Balancing Acts: Rethinking Robot Autonomy and Efficiency through the Lens of Basic Psychological Needs Theory

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Abstract

As industrial robotics and in particular humanoid robots move from controlled environments into shared human spaces, a critical design tension has emerged. Both industrial development and technical academic domains often prioritise "robot autonomy" and "performance-based values," such as task efficiency and machine effectiveness. From a human-centred academic perspective, this focus creates a "Blind Spot": it optimizes the robot's ability to act independently but risks neglecting how these machines actually intertwine with human life and psychological health. This opinion paper argues that to deepen HRI research and practical application, we must pivot from engineering metrics to an organismic framework. By applying Self-Determination Theory (SDT) and the Basic Psychological Needs Theory (BPNT) via the METUX model, we can move beyond mere user satisfaction toward robots that are integrated into daily life to enhance human well-being. We propose three core design pillars—Robot Legibility, Humane Shared Control, and Social Integration—as necessary insights to ensure that future robots support, rather than thwart, the fundamental human needs for Autonomy, Competence, and Relatedness

CCS Concepts

• Human-centered computing → HCI theory, concepts and models; **User models**; **• Computer systems organization → Robotic autonomy**.

Keywords

human-robot interaction, collaboration, basic psychological needs, well-being, Self-determination theory

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1 Introduction

The landscape of robotics, particularly in the domain of industrial manipulators and emerging humanoid platforms, is currently dominated by a drive for robot autonomy and performance optimization.

In the industrial sector as well as in many technical fields of robotics research, the primary metrics for success are efficiency, speed, and effectiveness in relation to specific tasks. Research in this field is often driven by performance-based values, asking how the robot can complete a task as autonomously and quickly as possible. While this approach drives economic value, it creates a "Blind Spot" regarding the human collaborators. When robots are designed solely for self-autonomy, the human role is often relegated to that of a passive supervisor or a "human-in-the-loop" merely for error correction. A pertinent analogy can be found in the automotive industry with Lane Keeping Assistance (LKA) systems. While these systems technically increase safety and efficiency, they can induce a feeling of being "replaced" or losing agency over the driving process. In industrial settings, if a robot takes over a task completely to maximize efficiency, it may inadvertently signal to the worker that their skills are obsolete or that they have no choice in how the work is performed. This creates a psychological friction where the "autonomy" of the machine directly competes with the autonomy of the human. As noted in recent HRI research, this friction arises because we lack a theory-based framework that identifies specific well-being determinants in robot design across different spheres of experience [4].

2 Theoretical Framework: Self-Determination Theory and BPNT

To address this challenge, we must look beyond engineering metrics and adopt a psychological framework that explains human motivation and wellness. We propose Self-Determination Theory (SDT), specifically its sub-theory Basic Psychological Needs Theory (BPNT), as the foundational logic for humane HRI.

2.1 SDT as an Organismic Approach

SDT represents a comprehensive framework for the study of human motivation, personality development, and wellness [10]. Crucially, SDT is an "organismic" approach. It posits that humans are not passive entities waiting to be programmed or controlled; rather, they are active living organisms that inherently strive for growth, integration, and the mastery of their environment. In an industrial context, this distinction is vital. If practitioners assume an inner growth propensity in users, their design focus shifts to nurturing that resource. Conversely, in the absence of this assumption, attention defaults to "controlling, shaping, and training" people to act in specific ways to suit the machine.

2.2 Basic Psychological Needs Theory (BPNT)

Within SDT, BPNT identifies three innate psychological "nutrients" that are essential for integrity, adjustment, and growth. Just as a plant requires water and sunlight, humans require the satisfaction of Autonomy, Competence, and Relatedness to thrive.

- Autonomy (Volition, not Isolation): In the context of HRI, "Autonomy" is frequently misunderstood as independence or acting without help. However, in SDT, Autonomy refers to the experience of volition and integrity. It means that one's actions, thoughts, and feelings are self-endorsed and authentic. A human can be dependent on a robot for physical assistance (e.g., a robotic arm for a user with limited mobility) and still feel autonomous if they feel they are the author of the action. Implication for HRI: Technology must not impair the human sense of autonomy. Even as robots become more autonomous, their behavior must not override the human's sense of volition or create perceived pressure and conflict.
- Competence (Mastery and Efficacy): Competence concerns the basic need to feel effective in one's interactions with the environment. It involves participating in activities, utilizing one's skills, and experiencing mastery. Implication for HRI: Automation often threatens competence by "de-skilling" the worker. A robot designed for well-being should aim to strengthen the user's feeling of efficacy. It should make the user feel capable of achieving new goals, rather than making them feel like an unskilled observer of a perfect machine.
- Relatedness (Connection and Care): Relatedness is the need to feel connected to others, to care for and be cared for, and to belong to a community. Implication for HRI: Industrial robots often isolate workers. However, technology should act as a mediator that strengthens social connectedness. The integration of robots into the workspace must not lead to social alienation but should facilitate meaningful connections between humans.

It is critical to understand that these needs are distinct. For example, a worker might be forced to learn a new, high-tech robot interface. They might achieve high Competence (mastering the skills), but because they were forced to do so against their will, their Autonomy is thwarted. Conversely, a user might autonomously choose to use a robot, but if the interface is confusing and they fail to control it, their Competence is frustrated. For well-being to occur, HRI design must satisfy all three needs simultaneously.

2.3 Integrating Needs via the METUX Model

Applying these high-level psychological concepts to the practicalities of robot design requires a translation layer. The METUX model (Motivation, Engagement, and Thriving in User Experience), originally introduced by Peters et al. [9] and adapted for social robotics by [4], fills this gap by breaking down the user experience into specific Spheres of Experience. Crucially, this model posits that technology is not neutral; it can support or thwart needs at the level of the Interface (how users interact with the robot), the Task (what activity is performed), the Behavior (the overarching habit supported), and Life (cumulative well-being). This granular view is essential for HRI because a robot might support needs in one sphere while thwarting them in another. For example, an industrial robot might have a highly usable interface (supporting Competence in the Interface sphere) but force the worker into a rigid, prescriptive workflow that eliminates choice (thwarting Autonomy in the Task sphere). By adopting METUX, we can move beyond simply asking if a robot is "usable" and instead evaluate how specific HRI design choices—such as how feedback is visualized or how control is shared—impact the user's psychological needs across the entire workflow.

3 Bridging the Gap: What is Necessary for Humane HRI?

To move from an industry-centric view of "performance" to a human-centric view of "well-being," we apply the lens of BPNT to three specific HRI challenges: Robot Legibility, Shared Control, and Social Integration.

3.1 Robot Legibility: Supporting Competence

The first challenge is Robot Legibility. In industrial environments, "trust" is often discussed, but trust is predicated on understanding. If a human cannot decipher a robot's behavior, they cannot feel competent in the interaction (Interface Sphere). Current research often focuses on communicating "Motion Intent"—showing where the robot will move. However, our scoping review of the field reveals that intent is multifaceted [7]. To truly support the human need for Competence, robots must communicate not just motion, but also attention, state, and instruction.

For example, our work with Augmented Reality (AR) visualizations, such as the "Ghost Arm" or directional arrows, helps users anticipate robot trajectories [6, 8]. By explicitly visualizing the robot's "mind" (its state and future intent), we transform the human from a passive observer into an informed collaborator. This clarity reduces cognitive load and increases the feeling of mastery over the system. Furthermore, clear communication via tools like ARTHUR [5] allows users to create and edit these visualizations, further enhancing their sense of control (Autonomy) and understanding (Competence).

3.2 Humane Shared Control: Prioritizing Human Autonomy

The second challenge is Humane Shared Control. This stands in contrast to the binary view of "Manual vs. Autonomous" often found in industry. Our research with users with limited upper limb mobility indicates that users often do not want full autonomy; they want to stay in control to feel a sense of agency [3]. This is a direct application of supporting Autonomy in the Task Sphere. We advocate for paradigms like Adaptive DoF Mapping Control (ADMC). In this approach, AI analyzes the scene and suggests the most likely movements, effectively mapping a complex 7-DoF robot arm to a simple input device [2]. However, the way this assistance is offered matters. In our "DoF-Adaptiv" project, we compared "Continuous" assistance (where AI constantly visualizes suggestions) vs. "Threshold" assistance (where AI only intervenes when the user deviates significantly) [8]. While continuous assistance might be efficient, it risks creating an "auto-pilot" effect where the user feels passive. "Threshold" methods, or allowing users to explicitly accept/reject AI suggestions, preserve the feeling of agency. Thus, "Humane" shared control prioritizes the user's Autonomy—the feeling that they are the author of the action—even if it creates a slight trade-off in theoretical system efficiency.

3.3 Social Integration: Mediating Relatedness

The third challenge is Social Integration. Robots in industry are often treated as isolated tools or replacements. This poses a threat to Relatedness in the Behavior and Life spheres. If a robot is designed solely for efficiency, it might segregate workers to optimize individual throughput. A METUX-informed design views the robot as a social mediator [4]. For instance, in assistive contexts, a robot should not just perform a task for a human (isolating them), but enable them to participate in social practices (e.g., dining with others, working in a team). As outlined in Flemisch et al. [1], shared control is the "sharp end" of cooperation. To be truly effective, it must be supported by cooperation at higher levels—guidance and navigation. This means the robot must be designed to integrate into the human's social fabric, supporting their ability to connect with others rather than replacing those connections.

4 Conclusion

The divide in HRI is not just between industry and academia, but between efficiency-driven engineering and human-driven well-being. To truly "cross lenses", we must adopt theoretical frameworks that treat the human not as a task-supervisor, but as a growth-oriented organism. To deepen the work, we propose that the HRI community should:

- Adopt BPNT as a diagnostic tool: Evaluate if current "efficient" designs are thwarting human needs for Autonomy, Competence, or Relatedness.
- Utilize the METUX model: Analyse robot impact across all spheres—from the interface to overall life satisfaction—to avoid "addictive" or de-skilling over-engagement.
- Prioritise "Humane" metrics: Shift success criteria from "robot autonomy level" to "human agency level".
- Engage in Longitudinal Research: Because basic needs develop and change over time with skill acquisition, we need long-term studies to understand the true impact of humanoid robots on human thriving.

By focusing on Robot Legibility, Humane Shared Control, and Social Integration, we can ensure that the robots of the future are not just faster and more autonomous, but are truly humane partners that facilitate human flourishing.

Acknowledgments

dedicated to Phy, for the good old times.

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