Highlights

A Robot for Encouraging Exploration of New Experiences

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- Adding minimal attentive gestures to robots' behavior can encourage exploration.
- Robotic attentiveness can enhance the emotional basis required for exploration.
- Inattentive robotic behavior decreases willingness to explore new experiences.
- Non-humanoid robots can become a tool for encouraging human exploration.

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ABSTRACT

The human drive to explore new experiences is critical to psychological well-being. However, the novelty and ambiguity that are inherent characteristics of unfamiliar experiences are commonly challenging and can detract exploration unless the person feels emotionally secure that nothing wrong will happen. In this work, we examined whether an interaction with an attentive robotic object can provide a secure basis for exploration of new experiences. Participants were randomly assigned to one of three conditions: (1) Interaction with an *attentive* robotic object (the robot performed attentive gestures); (2) interaction with an *inattentive* robotic object (the robot performed inattentive gestures); and (3) no interaction with a robotic object *(control condition)*. Exploratory behavior was tested in a subsequent task where participants indicated their willingness to experience familiar and unfamiliar stimuli. As compared to the *control condition*, participants who interacted with an *attentive robotic object* were more willing to experience unfamiliar stimuli and spent more time exploring them. In contrast, participants who interacted with an *inattentive robotic object*were less willing to explore unfamiliar stimuli than those in the *control condition*. It seems that robots' attentiveness can support human natural curiosity and encourage exploration of new experiences.

1. Introduction

Robotic technologies are increasingly used to enhance our well-being (1; 2; 3). While robots have been originally developed to support our practical needs, in recent years, there has been a growing interest in designing robots that also support psychological needs (4; 5; 6; 2). These studies indicate that robots (even very simple ones) can have a profound impact on humans' cognitive and emotional states. This impact can be both positive (7) and negative (8). One fundamental need that is yet to be explored in the context of Human-Robot Interaction (HRI) concerns the exploration of new experiences, an evolutionary drive that is active from infancy (9; 10). This evolutionary drive is the basis for curious behavior and motivates people to investigate, manipulate, and master their environment (9). It is crucial for learning new skills, adjusting to changes, and participating in novel social interactions (10; 11; 12). Despite the tremendous importance of exploration for personal development, supporting a person's need for exploration of novel experiences was hardly studied in social robotics.

When a person's need for exploration is supported, people can learn new things and expand their beliefs and perspectives (9; 10). As a result, individuals are more likely to develop a personal sense of value and self-efficacy in learning and mastering their environment (9; 13). In addition, they are more likely to achieve a sense of mastery (14), which can encourage attempts to change their environment and lead to desired outcomes (9; 13). Such positive outcomes reinforce future exploration tendencies and ultimately support psychological well-being.

Despite our fundamental need for exploration, engaging in actual exploratory behavior is not trivial. Exploration involves facing novel situations that can be emotionally challenging (15). Novel situations are characterized by ambiguity and uncertainty, and exploration of these situations

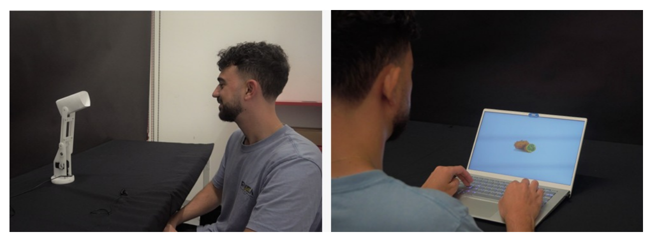

Figure 1: A participant interacting with an attentive robot (Left); After the interaction, the participant performs a task measuring willingness to explore new experiences (Right).

involve undertaking of actions that may be perceived as unsafe (16). Depending on a person's confidence and sense of security, novel experiences can be alternatively perceived as an opportunity to satisfy exploration and curiosity or situations fraught with anxiety and risk (16; 17).

Without the appropriate sense of security, people will likely search for familiar and safe experiences while inhibiting their need for exploration (13; 18). In order to be curious about novel experiences and to actually engage in exploratory behavior, individuals need a strong emotional basis that involves self-confidence and trust. Therefore, a person's sense of security determines whether new experiences are perceived as opportunities for exploration or threatening situations that should be avoided (9; 13).

Achieving the sense of security required for exploration depends on the actual or symbolic availability of attentive, responsive, and supportive others in times of need. Interactions with these caring others lead to the formation of positive beliefs about their benevolence and sustain what Bowlby (1988) called a secure base for exploration – a sense that one can explore novel and challenging experiences with the confidence that support will be available when needed. However, when important others are inattentive, this sense of security is thwarted and doubts about support

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availability during exploratory and challenging activities are ensued. These insecurities foster endorsement of more self-protective behaviors, thereby reducing openness towards novelty and inhibiting the need for exploration (10; 11). This dynamic interplay between a person's sense of security and willingness to explore presents a real challenge because achieving and maintaining this subjective sense of security is not trivial (10; 11).

A profound change in one's sense of security typically requires long-term interventions (10). However, various studies indicate the possibility of increasing (and decreasing) one's state-like sense of security. Apart from being a relatively stable trait-like construct, security is shown to have state-like components that can change across contexts and from day to day (19). These state-like components are influenced by situational changes that depend on social interactions and other environmental factors (19). There are consistent indications that it is possible to increase one's state-like sense of security via short-term actual, recalled, or imaginary interactions with supportive others (20; 21). Even minimal attentive and responsive gestures, inserted during interactions between strangers, can contribute to individuals' sense of security (21). Adding behaviors indicating attentiveness (e.g, leaning, gazing, smiling) and smile to an interaction, can increase feelings of trust and security, even without having long-term consequences for a person's relational functioning (20; 21). For example, presenting a picture of a stranger's genuine smile or asking participants to imagine someone stroking them was shown to temporarily increase participants' sense of security (20; 21; 22). On this basis, we assume that one can potentially encourage exploration by applying minimal and simple changes to one's environment and leveraging social cues that support the sense of security (19).

Previous studies also indicated that security-related experiences are not limited to human-human interactions (23; 5). Pets and objects have been indicated as candidates for providing security in adulthood (10; 24; 25). Having secure-related experiences with pets and objects where shown to enhance a person's self-confidence temporarily (10), increase motivation to achieve (25), and increase exploratory behaviors in general (26; 18; 27).

Taken together, these previous studies suggest that if designed appropriately, short-term (and even minimal) interactions with responsive entities (not necessarily humans) can be leveraged to enhance the self-confidence and security required for encouraging exploration. This idea is supported by HRI studies indicating that robotic behaviors, such as availability, attentiveness, and responsiveness, are associated with an increase in a person's sense of security (for review, see Rabb et al., 2021 (28)). Such human-robot interactions typically lead to positive emotions and an increase in well-being (2; 3; 1).

Specifically, non-humanoid robots (also known as robotic objects) have been indicated as a promising technology for enhancing a person's sense of security. These robots are often simple and easily accessible (7; 29). They are perceived as valid participants in social interactions, despite having limited communication modalities, which typically involve minimal non-verbal gestures (29; 30; 7; 31; 32; 33; 5). Previous studies indicate that interactions with simple robotic objects performing minimal gestures as their sole communication modality are automatically interpreted as social cues leading to intense social experiences (33; 8; 34).In the context of facilitating a sense of security, robotic objects' limited communication modalities are an advantage as they lead to interactions that are not likely to replace human relationships. Despite being able to trigger intense social experiences, non-humanoid robots are not perceived as artificial humans (7), and participants continuously perceive them as machines (35; 8; 34). This duality in the perception of non-humanoid robots (both a mechanical entity and a social entity) suggests that humans may perceive them as a tool for temporarily sustaining the sense of security required for exploration rather than a replacement of meaningful others. Hence, their mechanical nature is their main advantage when considering them as candidates for providing a state-like sense of security in a given context.

Designing attentive robotic behavior that would enhance people's sense of security is possible due to the human tendency to perceive the world through a social lens. Previous studies indicate that robotic movements are automatically interpreted as social cues, even if the robot has a non-humanoid appearance and cannot directly mimic human behavior (33). Gestures performed by robots designed with non-humanoid appearances, such as a desk lamp (36), a ball rolling on a dome (7), or a robotic arm (32), were interpreted as indicating caring (34), attentiveness (36), interest (5; 37), and a general willingness to interact with the participant (7). Moreover, social interactions with robots led to profound effects on participants' psychological state, highlighting the potential for these machines to have a significant impact on human emotions and behavior (7; 8; 35; 5; 34).

A few studies have already indicated that attentive and responsive gestures made by non-humanoid robots can specifically support participants' self-confidence and enhance general trust (23; 5). More directly, Manor et al. (2022) have recently shown that a simple non-humanoid robot can influence participants' sense of security. In their work, a lamp-like robotic object performed attentive and responsive gestures that temporarily enhanced participants' self-confidence and sense of security. When performing opposite behaviors (i.e. inattentive), the robot decreased participants' confidence and triggered emotional insecurity (5). While these studies indicate that non-humanoid robots can influence humans' sense of security, we want to go one step further and evaluate if such robotic behaviors can provide the emotional basis required for supporting the exploration of new experiences.

In the current study, we tested whether attentive and responsive robotic behavior can facilitate people's sense of security and self-confidence, allowing them to remain open and receptive to novel experiences. We additionally

Figure 2: The robotic object, used with permission (38).

tested whether an opposite robotic behavior (inattentive) would decrease humans' willingness to explore new experiences. Participants' exploration tendencies were assessed after a short interaction with a non-humanoid robot (used with permission (38); see Figure 2). The robot's behavior was designed to increase or decrease participants' sense of security by applying attentive and inattentive gestures, based on Manor et al. (2022) (5). We compared participants' willingness to explore new experiences in these conditions to that of participants in a control condition that did not involve an interaction with a robot.

2. Related Work

Relevant previous work includes the evaluation of interventions for encouraging exploration and technologies designed to support and enhance the sense of security.

2.1. Interventions for encouraging exploration

A few studies indicated that interactions with robots can encourage exploration. Huang et al. (2013) showed that successfully building a robot over the course of several weeks can have a positive influence on exploratory behavior. Participants reported increased self-efficacy and believed they could perform complex tasks that they previously perceived as beyond their capabilities. The increase in self-efficacy encouraged future exploratory behaviors, including addressing novel challenges and engaging in complex tasks (39). Another example was presented by Wada and Shibata (2007, 2011), who showed that a robot could encourage exploration in the context of social interactions. Participants living in an elderly-care institution interacted with a Paro seal robot. When they cared for the robot, other residents showed curiosity and interest, and then the likelihood of social interactions increased (2; 6). Robots were also used as a method for modeling curious behavior. Gordon et al. (2015) tested a robotic behavior designed to trigger children's curiosity. Children interacted with a curious or non-curious robot while using a novel story-maker app. The curious robot demonstrated enthusiasm towards the learning activity, challenged the child by asking questions, and suggested novel moves on the app. The non-curious robot played with the child, yet did not express any willingness to learn new things. Children who interacted with the curious robot demonstrated increased curiosity compared to those who interacted with the non-curious one (40).

While these studies indicate the potential of using robots for mediating exploration, they do not leverage their ability to facilitate the sense of security required for engaging in exploratory behavior.

2.2. Enhancing a sense of security

Several studies indicated robots' potential to enhance humans' sense of security. For example, Garreau (2007) studied the relationship between a bomb disposal robot and the soldiers operating it. He showed that the robot provided physical safety, leading to a sense of security and a strong attachment to the robot. Soldiers refused to replace outdated robots with identical versions and insisted on repairing the specific robot that they owned. When a repair was impossible, soldiers organized funerals that included an honorary salvo (3).

More directly, several studies evaluated robotic behaviors intentionally designed to facilitate a sense of security (23; 41). Birnbaum et al. (2016) showed that a non-humanoid robot could demonstrate the attentiveness required for enhancing trust and self-confidence. They asked participants to disclose an adverse personal event during an interaction with the robot. The robot's attentive behavior (i.e., performing non-verbal gestures and providing text messages) increased the acceptance of the robot's companionship when alone or under stressful circumstances. Such acceptance was interpreted as an indication that the robot can increase people's sense of security (23). In a recent study by Manor et al. (2022), a robot's attentiveness was also found to be directly related to participants' sense of security. The authors compared interactions that involved either attentive or inattentive robotic behaviors to a control condition that did not involve an interaction with the robot. To evaluate the robot's impact on sense of security, Manor et al. (2022) used the lexical decision task, a well-known reaction time measure, designed to provide an objective indication of participants' emotional state (42) including their sense of security (21). [1]. Their findings showed that a robot performing attentive gestures significantly increased participants' sense of security. They also found that interaction with an inattentive robot was perceived as a highly distress-eliciting experience and resulted in a decrease in the sense of security (41). The lexical decision findings were supported by participants' explicit descriptions of their interactions with the robot. Taken together, these studies indicate robots' potential to enhance participants' sense of security. However, previous studies did not explore the possibility to leverage robots' ability to facilitate a sense of security for exploring new experiences. Since it is impossible to engage in exploration without the appropriate

[1]Lexical decision is considered a general tool for objectively indicating participants' experience in a specific context (43; 44) and was used for evaluating participants' sense of security in several studies in the psychology domain (21)

emotional basis, robots providing a sense of security can become a powerful tool for supporting the fundamental human need to explore. We, therefore, examined if an attentive robotic behavior would increase participants' security and encourage exploration. We also tested the possibility that inattentive robotic behavior, associated with emotional insecurity, would result in a decrease in participants' willingness to explore new experiences.

3. Method

To examine if a robot can enhance the willingness to explore new experiences, we tested participants' openness to novelty after a short interaction with a robotic object. In all conditions, participants were asked to share their plans for the future while seated in front of a robot. We evaluated willingness to explore new experiences in three robotic conditions: (1) after an interaction with a robot performing attentive and responsive gestures (attentive robot), (2) after an interaction with a robot performing inattentive and non-responsive gestures (inattentive robot), and (3) in a control that did not involve an interaction with the robot. The study was approved by the ethics committee of the research institute and conducted under strict COVID-19 safety regulations.

3.1. Participants

Sixty-three undergraduate students from the university's Communications, Psychology, and Computer Science departments participated in the study (51 females, 12 males; M = 24.8, SD =1.2). All participants were native speakers of the country's language. Participants signed an informed consent form and received extra course credits or a "coffee and pastry" gift card to a local coffee chain. To determine the sample size, we ran a G-power analysis (45) with a medium effect size (based on Feeney, 2004; (11)) and three conditions. The G-power analysis indicated that the required sample size was 60 participants.

3.2. Experimental settings

The experiment took place in a quiet, dedicated room. The robotic object was placed on the table. Its top part was placed 75cm from the participant's forehead so that its upper part matched the height of the participant's head. The robots' control hardware was attached to the underside of the table. The robot was powered by the Butter Robotics MAS platform (46). A web-based graphical user interface allowed the researcher to sequence and execute pre-scripted robot commands. In addition to the robot, a small microphone was placed on the table between the robot and the participant. A small camera was placed on a shelf at the back of the room. (see figure 3).

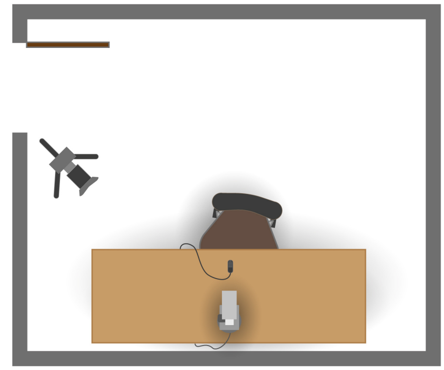

Figure 3: The experimental settings

3.3. Experimental Design

The between-participant experimental design included three conditions (21 participants in each condition): *Attentive Robot, Inattentive Robot, Control*. To manipulate the robot's security-related behavior, we applied robotic gestures previously shown to increase (and decrease) participants' sense of security (**?**). Some of these gestures (i.e., lean, gaze, and nod) are believed to be the basis for forming a sense of security bonds between humans (47). The gestures were sequenced, forming a robotic behavior that lasted exactly 2.5 minutes. This time frame was indicated in previous studies as appropriate for sharing future plans (41). The robotic behaviors in the three conditions were designed as follows:

1. *Attentive Robot* condition: The robot's behavior consisted of three types of gestures.
    - The robot turned toward the participant's direction.
    - The robot performed a "lean and gaze" gesture where its upper part moved up and towards the participant in a repetitive manner.
    - The robot maintained its posture and performed small movements simulating a "nodding" gesture.

    These gestures were sequenced into fluent robotic behavior presented in Figure 5. The robot was constantly directed toward the participants providing a sense of "full" attention (see Figure 4).
2. *Inattentive Robot* condition: The robot's behavior consisted of four types of gestures.
    - The robot turned toward the participant's direction.

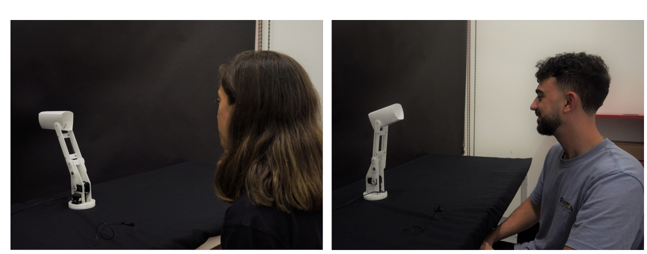

Figure 4: The robot's attentive and inattentive behavior: *Inattentive Robot* condition (Left); *Attentive Robot* condition (Right).

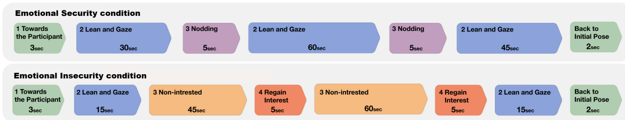

Figure 5: The gesture sequences used in the *Attentive Robot* and *Inattentive Robot* conditions.

- The robot performed a ”lean and gaze” gesture where its upper part moved up and towards the participant in a repetitive manner.
- The robot performed a ”non-interested” gesture where it slowly leaned back, turned away from the participant and toward the wall, performing right and left movements while facing the wall.
- The robot performed a ”regain interest” gesture where it turned back to the participant.

These gestures were sequenced into fluent robotic behavior presented in Figure 5. The robot was mostly directed away from the participant as if it was not attentive (see Figure 4).

3. *Control* condition: while the robot was placed on the table, it did not move and participants did not interact with it.

Participants were *randomly* assigned to one of the three conditions using a matching technique that balanced gender, academic department, negative attitudes toward robots (48), and attachment style (49). To control for early differences in attitudes toward robots, we used the Negative Attitude towards Robots Scale (Nomura et al., 2006). To control for trait-like differences in the sense of security, we used the Experiences in Close Relationships scale (ECR; Brennan et al., 1998). This scale taps a person’s attachment insecurities in close relationships, which have been found to be associated with less willingness to engage in exploratory behaviors (26). To verify that the groups were balanced we conducted a Bayesian analysis, using each scale as a dependent measure. The analyses indicated that there were no early differences between the groups, NARS: BF10=0.15; ECR: BF10=0.18.

To control for early differences in exploration tendencies, we used an attachment scale (ECR; Brennan et al., 1998). As explained earlier, attachment insecurities (assessed by the ECR) determine people’s experiential openness (see the introduction section). To verify that the groups were balanced we conducted a Bayesian analysis, using each scale as a dependent measure. The analyses indicated that there were no early differences between the groups, NARS: BF10=0.15; ECR: BF10=0.18.

3.4. Measures

Quantitative and qualitative measures were used to assess participants’ willingness to explore new experiences after the interaction with the robotic object.

3.4.1. *Quantitative measure - Exploration task*

The exploration task is a computerized task designed to assess participants’ willingness to explore new experiences (50). Participants were asked to indicate their willingness to experience familiar and unfamiliar stimuli presented as pictures on the screen. The task involved 32 stimuli from three broad categories: fruits, furniture, and people (8 stimuli in the fruits and furniture categories; 16 stimuli in the people category, divided into 8 females and 8 males). In each category, half of the stimuli were unfamiliar and exotic (e.g., exotic fruits, unfamiliar furniture, and unfamiliar people). The other half of the stimuli in each category were familiar, well-known stimuli, such as familiar fruits (e.g., apple, banana), traditional types of furniture, and familiar people (see Figure 6 for examples). The presentation order of the categories and stimuli in each category were counterbalanced across participants. In each trial, a single stimulus was presented on the screen. Participants were asked to indicate whether they ’were open to an experience involving the stimulus (i.e., taste the fruit, furnish their house with the furniture, and eat lunch with the person in the picture). The task was computerized using the e-prime software (51). Participants’ willingness to explore new experiences in each robotic condition was assessed by two measures: (1) The percentage of the unfamiliar (vs. familiar) stimuli chosen by the participant; (2) The difference in average reaction time between unfamiliar and familiar stimuli.

3.4.2. *Qualitative measure - Interview*

A semi-structured interview was conducted to better understand participants’ thoughts and attitudes (52; 53). We first defined eight questions as a manipulation check and replication of the qualitative data presented by Manor et al. (2022). The questions were designed to evaluate participants’ experience with the robot and to assess whether it involved emotions related to a sense of security and confidence. For example: ”Describe the experience" and "What did you feel during the experience?". At the end of the interview, the researcher showed the participants pictures of each fruit presented in the exploration task and asked them to choose three fruits they would like to eat or taste. The researcher then asked the participants to explain their choices.

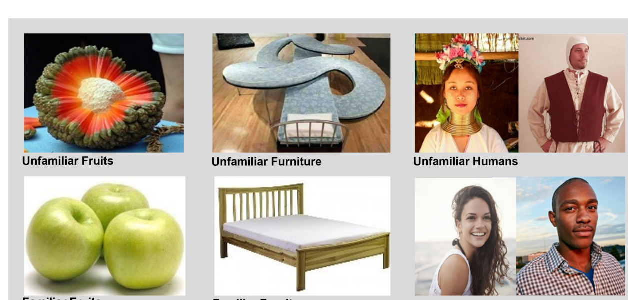

Figure 6: Examples of the unfamiliar and familiar stimuli that were used in the exploration task.

3.5. Procedure

A few days before the experiment, participants received pretest questionnaires by email. The pretest questionnaires included the NARS and ECR scales and a demographic questionnaire. Once the participant arrived in the lab, the researcher explained that the purpose of the study was to create an audio database that would be used to train an algorithm to understand natural language. The participant was informed that the experiment involved talking to a microphone in a quiet room. The researcher mentioned that a robotic object would be present in the room, and it may or may not move. The participant signed a consent form and was invited to enter the experiment room. The participant was asked to sit on a chair in front of a table with a small microphone and the robotic object. The researcher then asked the participant to talk about plans for the future, any important goals for the coming year, and overall life goals. The researcher left the room and activated the sequence of gestures appropriate for each of the experimental conditions. After exactly 2.5 minutes, the researcher re-entered the room with a laptop and asked the participant to perform the exploration task (see Figure 3). The researcher then left the room again. Once the participant completed the task, the researcher re-entered the room and conducted the semi-structured interview. Finally, the participant was asked to describe a recent positive experience (to mitigate any negative affect elicited by the manipulation). The researcher then debriefed the participant and verified that the experience was overall positive.

4. Findings

Both quantitative and qualitative analyses indicated that the robot's attentiveness was associated with participants' willingness to explore new experiences.

4.1. Quantitative analysis - Exploration task

Participants' responses in the exploration task were analyzed using a 2-way ANOVA examining the interaction between robotic conditions (*Attentive Robot; Inattentive Robot; Control*) and the familiarity of the stimuli in the exploration task (familiar vs. unfamiliar). Whereas the robotic condition was a between-participant factor, the familiarity of the stimuli was a within-participant repeated factor. The analysis was conducted for two dependent measures: Reaction time for choosing stimuli and the ratio of unfamiliar and familiar stimuli chosen by the participant.

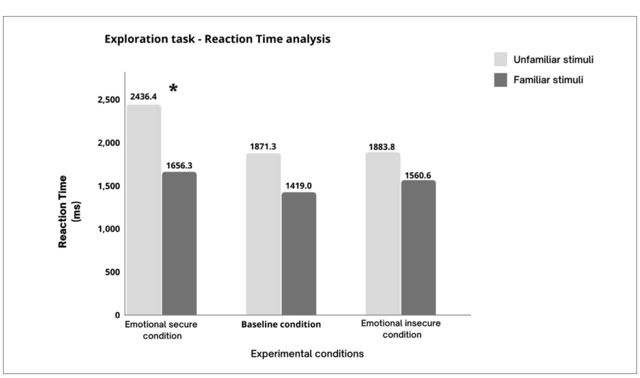

Figure 7: Reaction times averages for familiar and unfamiliar stimuli in the different conditions (exploration task).

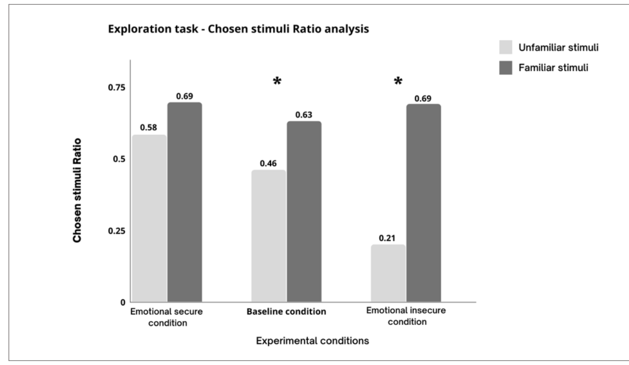

Figure 8: The choice-ratio of familiar and unfamiliar stimuli in the different conditions (exploration task).

The reaction time analysis revealed a significant interaction, F(2,59) = 3.18, p = 0.05, $\eta_p^2 = 0.12$ (see Figure 7). Scheffe post-hoc analysis indicated that in the *Attentive Robot* condition, participants spent more time exploring unfamiliar stimuli in comparison to familiar stimuli (p < 0.001). This effect was not observed in the *Inattentive Robot* and *Control* conditions. Using planned contrasts we verified that the difference between the effect in the *Attentive Robot* condition to the two other conditions was significant (p<0.001 for both comparisons). The stimuli choice-ratio analysis also revealed a significant interaction, F(2,59) = 21.06, p < 0.001, $\eta_p^2 = 0.2$ (see Figure 8). Scheffe post-hoc analysis indicated that in the *Inattentive Robot* condition, participants chose much fewer unfamiliar stimuli in comparison to familiar stimuli (p < 0.001). A similar but smaller effect was also observed in the *Control* condition (p = 0.05). In the *Attentive Robot* condition, participants did not show a specific preference and chose both familiar and unfamiliar stimuli to the same extent. Using planned contrasts, we verified that the difference in the pattern of responses to familiar and unfamiliar stimuli in the robotic conditions was significant (*Attentive Robot* vs *Control*, p = 0.04; *Inattentive Robot* vs. *Control*, p = 0.02).

4.2. Qualitative analysis

The interviews were transcribed and analyzed using Thematic Coding, which is a qualitative analysis methodology commonly used in HCI and HRI (52; 53). The analysis included five stages: (1) Several transcriptions from each condition were read to develop a general understanding of the data; (2) two researchers individually identified initial themes and discussed them in-depth with a third researcher until inconsistencies were resolved; (3) a list of mutually-agreed themes was defined; (4) the researchers used the mutually-agreed themes to analyze a selection of the interviews independently, and inter-rater reliability was assessed (Kappa=88.4%); (5) following inter-rater reliability confirmation, the two researchers analyzed the rest of the data. In total, 552 quotes were analyzed and categorized into four main themes: Willingness to Explore New Experiences, Robot's Attentiveness and Responsiveness, How The Robot Made Me Feel, and Robot's Perception and Likability. While the exploration theme was the main focus of this study, the additional themes indicated the underlying process responsible for the robot's impact on the participants' willingness to explore new experiences (i.e., sense of security) and replicated Manor et al.'s (2022) qualitative results.

4.2.1. *Theme 1 - Willingness to Explore New Experiences*

When asked to explain their choice of stimuli, participants expressed different levels of exploratory behavior. In the *Attentive Robot* condition, 17/21 participants expressed their curiosity and interest in unfamiliar fruits: *"Right now I'm feeling that I would like to taste fruits that I've never tried before"* (P.12, M). The rest of the participants (5/17) mentioned both their willingness for familiar stimuli and rejection of unfamiliar ones. 3/21 participants preferred to choose fruits that they already know: *"Pineapples, bananas, and apples are my favorites fruits and I would always be happy to eat them"* (P.48, F). 2/21 participants explicitly stated that they do not want to take any chances so they preferred not to choose unfamiliar fruits: *"I don't like trying new fruits, especially if I've never seen them before, it grosses me out"* (P.7, F).

In the *Inattentive Robot* condition, only 4/21 participants expressed their curiosity and willingness to try unfamiliar fruits: *"I don't know this fruit but it looks spicy and I love spicy food, it's very cool"* (P.56, M). 17/21 the participants mentioned both their preference for familiar fruits and rejection of unfamiliar ones. 17/21 of the participants expressed their preferences for familiar fruits: *"Every day I eat apples and bananas, I will always prefer fruits that I know and like"* (P.63, F). In addition, 12/21 of the participants refused to consider unfamiliar fruits: *"I don't like these fruits since they don't look standard, it seems that if I taste one of them, I'll have to go immediately to the hospital, it looks unsafe"*; *"Why would I try something that I don't know?"* (P.24, F).

In the *Control* condition, 9/21 of the participants used terms related to curiosity and chose unfamiliar fruits: *"I chose this fruit because I always like to try new things"* (P.33, M). The rest of the participants mentioned both their preference for familiar fruits and rejection of unfamiliar ones. 13/21 participants preferred familiar fruits because they are used to them and know them: *"I prefer the fruits that I know"* (P.15, M). 6/21 of the participants mentioned that they did not want to take any chances by trying unfamiliar fruits: *"I prefer to eat a fruit that will not hurt me"* (P.32, F).

Participants' willingness to explore new experiences was also expressed by their spontaneous interest in becoming research assistants in the research lab. Despite not being asked about it, almost half of the participants in the *Attentive Robot* condition (9/21) brought it up at the end of the interview: *"It looks like you are doing very interesting things here, is it possible to join the lab as a research assistant"* (P.13, F); *"How can I join this lab as a research assistant?"* (P.20, M). This spontaneous tendency for exploration was not evident in the *Inattentive Robot* and *Control* conditions.

4.2.2. *Theme 2 - Robot's Attentiveness and Responsiveness*

Participants in all conditions explicitly mentioned the level of the robot's attentiveness and responsiveness in the interaction. Their responses varied between the conditions. In the *Attentive Robot* condition, 17/21 participants directly mentioned the robot's responsiveness. They stated that the robot was attentive and understanding: *"When I finished saying something, the robot moved its head up, like nodding, almost like a person that understands me"* (P.46, F); *"The robot listened to me and made me feel that I'm saying interesting things, he encouraged me to keep on talking"* (P.48, F). Most participants associated their entire experience with the robot's attentive and responsive behavior: *"It reminded me of my psychologist that does not judge me and will always listen to me"* (P.12, M). Yet, 4/21 of the participants stated that the robot was not attentive enough: *"I didn't feel that he was fully attentive to me or listened to me"* (P.19, M).

In the *Inattentive Robot* condition, 19/21 of the participants said that the robot was not attentive: *"At first, I thought that it was looking at me, and then he just turned away, distancing itself. Eventually, it felt like talking to the wall"* (P.23, M). Most of the participants in this condition perceived the robot's responses as ignoring them: *"I felt like I was boring the robot, he kept moving away"* (P.45, M). Participants were frustrated by the robot's inattentiveness: *"It just turned away from me, doing anything but listening to me."* (P.24, F). 2/21 of the participants in this condition perceived the robot's responses in a more positive way: *"The way it turned away made me laugh, like a silly boy that wants to have fun"* (P.26, F).

10/21 participants in the *Control* condition expressed their desire to have an attentive interaction with the robot: *"I would like the robot to show me that he understands me and the challenges I shared with him"* (P.15, M); *"I really wanted it to look at me"* (P.32, F). 9/21 of the participants said that they ignored the robot during the interaction and did not notice that it was in the room: *"At first I thought it was eavesdropping but eventually I just ignore it"* (P.37, F); *He didn't do anything. I didn't pay attention to it at all"* (P.43, F).

4.2.3. *Theme 3 - How The Robot Made Me Feel*

Participants explicitly reflected on how the robot made them feel in the interaction. 16/21 of the participants in the *Attentive Robot* condition mentioned positive emotions related to security: *"The robot made me feel that it was safe to share with it my challenges"* (P.18, F) and stated that the robot made them open up: *"He made me feel that he is listening to me, so I wanted to share more with him"* (P.1, F); *"His calming movements made me feel safe to share any* *thoughts and wishes with it"* (P.8, M). They shared that even though they knew it was a robot, they felt that they were being seen: *"I felt sympathy from the robot, as if he wanted me to know that he feels me and understands me"* (P.7, F); They even stated that there is an advantage to interacting specifically with a robot: *"Because it was only listening to me, and it is a robot, I knew that it won't judge me and will accept anything I would say"* (P.36, F). 5/21 participants in this condition experienced negative emotions: *"I felt uncomfortable that a robot, and not a person, listens to my future plans, it was weird and strange"* (P.52, F).

In the *Inattentive Robot* condition 20/21 participants mentioned negative emotions: *"I felt that the robot was judging me and I felt bad, it was super weird and very uncomfortable"* (P.45, M). Most of them reported a decrease in their sense of security: *"Every time the robot ignored me, it made me stutter, I kind of lost my confidence"* (P.56, M); *"I felt really bad during the interaction, it was not sensitive to the people around it"* (P.29, F). They also described how the robot made them feel alone: *"It felt lonely as if no one was hearing me"* (P.28, F). Only one participant shared positive emotions: *"It made me feel that it understood what I was saying, it was good"* (P.2, F).

In the *Control* condition, most participants did not describe any emotions related to the robot.

4.2.4. Theme 4 - Robot's Perception and Likability

Most participants mentioned their perception of the robot and discussed its likability. In the *Attentive Robot* condition, 16/21 of the participants stated that they liked the robot: *"It is a friendly robot, I love it and he is very cute"* (P.18, F). Some of them specifically associated their appreciation of the robot with its security-related behavior: *"I like it because even though it is a robot he listens to me all the time and I know that it will always be there, just like my dog that is always happy to see me"* (P.44, F). Yet, 4/21 of the participants did not like the robot: *"It was difficult for me to open up to an object without a face that can not talk"* (P.19, M); *"I don't think that people should share their fears and personal thoughts to a robot"* (P.40, M).

In the *Inattentive Robot* condition, only one participant stated that he liked the robot but suggested that it is appropriate for other people: *"I like the idea of this robot, it will be great if older adults would use it and get help from it"* (P.23, M). 17/21 participants didn't like the robot: *"It has no value. It was on its own, so I just don't see the point of using it"* (P.47, M); *"It reminds me of a friend that doesn't really care about me and doesn't really want to listen to me"* (P.29, F).

In the *Control* condition, none of the participants stated that they liked the robot. 3/21 of the participants thought that the robot collected their data: *"I felt like it's watching me and calculating everything, this robot is very creepy"* (P.58, F).

5. Discussion

In this work, we show that interaction with a simple non-humanoid robot can support the secure basis needed for remaining open and receptive to new experiences. In our study, a short interaction with an attentive robot, dramatically increased participants' openness to experience unfamiliar stimuli. Participants in the *Attentive Robot* condition spent more time inspecting the unfamiliar stimuli and overcame the tendency to prefer familiar stimuli over unfamiliar ones. Participants' explanations for their willingness to experience unfamiliar stimuli also indicated their greater openness to exploration. They described their *"interest"* and *"curiosity"*, and stated that they wish to *"try new things"* and to *"take part in novel experiences"*. Half of the participants in the *Attentive Robot* condition also demonstrated their willingness to explore new experiences by spontaneously asking about the possibility of joining the lab as a research assistant. The researcher never mentioned this possibility, and no environmental cue could have prompted the inquiry, such as a sign advertising research opportunities. This spontaneous interest in exploring novel academic experiences was not evident in any of the other conditions. Overall, this dramatic increase in exploratory behavior, shown only in the *Attentive Robot* condition, indicates that attentive gestures of simple robotic objects can facilitate the sense of security required for exploring unfamiliar experiences and coping with their inherent ambiguity.

While the above results show the potential of leveraging attentive non-humanoid robots to encourage exploratory behavior, our findings also indicate a possible risk. Interaction with a robot performing inattentive gestures significantly decreased participants' willingness to experience unfamiliar stimuli. Participants in this condition (*Inattentive Robot*) explained their rejection of unfamiliar stimuli using words and phrases directly related to emotional insecurity, including *"fear," "feeling unsafe," "getting hurt"*, and even expressed concerns about their *"physical wellness"*. None of the participants in the *Attentive Robot* condition expressed similar concerns. Participants who interacted with the inattentive robot also explicitly stated their need to avoid risks and expressed their preference for familiar experiences and surroundings in which they would feel comfortable and safe. This strong tendency to avoid novelty indicates that inattentive robotic behavior may trigger emotional insecurity that could lead to the inhibition of the need of exploration and to the perception of novelty as a threat.

The underlying process responsible for the robot's impact on participants' exploratory behavior was indicated in their descriptions of the interaction with the robot. In both the *Attentive Robot* and *Inattentive Robot* conditions, participants associated their experience with their sense of security and specifically mentioned the robot's impact on their self-confidence. In the *Attentive Robot* condition (which resulted in enhancing exploration) participants described the robot's behavior using words such as *"supportive", "caring",* and *"showing interest"*. They stated that the interaction made them feel *"safe", "confident",* and *"open"*.

In contrast, in the *Inattentive Robot* condition (which resulted in inhibiting exploration), participants described the robot's behavior as *"ignoring", "avoiding", "leaving them alone",* and *"insensitive"*. They explicitly stated that the interaction made them *"insecure", "feel unsafe",* and *"lose their confidence"*.

Taken together, our findings suggest that human-robot interactions, which influence the emotional state of participants can also have an impact on their subsequent exploratory behavior. Specifically, our findings demonstrate that the well-known relationship between the sense of security and exploratory behavior (9; 10; 18; 26) can be easily applied to human-robot interactions. Attentive robotic behavior can empower people to step out of their comfort zone and explore desired new challenging experiences. Robots can be leveraged to open to people interactions with new people despite initial awkwardness, new challenging ideas, and unfamiliar novel experiences. At the same time, our findings also point to the risks posed by emotionally insecure human-robot interactions, suggesting that robot designers should carefully avoid robotic gestures that may be perceived as indicating that the robot is inattentive. Such robotic behaviors may push people into their comfort zone and increase anxiety when facing novelty.

Notably, we show that these positive and negative changes in exploration tendencies can be triggered by an interaction with a simple non-humanoid robot. Participants perceived the robotic object as a valid entity for enhancing their sense of security, mentioning the robot's mechanical nature as an advantage due to its perceived objectivity and persistent existence: *"I love it because he listens to me all the time and I know that it will always be there, always happy to see me"* (P.44, F); *"The robot will never judge me like other humans do"* (P.12 M). Participants mentioned that this sense of acceptance makes them feel that they can: *"Open up and share everything that's on their mind"* (P.20, M). With previous studies indicating that having a consistent sense of security is not trivial (26; 10), the advantages mentioned by our participants suggest that attentive robotic objects may assist in dealing with this challenge. Non-humanoid robots are also well suited to the task because they are unlikely to be considered as an alternative for relationships with other humans. Instead, robotic objects are perceived as a technology that can eventually encourage the formation of novel relationships with other humans by supporting the exploration of new experiences (like novel social interactions).

Our findings also highlight the importance of perceived attentiveness in the design of human-robot interactions. As robots become an integral part of daily life, designers and developers should pay greater attention to unintended influences on people's capacity to remain open and receptive to novel experiences. Today, designers and developers focus mostly on a robot's functionality, with very limited awareness of its impact on people's emotional needs. Failing to consider the robot's attentiveness during the design process could result in unintended consequences to human behavior, including a decrease in self-confidence, exploration, learning, and adjustment to changing circumstances. While this may be a temporary effect, it can lead to missing out on important opportunities and avoiding meaningful experiences.

6. Limitations

This study has several limitations. First, our findings do not provide information about the extent to which the observed effect persists over time, because willingness to explore was only measured immediately following the interaction with the robot. Future studies should examine the robot's impact over time. Further work should also examine the robot's effects in other contexts that demand the exploration of novel experiences, such as forming a new relationship or adjusting to changing circumstances. Apart from additional contexts, testing the effect in less controlled real-life settings is also required. Another limitation concerns the interview. Participants' answers may have been affected by the "good subject effect" (54), in which participants tend to provide responses they perceive to be pleasing to the researchers. To minimize the effect, participants were reassured that anything said was helpful and valuable, and they were explicitly asked to share both positive and negative responses. Moreover, to minimize any influence the interviewer may have had on the interviewee, a strict interview protocol was followed (55).

7. Conclusion

We show that an interaction with a simple non-humanoid robot can dramatically impact a person's willingness to explore new experiences. A short interaction with an attentive robotic object was found to enhance a person's willingness to experience novel, exotic stimuli. In our view, the attentive robotic object might have increased confidence in the face of unfamiliar situations, which, in turn, contributes to a person's ability to remain curious, learn new things, and form new social relationships. Interaction designers should be keenly aware of humans' sensitivity to attentive interactions and leverage responsive robotic behaviors to support the fundamental need for exploration. At the same time, interaction designers should also consider the dramatic impact of inattentive robotic behaviors that can create a sense of insecurity and decrease a person's willingness to explore new experiences.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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