

Toward Neurocognitive Intelligence for Assistive Humanoid Robots in Geriatric Care

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Abstract—The increasing demand for elderly care assistance, combined with global caregiver shortages and the growing complexity of aging-related healthcare needs, has accelerated interest in assistive humanoid robots capable of supporting older adults in clinical and home environments. Despite recent advances in robotics, deep learning, multimodal perception, and embodied artificial intelligence, most current humanoid systems remain fundamentally reactive, task-driven, and fragmented in their cognitive design. Existing architectures typically separate perception, memory, reasoning, and action into isolated computational modules, limiting their ability to maintain contextual continuity, adapt behavior over long interaction horizons, and operate reliably under dynamic real world conditions. These limitations become particularly critical in geriatric care settings where safety, contextual awareness, emotional sensitivity, and long-term human interaction are essential. This position paper argues that the next generation of assistive humanoid robots requires a transition toward neurocognitive intelligence frameworks inspired by principles of biological cognition. The paper proposes a conceptual neurocognitive architecture centered around closed-loop perception-action coupling, attention-regulated perception, episodic memory integration, predictive reasoning, adaptive decision-making, and cognitive safety regulation. The proposed framework emphasizes continuous interaction among cognitive processes rather than isolated reactive modules, enabling more context-aware, adaptive, and human-centered robotic behavior. Furthermore, the paper discusses why geriatric care environments uniquely require neurocognitive capabilities, identifies key limitations of current humanoid systems, and outlines major open challenges related to lifelong adaptation, contextual memory, uncertainty-aware reasoning, and safe human-robot interaction. Finally, future research directions are discussed toward developing trustworthy and resilient neurocognitive humanoid systems capable of functioning effectively in elder care environments.

Index Terms—Elderly care assistance, humanoid systems, biological cognition, human-robot-interaction

I. INTRODUCTION

THE rapid growth of aging populations across the world is creating significant pressure on healthcare systems, long-term care facilities, and family-based caregiving environments.

Older adults increasingly require continuous assistance for mobility, medication management, cognitive support, fall prevention, and daily living activities, while healthcare institutions simultaneously face shortages of trained caregivers and rising operational costs. These challenges have accelerated interest in assistive robotic technologies capable of supporting elderly individuals in clinical and home environments. Humanoid embodiment is particularly important in geriatric care because healthcare and home environments are inherently structured around human physical interaction patterns and daily living activities. Human-like morphology may enable more intuitive communication, safer physical assistance, object manipulation, mobility support, and environmental compatibility compared to non-humanoid robotic platforms. Such characteristics may improve the robot's ability to operate naturally within elder care settings while supporting more effective human-robot interaction.

Recent advances in robotics, artificial intelligence, computer vision, and multimodal sensing [1] [2] have improved the capabilities of humanoid systems in navigation, object manipulation, speech interaction, and environmental perception. Despite this progress, current humanoid robots remain fundamentally limited in their ability to operate as adaptive and cognitively aware assistive agents in real-world geriatric settings.

Most existing humanoid systems rely heavily on modular and reactive artificial intelligence pipelines that process sensory information independently from long-term reasoning, contextual memory, and adaptive behavioral understanding. Although these systems can perform predefined tasks under constrained conditions, they often struggle when operating in dynamic and unpredictable human-centered environments where contextual interpretation and cognitive continuity are essential. Elder care environments are characterized by evolving routines, emotional variability, safety-critical situations, and long-term human interaction patterns that cannot be addressed solely through task-specific perception and control modules.

A robot assisting an older adult must not only recognize objects and execute commands, but also understand contextual changes, maintain awareness of historical interactions, anticipate potential risks, and adapt behavior over extended periods of time. These requirements expose fundamental gaps in current robotic intelligence architectures.

Human cognition provides an important source of inspiration for addressing these limitations. Biological intelligence does not operate through isolated perception and action modules [3] [4] [5]. Instead, cognition emerges from tightly integrated processes involving attention, memory, reasoning, prediction, adaptation, and continuous perception-action feedback loops [6] [7] [8]. Humans selectively focus on relevant stimuli, retain contextual experiences over long temporal horizons, anticipate future events, and regulate actions based on uncertainty and environmental dynamics. These neurocognitive mechanisms enable robust and adaptive behavior even in highly complex environments. Translating such principles into assistive humanoid robotics may provide a pathway toward more resilient, interpretable, and context-aware intelligent systems capable of supporting elderly individuals safely and effectively.

This position paper argues that the next generation of assistive humanoid robots will require a transition from purely reactive artificial intelligence systems toward neurocognitive intelligence frameworks inspired by principles of human cognition. The novelty of this position paper does not lie in treating attention, episodic memory, predictive reasoning, lifelong learning, or safety regulation as isolated new mechanisms. Rather, this paper advances a sharper position: geriatric humanoid assistance should be treated as a temporally continuous and safety sensitive cognitive regulation problem rather than a sequence of isolated perception and control tasks. From this position, we make three specific arguments. First, long horizon geriatric care requires memory grounded robotic cognition, because routine deviations and emerging risks can only be interpreted relative to prior user specific interaction history. Second, attention and episodic memory should actively regulate reasoning and action selection, rather than serving only as auxiliary perception or storage modules. Third, cognitive safety should be modeled as a decision level regulatory process that constrains autonomy under uncertainty, instead of being limited to physical collision avoidance or predefined safety rules. Together, these arguments define the contribution of this paper as a geriatric care oriented neurocognitive framework that integrates established cognitive principles into an implementable closed loop model for adaptive, personalized, and trustworthy assistive humanoid behavior.

The paper further examines the limitations of existing humanoid systems, discusses why geriatric care presents unique cognitive and behavioral challenges, and proposes a neurocognitive framework for assistive humanoid robotics centered around closed-loop perception-action coupling, attention-regulated perception, episodic memory, adaptive reasoning, and cognitive safety mechanisms. Furthermore, the paper highlights key open research challenges and outlines future di-

rections for developing human-centered neurocognitive robotic systems capable of operating reliably in elder care environments.

II. LIMITATIONS OF CURRENT HUMANOID SYSTEMS

Recent humanoid robots have demonstrated remarkable progress in locomotion, manipulation, visual recognition, and conversational interaction. Advances in deep learning, reinforcement learning, multimodal perception, and large-scale foundation models [9] [10] [11] [12] [13] have enabled robots to perform increasingly sophisticated tasks under controlled environments. Humanoid systems are now capable of object grasping, gesture recognition, speech-driven interaction, and autonomous navigation within indoor spaces. While these developments represent important milestones in embodied artificial intelligence, the majority of current systems remain fundamentally task-driven and reactive in nature. Their intelligence is largely dependent on statistical pattern recognition [14] [5] rather than persistent contextual understanding or adaptive cognition.

One of the major limitations of existing humanoid systems is the fragmentation of perception, reasoning, memory, and action into isolated computational modules. In many robotic architectures, visual perception operates independently from behavioral planning, while memory mechanisms are often limited to short-term state estimation or predefined task histories. As a result, robots frequently fail to maintain long-term contextual continuity during extended interactions with humans. This limitation becomes especially problematic in geriatric care environments where daily routines, behavioral habits, and contextual deviations may evolve gradually over time. A robot may successfully recognize an individual or execute a command, yet remain incapable of understanding whether subtle changes in movement patterns, emotional responses, or environmental interactions indicate emerging safety or health concerns.

Another important limitation involves the lack of adaptive attentional regulation within current robotic systems. Contemporary AI architectures process large amounts of sensory information simultaneously, often without robust mechanisms for prioritizing cognitively relevant stimuli under dynamic conditions. Human cognition continuously filters environmental information according to context, uncertainty, behavioral importance, and task relevance. Existing humanoid robots, however, often rely on static perception pipelines that struggle under noisy, cluttered, or rapidly changing environments. In elderly care settings, where environmental uncertainty and behavioral variability are common, such limitations can significantly reduce reliability and safety. A humanoid assistant operating near vulnerable individuals must continuously identify and prioritize safety-critical signals such as instability in gait, confusion during communication, or unusual inactivity patterns.

Current humanoid systems also face challenges related to long-horizon adaptation and behavioral resilience. Many

TABLE I
COMPARISON BETWEEN CONVENTIONAL HUMANOID SYSTEMS AND NEUROCOGNITIVE HUMANOID INTELLIGENCE

Aspect	Conventional Humanoid Systems	Neurocognitive Humanoid Intelligence
Perception	Primarily reactive sensory processing	Context-aware and attention-regulated perception
Memory	Short-term task-dependent memory	Long-term episodic and contextual memory
Decision-Making	Rule-based or task-specific responses	Adaptive and predictive reasoning
Human Interaction	Limited contextual continuity	Personalized and continuous interaction
Adaptation	Limited long-horizon adaptation	Lifelong and experience-driven adaptation
Safety	Physical safety constraints only	Cognitive safety and uncertainty-aware regulation
Environmental Understanding	Static or predefined environment assumptions	Dynamic contextual interpretation
Learning	Task-specific optimization	Continuous neurocognitive learning
Robustness	Sensitive to uncertainty and distribution shifts	Cognitive resilience under dynamic conditions
Role in Geriatric Care	Task assistance	Human-centered assistive companionship

robotic models are optimized for short-term task completion rather than continuous learning across extended human interactions. Consequently, robots often fail to personalize assistance according to the preferences, routines, or cognitive states of individual users. In real-world elder care scenarios, effective assistance requires gradual adaptation to evolving behavioral patterns and environmental contexts rather than rigid execution of predefined tasks. Without mechanisms for episodic memory integration, predictive reasoning, and adaptive behavioral regulation, humanoid robots remain limited in their ability to function as trustworthy and context-aware assistive companions.

Safety and interpretability present additional concerns for the deployment of humanoid systems in human-centered environments. Deep learning-driven robotic policies may generate unpredictable behavior under distribution shifts, adversarial perturbations [15] [16], or unforeseen environmental conditions. In safety-critical settings involving older adults, even minor failures may lead to severe consequences such as falls, medication errors, or hazardous interactions. Existing robotic systems often lack internal cognitive monitoring mechanisms capable of regulating actions under uncertainty or preventing unsafe behavioral outputs. These limitations suggest that improvements in robotic hardware and perception alone are insufficient for achieving reliable assistive humanoid intelligence. Instead, fundamentally new cognitive architectures are required to support adaptive, safe, and human-centered robotic behavior.

The limitations discussed above highlight a fundamental gap between current reactive humanoid systems and the requirements of adaptive, human-centered assistive intelligence in geriatric care environments. To further clarify these differences, Table I summarizes the key distinctions between conventional humanoid robotic architectures and the proposed neurocognitive intelligence perspective.

These limitations should also be interpreted in relation to several established research directions. Cognitive architectures and neuroscience inspired AI have long studied how percep-

tion, memory, reasoning, and action can be organized within intelligent agents [3] [4] [5], while embodied cognition and embodied AI emphasize the coupling between perception and action in situated environments [8] [10] [13]. Lifelong robotic learning and continual learning address adaptation over time [17] [18], and memory augmented agents provide mechanisms for retaining and retrieving prior experience [19]. However, these directions are often studied as separate research problems or evaluated in general task domains rather than in safety sensitive elder care interaction. Existing humanoid systems may incorporate selected elements of attention, memory, learning, or safety, but they rarely define how these mechanisms should jointly regulate action selection during long horizon interaction with vulnerable users. The position advanced in this paper is therefore not that each mechanism is individually new, but that geriatric humanoid assistance requires their integration into a unified cognitive control loop where attention filters relevant stimuli, episodic memory provides user specific context, reasoning predicts risk, and cognitive safety constrains decisions under uncertainty.

III. WHY GERIATRIC CARE REQUIRES NEUROCOGNITIVE INTELLIGENCE

Geriatric care environments present a uniquely complex set of cognitive, behavioral, and safety-related challenges that differ substantially from traditional robotic application domains. Unlike industrial or highly structured environments, elder care settings are dynamic, emotionally sensitive, and deeply dependent on long-term contextual interaction. Older adults may experience gradual cognitive decline [20], reduced mobility, sensory impairments, memory disorders, emotional variability, or fluctuating health conditions that evolve over time. Effective robotic assistance within these environments therefore requires far more than object recognition or predefined task execution. It requires systems capable of contextual understanding, behavioral adaptation, and continuous cognitive awareness.

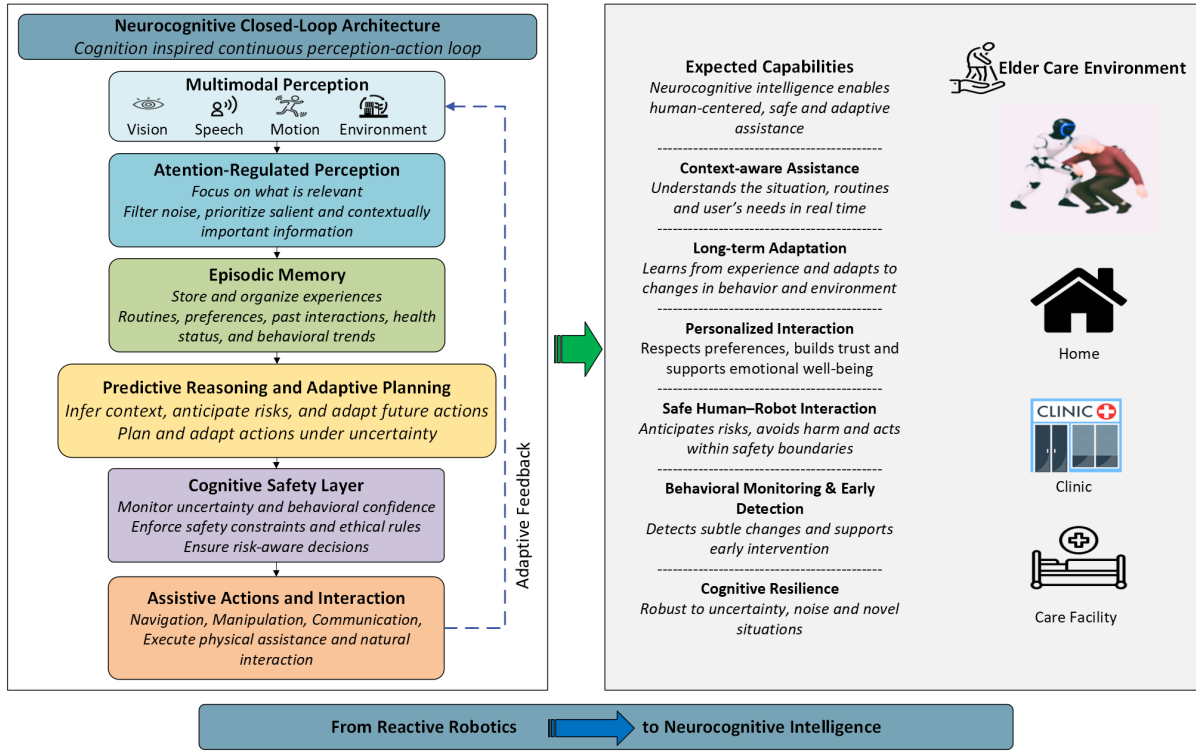


Fig. 1. Conceptual neurocognitive closed-loop framework for assistive humanoid robotics in geriatric care. The proposed architecture integrates multimodal perception, attention-regulated perception, episodic memory, predictive reasoning, adaptive planning, cognitive safety regulation, and adaptive feedback mechanisms to support safe, context-aware, and human-centered robotic assistance.

Human caregiving inherently relies on neurocognitive processes that extend beyond reactive perception [21] [3]. Caregivers continuously monitor behavioral patterns, remember prior interactions, interpret subtle changes in emotional or physical states, and anticipate future needs before explicit requests are made. A caregiver may recognize that a patient appears more disoriented than usual, notice changes in walking stability, or detect unusual inactivity patterns that suggest emerging medical concerns. These observations are rarely based on isolated sensory events. Instead, they emerge from accumulated contextual memory, temporal reasoning, and adaptive interpretation of ongoing interactions. Current humanoid robots lack many of these capabilities because they primarily operate through instantaneous sensory-response mechanisms rather than integrated cognitive frameworks.

The importance of neurocognitive intelligence becomes even more evident when considering the long-term nature of geriatric assistance. Elder care often involves repetitive interactions occurring over weeks, months, or years. During this time, individuals may develop unique behavioral routines, communication preferences, medication schedules, mobility patterns, and emotional responses. A truly assistive humanoid robot must therefore maintain persistent contextual understanding rather than treating each interaction independently. Episodic memory mechanisms become essential for enabling personalized assistance, behavioral continuity, and adaptive

decision-making across extended temporal horizons [22] [6].

Safety considerations further reinforce the need for neurocognitive intelligence in assistive humanoid robotics. Elderly individuals are particularly vulnerable to environmental hazards, cognitive confusion, and mobility-related accidents. A robot operating in such settings must continuously evaluate uncertainty, predict potential risks, and regulate actions according to safety constraints. This requires more than obstacle avoidance or collision detection. The robot must understand contextually meaningful risk patterns such as increasing instability during walking, repeated forgetfulness regarding medication, or abnormal behavioral deviations from established routines. These capabilities depend on integrated cognitive reasoning processes that combine perception, memory, prediction, and adaptive decision-making within a unified framework.

Emotional and social interaction also play a significant role in geriatric care. Older adults often experience loneliness, anxiety, or reduced social engagement, particularly within long-term care environments. Assistive humanoid systems that lack contextual sensitivity may produce interactions that feel repetitive, mechanical, or emotionally disconnected. Neurocognitive approaches offer the potential to improve human-centered interaction by enabling robots to adapt communication styles, maintain interaction continuity, and respond more appropriately to contextual emotional states. While humanoid robots are unlikely to replace human caregivers,

neurocognitive intelligence may allow them to function as more supportive, adaptive, and trustworthy assistive systems within aging societies.

IV. PROPOSED NEUROCOGNITIVE FRAMEWORK

The proposed neurocognitive framework, as shown in Fig. 1, is based on the premise that assistive humanoid robots should operate through tightly integrated cognitive loops rather than isolated perception and control modules [3] [4] [19]. Instead of treating perception, memory, reasoning, and action as independent computational stages, the framework emphasizes continuous interaction among these processes within a closed-loop architecture inspired by principles of human cognition. Such an approach aims to support adaptive, context-aware, and safety-conscious behavior during long-term interaction with elderly individuals in real world environments.

From an implementation perspective, each neurocognitive principle can be conceptually mapped to a corresponding robotic mechanism. Attention can be implemented as risk weighted multimodal perception that prioritizes safety relevant signals such as gait instability, confusion, emotional distress, or abnormal inactivity. Episodic memory can be represented as a user specific history of routines, interaction patterns, mobility trends, medication behavior, and prior caregiver interventions. Predictive reasoning can be implemented through next state estimation, anomaly forecasting, and risk prediction based on both current observations and retrieved memory. Adaptive decision making can be modeled as context aware policy selection that chooses between reminder, assistance, monitoring, confirmation, or escalation actions. Cognitive safety regulation can be implemented through uncertainty thresholds, risk constraints, caregiver confirmation, action suppression, or safe stop behavior. Lifelong learning can support gradual personalization by updating user specific models while maintaining stability and avoiding unsafe behavioral drift.

At the core of the framework is a perception-action feedback mechanism that continuously updates internal representations according to environmental observations, behavioral history, and contextual uncertainty. Sensory inputs originating from vision, speech, motion, tactile interaction, and environmental sensors are dynamically processed through attention-regulated perception modules [7] [23] that prioritize cognitively relevant information. Rather than processing all stimuli uniformly, the system selectively focuses on signals associated with safety risks, behavioral deviations, emotional changes, or contextual anomalies. This adaptive attentional regulation enables more efficient and robust interaction under noisy and dynamic conditions commonly encountered in geriatric care environments.

The framework also incorporates episodic memory mechanisms designed to preserve contextual information across long temporal horizons. Unlike conventional robotic memory systems that primarily store short-term task states, episodic memory allows the robot to maintain historical representations of routines, interactions, environmental conditions, and behavioral trends associated with specific individuals [22] [24]. Such memory structures enable personalized assistance and support

predictive reasoning regarding future needs or emerging risks. For example, gradual changes in mobility patterns or repeated deviations from daily routines may be interpreted as indicators of deteriorating health conditions or cognitive decline.

Reasoning and adaptive decision-making modules form another central component of the proposed architecture. These modules continuously integrate current sensory observations with historical memory representations and contextual constraints to generate behaviorally appropriate actions. Importantly, the framework emphasizes cognitive safety regulation through internal monitoring mechanisms capable of constraining robotic behavior under uncertainty. Instead of relying solely on external safety rules, the system maintains continuous awareness of confidence levels, environmental ambiguity, and potential risk conditions before executing actions. This neurocognitive safety layer may reduce unsafe behavior arising from perception failures, environmental uncertainty, or unpredictable human interaction dynamics.

To illustrate the full cognitive loop, consider a long horizon care scenario in which a humanoid robot assists an older adult during daily movement and medication routines. The robot first receives multimodal observations from vision, speech, motion, and environmental sensors. Under interference from background noise or multiple simultaneous stimuli, the attention regulated perception module prioritizes safety relevant signals, such as slower walking speed, repeated hesitation, or confusion during communication. The episodic memory module then compares these observations with the user's historical routines, prior mobility patterns, and medication behavior. If the current pattern deviates from the user's normal behavior, the predictive reasoning module estimates whether the situation may indicate increased fall risk, medication confusion, or abnormal inactivity. Before acting, the cognitive safety layer evaluates uncertainty and potential harm. The robot may then choose an appropriate decision, such as issuing a gentle reminder, slowing its physical assistance, requesting confirmation, or escalating the situation to a caregiver. This scenario shows how perception, attention, episodic memory, reasoning, safety regulation, and decision making can operate as an integrated loop rather than as isolated modules.

The proposed framework is not intended as a finalized implementation architecture, but rather as a conceptual direction for future humanoid intelligence systems. Its primary contribution lies in advocating a transition from reactive robotics toward integrated neurocognitive intelligence capable of supporting adaptive and human-centered assistive behavior. By combining perception, attention, memory, reasoning, prediction, and safety regulation within continuous feedback loops, the framework seeks to establish a foundation for more resilient and context-aware humanoid robotics in geriatric care environments.

V. CORE COMPONENTS

A. Attention-Regulated Perception

Attention-regulated perception [23] [25] enables the humanoid robot to selectively prioritize relevant environmental

and behavioral information according to contextual demands. Human cognition continuously filters sensory input to focus on important stimuli while suppressing irrelevant information. Replicating such mechanisms within assistive humanoid systems may improve robustness under cluttered and dynamic environments. In geriatric care settings, attention mechanisms could prioritize instability in movement, signs of confusion, emotional distress, or unusual inactivity patterns while reducing sensitivity to irrelevant environmental noise.

Adaptive attentional regulation also contributes to computational efficiency and behavioral stability. Instead of processing all sensory streams uniformly, the robot dynamically allocates resources toward cognitively meaningful observations. This capability becomes particularly important in long-duration interactions where continuous multimodal monitoring may otherwise generate excessive computational overhead and unstable decision-making behavior.

B. Episodic Memory and Contextual Continuity

Episodic memory [22] [6] [24] provides the foundation for long-term contextual understanding and personalized interaction. Human caregivers naturally accumulate memories regarding behavioral habits, routines, emotional tendencies, and environmental preferences associated with individuals under their care. Assistive humanoid systems require similar capabilities to maintain continuity across extended interactions.

The integration of episodic memory may allow robots to identify deviations from established behavioral patterns and adapt assistance accordingly. Such memory-driven adaptation supports more context-aware interaction and improves the system's ability to recognize gradual changes that may indicate cognitive or physical decline. Episodic memory also contributes to more natural communication by enabling the robot to maintain awareness of prior interactions and user preferences over time.

C. Predictive Reasoning and Adaptive Decision-Making

Predictive reasoning [8] [3] enables humanoid systems to anticipate future events rather than responding solely to immediate stimuli. Human cognition frequently operates through predictive inference mechanisms that estimate likely outcomes based on contextual observations and prior experiences. In geriatric care environments, predictive reasoning may support early identification of safety risks, behavioral anomalies, or emerging health concerns.

Adaptive decision-making mechanisms allow the robot to modify behavior according to changing environmental and human conditions. Such adaptability is essential because elderly individuals may exhibit substantial variability in cognitive state, emotional response, and physical capability over time. Static robotic policies are unlikely to provide reliable long-term assistance within such dynamic environments.

D. Cognitive Safety Regulation

Cognitive safety regulation [16] [26] represents a critical requirement for assistive humanoid systems operating near

vulnerable populations. Traditional robotic safety approaches primarily focus on physical constraints such as collision avoidance, force limitation, and motion control. However, in geriatric care environments, unsafe behavior may also arise from incorrect contextual interpretation, uncertainty in perception, inappropriate assistance, or overconfident decision making. In this paper, cognitive safety regulation is defined as an internal monitoring and control process that evaluates candidate robotic actions before execution based on estimated risk, model uncertainty, contextual appropriateness, and the user's current physical, cognitive, and emotional state. A candidate action should be executed only when the predicted risk is below an acceptable threshold, the uncertainty level is sufficiently low, and the action is consistent with the current care context.

This mechanism can be operationalized through several safety control responses. When risk or uncertainty exceeds an acceptable level, the robot may modify the planned action, reduce behavioral complexity, request caregiver confirmation, delay execution, or enter a safe stop state. For example, if the robot detects possible walking instability but has low confidence in its perception, it should avoid initiating physical assistance without additional confirmation. The effectiveness of cognitive safety regulation can be evaluated using metrics such as unsafe action rate, missed risk detection, false alarm rate, uncertainty calibration, time to intervention, caregiver override frequency, and human escalation accuracy. In this way, cognitive safety regulation acts as an internal cognitive guardrail that supports safer and more trustworthy robotic behavior in long horizon geriatric care scenarios.

VI. OPEN CHALLENGES

Despite the promise of neurocognitive intelligence for assistive humanoid robotics, numerous scientific and engineering challenges remain unresolved. One of the most significant challenges involves translating abstract neurocognitive principles into computationally tractable robotic architectures capable of operating in real time. Human cognition emerges from highly complex neural dynamics that are not yet fully understood, making direct replication infeasible [4]. Consequently, future research must identify biologically inspired abstractions that preserve essential cognitive functionality while remaining computationally efficient and practically deployable.

Another major challenge concerns the integration of long-term memory mechanisms within continuous robotic control systems. Episodic memory may improve contextual understanding and personalization, but maintaining and updating such memory structures over extended periods introduces difficulties related to scalability, stability, forgetting, and contextual retrieval. Poorly designed memory systems may generate behavioral inconsistencies or outdated contextual interpretations that negatively affect interaction quality and safety.

Robustness and generalization also remain critical obstacles. Real-world geriatric environments are highly variable and often contain noisy sensory conditions, unpredictable behavioral dynamics, and changing environmental layouts.

Neurocognitive humanoid systems must therefore operate reliably under substantial uncertainty and distribution shifts [15]. Existing deep learning models frequently exhibit brittle behavior outside their training distributions, raising important concerns regarding safety and trustworthiness in healthcare-related environments.

Ethical and societal considerations further complicate the deployment of assistive humanoid systems. Questions surrounding privacy, emotional dependence, autonomy, accountability, and human dignity require careful consideration during system design and deployment. Elder care environments involve sensitive human interactions where excessive automation or inappropriate behavioral responses may produce psychological or ethical concerns. Future neurocognitive robotic systems must therefore prioritize transparency, human oversight, and human-centered interaction principles alongside technical performance.

VII. FUTURE DIRECTIONS

Future research in neurocognitive humanoid intelligence will likely require increasingly interdisciplinary collaboration across robotics, neuroscience, artificial intelligence, cognitive science, psychology, and healthcare. Progress in this area depends not only on advances in machine learning algorithms, but also on deeper understanding of how biological cognition regulates perception, memory, adaptation, and decision-making under uncertainty. Neurophysiological insights related to attention dynamics, predictive processing, and memory organization may provide valuable guidance for designing more adaptive robotic intelligence architectures.

One promising direction involves the development of life-long learning mechanisms [17] capable of supporting continuous adaptation without catastrophic forgetting [18]. Assistive humanoid robots operating in elder care settings must gradually personalize behavior according to long-term interaction history while maintaining behavioral stability and safety. Achieving this capability will require advances in memory consolidation, online adaptation, and context-aware learning systems capable of balancing plasticity and stability over time.

Another important direction concerns multimodal neurocognitive reasoning across vision, speech, environmental sensing, and physiological monitoring [27]. Elder care environments often require interpretation of subtle contextual signals that cannot be captured through isolated sensory modalities. Future humanoid systems may benefit from integrated multimodal cognitive models capable of reasoning across behavioral, environmental, and physiological information simultaneously. Such capabilities may improve contextual awareness, predictive reasoning, and adaptive interaction quality.

The incorporation of cognitive safety and self-monitoring mechanisms will also become increasingly important as humanoid systems gain greater autonomy. Future research should investigate architectures capable of evaluating uncertainty, detecting abnormal internal states, and constraining unsafe behavior before harmful actions occur. These mechanisms may

ultimately function as cognitive guardrails that regulate robotic decision-making under complex and uncertain conditions.

Another important future direction is the development of simulation based evaluation and geriatric care oriented benchmarks for neurocognitive humanoid intelligence. Existing embodied AI and robotic simulation environments may support early validation of perception, navigation, manipulation, and interaction capabilities under controlled indoor scenarios. However, current simulation settings may not fully capture the long horizon, personalized, and safety sensitive nature of elder care. New benchmarks are therefore needed to evaluate the complete cognitive loop, including attention regulated perception, episodic memory, cognitive state tracking, routine deviation detection, uncertainty aware decision making, caregiver escalation, and safety critical interaction over extended periods. Representative benchmark tasks may include fall risk recognition, medication reminder adaptation, detection of unusual inactivity, response to user confusion, personalized routine assistance, and safe handoff to human caregivers. To assess the contribution of the proposed hybrid framework, future studies should compare the full neurocognitive architecture with ablated baselines that remove episodic memory, attention regulation, predictive reasoning, or the cognitive safety layer. Possible evaluation metrics include risk detection accuracy, reaction time, unsafe or uncertain decision rate, false alarm rate, memory retrieval accuracy, routine deviation detection, adaptation quality, caregiver escalation accuracy, and continuity of interaction. Such benchmarks would provide a more concrete basis for evaluating whether neurocognitive humanoid systems can behave safely, adaptively, and contextually in geriatric care environments.

These benchmark directions can be further organized around several testable research hypotheses. H1: a humanoid robot with episodic memory will detect user specific routine deviations more accurately than a robot relying only on short term state history. H2: attention regulated perception will improve risk detection and reduce reaction time under noisy or multi stimulus conditions compared with uniform sensory processing. H3: predictive reasoning based on both current observations and retrieved memory will improve early recognition of fall risk, medication confusion, or abnormal inactivity. H4: a cognitive safety layer will reduce unsafe or uncertain decisions compared with a baseline policy that directly executes planned actions without uncertainty based regulation. These hypotheses make the proposed framework empirically testable while preserving the paper's role as a position paper.

Long-term validation within realistic assistive environments represents another critical future direction. While position papers and conceptual frameworks establish important foundations, future work must eventually evaluate neurocognitive humanoid systems under extended real-world interaction scenarios involving elderly individuals, caregivers, and healthcare environments. Such studies will be necessary for understanding the practical effectiveness, safety, and societal implications of neurocognitive assistive robotics.

VIII. CONCLUSION

This paper has argued that current humanoid robotic systems remain fundamentally limited in their ability to function as adaptive and context-aware assistive agents within geriatric care environments. Although recent advances in artificial intelligence and robotics have improved perception, interaction, and mobility capabilities, most existing systems continue to rely on reactive and fragmented architectures that lack persistent contextual understanding, long-term adaptation, and integrated cognitive reasoning. These limitations become particularly significant in elder care settings where safety, behavioral continuity, emotional sensitivity, and long-term contextual interaction are essential.

To address these challenges, the paper proposed a neurocognitive intelligence framework for assistive humanoid robotics inspired by principles of human cognition. The framework emphasizes closed-loop perception-action coupling, attention-regulated perception, episodic memory integration, predictive reasoning, adaptive decision-making, and cognitive safety regulation. Rather than viewing humanoid robots as isolated task-execution systems, the proposed perspective advocates the development of cognitively integrated and human-centered robotic agents capable of operating robustly within dynamic healthcare environments. The transition toward neurocognitive humanoid intelligence represents both a scientific challenge and a societal opportunity. Developing such systems will require substantial advances in artificial intelligence, robotics, neuroscience, and human-centered system design. Nevertheless, neurocognitive approaches may ultimately provide a pathway toward more trustworthy, adaptive, and context-aware assistive technologies capable of supporting aging populations while complementing human caregivers in future healthcare ecosystems.

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