands. To operationalize this framework, a novel behavioral paradigm, the Internal Timing Regulation Paradigm (ITRP), is proposed, including Linear, Asymmetric, and Incentive conditions targeting baseline timing, attentional-temporal integration, and motivational regulation. Potential relevance is discussed in relation to ADHD, addictive disorders, and dimensional differences in self-regulation, with directions for empirical validation outlined.

Keywords: *impulsivity; time perception; ADHD; self-regulation; executive functioning; interval timing; decision-making; behavioral assessment*

1. INTRODUCTION

Impulsivity is widely regarded as a multidimensional construct involving motor disinhibition, poor planning, premature responding, and reduced tolerance for delayed gratification (Evenden, 1999; Stanford et al., 2009). It is relevant to everyday differences in personality and to several clinical conditions, including ADHD, substance-use disorders, behavioral addictions, and other disorders marked by difficulties with self-regulation. Despite its importance, impulsivity remains challenging to assess comprehensively. Common paradigms such as the Go/No-Go task, Stop-Signal task, and delay discounting procedures each assess particular components of impulsivity, such as inhibitory control or reward preference, while self-report measures remain vulnerable to response bias, social desirability, limited insight, inaccurate recall, transient mood states, motivational factors, and situational influences during assessment. This has maintained interest in complementary behavioral

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indicators that may capture underlying cognitive mechanisms more directly, while avoiding some limitations of self-report alone.

One comparatively underexplored, though increasingly relevant, area concerns time perception. Subjective time estimation and interval reproduction tasks have repeatedly been associated with impulsive traits and dysregulated behavior (Wittmann & Paulus, 2008). Individuals with elevated impulsivity often display reduced temporal accuracy and greater trial-to-trial response variability, particularly when required to reproduce a previously learned interval or decide when to respond without external timing cues. Related impairments in time estimation and temporal variability have been reported in ADHD populations (Toplak et al., 2006) and individuals with stimulant-use dependence (Wittmann et al., 2011).

Traditional models such as Scalar Expectancy Theory suggest that subjective duration emerges through interactions among pacemaker processes, attention, and memory. However, real-world behavior may depend less on passive duration estimation alone and more on the capacity to align internal timing with adaptive decisions under uncertainty, distraction, emotional load, or reward pressure.

Building on these observations, the present theoretical paper advances the concept of Temporal Decision Control, defined as the capacity to use internally represented temporal information to regulate behavior adaptively under changing demands. From this perspective, impulsive behavior may partly emerge when internal timing processes fail to support effective pacing, delay tolerance, or behavioral recalibration. The present paper develops this proposition theoretically and outlines a framework for future empirical testing.

2. OBJECTIVE AND HYPOTHESES

2.1. OBJECTIVE

The primary objective of the present theoretical paper is to examine and integrate existing evidence on the relationship between time perception and impulsive behavior, with particular attention to how distortions in subjective timing may contribute to impaired decision-making and premature responding.

A second objective is to consider whether traditional interpretations of timing deficits, often framed solely as perceptual inaccuracies, may be too narrow. Instead, this paper considers the possibility that many timing-related impairments reflect broader dysfunctions in the ability to coordinate internal temporal representations with contextually appropriate behavior.

A further objective is to outline a novel timing-based experimental paradigm, provisionally referred to as the Internal Timing Regulation Paradigm (ITRP), designed to examine how individuals estimate, maintain, and respond to internally represented time intervals under varying task demands.

The broader aim is to clarify how temporal cognition may account for self-regulation and impulsive behavior across clinical and non-clinical populations.

2.2. HYPOTHESES

As a theoretical paper, the present article does not test empirical hypotheses directly. However, based on the reviewed literature and the proposed clinical-cognitive framework, three conceptual hypotheses are advanced to guide future research.

Hypothesis 1. Disturbances in internal timing are associated with impulsive behavior.

Individuals exhibiting elevated impulsive traits would be expected to demonstrate reduced temporal accuracy and greater response variability, particularly in tasks requiring internally guided estimation or reproduction of time intervals. From a clinical perspective, such disturbances may reflect deficits in self-monitoring and inhibitory control rather than isolated perceptual error alone.

Hypothesis 2. Temporal performance deteriorates under reward pressure, emotional arousal, or distraction.

Timing-related impairments are expected to become more pronounced when tasks involve motivational conflict, delayed reward, frustration, or competing attentional demands. This hypothesis is consistent with clinical observations that impulsive behavior often intensifies under stress, arousal, or immediate reinforcement pressure.

Hypothesis 3. Temporal Decision Control predicts dysregulated behavior more effectively than timing accuracy alone.

The ability to align subjective time estimation with adaptive action is expected to predict impulsive tendencies more effectively than simple duration estimation measures. Clinically meaningful impairment may arise from failure to use temporal information strategically in real-world decision contexts.

3. METHOD

3.1. CONCEPTUAL APPROACH

As a theoretical paper, the present article adopts an integrative review approach drawing on specialized empirical and clinical literature related to time perception, impulsivity, self-regulation, neuropsychological functioning, and behavioral decision-making. Particular attention is given to studies involving clinical populations, experimental temporal paradigms, and contemporary models of cognitive control. Empirical findings and theoretical frameworks were synthesized for the present analysis to develop the proposed construct of Temporal Decision Control and to guide the design of a future experimental paradigm.

3.2. PROPOSED EXPERIMENTAL PARADIGM: INTERNAL TIMING REGULATION PARADIGM (ITRP)

The Internal Timing Regulation Paradigm (ITRP) is proposed as a structured behavioral paradigm designed to examine how individuals estimate, maintain, and regulate internally represented temporal intervals under varying cognitive and motivational demands.

In particular, the paradigm is intended to examine whether disturbances in internal temporal regulation are associated with premature responding, inconsistent pacing, and reduced adaptive recalibration following error or feedback. The Linear condition is primarily relevant to Hypothesis 1, the Incentive condition to Hypothesis 2, and multidimensional performance indices to Hypothesis 3.

In a basic version of the task, participants are first exposed to a pacing sequence composed of visual or auditory intervals. These intervals may be constant or intentionally variable (e.g., alternating faster and slower rhythms) in order to reduce reliance on simple counting strategies and increase dependence on internal temporal encoding. Following the exposure phase, external cues are removed and participants are instructed to signal when they judge that a predefined target interval has elapsed, or when the learned pacing sequence would be expected to reach a specified endpoint. Primary performance indices include temporal accuracy, trial-to-trial response variability, premature responding, delayed responding, and adaptive adjustment across repeated trials.

To increase ecological and clinical relevance, additional task conditions may include reward incentives for accurate responding, penalties for premature responses, distraction manipulations, emotionally salient stimuli, or uncertainty regarding target duration. These manipulations are intended to evaluate Temporal Decision Control under motivational and cognitive pressure. The paradigm may be administered through computerized, web-based, or mobile platforms, allowing standardized delivery and repeated measurement across clinical and non-clinical populations.

3.2.1 ITRP-Linear condition

In the Linear condition, participants are exposed to a regular and constant pacing sequence presented either visually (e.g., second-marked clock) or auditorily (e.g., metronome clicks). Each trial consists of a predefined target interval (e.g., 12, 20, 30, 40, 50, 60 seconds), during which temporal information unfolds at a stable rate.

Following the pacing phase, external temporal cues are removed and participants are instructed to reproduce the duration as accurately as possible. Reproduction is typically operationalized via a keypress or response hold paradigm, where participants indicate the perceived passage of the original interval. This condition is intended to primarily engage baseline interval encoding processes commonly associated with internal timing models, allowing estimation of systematic distortions in subjective duration (bias).

3.2.2 ITRP-Asymmetric condition

In the Asymmetric condition, participants are exposed to a non-uniform pacing structure, in which temporal intervals vary in rhythm within the same total duration (e.g., alternating faster and slower segments such as fast–slow–fast sequences). The total interval duration remains equivalent to the Linear condition, but the internal structure is intentionally irregular. This manipulation is designed to reduce reliance on explicit counting strategies and increase dependence on continuous temporal integration and attentional allocation.

After exposure, participants reproduce the overall duration without external cues.

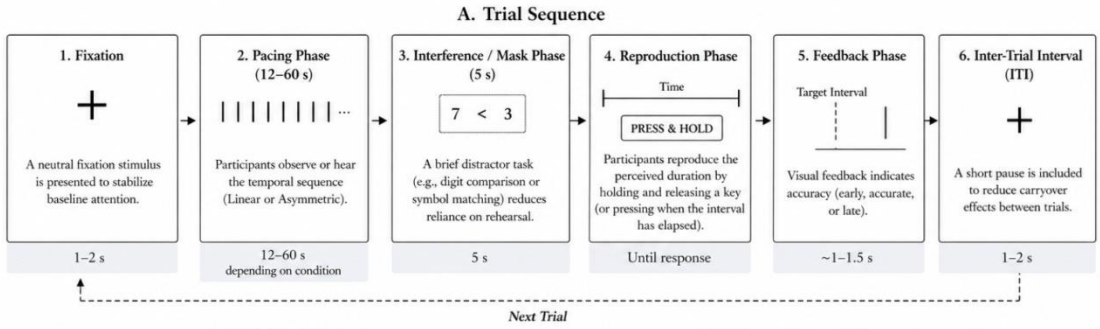
This condition is intended to increase sensitivity to attentional instability and variability in temporal encoding, operationalized primarily through intra-individual variability (coefficient of variation, CV). This condition is expected to place greater demands on attentional continuity and dynamic temporal integration than the Linear condition.

3.2.3 ITRP – Incentive Condition

In the Incentive condition, participants complete Linear or Asymmetric trials under explicit reward and penalty contingencies. Accurate reproduction within a predefined tolerance window (e.g., ±5–10%) is associated with point gains, monetary reward, or performance feedback, whereas premature or substantially delayed responses result in point loss, omission of reward, or corrective feedback. This condition is intended to increase motivational salience and simulate real-world contexts in which timing decisions carry consequences. It would be expected to place additional demands on inhibitory control, reward sensitivity, emotional regulation, and strategic pacing.

Primary indices include changes in bias, variability, premature responding, post-error adjustment, and sensitivity to reinforcement contingencies relative to neutral conditions.
In selected trials, tolerance windows or interval duration may vary unpredictably, introducing decision-making under uncertainty.

3.2.4 Trial structure and procedure



B. Task Conditions

Condition	Description	Primary Purpose
Linear Condition (Baseline)	Constant pacing across the interval.	Assesses baseline interval encoding and reproduction under predictable structure.
Asymmetric Condition (Attention / Integration)	Irregular pacing within the interval.	Increases attentional and temporal integration demands.
Incentive Condition (Reward Regulation)	Constant pacing with reward or penalty contingencies.	Introduces motivational pressure to engage reward processing and inhibitory control.

C. Primary Outcome Measures

Measure	Description
Temporal Bias (Mean Error)	Average signed deviation from the target interval (negative = early; positive = late).
Temporal Accuracy (Absolute Error)	Average absolute deviation from the target interval, regardless of direction.
Response Variability (Intra-individual SD)	Trial-to-trial variability of reproduced intervals, reflecting timing consistency.
Adaptive Correction Index (ACI)	Extent of adjustment in the subsequent trial following an error (direction and magnitude).

Figure 2. Structure of the Internal Timing Regulation Paradigm (ITRP)

Each trial in the ITRP follows a standardized sequence:
Fixation phase (1–2s)
A neutral fixation stimulus is presented to stabilize baseline attention.
Pacing phase (12–60 s depending on condition)
Participants observe or hear the temporal sequence (Linear or Asymmetric).

Interference / mask phase (5s).

A brief distractor task (e.g., simple digit comparison or symbol matching) is introduced to reduce reliance on short-term rehearsal of temporal cues.

Reproduction phase

Participants reproduce the perceived duration by holding and releasing a response key or pressing a button when they believe the original interval has elapsed.

Inter-trial interval (ITI)

A short pause is included to reduce carryover effects between trials.

The full task comprises approximately 24–36 trials, balanced across conditions and randomized in order to control for fatigue and learning effects.

3.2.5 Control mechanisms

To ensure that performance reflects internal temporal processing rather than strategy use or external compensation mechanisms, several controls are implemented:

Articulatory suppression (e.g., repeating a neutral syllable during reproduction) to reduce subvocal counting strategies

Randomized interval ordering to prevent anticipation effects

Masking task between encoding and reproduction to limit short-term rehearsal

Counterbalancing of condition order (Linear vs Asymmetric) to control for learning, fatigue, and adaptation effects

Optional recording of self-reported strategies post-task to identify counting or rhythm-based heuristics.

Exclusion criteria for noncompliance or excessive missed trials may be predefined.

3.2.6 Outcome measures

Performance in the Internal Timing Regulation Paradigm (ITRP) is quantified using four primary indices:

Bias (systematic temporal distortion):

(Reproduced duration − Target duration) / Target duration

Accuracy (absolute error):

Mean absolute percentage error (MAPE) across trials.

Variability (temporal stability):

Coefficient of variation (CV = standard deviation / mean reproduced duration).

Adaptive Correction Index (behavioral recalibration):

Mean reduction in absolute error on trials immediately following feedback, penalties, or inaccurate responses.

Bias is interpreted as an index of systematic deviation in subjective temporal estimation. Accuracy reflects overall precision of interval reproduction, whereas variability captures temporal stability across repeated trials. The Adaptive Correction Index reflects the capacity to incorporate corrective information and modify subsequent behavior in a goal-directed manner.

3.2.7 Theoretical role of the ITRP

The ITRP is not conceptualized as a standalone diagnostic instrument but as an experimental framework for isolating components of Temporal Decision Control. The Linear and Asymmetric conditions are intended to differentially engage pacemaker-based timing mechanisms and attentional integration processes, respectively, allowing mechanistic inference from dissociable performance patterns.

Collectively, these conditions are intended to differentiate baseline timing bias, attentional-temporal instability, and motivationally influenced regulation, thereby providing a multidimensional operationalization of Temporal Decision Control.

4. CLINICAL OBSERVATIONS, EXPECTED PATTERNS, AND CONCEPTUAL GAPS

4.1. CLINICAL OBSERVATION AND CONCEPTUAL ORIGIN OF THE PARADIGM

The conceptual basis of the present paper was partly shaped by early observational experiences encountered during prior volunteer work conducted by the author at SOS Children's Villages in Bucharest, Romania. Within this setting, repeated contact with children presenting attentional difficulties, impulsive behavior, emotional dysregulation, and reported or suspected neurodevelopmental features consistent with ADHD provided an applied context for considering how self-regulation difficulties may manifest beyond formal clinical interviews or questionnaire-based assessment. During educational and activity-based interactions, some children appeared to struggle with turn-taking, sustaining attention, and pacing their behavior in relation to time. Informal timing exercises resembling early versions of the proposed Internal Timing Regulation Paradigm (ITRP) suggested that certain participants had difficulty internalizing a simple learned rhythm and reproducing a target interval consistently. Some responded prematurely, others substantially overshot the intended interval, while others showed marked inconsistency across repeated attempts.

These observations were informal, were not collected under standardized research conditions, and should not be interpreted as empirical findings. However, they were clinically meaningful in that they raised the possibility that some impulsive or poorly regulated behavior may involve disturbances in internal pacing and temporal monitoring rather than inhibitory failure alone. This interpretation is broadly consistent with later literature indicating that populations characterized by attentional and self-regulatory difficulties often show impairments in time estimation, time reproduction, and increased temporal variability across tasks (Toplak et al., 2006; Noreika et al., 2013; Marx et al., 2022).

In parallel, reaction-time variability has repeatedly been identified as a robust feature in neurodevelopmental and attentional-control research, suggesting fluctuating state regulation and inconsistent cognitive control (Kofler et al., 2013; Castellanos & Tannock, 2002). From this perspective, the present paradigm emerged from a broader clinical question: when some individuals respond too quickly, too slowly, or inconsistently, could part of the underlying difficulty lie in how internal time is perceived and used to guide behavior?

4.2. EXPECTED PERFORMANCE PATTERNS

Based on the reviewed literature and the proposed framework of Temporal Decision Control, several performance patterns would be expected within the Internal Timing Regulation Paradigm (ITRP).

Individuals exhibiting elevated impulsive traits would be expected to demonstrate lower temporal accuracy and greater trial-to-trial variability than comparison participants, particularly in conditions requiring internally guided pacing without external cues. Performance may be characterized by premature responses, delayed responses, or inconsistent reproduction of previously learned temporal intervals.

These differences would be expected to become more pronounced under conditions involving reward pressure, distraction, emotional salience, or uncertainty regarding target duration. Such manipulations are likely to place additional demands on inhibitory control, sustained attention, and behavioral self-monitoring, thereby increasing the probability of dysregulated responding. Participants with stronger executive control capacities may be expected to recalibrate performance across repeated trials, showing improved accuracy following feedback, penalties, or missed targets. In contrast, individuals with greater self-regulatory difficulties may continue to respond inconsistently despite corrective information or motivational incentives.

Distinct performance profiles may also emerge across clinical and non-clinical groups. For example, some individuals may primarily exhibit premature responding, whereas others may show marked variability or reduced adaptive learning across trials. This suggests that temporal dysregulation may not represent a single deficit, but a heterogeneous process expressed through different behavioral patterns. If supported empirically, these findings would strengthen the proposition that impulsive behavior may arise from difficulties coordinating internal temporal representations with contextually appropriate action.

4.3. CLINICAL AND RESEARCH IMPLICATIONS

In clinical settings, the Internal Timing Regulation Paradigm (ITRP) may help identify subgroups of individuals whose impulsive or dysregulated behavior is linked more strongly to disturbances in internal pacing, temporal monitoring, or reduced adaptive calibration following feedback. This may be particularly relevant in populations presenting with ADHD, substance-use disorders, behavioral addictions, and other conditions characterized by impaired self-regulation.

The paradigm may also hold value for treatment planning and progress monitoring. For example, individuals who demonstrate improved performance when external pacing cues, structured feedback, or reinforcement contingencies are introduced may benefit from interventions emphasizing scheduling routines, countdown systems, cue-based prompting, or other strategies designed to scaffold temporal control in everyday functioning.

From a research perspective, the proposed model supports a broader reconceptualization of impulsive behavior. This perspective may help integrate findings across cognitive psychology, clinical science, and neuropsychological models of self-regulation. Future studies should examine the reliability, convergent validity, discriminant

validity, and clinical sensitivity of the ITRP across developmental stages and diagnostic groups. Longitudinal and cross-cultural research may further clarify whether disturbances in temporal regulation represent stable traits, context-dependent states, or modifiable targets for intervention.

4.4. METHODOLOGICAL AND THEORETICAL GAPS

Despite its potential value, the proposed Internal Timing Regulation Paradigm (ITRP) raises several methodological and conceptual questions that require systematic investigation.

First, performance within the paradigm may reflect multiple overlapping processes, including time perception, attention, working memory, motivational state, anxiety under evaluation, and inhibitory control. Future studies will need to determine the extent to which observed deficits are specific to temporal regulation, as opposed to reflecting broader attentional, mnemonic, or motivational processes.

Second, participants may rely on compensatory strategies such as silent counting, motor pacing, or learned heuristics rather than internal temporal estimation alone. Task design should therefore consider irregular pacing conditions, randomized intervals, and strategy monitoring procedures.

Third, repeated administration may produce practice effects, improved calibration, or fatigue-related decline. Establishing test-retest reliability and sensitivity to change will be essential before clinical application.

Fourth, individual differences including age, education, cultural rhythm exposure, musical training, neurodevelopmental history, sleep quality, and medication status may substantially influence performance. Normative data across populations would therefore be required.

At a theoretical level, further work is needed to clarify whether Temporal Decision Control represents a distinct construct or a higher-order expression of already established processes such as executive control, delay tolerance, or behavioral monitoring. Accordingly, the present framework should be regarded as hypothesis-generating and preliminary until validated through rigorous experimental and clinical research.

5. DISCUSSION

5.1. RECONCEPTUALIZING IMPULSIVITY THROUGH TEMPORAL DECISION CONTROL

Impulsivity has traditionally been conceptualized in terms of deficient inhibitory control, preference for immediate reward, impaired planning, or heightened sensitivity to salient stimuli. These perspectives have generated valuable theoretical models and widely used assessment tools. However, they may not fully account for why some individuals repeatedly respond too early, too late, or inconsistently across situations that require pacing, waiting, or adaptive timing.

This reconceptualization may help explain why individuals with similar scores on conventional impulsivity measures sometimes display markedly different real-world

behavior. One person may primarily struggle with motor inhibition, whereas another may show relatively intact inhibition but poor temporal regulation, inconsistent pacing, or difficulty using time strategically. A timing-based framework may therefore capture clinically meaningful heterogeneity within impulsive presentations.

The concept of Temporal Decision Control also supports a more dynamic understanding of self-regulation. Rather than viewing impulsivity as a static trait, it may be more accurately understood as a context-sensitive process shaped by the interaction of internal timing, motivational state, attention, emotional arousal, and feedback learning. This may help explain why impulsive behavior often fluctuates across settings, stress levels, and reward conditions.

Importantly, the present model does not seek to replace established theories of impulsivity, but to extend them. Inhibitory control, reward valuation, executive functioning, and temporal regulation are likely to interact rather than operate independently. The proposed framework suggests that disturbances in internal timing may represent one neglected pathway through which impulsive behavior is expressed.

5.2. RELATIONSHIP TO EXISTING MODELS

Several established models help explain impulsive behavior, each emphasizing different underlying mechanisms.

Inhibitory-control models emphasize difficulty suppressing prepotent responses and have informed paradigms such as the Go/No-Go and Stop-Signal tasks. These models remain highly relevant, particularly in neurodevelopmental and externalizing conditions. However, brief inhibition tasks do not always explain why some individuals perform adequately in laboratory settings yet struggle in everyday contexts requiring pacing, waiting, planning, and sustained regulation over time.

Reward-based accounts, including delay discounting paradigms, focus on preference for smaller immediate rewards over larger delayed rewards. This work has advanced understanding of impulsive choice. Nevertheless, many real-life self-regulation failures involve not only reward valuation, but also the practical ability to tolerate delay, estimate duration, maintain effort, and organize behavior during waiting periods. Distorted temporal processing may therefore interact with reward sensitivity rather than function independently.

Executive-function models provide a further explanatory framework. Working memory, sustained attention, cognitive flexibility, and self-monitoring are consistently implicated in impulsive behavior. Evidence also suggests that timing deficits may be partly mediated by these broader systems. For example, attentional control and reaction-time performance have been linked to time-perception inaccuracy in clinical populations with attentional dysregulation.

Temporal Decision Control is not proposed as a wholly separate construct independent of executive functioning. Rather, it is a functional integration construct describing how timing-related information is monitored, maintained, and behaviorally used during goal-directed action.

Recent clinical literature further supports the relevance of temporal dysfunction. Meta-analytic findings in ADHD populations suggest moderate time-perception deficits, with

working memory moderating effect sizes (Marx et al., 2022). Other studies indicate that altered time perception may affect prospective timing, task completion, and everyday organization in adults (Weissenberger et al., 2021; Mette et al., 2023).

In this context, Temporal Decision Control may be understood as an integrative construct situated at the intersection of inhibition, executive control, reward processing, and subjective timing. This may help explain why individuals with similar impulsivity scores differ substantially in real-world functioning: one may primarily struggle with inhibition, another with temporal regulation, pacing, or strategic use of delay.

5.3. CLINICAL RELEVANCE AND POTENTIAL APPLICATIONS

If supported by future empirical research, the proposed framework of Temporal Decision Control and the associated Internal Timing Regulation Paradigm (ITRP) may hold meaningful clinical value across assessment, case formulation, and intervention planning. In assessment contexts, the paradigm may provide complementary information beyond conventional self-report inventories or brief inhibitory-control tasks. While questionnaires can capture perceived tendencies and symptom burden, they are often influenced by insight, recall bias, and situational factors. Likewise, traditional laboratory paradigms frequently isolate narrow components of impulsivity.

A timing-based task may help identify individuals whose primary difficulties involve internal pacing, inconsistent behavioral calibration, premature responding under pressure, or poor regulation during delay.

From an intervention perspective, the framework may support more individualized treatment planning. Individuals who improve when external pacing cues, countdown structures, scheduled prompts, or feedback contingencies are introduced may benefit from strategies that compensate for weak internal timing processes. These may include digital reminders, structured routines, visual timers, rhythm-based pacing tools, and behavioral reinforcement systems.

The model may also be relevant for psychotherapy. Patients who repeatedly interrupt goals through premature decisions, abandonment of long-term plans, or inconsistent follow-through may benefit from interventions that explicitly target temporal awareness, delay tolerance, and pacing of action. In cognitive-behavioral approaches, this could involve training in task segmentation, structured waiting strategies, response delay techniques, and monitoring of time-related decision errors.

Importantly, the present proposal is not intended as a stand-alone diagnostic tool. Rather, it is best conceptualized as a supplementary framework that may help clinicians identify distinct pathways to impulsive behavior. Some individuals may primarily struggle with inhibition, others with reward valuation, and others with temporal regulation. Recognizing these differences may support more precise and personalized care.

Table 1. Hypothesized Profiles of Temporal Dysregulation in Impulsive Behavior

The profiles below are theoretical and illustrative. They reflect distinct patterns that may emerge on the Internal Timing Regulation Paradigm (ITRP) and correspond to different underlying mechanisms of dysregulation

Profile	Core Characteristic	Expected ITRP Pattern	Key Performance Indicators	Potential Interpretation
Inhibitory Subtype (Premature Responding)	Tendency to act before the optimal moment.	More premature responses Consistent underestimation across conditions Especially evident in Linear and Incentive conditions	• Negative Temporal Bias • Moderate to high premature response rate • Normal to mildly elevated variability • Average Adaptive Correction Index (ACI)	Deficits primarily in inhibitory control of action initiation rather than temporal representation per se.
Reward-Sensitive Subtype (Incentive-Dominant)	Strong influence of reward cues on timing and decision-making.	Markedly worse performance in Incentive condition. Increased premature responding under reward pressure. Larger bias shift relative to Linear condition.	• More negative bias in Incentive condition vs. Linear • Higher absolute error under incentive • Elevated premature response rate under reward • Lower ACI under incentive	Motivational factors override optimal timing control, leading to risk-taking and impatience when rewards are present.
Temporal Dysregulation Subtype (Timing Instability)	Inconsistent and unstable internal timing across contexts.	High variability across trials in all conditions Fluctuating bias (no consistent direction) Inconsistent pacing even without incentives	• High Response Variability • Variable bias (near zero mean but higher fluctuation) • Reduced accuracy despite normal bias • Average to low ACI	Core instability in internal time representation or monitoring processes, independent of inhibitory control or reward sensitivity
Feedback-Insensitive Subtype (Poor Recalibration)	Limited learning from errors and feedback.	Repetition of similar error patterns across trials Minimal adjustment after feedback Low improvement over time	• Low Adaptive Correction Index (ACI) • Persistently high error across blocks • Stable bias despite feedback • Little reduction in variability	Deficit in using feedback to update temporal estimates and strategies; weak learning and self-monitoring

Note. These profiles are not mutually exclusive; individuals may show features of more than one pattern. Empirical validation is required to determine the reliability, stability, and clinical relevance of these profiles.

5.4. FUTURE DIRECTIONS

Future research should first establish the psychometric properties of the Internal Timing Regulation Paradigm (ITRP), including reliability, feasibility, and sensitivity to change. Construct validity should then be examined through associations with impulsivity, executive functioning, attention, working memory, and delay discounting measures.

Comparative studies involving ADHD, addictive disorders, and control groups may clarify whether temporal dysregulation reflects a transdiagnostic process or disorder-specific profile. Longitudinal work may help distinguish trait-like vulnerabilities from state-dependent

influences such as stress, sleep disruption, or stimulant use. Intervention studies should test whether external pacing tools, structured routines, countdown systems, or feedback-based strategies improve both task performance and real-world self-regulation. Finally, digital and mobile formats may allow scalable assessment in naturalistic settings.

6. CONCLUSIONS

Impulsivity is commonly linked to inhibitory failure, reward sensitivity, and executive dysfunction. While these models remain central, they may not fully explain difficulties that arise in situations requiring pacing, waiting, and adaptive regulation over time. The present paper has argued that disturbances in the perception, monitoring, and behavioral use of internal time may represent an additional pathway to dysregulated action.

To address this possibility, the construct of Temporal Decision Control was introduced as the capacity to use internally represented temporal information to guide behavior under changing demands. From this perspective, some impulsive behaviors may reflect difficulties in sustaining pace, tolerating delay, recalibrating after errors, or coordinating action with subjective time.

The paper also outlined the Internal Timing Regulation Paradigm (ITRP) as a proposed behavioral framework for examining internally guided timing across neutral, cognitively demanding, and incentive-based conditions. Rather than serving as a stand-alone diagnostic instrument, the paradigm is intended as a complementary tool for investigating heterogeneity within impulsive behavior.

If supported through empirical research, this model may be relevant for populations in which timing, organization, and inconsistent responding are common, including ADHD, addictive disorders, and dimensional differences in self-regulation more broadly. Future studies will need to determine whether temporal regulation deficits reflect stable traits, context-dependent states, or modifiable intervention targets.

More broadly, the study of impulsivity may benefit from asking not only why individuals act too soon, but also how they perceive, organize, and use time in the service of adaptive behavior. This perspective may contribute to more differentiated theories of self-control and more targeted approaches to psychological assessment and intervention.

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