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NAIL-C: A Neurodiversity-Adaptive Framework for Inclusive Language Learning in the Age of AI

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Abstract

Theories of second language acquisition (SLA) have largely assumed that learners can access input and take part in interaction under broadly stable sensory, cognitive, and emotional conditions. Neurodiversity shows that these conditions vary within and across learners, while large language models (LLMs) now mediate much everyday language work. This conceptual article argues that the relationship between regulated access, communicative competence, and AI mediation remains under-theorized in SLA. Through a theoretical synthesis of SLA, neurodiversity scholarship, ecological and distributed cognition, multimodality, and research on AI-mediated communication, it proposes NAIL-C, a neurodiversity-adaptive framework with five interdependent components: Neurodiversity-Centered Design, Adaptive Regulation, Tolerable and Adaptive Input, Learning as Dynamic Alignment, and Multimodality-Adaptive Communicative Competence. The framework treats regulated access as a boundary condition on acquisition, defines communicative competence so that multimodal and variable participation can count as evidence, and positions AI as a potential regulatory scaffold that requires human oversight. NAIL-C complements Universal Design for Learning by offering an SLA-specific account of usable input and competence. The article specifies falsifiable predictions and outlines implications for assessment, pedagogy, and research.

Keywords: *Accessibility, artificial intelligence, communicative competence, inclusive language education, neurodiversity, second language acquisition.*

NAIL-C: Yapay Zeka Çağında Kapsayıcı Dil Öğrenimi İçin Nöroçeşitliliğe Uyum Sağlayan Bir Çerçeve

Öz

İkinci dil edinimi (İDE) kuramları, öğrenenlerin girdiye erişebildiğini ve etkileşime büyük ölçüde istikrarlı duyusal, bilişsel ve duygusal koşullar altında katılabildiğini genellikle varsaymıştır. Nöroçeşitlilik bu koşulların öğrenenler arasında ve aynı öğrenenin kendi içinde değiştiğini göstermektedir; büyük dil modelleri (BDM) ise gündelik dil kullanımının önemli bir bölümüne artık aracılık etmektedir. Bu kavramsal makale, düzenlenmiş erişim (regulated access), iletişim yetisi ve yapay zekâ aracılığı arasındaki ilişkinin İDE alanında yeterince kuramsallaştırılmadığını ileri sürmektedir. İDE, nöroçeşitlilik çalışmaları, ekolojik ve dağıtılmış biliş, çok kiplilik ve yapay zekâ aracılı iletişim araştırmalarının kuramsal sentezine dayanan makale, birbirine bağlı beş bileşenden oluşan ve nöroçeşitliliğe uyarlanabilen (neurodiversity-adaptive) NAIL-C çerçevesini önermektedir: Nöroçeşitlilik Merkezli Tasarım (Neurodiversity-Centered Design, NCD), Uyarlanabilir Düzenleme (Adaptive Regulation), Tolere Edilebilir ve Uyarlanabilir Girdi (Tolerable and Adaptive Input, TAI), Dinamik Uyum Olarak Öğrenme (Learning as Dynamic Alignment) ve Çok Kipliliğe Uyarlanabilir İletişim Yetisi (Multimodality-Adaptive Communicative Competence, M-ACC). Çerçeve, düzenlenmiş erişimi edinim için bir sınır koşulu olarak ele almakta, iletişim yetisini çok kipli ve

değişken katılımı kanıt olarak kabul edecek biçimde tanımlamakta ve yapay zekâyı insan denetimi gerektiren olası bir düzenleyici iskele (regulatory scaffold) olarak konumlandırmaktadır. NAIL-C, kullanılabilir girdi ve yeti konusunda İDE'ye özgü bir açıklama sunarak Öğrenme için Evrensel Tasarım'ı tamamlamaktadır. Makale yanlışlanabilir öngörüler belirlemekte ve ölçme-değerlendirme, öğretim ve araştırma için çıkarımlar sunmaktadır.

Anahtar Kelimeler: E*rişilebilirlik, ikinci dil edinimi, iletişim yetisi, kapsayıcı dil eğitimi, nöroçeşitlilik, yapay zekâ*

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INTRODUCTION

Language classrooms are changing in two ways that SLA theory has not yet brought together. Learners differ, systematically rather than occasionally, in how they attend to, regulate, and process sensory and linguistic information. At the same time, AI tools, and large language models (LLMs) in particular, increasingly take part in drafting, rephrasing, planning, and managing interaction. Both developments alter what learners can access, how they participate, and what counts as successful communication, yet many instructional routines and evaluative norms still assume a narrow range of "typical" participation.

Influential accounts of second language acquisition (SLA) explain learning through input, attention, interaction, output, mediation, and usage (Ellis, 2003; Krashen, 1982; Long, 1996; Schmidt, 1990; Swain, 1985; Vygotsky, 1978). They differ in many respects, but they tend to share an implicit stability assumption: that learners can reliably access input and sustain engagement under reasonably predictable sensory, temporal, and social conditions. Individual differences are usually modeled through variables such as aptitude and motivation (Dörnyei & Skehan, 2003), whereas variability in sensory processing, regulation, and fit with speech-first norms tends to remain in the background. Research on specific learning differences in additional language learning has grown considerably (Kormos & Indrarathne, 2026), but the consequences of such variability for acquisition mechanisms themselves remain under-theorized.

Neurodiversity makes this assumption visible. A neurodiversity-informed view locates many learning barriers in person–environment misfit rather than in deficit alone (Dwyer, 2022; Walker, 2021) and treats communicative breakdown as potentially reciprocal (Milton, 2012). If access and regulation fluctuate, a learner's silence or disengagement may reflect temporarily unusable input rather than missing linguistic knowledge. This article refers to this as the regulated-access problem: learning mechanisms may be present yet temporarily inaccessible when sensory, cognitive, or emotional load exceeds what a learner can regulate in a given task ecology.

AI makes the problem more urgent and more complex. From the perspective of distributed and extended cognition, tools can become part of the functional system that accomplishes a task (Clark & Chalmers, 1998; Hutchins, 1995). When LLMs propose phrasing or restructure discourse (Hancock et al., 2020), or act as interlocutor-like partners, they alter what counts as input, feedback, and output. Some autistic adults describe conversational AI as a non-judgmental space for everyday communication tasks (Choi et al., 2024), but such tools also shift demands toward monitoring and verification and introduce risks of error, bias, and overreliance (Bommasani et al., 2021; Kasneci et al., 2023). The theoretical question is therefore not whether AI makes language work easier but how it redistributes regulation, scaffolding, and communicative agency.

These developments have rarely been examined within a single theoretical account. The purpose of this article is to develop NAIL-C, a neurodiversity-adaptive framework for inclusive language learning in AI-mediated environments. NAIL-C comprises five interdependent components: Neurodiversity-Centered Design (NCD), Adaptive Regulation, Tolerable and Adaptive Input (TAI), Learning as Dynamic Alignment, and Multimodality-Adaptive Communicative Competence (M-ACC). The article makes three contributions. It reframes access as a boundary condition on acquisition rather than a background assumption; it redefines communicative competence so that multimodal and variable-access participation can count as legitimate evidence; and it theorizes AI as a potential regulatory scaffold whose value depends on governance, transparency, and learner agency. NAIL-C does not replace established SLA theories or Universal Design for Learning (UDL); it specifies testable conditions under which their mechanisms and principles can operate in language learning (Section 5.1).

The stakes are practical as well as theoretical. Inclusive language education increasingly asks teachers to accommodate diverse learners, and teachers increasingly encounter learners who use AI tools, often without a principled account of what either development means for acquisition. Without such an account, accommodations risk being treated as concessions that lower standards, and AI use risks being treated only as a threat to integrity. A framework that specifies when access conditions, rather than linguistic readiness, limit learning can help teachers, test designers, and researchers decide which adaptations preserve the learning target and which change it.

The article is conceptual. Section 2 reviews the literatures that the framework brings into dialogue, Section 3 describes the conceptual synthesis through which NAIL-C was developed, and Section 4 presents the framework as the outcome of that synthesis, including falsifiable predictions. Section 5 discusses implications, counterarguments, and ethical constraints, and Section 6 concludes.

LITERATURE REVIEW

Neurodiversity, Accessibility, and Person–Environment Fit

The neurodiversity paradigm treats cognitive variability as a natural feature of human populations and locates many barriers in environments designed around narrow performance expectations (Walker, 2021). This does not deny genuine constraints in attention, sensory processing, or language processing. Rather, it explains why the same learner may thrive in one context and struggle in another, depending on pacing, sensory density, interaction format, and evaluative pressure (Dwyer, 2022). Challenges and strengths can coexist within the same person (Dwyer, 2022; Kapp et al., 2013), and autism research has increasingly called for inquiry that takes lived experience and real-world contexts seriously (Pellicano & den Houting, 2022). Milton's (2012) double empathy problem further suggests that breakdown between autistic and non-autistic interlocutors can arise from mutual differences in expectation and inference rather than from a one-sided deficit.

Two cautions shape how this literature is used here. First, neurodivergent populations are heterogeneous: autism, attention-deficit/hyperactivity disorder (ADHD), dyslexia, and developmental language disorder (DLD) involve different profiles, and variability within each category is substantial. Second, evidence gathered with one population cannot automatically be generalized to another. This article uses autism as an anchor case because its documented sensory, attentional, and communicative variability makes participation assumptions in SLA particularly visible (Ben-Sasson et al., 2009; Eigsti et al., 2011; Keehn et al., 2013), and it draws on L2 research on specific learning differences such as dyslexia where available (Kormos & Indrarathne, 2026). The framework is functional and transdiagnostic in intent, but its transdiagnostic scope is a hypothesis rather than an established finding. Teacher knowledge also matters: Research in Türkiye has examined what EFL teachers know about dyslexia (Genç & Atar, 2026), and where such knowledge is limited, access-related breakdowns are more easily read as low ability or motivation.

The framework is designed to extend beyond its anchor case, as ADHD illustrates. Meta-analytic evidence indicates that children with ADHD are, on average, on task less often and more variably in classrooms, with differences that depend partly on setting (Kofler et al., 2008); that their Go/No-Go performance is sensitive to event rate (pacing; Metin et al., 2012); and that group differences across neurocognitive domains, including working memory, reaction time variability, and inhibition, are moderate (Pievsky & McGrath, 2018). These general cognitive and classroom findings bear on tolerability and on the timing and pacing of adjustments, without implying sensory overload or a single ADHD profile. Because ADHD-specific evidence on additional language learning remains scarce (Silawi et al., 2025), NAIL-C's applicability to ADHD-related regulatory profiles is a theoretical claim requiring empirical testing.

Regulation, Attention, and Usable Input

Input-based accounts center acquisition on exposure to language slightly beyond the learner's current level (Krashen, 1982). Critics have long noted that Krashen's constructs, including the current level and the increment, are difficult to operationalize (Gregg, 1984; McLaughlin, 1978), but a different limitation matters here: apart from the affective filter, access to input is typically treated as a matter of linguistic comprehensibility. Autism research documents differences in sensory responsivity and perception, including over- and under-responsivity and sensory seeking (Ben-Sasson et al., 2009; Robertson & Baron-Cohen, 2017), and such differences, for instance in reactions to classroom noise, can affect how autistic pupils access

classroom learning (Jones et al., 2020; Mallory & Keehn, 2021). Cognitive load theory adds that extraneous load arising from how information is presented competes with processing capacity (Paas et al., 2003; Sweller, 1988). When sensory or regulatory effort consumes that capacity, input may be comprehensible in principle yet unusable in practice.

Attention-based accounts sharpen the point. The Noticing Hypothesis holds that features must be registered for acquisition to proceed (Schmidt, 1990), and attention can be decomposed into alertness, orientation, and detection (Tomlin & Villa, 1994). Autism research, however, describes attentional patterns such as intense focus on narrow domains and difficulty disengaging attention (Keehn et al., 2013; Murray et al., 2005) and links emotion-regulation difficulties with anxiety and other socioemotional and behavioral problems (Mazefsky et al., 2013). More generally, achievement emotions are theorized to shape engagement and strategy use (Pekrun, 2006), and confusion can return to engagement or escalate into frustration and boredom depending on whether the underlying impasse is resolved (D'Mello & Graesser, 2012). What an instructor intends to make salient may therefore not be what a learner can attend to, and additional cues may add to rather than relieve demand. Usage-based accounts, which treat acquisition as emerging from experience (Ellis, 2003), accommodate variability in exposure; evidence on statistical learning, however, differs by profile, appearing largely intact in autism but reduced on average in DLD (Bell et al., 2026; Obeid et al., 2016). Across these traditions, the availability of attention and regulation is rarely specified as a variable.

Interaction, Multimodality, and Communicative Competence

Interactionist and output-based accounts hold that negotiation of meaning, feedback, and pushed output support development (Long, 1996; Swain, 1985). In classrooms, these ideas are often realized through rapid, face-to-face exchange that bundles linguistic work with turn-taking, pragmatic inference, and social evaluation. Many autistic adults report camouflaging, that is, deliberately performing neurotypical interactional behaviors, which they associate with exhaustion and distress (Hull et al., 2017). Studies of computer-mediated communication indicate that some autistic adults value text-based and asynchronous formats, although these formats bring challenges of their own (Ritzman & Subramanian, 2024; van der Aa et al., 2016). The conditions of interaction, and not only its presence, therefore matter.

A parallel issue concerns competence. Communicative competence models broadened the construct beyond grammar (Bachman, 1990; Canale & Swain, 1980; Celce-Murcia et al., 1995), yet their operationalization in teaching and testing has often privileged speech-like performance under normative timing. Multimodality research treats meaning as designed through ensembles of modes (Jewitt, 2008; Kress, 2010; New London Group, 1996), and multimodal communicative competence has been developed through explicit pedagogy in EFL (Dai & Wu, 2021). Research on augmentative and alternative communication (AAC) defines communicative competence functionally, in terms of participation across interpersonal contexts (Light & McNaughton, 2014), and high-tech AAC interventions have been appraised as evidence-based practice (Morin et al., 2018). These literatures offer resources for a competence construct that does not equate competence with rapid, unaided speech, but they have rarely been integrated into SLA accounts of development under variable access.

Mediation, Distributed Cognition, and AI

Sociocultural theory established that learning is mediated activity and that support can enable performance beyond independent ability (Lantolf & Thorne, 2006; Vygotsky, 1978). Applied work has tended to locate mediation in human partners, yet for some neurodivergent learners

human mediation can itself carry regulatory cost through social unpredictability and evaluative pressure. Distributed cognition and the extended mind thesis offer a way beyond exclusively human mediation: cognitive activity can span people and artifacts, and reliably integrated tools can operate as parts of a cognitive system (Clark & Chalmers, 1998; Hutchins, 1995). Research on cognitive offloading adds that external resources can free capacity but may also change what is learned and remembered (Risko & Gilbert, 2016).

AI-mediated communication extends these ideas to language itself, because systems that generate, modify, or suggest messages alter authorship, agency, and trust (Hancock et al., 2020). Educational analyses of LLMs identify opportunities for explanation and practice alongside risks of error, bias, and overreliance (Bommasani et al., 2021; Kasneci et al., 2023), and correlational evidence associates frequent AI tool use with greater cognitive offloading and lower critical-thinking scores (Gerlich, 2025). Evidence from specific populations is emerging. Autistic adults have described integrating conversational AI into daily life, valuing its availability and non-judgmental responses (Choi et al., 2024), and AAC users have reported that LLM-generated suggestions can both enhance and impede communication, including concerns about authenticity and control (Valencia et al., 2023). This evidence is early, heterogeneous, and mostly not drawn from language classrooms, which limits what can be claimed.

The Theoretical Gap

Taken together, these literatures reveal a pattern. Neurodiversity scholarship has advanced ecological and relational accounts of learning barriers; SLA has refined acquisition mechanisms without systematically integrating those accounts; and research on AI in language education has focused largely on effectiveness, general affordances, and academic integrity rather than on how tool mediation interacts with regulation and access (e.g., Kasneci et al., 2023; Uygun, 2026; Uygun & Demir, 2026). Three gaps follow. SLA theory has rarely treated sensory, cognitive, and emotional access as a boundary condition on its own mechanisms. Assessment practice often draws evidence from speech-first, time-pressured formats that may introduce construct-irrelevant variance for learners whose participation profiles diverge from these norms (Kormos & Indrarathne, 2026; Messick, 1989). And the regulatory role of AI mediation in language learning remains under-theorized. UDL offers well-established design principles for addressing variability (CAST, 2024; Meyer et al., 2014), but it is not designed to specify what counts as usable input for acquisition, how communicative competence should be defined under variable access, or how AI alters scaffolding and output. NAIL-C is proposed to address these questions.

METHODOLOGY: CONCEPTUAL AND THEORETICAL SYNTHESIS

This is a theoretical article. It does not report primary data and is not a systematic, scoping, or integrative review. Its method is conceptual synthesis: the purposeful integration of established constructs from several fields in order to identify an unexamined assumption and to propose a framework that addresses it.

The synthesis drew on five domains: SLA theory (input, noticing, interaction, output, sociocultural mediation, usage-based learning, and communicative competence); neurodiversity-informed and ecological accounts of disability and learning; research on regulation, cognitive load, and achievement emotions; multimodality and AAC research; and scholarship on distributed cognition and AI-mediated communication. Sources were selected purposively rather than through database searching. Foundational works were included where

they define a construct that NAIL-C re-examines, and contemporary reviews and empirical studies were included where they provide evidence about sensory, attentional, regulatory, or communicative variability, or about AI-mediated communication with neurodivergent and disabled users. Reviews and meta-analyses were preferred where available.

The analysis proceeded in three interpretive steps. First, for each SLA construct, the operating conditions it implicitly assumes were identified, for example stable attention during noticing or real-time availability during negotiation of meaning. Second, these assumptions were compared with evidence from neurodiversity, regulation, and multimodality research to establish where they fail and what follows theoretically. Third, constructs recurring across domains, including person–environment fit, regulatory load, usable input, multimodal participation, and tool-mediated agency, were mapped onto one another and consolidated into three framework propositions and five components: a design orientation (NCD), moment-to-moment responsiveness (Adaptive Regulation), a construct of usable input (TAI), a mechanism-level account (Learning as Dynamic Alignment), and a definition of competence (M-ACC).

Each component answers a distinct question left implicit by the stability assumption: where friction originates before engagement (NCD, from ecological accounts of person–environment fit and UDL), how access is maintained as learner state changes (Adaptive Regulation, from regulation and emotion research), when input becomes usable (TAI, from input and attention accounts read against sensory and cognitive-load evidence), how mechanisms behave when these conditions vary (Learning as Dynamic Alignment, from interactionist, sociocultural, and distributed accounts), and what counts as evidence of competence (M-ACC, from competence, multimodality, and AAC research). The components are thus distinct explanatory functions at different levels of analysis rather than mutually exclusive empirical categories; one classroom event can be analyzed through all five. This account clarifies the framework's organization; it is not a coding scheme, and the boundaries are not empirically validated.

To keep epistemic status visible, the article distinguishes established evidence, reported with citations and scoped to the populations studied; theoretical inferences drawn from that evidence; framework propositions, which are the article's own claims; and empirical predictions, which specify how the propositions could be tested. This procedure can generate coherent and testable propositions, but it cannot establish causal effects, prevalence, or population-level generalizability. These require the empirical work outlined in Sections 4.7 and 5.4.

Two further limitations should be stated. Because the synthesis relies heavily on autism research, the framework may reflect the regulatory profile most visible in that literature more than those associated with ADHD, dyslexia, or DLD. And because much of the AI evidence comes from human-computer interaction research outside language classrooms, claims about AI-mediated regulation in language learning are framed as hypotheses. Both limitations are carried forward into the predictions in Section 4.7.

FINDINGS: THE NAIL-C FRAMEWORK

The conceptual synthesis produced five interdependent components that constitute the NAIL-C framework. This section presents them as framework propositions derived from the synthesis, not as empirical findings.

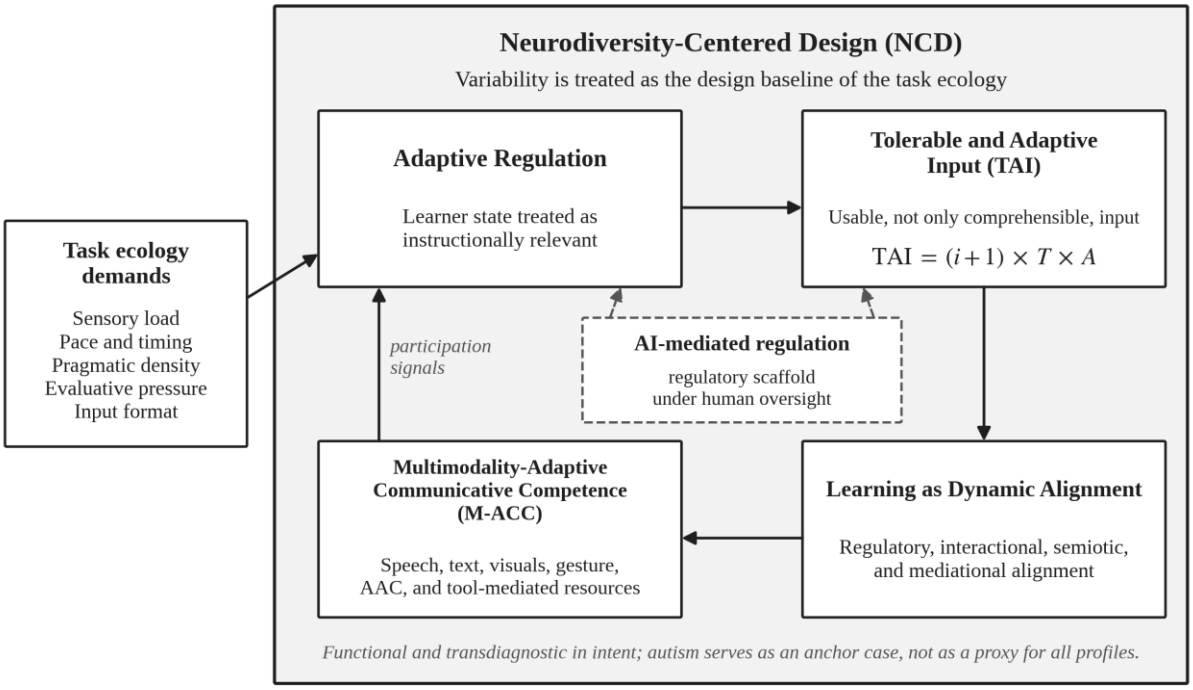
Overview of the NAIL-C Framework

NAIL-C (Neurodiversity-Adaptive Input and Learning with Communicative competence) rests on three propositions.

> *Proposition 1 (Regulated Access).* Input processing, noticing, interaction, and output operate only when sensory, cognitive, and emotional access conditions remain within tolerable bounds, and these bounds can shift during a task. Access is therefore a boundary condition on acquisition rather than a background assumption.
>
> *Proposition 2 (Multimodal Competence).* Communicative competence is the capacity to achieve communicative goals by selecting, coordinating, sustaining, and flexibly switching between semiotic modes as regulatory and communicative demands change, in ways that remain viable within a learner's regulatory profile and intelligible to interlocutors.
>
> *Proposition 3 (Mediated Regulation).* Under conditions of transparency, learner agency, and human oversight, AI tools, including LLMs, can function as regulatory scaffolds that help stabilize access and participation, rather than serving only as content generators.

The propositions interlock. If access is a boundary condition (Proposition 1), competence must be defined in terms that respect variable access (Proposition 2), and tools that stabilize access become theoretically relevant rather than peripheral (Proposition 3). NCD and Adaptive Regulation establish the conditions for Proposition 1, TAI specifies it at the level of input, Learning as Dynamic Alignment describes how mechanisms behave when access varies, and M-ACC specifies Proposition 2; Proposition 3 runs across the framework (Figure 1). NAIL-C is analytic and heuristic rather than a prescriptive method.

Figure 1. *The NAIL-C Framework: Five interdependent components*



Note. NCD = Neurodiversity-Centered Design; TAI = Tolerable and Adaptive Input; M-ACC = Multimodality-Adaptive Communicative Competence; AAC = augmentative and alternative communication. Solid arrows show

the main relations among components; dashed elements show AI-mediated regulation, which operates only under human oversight. The TAI expression is a conceptual heuristic, not an estimated equation.

Neurodiversity-Centered Design

NCD is the framework's foundational stance: it treats variability as a predictable property of language-learning environments rather than as deviation from a norm. The problem it addresses is retrofitting, whereby accommodations are added after breakdowns occur while the task ecology itself remains unexamined. Consistent with ecological accounts (Dwyer, 2022; Pellicano & den Houting, 2022), NCD moves analysis away from learner limitations toward sources of friction in the task ecology: input format, pacing, interactional norms, affective demands, and assessment expectations. Many routines implicitly privilege a narrow engagement profile, including rapid turn-taking, tolerance for noise and ambiguity, and speech-first output. NCD does not assume that all neurodivergent learners diverge from this profile in the same way; it assumes that some will, and that the pattern will vary.

NCD builds on UDL's principles of multiple means of engagement, representation, and action and expression (CAST, 2024; Meyer et al., 2014) and treats them as a necessary foundation. UDL already frames these principles around learning and learner agency, not access alone; NCD adds the SLA-specific question of whether a design keeps particular acquisition mechanisms operating for a specified linguistic target. Predictable routines, clear task boundaries, reduced unnecessary pragmatic load, and multimodal options for input and expression are therefore treated as design variables with consequences for learning. This does not lower linguistic goals; it clarifies which demands belong to the target construct and which do not. NCD becomes testable when design features are manipulated while linguistic targets are held constant.

An illustration clarifies the stance. A task that requires learners to defend an opinion using hedging and concessive structures may be organized as a timed oral pair discussion in a noisy room. For some learners, the sensory environment and the demand for rapid turn-taking may consume the resources needed for the linguistic target itself. NCD does not remove the target; it asks whether the same target can also be pursued through a quieter setting, a text-based exchange, or preparation time, and whether the oral format is itself part of what is being taught. Where spontaneous speaking is the goal, the oral format stays; where it is not, it becomes a design choice rather than a requirement.

Adaptive Regulation

Whereas NCD concerns design before engagement, Adaptive Regulation concerns responsiveness during it. Regulation is understood in a learning-sciences sense that spans self-regulation, co-regulation, and shared regulation among learners, interlocutors, and tools (Hadwin et al., 2017; Zimmerman, 2002). The problem it addresses is that SLA tends to treat learner state, the momentary configuration of attention, arousal, cognitive load, and affect, as background variation. Theory and evidence that emotion regulation and affective states shape engagement (D'Mello & Graesser, 2012; Mazefsky et al., 2013; Pekrun, 2006) support a different inference: more exposure or interaction does not guarantee learning if exposure and interaction cannot be regulated.

Adaptive Regulation therefore treats learner state as instructionally relevant and calls for timely adjustment of task demands, modality, and pacing by the learner, a teacher, a peer, or a tool. Adaptive educational systems have long pursued such responsiveness through user modeling (Brusilovsky, 2001), and affect-aware tutoring systems report learning benefits in

some contexts (Fernández-Herrero, 2024). LLMs add a distinctive affordance profile: on request, they can rephrase input, adjust explicitness, support rehearsal, and sustain interactional continuity. The framework does not assume that AI can reliably detect a learner's regulatory state. Its claim is narrower: when regulation is supported through timely, learner-controlled adjustments, neurodivergent learners may gain more consistent access to noticing, practice, and meaning-making. Because LLMs can misread intent, produce incorrect guidance, and reproduce bias, their regulatory role remains subject to human oversight (Bommasani et al., 2021; Kasneci et al., 2023).

Adaptive Regulation also clarifies the teacher's role. Reading signals of overload, withdrawal, or shutdown becomes part of pedagogical competence, not because teachers should diagnose learners but because learning is unlikely when access collapses. Co-regulation can take simple forms, such as agreed signals for a pause, predictable transitions, or a standing option to switch to written participation. Such routines keep control with the learner and reduce the need for monitoring technologies. The component becomes testable when the timing of adjustments is varied: the framework predicts that adjustments made before disengagement preserve more learning opportunities than equally accurate support offered after it, since unresolved confusion tends to escalate (D'Mello & Graesser, 2012).

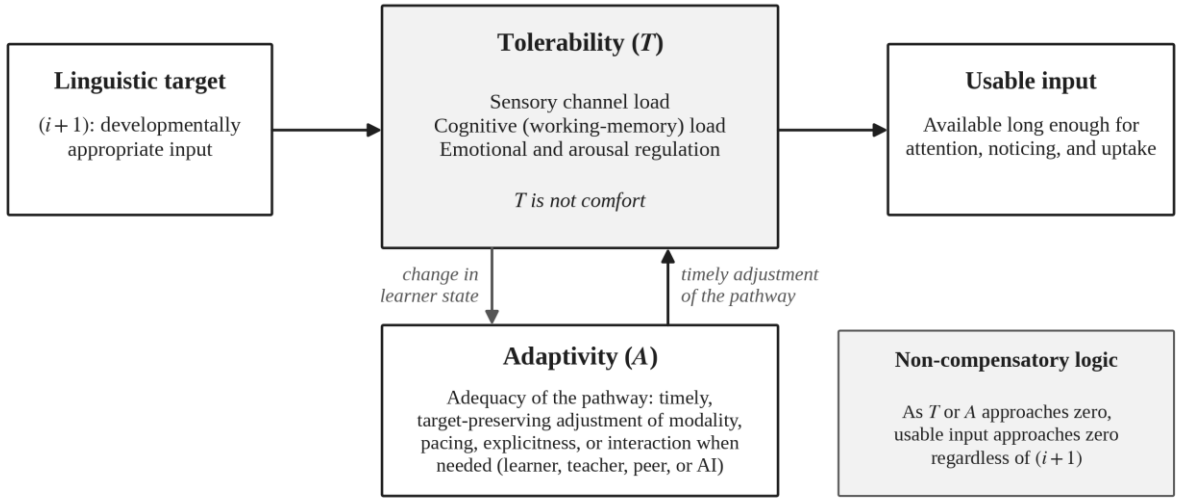
Tolerable and Adaptive Input

TAI specifies what regulated access means at the level of input. It preserves the developmental intuition of input slightly beyond current competence (Krashen, 1982) but separates two properties that are often conflated: linguistic comprehensibility and functional accessibility. A message may be comprehensible in principle yet functionally inaccessible if it arrives through an overwhelming sensory channel (Jones et al., 2020; Mallory & Keehn, 2021), exceeds working-memory capacity (Sweller, 1988), or coincides with affective dysregulation (Mazefsky et al., 2013; Pekrun, 2006). The question shifts from whether input is developmentally appropriate to whether it remains accessible long enough for noticing and uptake. NAIL-C expresses this shift as a conceptual heuristic:

$$\text{TAI} = (i{+}1) \times T \times A$$

Here, (i+1) denotes the developmental appropriateness of the linguistic target. T (tolerability) denotes the extent to which sensory, cognitive, and emotional conditions keep input available for sustained processing; tolerability is not comfort, preference, or the absence of challenge. A (adaptivity) denotes the adequacy of the pathway to the input, where NCD and Adaptive Regulation meet: its fit with the learner's current state and its timely, target-preserving adjustment when that state changes. A is high when the pathway already fits and needs no adjustment, or when a needed change in modality, pacing, explicitness, or interactional structure comes in time and leaves the target constant; it is low when a shift in learner state that undermines access is answered late, not at all, or by lowering the target. Adaptivity is therefore neither the number of adjustments made nor simplification. The expression is not an estimated equation, and its terms have no agreed metric. Its multiplicative form encodes a non-compensatory claim: linguistic quality cannot compensate for inaccessible delivery, so as T or A approaches zero, the learning value of input collapses regardless of (i+1). Because the terms lack ratio-scale measurement, the product implies no proportional effects and specifies no threshold values, and "zero" marks a limiting case (input unavailable for processing), not a measured value. The product treats T and A as jointly necessary but does not model drift: input within tolerable bounds can move outside them unless the pathway adapts in time, a dependence of T on A that Figure 2 depicts.

Figure 2. *Tolerable and adaptive input as a conceptual heuristic*



Note. TAI = (i+1) × T × A, where T = tolerability and A = adaptivity (pathway adequacy, not the number of adjustments). The expression is a conceptual heuristic, not an empirically estimated equation.

Read through attention theory, TAI implies that the bottleneck to noticing is sometimes not the salience of linguistic cues but the stability of the window in which they can be attended to (Schmidt, 1990; Tomlin & Villa, 1994). This yields a prediction: interventions that only increase explicitness should have limited effects when T is low, whereas interventions that raise T and secure A through timely adjustment should improve engagement and uptake on the same target. LLMs are relevant mainly to A rather than to (i+1), because they can re-represent input through chunking, modality shifts, or pacing while leaving the target unchanged. Whether they do so reliably and accurately is an empirical question, and their output requires human verification.

Learning as Dynamic Alignment

Learning as Dynamic Alignment describes how acquisition proceeds when access varies. Within NAIL-C, learning is not the additive effect of input, interaction, and output but an outcome of sustained alignment among regulatory, interactional, semiotic, and mediational conditions. The problem this component addresses is misattribution: apparent failures of noticing, interaction, or output may reflect misalignment between learner state and task demands rather than absent competence. On this account, learning mechanisms are not missing but intermittently unavailable. Table 1 applies this reinterpretation to four SLA constructs.

Table 1. *Realigning core SLA constructs under variable access*

Construct	Conventional assumption	NAIL-C reinterpretation
Noticing	Registration of form–meaning relations depends on the learner's allocation of attention (Schmidt, 1990; Tomlin & Villa, 1994).	Noticing is regulation-dependent: overload or affective stress can close the window for sustained attention (D'Mello & Graesser, 2012; Pekrun, 2006).

Construct	Conventional assumption	NAIL-C reinterpretation
Interaction	Negotiation of meaning in real-time talk supplies feedback and repair (Long, 1996).	Interaction format matters: breakdown may reflect misaligned pace, sensory load, or pragmatic demand rather than lack of communicative intent (Hull et al., 2017; Milton, 2012).
Output	Pushed output drives syntactic processing and hypothesis testing (Swain, 1985).	Output includes text, visuals, gesture, and AAC when these sustain participation; tool-mediated output is judged by the learner's monitoring and decisions (Jewitt, 2008; Light & McNaughton, 2014).
Mediation	Human partners scaffold performance within the Zone of Proximal Development (Lantolf & Thorne, 2006; Vygotsky, 1978).	Mediation can also stabilize regulatory conditions; tools, including AI, may carry part of the regulatory load (Clark & Chalmers, 1998; Risko & Gilbert, 2016).

Note. SLA = second language acquisition; AAC = augmentative and alternative communication. Reinterpretations are framework propositions, not established findings.

Across the rows, the same move recurs: a process usually described as internal to the learner is reinterpreted as dependent on alignment between learner state and task ecology. Dynamic alignment is therefore not an additional acquisition mechanism but an account of how NCD, Adaptive Regulation, and TAI combine at the level of mechanism. It becomes testable through process data showing whether breakdowns coincide with measurable changes in load and recede when conditions are realigned.

Consider a learner who falls silent during a fast group discussion and later produces accurate, well-argued written contributions on the same topic. A conventional reading might attribute silence to limited speaking competence or low motivation. Dynamic alignment offers an alternative that can be checked: the silence may coincide with increased pragmatic and sensory load, and participation may recover when the same interactional goal is pursued under different conditions. The two readings make different predictions about what happens when conditions change, which is what makes the distinction empirically useful rather than merely charitable.

Multimodality-Adaptive Communicative Competence

M-ACC specifies what counts as communicative success when alignment conditions vary. It defines competence as a learner's developing capacity to achieve communicative goals by selecting, coordinating, sustaining, and flexibly switching between modes, including speech, text, visuals, gesture, AAC, and tool-mediated resources, as regulatory and communicative demands change, in ways that remain viable within the learner's regulatory profile and meet contextual and interlocutor expectations. For example, a learner who moves from speech to writing when cognitive or sensory load rises, adds a visual when written explanation becomes too dense, or shifts to asynchronous participation or an authorized tool can maintain communicative continuity when a channel becomes temporarily inaccessible. Such switching extends strategic competence, the verbal and non-verbal strategies that compensate for breakdown (Canale & Swain, 1980), to mode changes that sustain participation as regulation fluctuates. The evidential value of switching depends on the intended construct: a written turn

can show control of a target structure or negotiation of meaning, but not spontaneous speaking when that is what is assessed. Earlier competence models are not wrong; they leave modality and regulatory sustainability under-specified. M-ACC therefore brings SLA competence models together with multimodality research (Kress, 2010; New London Group, 1996), the participation-centered definition of competence in AAC (Light & McNaughton, 2014), distributed cognition (Hutchins, 1995), and research on agency in AI-mediated communication (Hancock et al., 2020). Table 2 contrasts M-ACC with conventional assumptions.

Table 2. *Conventional communicative competence assumptions and M-ACC*

Dimension	Conventional assumption	M-ACC reinterpretation
Goal	Competence is judged by approximation to speech norms.	Competence is judged by goal attainment, intelligibility, and sustained participation (Light & McNaughton, 2014).
Modality	Speech is primary; other modes are paralinguistic support.	Modality choice is competence-relevant because meaning is designed across modes (Jewitt, 2008; Kress, 2010).
Coordination	Integrating modes happens implicitly.	Multimodal coordination can be developed through explicit pedagogy (Dai & Wu, 2021).
Switching	A change of mode mid-task signals avoidance or reduced competence.	Strategic switching, such as from speech to text when load rises, can sustain participation and is judged against the intended construct (Canale & Swain, 1980).
Breakdown	Silence or hesitation signals missing knowledge or motivation.	Breakdown may signal overload or misfit and requires analysis of task conditions before any inference about competence (Jones et al., 2020; Mallory & Keehn, 2021).
Tools	Tools are external aids to "real" competence.	Managing mediational resources is part of skilled communication; the risk is unmonitored offloading, not tool use itself (Risko & Gilbert, 2016).
AI mediation	AI is a shortcut or an integrity threat.	When LLMs contribute text, competence includes agency over intent, evaluation of fit, and calibrated trust (Hancock et al., 2020; Lee & See, 2004).

Note. M-ACC = Multimodality-Adaptive Communicative Competence; LLM = large language model. Reinterpretations are framework propositions, not established findings.

Two features distinguish M-ACC from a general call for flexibility. Once breakdown is no longer read automatically as deficit, the criterion of success shifts toward sustainable goal attainment; and modality selection, coordination, and switching become competence dimensions to be developed rather than delivery alternatives. The AI row does not claim that AI-assisted text demonstrates the same competence as unaided production. It claims that where LLMs routinely take part in communication, evaluating, modifying, or rejecting their contributions is itself a communicative capacity, and that tool use alone should not be read as reduced competence. Although neurodiversity exposes the assumption of stable channels,

these demands apply to all learners as multimodal and AI-mediated communication becomes common.

M-ACC does not dissolve standards. Intelligibility to interlocutors, coherence across modes, appropriate repair, and fit with the communicative purpose remain criteria in every mode. What changes is that these criteria are applied to the evidence a learner can produce under viable conditions, instead of being filtered through a single channel. The construct becomes testable through parallel tasks completed in different modes and scored against the same goal-referenced rubric, which allows researchers to ask whether mode choice changes judgments of competence or only the route by which competence is shown.

Boundary Conditions and Falsifiable Predictions

NAIL-C depends on four commitments: access conditions vary enough within and across learners to affect whether mechanisms operate; the interaction of learner state and task ecology, not learner characteristics alone, determines whether input becomes usable; communicative competence can be evidenced through several modes without construct loss when goals and intelligibility standards are held constant and mode is not construct-defining; and tool-mediated regulation can be distinguished from task simplification. Table 3 translates these commitments into predictions that could support or challenge the framework.

Table 3. *Empirical predictions for NAIL-C*

Claim	Supporting evidence would show	Challenging evidence would show
Regulated access (Proposition 1, TAI)	With the target held constant, raising T or securing A through timely adjustment improves engagement, recovery from disruption, and uptake.	Manipulations intended to raise T or secure A leave breakdown rates, re-engagement, and uptake unchanged despite measurable fluctuation in learner state.
Preserved target (TAI)	Gains under adapted conditions persist on the same linguistic target.	Gains disappear once linguistic demand is equated, indicating simplification rather than improved access.
Multimodal competence (Proposition 2, M-ACC)	Multimodal options, including strategic switching, increase goal attainment and intelligibility on parallel tasks scored with modality-neutral rubrics where mode is not construct-defining.	Modality-neutral rubrics fail to reach acceptable reliability or to discriminate between levels of competence, or switching lowers coherence and goal attainment.
Mediated regulation (Proposition 3)	LLM access reduces task abandonment while learners monitor, revise, and reject suggestions.	LLM access is followed by unmonitored acceptance of output, increased load, or declining independent performance.

Note. TAI = Tolerable and Adaptive Input; T = tolerability; A = adaptivity; M-ACC = Multimodality-Adaptive Communicative Competence; LLM = large language model.

Two interpretive rules follow. Evidence that multimodal scoring is unreliable would require revision of how M-ACC is operationalized without, by itself, refuting the claim that

competence exceeds speech-first performance. Evidence that adaptation works only by lowering demand, by contrast, would challenge TAI directly.

The predictions can be examined through several designs. Within-subject experiments suit TAI because they compare the same learner across adapted and non-adapted conditions, which respects heterogeneity better than group averages. Event-contingent and time-series analyses suit Adaptive Regulation because regulatory states change within sessions. Design-based research suits NCD because design features interact with local classroom ecologies, and longitudinal studies are needed to test whether gains in access translate into durable acquisition. Across designs, studies should report participants' profiles in functional terms and avoid treating diagnostic labels as sufficient descriptions.

DISCUSSION

Implications for SLA Theory

NAIL-C does not propose a new acquisition mechanism. It proposes that established mechanisms have operating conditions that SLA theory has left implicit, and that these conditions vary. This changes how evidence is interpreted. A null effect of an input or feedback intervention may reflect a linguistically sound treatment delivered under inaccessible conditions, so that access-level failure masks mechanism-level success. Treating learner state as a variable, rather than as noise or an exclusion criterion, would allow SLA research to separate the two. The framework also extends sociocultural and distributed accounts: if mediation can target regulation as well as linguistic form, theories of scaffolding need to specify how regulatory functions are distributed across people and tools. AI-mediated communication further complicates the evidential status of output. When text is co-produced with an LLM, output is no longer a transparent window onto interlanguage; its value depends on what the learner monitored, evaluated, and decided, which shifts attention from product to process.

Individual-differences research has traditionally modeled variability as relatively stable differences between learners that predict rate and outcome (Dörnyei & Skehan, 2003); NAIL-C treats access as a within-learner condition that determines whether a mechanism operates on a given occasion and so predicts interactions between learner state and task conditions. Tolerability extends Krashen's (1982) affective filter beyond affect to sensory and cognitive conditions, is defined relative to the task ecology, and is paired with adaptivity, a pathway property that instruction can change. Complex dynamic systems theory already treats variability as developmentally meaningful (de Bot et al., 2007); NAIL-C asks when variability reflects access rather than development.

What NAIL-C does not claim is equally important. It does not claim that neurodivergent learners share a single profile, that accommodation should replace challenge, or that AI is inherently inclusive. Nor does it position itself against UDL. UDL provides broad, well-established design principles (CAST, 2024; Meyer et al., 2014), and reported benefits concern the learning process more than outcomes (Capp, 2017), alongside calls for more rigorous research (Basham & Lowrey, 2026). NAIL-C is complementary, and the difference lies in purpose and level of analysis rather than quality: UDL is a domain-general framework for designing learning environments around learner variability and agency, whereas NAIL-C offers an SLA-specific explanatory account of usable input, dynamic alignment, multimodal competence, and AI-mediated regulation that UDL-informed language teaching can draw on and test.

Implications for Inclusive Assessment and Pedagogy

Assessment is where the framework's claims have their most direct consequences. The key distinction is between the intended construct and the conditions under which evidence is elicited. When a task legitimately targets a modality-specific construct, such as spontaneous spoken interaction, speech under real-time conditions is part of what is assessed, and NAIL-C does not argue otherwise. When speech rate, sensory tolerance, or a particular modality is not part of the intended construct, however, inaccessible task conditions may introduce construct-irrelevant variance (Messick, 1989), so that scores partly reflect access rather than language ability (Kormos & Indrarathne, 2026). Accessibility in this sense does not lower expectations. It aims at equivalence of construct rather than sameness of format, and each accommodation must be justified by what the task is meant to measure; not every assessment needs to permit every modality.

For TAI, assessment evidence would include sustained engagement, recovery after disruption, and uptake on the same target across adapted and non-adapted conditions. For M-ACC, it would include goal attainment across permitted modes, intelligibility ratings on modality-neutral rubrics, repair sequences, the appropriateness of switches between modes, and learners' reflections on mode choice. Portfolio, task-based, and dynamic assessment (Poehner, 2008) traditions already provide much of the necessary infrastructure. Pedagogically, the central principle is to adapt the pathway rather than the target. Many such moves require no technology: reducing unnecessary sensory and pragmatic load, offering text-based or asynchronous participation routes alongside oral ones, and treating silence as a possible processing or regulatory pause rather than as automatic evidence of low competence.

These implications also bear on teacher education. Pre-service and in-service programs in EFL contexts, including those in Türkiye, could treat tolerability audits, modality-neutral rubric design, and critical AI literacy as connected competencies rather than separate topics. Research indicating that students' operational familiarity with AI can outpace their understanding of its ethical dimensions (Uygun, 2026) suggests that teachers will need to model monitoring, verification, and transparent use rather than simply permit or prohibit AI.

AI-Mediated Regulation: Opportunities, Constraints, and Ethical Risks

Three levels of claim should be kept apart. What current LLMs can technically do is generate and reformulate text on request. What emerging studies suggest is that some users, including some autistic adults and AAC users, find such support useful while also reporting limitations (Choi et al., 2024; Valencia et al., 2023). What NAIL-C hypothesizes is that, under governed conditions, LLMs can function as regulatory scaffolds that stabilize access to language learning. Only the first is established; the third requires empirical validation.

The risks are substantial. LLMs can generate plausible but incorrect content and reproduce bias (Bommasani et al., 2021; Kasneci et al., 2023). Frequent AI use has been associated with greater cognitive offloading (Gerlich, 2025), and offloading can remove processing that learning requires (Risko & Gilbert, 2016). AI support can also increase cognitive load when learners must verify, select among, and edit suggestions, and appropriate reliance depends on calibrated trust rather than blanket acceptance or rejection (Lee & See, 2004). Unequal access to devices, connectivity, or paid tools could turn a regulatory scaffold into a new source of inequity. Privacy and surveillance risks are particularly serious: AI-generated engagement or affect data should not inform grading or discipline, and atypical gaze, stimming, or interaction avoidance should not be algorithmically read as disengagement. NAIL-C-aligned practice therefore requires opt-in use, transparency about sources, data minimization, human review of

any evaluative decision, and learner control over when mediation is used. The aim is to support person-centered flexibility, not to replace it with algorithmic monitoring.

Counterarguments and Research Agenda

Several objections deserve direct response. First, adaptation might remove desirable difficulty. Some difficulties do enhance long-term learning (Bjork & Bjork, 2011), and NAIL-C accepts this; its claim is that difficulty arising from sensory overload or inaccessible formats is unlikely to be desirable because it does not engage the processes a task targets, whereas the linguistic challenge in (i+1) remains. Distinguishing regulatory support from simplification is therefore built into the predictions in Table 3. Second, mediated support might create dependency. The framework's adaptive logic implies that mediation should be available when demands exceed a learner's current regulatory capacity and should recede as stability grows, which research must test rather than assume. Third, multimodal flexibility might alter the construct; this risk is real and is managed through precise construct specification, as argued in Section 5.2. Fourth, neurodivergent populations may be too heterogeneous for a unified framework. NAIL-C responds by being functional rather than categorical, but its transdiagnostic scope must be demonstrated profile by profile. ADHD-related profiles offer a test: target-preserving adjustments to pacing and working-memory load should help learners whose breakdowns stem from attentional demands more than learners whose breakdowns have other sources.

Fifth, T and A may be difficult to operationalize. Neither is directly observable, so constructs, indicators, manipulable variables, and outcomes must be kept apart. Candidate indicators of T include learner-reported accessibility, perceived sensory load, and perceived cognitive load (Paas et al., 2003), measured with instruments designed with neurodivergent respondents, and the frequency of regulatory interruptions, withdrawal, and re-engagement (D'Mello & Graesser, 2012). Behavioral indicators are indirect: shorter time-on-task, for instance, may reflect efficiency or a planned pause rather than low tolerability, so they require triangulation with learner report. Indicators of A concern the pathway: whether adjustments were available, appropriate, timely, learner-controlled, and target-preserving, and whether unnecessary intervention was avoided. Modality, pacing, sensory density, and timing of support are manipulable variables; engagement and recovery after disruption are engagement outcomes, measured separately from any T indicator; uptake of the same target is the learning outcome. None is yet validated; if indicators fail to converge, or if gains appear only when linguistic demand falls, the constructs will need revision. Finally, implementation may exceed what teachers can manage, especially in under-resourced settings; the framework is an analytic lens and design orientation that can be applied incrementally. A research agenda follows. Within-subject experiments can manipulate modality, pacing, density, and scaffold type while holding targets constant; design-based research can refine support in authentic classrooms; and longitudinal studies can test whether gains transfer across tasks and partners. Studies of LLM-mediated regulation should compare conditions with and without AI access while tracking monitoring behavior, and they should involve neurodivergent learners as participants and as partners in design (Pellicano & den Houting, 2022).

CONCLUSIONS

This article began with a theoretical problem. Influential SLA accounts presuppose that learners can access input and participate in interaction under stable conditions, and this presupposition leaves learners with variable sensory, cognitive, and emotional profiles under-

theorized. Neurodiversity exposes the problem because the same learner can be linguistically ready yet temporarily unable to use input or join interaction. AI makes the problem more pressing because tools now take part in producing and interpreting language, which unsettles established notions of input, output, scaffolding, and authorship.

NAIL-C responds with five interdependent components. NCD treats variability as the design baseline, and Adaptive Regulation treats learner state as instructionally relevant. TAI distinguishes linguistic comprehensibility from functional accessibility and expresses, as a heuristic, the claim that linguistic quality cannot compensate for inaccessible delivery. Learning as Dynamic Alignment reinterprets apparent failures of acquisition as possible misalignment, and M-ACC defines communicative competence so that multimodal and tool-mediated participation can count as evidence without abandoning construct precision.

The central claim is that regulated access is a boundary condition on acquisition. If it holds, it matters for how SLA explains learning, how assessment separates language ability from access, and how inclusive language education designs tasks. It also reframes AI, which appears not only as a content generator or an integrity threat but as a potential regulatory scaffold whose contribution depends on transparency, learner agency, calibrated trust, and human oversight, and whose risks are as real as its possibilities.

These claims are theoretical and require validation. The decisive tests are whether adaptations that preserve the linguistic target improve engagement and uptake, whether modality-neutral assessment can be reliable, whether AI mediation supports rather than bypasses learning, and whether the framework's functional logic holds across different neurodivergent profiles. NAIL-C is offered as a set of claims that such evidence can support, refine, or overturn, and as a way of keeping learners whose participation varies within the scope of SLA theory rather than at its margins.

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