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Harnessing Uncertainty: Improvisation as a Model for Rapid Behavioral Expansion

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Abstract

While traditional sciences treat uncertainty as an obstacle to be minimized, this paper proposes an epistemic shift: viewing uncertainty as a resource to leverage. To enact this shift, we suggest adopting improvisation—where novel behaviors are instantaneously assembled to meet unpredictable constraints—as a model for real-time adaptation and behavioral expansion. In this practice, uncertainty is not merely managed but deliberately injected to disrupt the determinism of habitual routines. By unveiling a wider space of potential paths, increasing uncertainty fosters behavioral exploration, discovery, and collective decision-making amidst dissent. This perspective resonates across scales: in neuroscience, neural uncertainty is increasingly recognized as a hallmark of cognition and volition; in artificial systems, cultivating the models' inherent indeterminism can disrupt their biased attraction toward users' expectations, boosting the open-endedness of human-model interactions and fostering cognitive emancipation. In an era of systemic unpredictability, exploring the functional utility of uncertainty through the lens of improvisation is a timely necessity for understanding natural, psychosocial, and artificial systems. We present a general overview of empirical support for this framework, the promises of this emerging perspective, and the future directions it calls for.

Keywords: Uncertainty; Improvisation; Creativity; Collective behavior; Coordination dynamics; Interaction dynamics

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Human societies facing political, economic, health, and environmental crises must adapt to constantly changing and unpredictable situations. Coping with such uncertainty is vital (Berger & Marinacci, 2020), necessitating a move beyond habitual behaviors toward novel patterns. Yet, how can individuals quickly expand their behavioral and cognitive repertoire in high-risk situations where goals and outcomes are unclear? How can groups do so collaboratively when dissensus and conflicts are present? To better grasp the mechanics behind such abilities, we propose an epistemic shift that views uncertainty as a resource to leverage rather than an obstacle to avoid, and suggest using improvisation as a model of real-time behavioral expansion for collective adaptation.

In fields like finance (Christensen, de la Rosa, & Feltham, 2010), environmental studies (Cripps & Durrant-Whyte, 2023), epidemiology (Atkins et al., 2020), and biology (Kim, 2023), optimal adaptation is often deemed to be the reduction of uncertainty through prior knowledge to predict changes. Behavioral science methods also rely on reducing the complexity of variables at play, setting clear goals, and discarding unexplained variance and transient phenomena (Arocha, 2021). However, uncertainty, being inherent to complex interactions, has pressured and shaped the evolution of behavior and cognition (Nastase, Goldstein, & Hasson, 2020). Ignoring the role of uncertainty, therefore, risks overlooking valuable information that is mistaken for irrelevant noise (Delignières & Torre, 2009). To better understand how we make sense of uncertainty and to sharpen tools that reveal its informational nature, we need tasks that harness it. Improvisation is a prime example, where uncertainty is not only managed and embraced but also actively sought and leveraged—worked *with* rather than *against* (Borgo, 2006; Gallagher, 2023).

Improvisation (in music, dance, theater…) is the open-ended, unscripted creation of a performance, at most guided by a minimal set of constraints. Performers impress by making countless decisions from many possible paths, seamlessly assembling context-appropriate patterns on the spot—as if in perfect control and drawing from prelearned sensorimotor pools (Beaty, 2015; Norgaard, 2025; Norgaard, Bales, & Hansen, 2023; Pressing, 1984; Pinho, de Manzano, Fransson, Eriksson, & Ullén, 2014]. Nonetheless, it is precisely the mastery of preestablished patterns and the spontaneity of their recruitment that poses a strong challenge to improvisers. They risk becoming trapped in the overexploitation of known resources, which masks the potential of novel paths and hinders their discovery (Hart et al., 2018; Laroche & Kaddouch, 2014; Miura, Fujii, Yamamoto, & Kudo, 2015). Instead, *im*-provisation, which means "without provision," requires performers to stretch their repertoire in order to maximize the open-endedness of their space of possible actions (Kirsh, Stevens, & Piepers, 2020). Consequently, the *lack* of uncertainty provoked by the spontaneous attraction toward stable routines can be an issue.

To keep things interesting, "alive," and meaningfully attuned to the *moment*, improvisers must avoid the repetition of *past* paths by escaping the determinism imposed by their prior knowledge. In other words, their ability to quickly coordinate appropriate yet mundane solutions must be *problematized* (Laroche, Bachrach, & Noy, 2024). A key technique to achieve this involves transiently *loosening* sensorimotor control to disrupt habitual responses (Høffding & Satne, 2021; Melbye, 2021; Mudd, Holland, & Mulholland, 2019; Ravn & Høffding 2022). This self-destabilization *deliberately increases* the uncertainty of the

behavioral trajectory. It makes habitual patterns more precarious, vulnerable to change, thereby fueling the jump over the obstacle posed by their compelling stability.

Injecting uncertainty generates a wider variance among possible action paths, fostering flexibility and open-endedness (Kimmel, Hristova, & Kussmaul, 2018; Orth, Van der Kamp, Memmert, & Savelsbergh, 2017). Therefore, it can unveil unnoticed behavioral degrees of freedom that, while previously occluded by the saliency of habits, can now be recruited to assemble novel patterns less bound by habitual routines and more uniquely attuned to the idiosyncrasies of the moment. Computational models of improvisation confirm that stochasticity and limited reliance on the past encourage transitions between patterns (Setzler & Goldstone, 2022). As such, expert creative performance may hinge less on optimizing control and more on modulating degrees of uncertainty (see Hills & Kenett, 2024).

This applies well to group improvisation, where the complexity of sharing control can lead partners to retreat into their comfort zones, and cause their interaction to become trapped in safe, stable patterns of interaction that lack originality. Because intentions often diverge among performers (Gratier, Evans, & Stevanovic, 2017; Pras, Schober, & Spiro, 2017), the interdependence of individual decisions makes coordination inherently challenging (Saint-Germier & Canonne, 2022). Yet, the uncertainty provoked by this dissensus serves as a signal for creative change (Curşeu, Schruijer, & Fodor, 2022). Importantly, in this context, the destabilization of coordination—typically viewed negatively in musical ensembles (Demos & Palmer, 2023)—can introduce the very uncertainty necessary to disengage performers from their most spontaneous interactional behaviors (Laroche & Kaddouch, 2015). By soliciting dynamic shifts toward reorganized degrees of freedom among performers, uncertainty becomes a resource that catalyzes the expansion of potential collective actions (Goupil et al., 2020, Wolf, Goupil, & Canonne, 2023). Ultimately, uncertainty is an opportune resource to co-opt; by instilling suboptimal detours through moments of instability, it problematizes the deterministic influence of pre-established paths and fosters flexible, open-ended creative decision-making that expands both individual and group repertoires.

The informational role of uncertainty is being acknowledged across an increasingly wide range of contexts. It facilitates the exploration (Anselme & Robinson, 2019; Dahan, Noy, Hart, Mayo, & Alon, 2016; Reitich-Stolero et al., 2025; van Lieshout, de Lange, & Cools, 2021; Walker, Luque, Le Pelley, & Beesley, 2019), the discovery (Stephen, Dixon, & Isenhower, 2009), and the learning of novel patterns (Daikoku & Yumoto, 2023; Dotov & Froese, 2018; Lamnina & Chase, 2021). Furthermore, neural uncertainty is progressively recognized as a hallmark of—rather than a hindrance to—cognitive, conscious, and volitional activity (Froese, 2023, 2026; Lynn, Cornblath, Papadopoulos, Bertolero, & Bassett, 2021; Sergent et al., 2021). It precedes sudden shifts in experience (Lutz, Lachaux, Martinerie, & Varela, 2002) and may explain phase transitions in decision-making (Sánchez-Cañizares, 2024). By recycling uncertainty into a pragmatic tool for change, expert improvisation provides an ideal framework to study how such transient processes exert a catalytic pressure that drives dynamic shifts across system scales, moving away from inert equilibria.

Improvisation also provides a valuable model of rapid response to unexpected prompts for the design of artificial interactive agents (AIAs). Current AIAs are primarily goal-oriented, prioritizing seamless interaction through preference models that tend to minimize dissensus

(Sharma et al., 2023). This overoptimization creates sycophantic attractors (Gao et al., 2023; OpenAI, 2024; Malmqvist, 2025; Naddaf, 2025), which bias the model toward agreeable responses that reinforce a user's pre-established beliefs at the expense of truthfulness and information gain (Chen et al., 2025; Ibrahim et al., 2025; Kim & Khashabi, 2025; Liu et al., 2025; Sharma et al., 2023).

On the contrary, the inherent indeterminism in AIA implementations—typically dismissed as unwanted glitches—actually broadens the open-endedness of model outputs (Karelin et al., 2025). Distancing AIAs from predictable patterns in this manner does more than merely make them sound more authentic; it diversifies the potential trajectories of interaction, thereby expanding the user's own meaning-making horizon. This is particularly vital in an era where over-reliance on AI threatens to contract the space of scientific exploration itself (Hao, Xu, Li, & Evans, 2026).

A process-oriented approach inspired by improvisation would *leverage* this inherent uncertainty to weaken sycophantic attractors. Indeed, less predictable AIA responses would inevitably provoke misalignment with user expectations. Rather than being a failure, this misalignment could help users emancipate themselves from their own preference-based attractors by fostering flexible, co-constructive meaning-making (James et al., 2025; Laroche & Kaddouch, 2015). Instead of resolving this tension, an AIA could punctually and strategically amplify such divergence—particularly when a user attempts to nudge the model toward erroneous beliefs. By forcing a problematization of the dialogue, stepping out of deterministic attractors offers a roadmap to richer, more diversified trajectories of meaning-making (Froese & Taguchi, 2019; Laroche et al., 2024).

In sum, uncertainty plays a pivotal role in shaping behavior across natural, psychosocial, and artificial systems. Improvisation offers a sophisticated expert model for studying how such uncertainty can be constructively harnessed; consequently, future research should aim to identify the precise timing and dosing of its "injection" required to optimally expand behavioral repertoires.

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