Human-Robot Companionship in the Forest: Understanding the Effects of Engagement and Authority

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Abstract

Companion robots are increasingly envisioned as social partners beyond indoor settings, yet little is known about how companionship unfolds in outdoor environments. This study investigates how robot engagement (active vs. passive) and authority (leader vs. follower) shape human–robot companionship during forest-based walking experiences. We conducted a mixed-design field experiment in which participants walked with a mobile robot under different engagement and authority conditions. Companionship was assessed through connection and coordination rapport, with human–robot trust and robot social presence examined as mediating mechanisms. Results show that robot engagement and authority did not directly enhance companionship. Instead, trust and social presence emerged as strong predictors of companionship, with robot authority positively influencing trust. These findings suggest that companionship in outdoor contexts arises primarily through relational perceptions rather than overt behavioral cues, highlighting the importance of designing outdoor companion robots that emphasize reliability and social presence over expressive interaction.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**.

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1 Introduction

Companion robots are characterized by their ability to shape human experiences through social presence, emotional engagement, and relational interaction, rather than focusing solely on task efficiency [1]. Enabled by increasingly sophisticated social capabilities, such robots are becoming part of everyday life across domestic contexts, as well as leisure and well-being applications [12, 26]. To date, however, most empirical research on robot companionship has focused on indoor or highly controlled environments, where interaction unfolds with limited environmental complexity and fewer competing stimuli.

As companion robots move beyond controlled settings, their deployment in outdoor contexts has begun to attract attention, including studies of robots as jogging companions [15], walking companions [4], and provocateurs of forest-human interactions [2]. In parallel, robots have been extensively employed in forest environments for operational purposes such as data collection, monitoring, and forest management [10, 14, 23]. While these functional applications demonstrate strong technical promise, far less is known about the experiential and companionship potential of human–robot interaction (HRI) in forest settings.

Forest environments introduce fundamentally different interaction dynamics, as human attention is distributed across a rich and multisensory landscape [8]. By presenting abundant perceptual stimuli, these environments potentially create competition for attentional and experiential resources [29]. Introducing a robot into this setting adds another social stimulus, whose influence may depend on how its agency, presence, and behavioral cues integrate into the shared activity. Prior work suggests that factors such as robot engagement, agency, role adoption, and social responsiveness are critical in shaping whether robots are experienced as companions rather than tools [1, 5]. Here, companionship can be understood as a relational experience emerging through co-presence, shared movement, and mutual responsiveness rather than explicit social exchange. Accordingly, a robot's authority role or engagement style may critically shape how it is perceived as a companion. These findings align with perspectives inspired by the biophilia hypothesis [13, 20], which posits that humans tend to form affective connections with entities perceived as animate, responsive, or intentional. However, it remains unclear how such mechanisms operate when interaction unfolds in dynamic, uncontrolled environments rather than structured indoor settings, especially because of the presence of numerous dynamic interactive elements.

Against this backdrop, understanding robot companionship in forests is essential for extending human–robot companionship research beyond controlled indoor environments and toward a variety of other environments. In this study, we empirically investigate how robot engagement (active vs. passive) and robot authority (leader vs. follower) shape human–robot companionship during forest walking experiences. By situating a mobile robot as a companion in a natural walking context, this work contributes empirical insight into how robot roles and behaviors influence relational experiences in outdoor human–robot interaction.

2 Background and Hypothesis

Companionship in HRI is shaped by how robots are perceived as social and intentional partners rather than mere artifacts, pointing towards a relationship between humans and non-humans, such as human-animal relationships [6]. Two of the most important constructs that are central to the emergence of companionship between humans and non-humans are trust and perceived agency. In human–animal interaction, trust in a companion's competence, predictability, and responsiveness supports feelings of safety and relational closeness [19]. Similarly, trust in robots develops when they behave reliably, act coherently, and align with users' expectations, thereby enabling perceptions of partnership and companionship [1, 17].

Perceived agency further contributes to companionship by framing the companion as an intentional actor [24]. Companion animals are often attributed intentions, emotions, and motivations, which strengthens anthropomorphism and emotional bonding [11]. Comparable mechanisms have been observed in HRI, where robots that initiate actions, respond contingently, or act autonomously are more likely to be perceived as agentic, enhancing companionship experiences [3, 28]. In walking contexts, such perceptions may emerge not through explicit dialogue but through movement coordination, initiative, and shared activity.

Accordingly, actively engaging robots that initiate actions and respond to the environment may heighten perceived agency and trust by signaling intentionality and competence. Accordingly, we hypothesize:

H1: An actively engaging robot will elicit higher levels of companionship than a passive robot.

H1a: An actively engaging robot will evoke higher perceived agency than a passive robot.

H1b: An actively engaging robot will evoke higher perceived trust than a passive robot.

Similarly, a robot that adopts a leader role by guiding movement and setting the pace of the walk may be perceived as more purposeful and dependable, thereby strengthening companionship and trust. We therefore hypothesize:

H2: A leader robot will elicit higher levels of companionship than a follower robot.

H2a: A leader robot will evoke higher perceived trust than a follower robot.

3 The Empirical Study

3.1 Study Design and Procedure

We employed a mixed experimental design examining the effects of robot authority and engagement during forest walks. Robot authority (leader vs. follower) was manipulated between participants, while robot engagement (active vs. passive) was manipulated within participants. Participants were assigned to either a leader condition, in which the robot guided the walk, or a follower condition, in which the robot adapted to the participant's movements. Each participant completed two walks: one active and one passive, while the authority role remained constant; engagement order was counterbalanced. In the leader condition, the robot initiated movement, regulated pace, and guided the route, whereas in the follower condition it adjusted its trajectory and speed to the participant. Engagement conditions varied in environmental interaction: the passive robot traversed the route without stopping, while the active robot paused at six predefined locations, each representing a distinct forest element. Leader conditions were implemented using a Wizard-of-Oz approach by the first author, whereas follower conditions employed a detect-and-follow program. Across all conditions, the robot executed an identical predefined set of movements and behaviors to ensure consistency. All behaviors and interactions were pre-scripted, no adaptive framework was implemented on the robot, and the robot was not tested or calibrated to perform in the selected experiment site beforehand. Fig. 1 demonstrates different interaction modes consisting examples of leader, follower, and active modes.

The walking route was designed to ensure a consistent forest experience. As shown in Fig. 2, the walk began and ended at the same location, forming a semi-loop through the six stopping points. Walking direction, turns, and detours were indicated by yellow markers placed along the path, which participants followed throughout the walk.

Upon arrival, participants were briefed on the study and provided informed consent. All participants wore a custom waist-mounted

Figure 1: Different walking and interaction conditions: from the left, a) robot as follower, b) robot as leader, c) active robot in follower condition, and d) active robot in leader condition.

wearable with fiducial markers to enable robot following in follower conditions; the wearable was used across all conditions to ensure consistency. Participants were introduced to the robot companion and informed whether it would lead or follow during the walk. They received route and safety instructions and were informed that they would complete two walking sessions, with the condition details and order undisclosed. Each session lasted approximately 8–15 minutes, depending on the condition. After each walk, participants completed questionnaires, and upon completing both sessions, they were debriefed and compensated with a gift valued at up to 7 euros.

3.2 Participants

A total of 40 participants took part in the study, but 38 of them completed it, with two dropping out (21 female, 15 male, 1 non-binary, 1 undisclosed). Calls for participants were distributed online through university intranet, social media, research group website, and flyers. The participant sample (N=38) ages ranged from 18 to above 40, with three participants aged 18–20, 14 aged 21–25, nine aged 26–30, eight aged 31–40, and four above 40. Most participants reported frequent forest engagement, with 25 visiting forests one to two times per week, 10 visiting three to four times per week, and three visiting five times or more. The study used the Spot robot from Boston Dynamics [9], a mobile robot deployed as a companion capable of autonomous navigation in outdoor environments. Spot is a quadrupedal robot that resembles a canine in form and is equipped with state-of-the-art sensors and cameras. These features enable it to navigate dynamically and adapt to a wide range of terrains, including climbing stairs and traversing uneven or challenging environments. This versatility makes Spot particularly well-suited for accompanying humans in diverse outdoor walking scenarios.

3.3 Measurements and Questionnaires

Companionship was measured with the connection-coordination rapport scale [21], as there are no validated questionnaires to measure HRC yet. To explore potential mechanisms underlying human–nature connectedness, we additionally measured perceived agency using the Robot social presence scale [7] and trust using the HR trust perception scale [25]. All measurements used a 5-point Likert scale.

3.4 Reliability and Validity

Measurement reliability and validity were assessed following established PLS-SEM guidelines [16, 18]. Internal consistency reliability was evaluated using Cronbach's alpha and composite reliability (ρ_c). All constructs exceeded the recommended 0.70 threshold. Convergent validity was supported, as all constructs achieved AVE values above 0.50. Discriminant validity was evaluated using the heterotrait–monotrait ratio of correlations (HTMT). All HTMT values were well below the conservative threshold of 0.85, indicating strong discriminant validity across all construct pairs. Full statistics are reported in the supplementary materials.

3.5 Results

Figure 3 shows the structural model. Tables 3 and 4 present the results for total effects and specific indirect effects, respectively. Robot engagement did not exert significant total or indirect effects on companionship outcomes, providing no support for H1 or H1a. Robot authority positively predicted human–robot trust ($\beta = 0.50$, $p = .029$), offering partial support for H2a, but did not directly influence connection or coordination rapport (H2 not supported). None of the proposed mediation paths reached significance, as all bootstrapped confidence intervals included zero. In contrast, experiential relationship constructs were strong predictors of companionship: human–robot trust significantly predicted connection rapport ($\beta = 0.23$, $p = .032$) and coordination rapport ($\beta = 0.55$, $p < .001$), while robot social presence robustly predicted both connection ($\beta = 0.53$, $p < .001$) and coordination rapport ($\beta = 0.30$, $p < .001$). Overall, companionship in forest walking emerged from relational perceptions rather than from robot engagement or authority manipulations.

Descriptive statistics in Figure 4 shows that connection–coordination rapport tended to be higher in the active conditions, with Active Follower (C) and Active Leader (D) showing higher central tendencies compared to passive conditions. Perceived robot social presence was generally higher in Active Leader (D) and Active Follower (C)

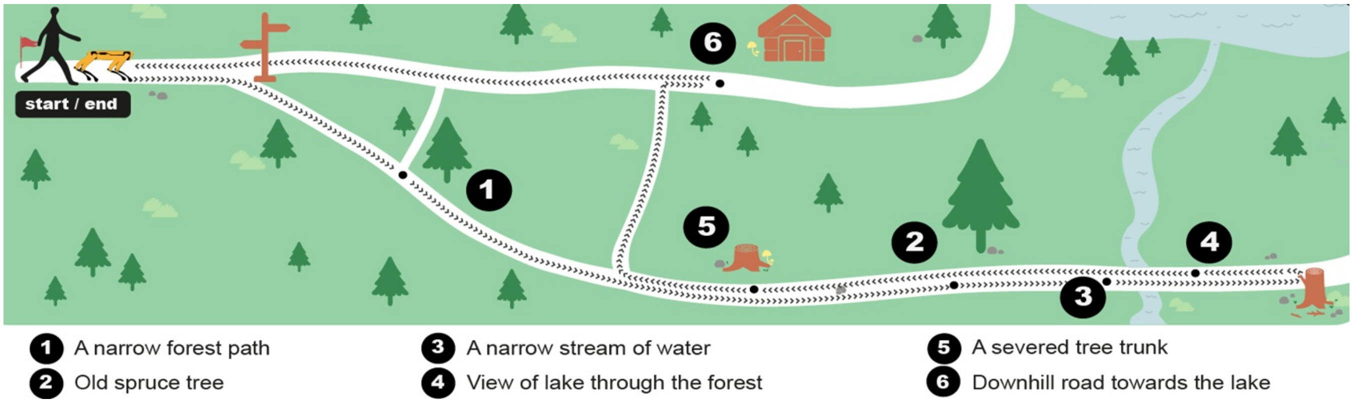

Figure 2: Walking Route including stopping points.

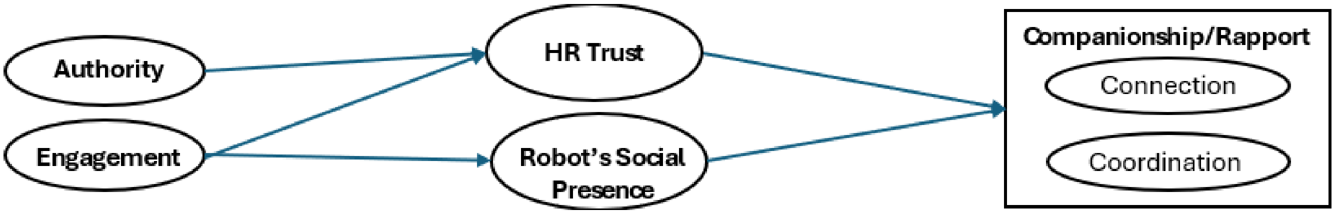

Figure 3: Structural Model.

Table 1: Total Effects for the Human–Robot Companionship Model

Path	*β*	*p*	95% CI
Authority ⟶ Connection Rapport	0.117	0.134	[-0.004, 0.292]
Authority ⟶ Coordination Rapport	0.275	0.052	[-0.004, 0.542]
Authority ⟶ Human–Robot Trust	0.498	0.029	[-0.014, 0.878]
Engagement ⟶ Connection Rapport	0.208	0.196	[-0.142, 0.504]
Engagement ⟶ Coordination Rapport	0.144	0.406	[-0.216, 0.465]
Engagement ⟶ Human–Robot Trust	0.062	0.787	[-0.383, 0.514]
Engagement ⟶ Robot's Social Presence	0.365	0.107	[-0.111, 0.781]
Human–Robot Trust ⟶ Connection Rapport	0.234	0.032	[-0.006, 0.424]
Human–Robot Trust ⟶ Coordination Rapport	0.552	0.000	[0.331, 0.684]
Robot's Social Presence ⟶ Connection Rapport	0.531	0.000	[0.318, 0.676]
Robot's Social Presence ⟶ Coordination Rapport	0.303	0.000	[0.130, 0.464]

Table 2: Specific Indirect Effects (Mediation Analysis)

Indirect Path	*β*	*p*	95% CI
Engagement ⟶ Trust ⟶ Coordination Rapport	0.034	0.787	[-0.219, 0.276]
Authority ⟶ Trust ⟶ Connection Rapport	0.117	0.134	[-0.004, 0.292]
Authority ⟶ Trust ⟶ Coordination Rapport	0.275	0.052	[-0.004, 0.542]
Engagement ⟶ Social Presence ⟶ Connection Rapport	0.193	0.139	[-0.050, 0.454]
Engagement ⟶ Trust ⟶ Connection Rapport	0.014	0.811	[-0.087, 0.167]
Engagement ⟶ Social Presence ⟶ Coordination Rapport	0.110	0.172	[-0.021, 0.292]

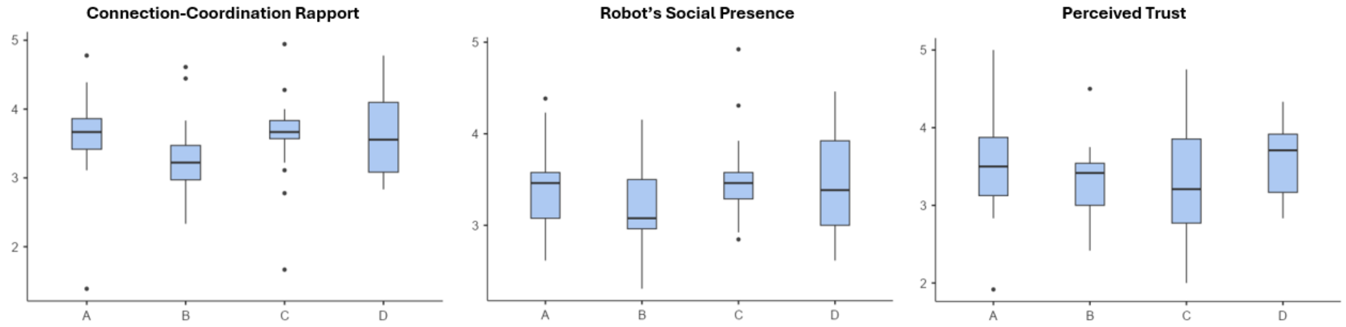

Figure 4: Box plots showing the distribution of outcome variables across four experimental conditions(A = Passive Follower, B = Passive Leader, C = Active Follower, and D = Active Leader).

conditions, suggesting that active engagement increased the robot's experiential salience in the forest. Perceived trust showed comparatively higher values in leader conditions, especially Active Leader (D), whereas Passive Leader (B) and Active Follower (C) exhibited slightly lower median trust ratings. Overall, the descriptive patterns suggest that robot engagement primarily elevated rapport and social presence, while leadership cues were more closely associated with trust.

4 Discussion

4.1 Implications and Contributions

First, the findings demonstrate that companionship in forest-based human–robot interaction is not primarily driven by overt behavioral manipulations such as engagement intensity or authority roles. Instead, companionship emerged through relational perceptions, specifically trust and social presence, suggesting that companionship is constructed through how the robot is interpreted as a social partner rather than how actively it behaves. This challenges common design assumptions [3, 22] that increased engagement or expressiveness will necessarily enhance companionship, particularly in outdoor contexts where attention is distributed across the environment. Importantly, these findings should be interpreted within the scope of low-risk, leisure-oriented forest walking contexts, where the interaction goal centers on shared experience rather than performance or safety-critical outcomes. From a design perspective, our results suggest that in experiential outdoor applications, designers should prioritize cues that support relational interpretation (e.g., consistent behavior, subtle responsiveness, and coherent social signaling) rather than increasing behavioral expressiveness alone.

Second, the results highlight trust as a critical intermediary in outdoor companionship. While robot authority did not directly increase companionship, it significantly predicted human–robot trust, indicating that leadership cues may function as signals of reliability and competence rather than as direct social affordances. This distinction refines existing models of companionship [27] by separating structural roles (e.g., leader vs. follower) from experiential outcomes, and suggests that authority may support companionship indirectly by stabilizing expectations rather than by fostering emotional connection. However, the role of authority observed here reflects a context in which leadership functions as a symbolic signal of competence rather than a requirement for task success. In environments where accuracy, safety, or efficiency are paramount, authority may have more direct behavioral consequences for user trust and reliance. Practically, this suggests that designers of outdoor companion robots should consider how authority is conveyed through stable pacing, predictable guidance, and clear movement coordination, particularly in applications where reliability must be communicated without overt dominance.

Third, this study contributes to the growing body of outdoor HRI research by empirically examining companionship in a forest setting, where interaction unfolds through shared movement rather than situated, face-to-face, or verbal exchanges. The strong effects of social presence and trust on both connection and coordination rapport indicate that companionship in such contexts is grounded in co-presence and mutual alignment rather than explicit interaction. By situating companionship within embodied, movement-based interaction, this work extends companionship research beyond indoor and task-oriented paradigms and provides design-relevant insights for deploying social robots in natural environments. At the same time, the present findings are most applicable to embodied, co-located walking interactions in natural environments and may not directly generalize to verbally rich, indoor, or high-risk domains. The mechanisms identified here: co-presence, mutual alignment, and movement-based coordination, are likely to be particularly relevant for leisure, well-being, or exploratory outdoor use cases. For designers, this implies that building companionship in such settings may depend less on complex dialogue systems and more on embodied synchrony, spatial awareness, and subtle social signaling embedded within shared movement.

4.2 Limitations and Future Directions

The study's tightly constrained robot behaviors and relatively short interaction duration may have limited the emergence of stronger companionship effects, particularly those driven by engagement and interaction richness. Additionally, novelty effects associated with encountering a robot in a forest may have shifted participants' attention toward the robot as an unusual presence, potentially attenuating relational processes that develop through sustained interaction. The modest sample size further limits statistical power and the generalizability of the findings, particularly for detecting smaller effects or individual differences in companionship formation. Future work should therefore explore longer-term or repeated interactions, incorporate more adaptive and context-aware robot behaviors, and examine alternative robot roles to better understand how companionship develops over time in outdoor environments.

5 Conclusion

This study investigated how robot engagement and authority shape human–robot companionship during forest-based walking experiences. Using a controlled field experiment, we found that neither active engagement nor leadership directly enhanced companionship outcomes. Instead, companionship emerged through relational perceptions, with human–robot trust and social presence strongly predicting both connection and coordination rapport. The findings suggest that companionship in outdoor contexts is grounded less in expressive or directive robot behaviors and more in stable relational cues that support co-presence during shared movement. Designing outdoor companion robots may therefore benefit from prioritizing trustworthiness and social presence over overt engagement, positioning robots as reliable partners within embodied, natural experiences.

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