"By the way, what's your name?": The Effect of Robotic Bar-stools on Human-human Opening-encounters

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ABSTRACT

Opening-encounters are an integral element of social interaction and are essential for social relationships. Specifically, opening-encounters between strangers form a complex social context and often involve awkwardness and tension. We explored whether augmenting everyday objects with autonomous capabilities can facilitate an opening-encounter between strangers. A pair of robotic bar-stools were designed to rotate participants sitting on them. We evaluated the opening-encounter experience in three conditions: bar-stools rotating participants towards one another; bar-stools rotating participants away from one another; and bar-stools with no rotation. Our initial findings indicate that rotating participants towards each other led to positive encounters, encouraged social interaction, and increased interpersonal communication. The other two conditions were less likely to initiate social interactions. This preliminary study highlights the potential of facilitating positive opening-encounters using autonomous furniture that are perceived as a natural part of the interaction, without altering its human-human nature.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative interaction**.

KEYWORDS

Human-Human-Robot Interaction; Non-humanoid Robots; Opening Encounters; Robotic Furniture.

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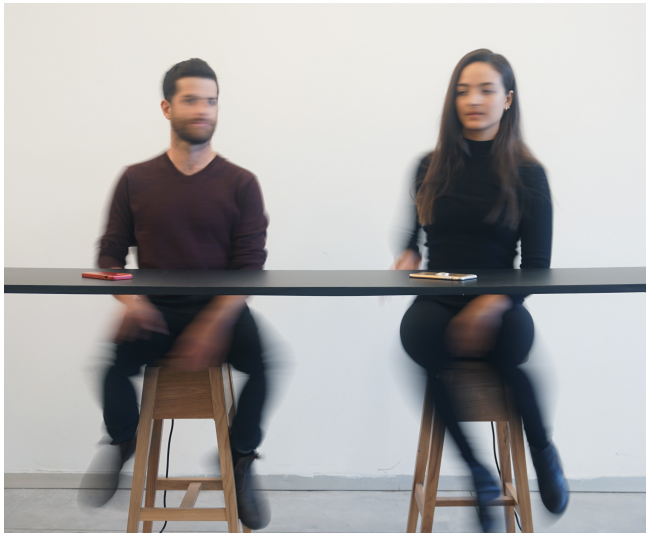

Figure 1: The robotic bar-stools, designed for facilitating human-human interaction in the context of an opening-encounter

1 INTRODUCTION

Human-robot Interaction (HRI) studies indicate the potential of integrating a robot in Human-Human Interactions (HHI) [5, 21, 27]. These studies suggest that robots can significantly enhance HHI in different contexts including human-human conversation [21], group dynamics [27], family dynamics [6], and even in intimate emotional-support interactions [5]. Together these studies point to the great potential of using robots for facilitating HHI.

One important and yet challenging type of HHI is an opening-encounter with a stranger (i.e., the initiation of interpersonal communication, [4]). It involves assessment of willingness for social interaction on both sides [1]. This assessment will often influence the

likelihood and course of following interactions. Positive opening-encounters can lead to prolonged social interactions, while negative ones can lead to avoidance of following interactions [13, 22]. Reaching a positive encounter with a stranger requires complex acts of social exchange that are often difficult to teach. Individuals often experience tension and awkwardness. Even when there is a mutual willingness to interact, initiating a social interaction with a stranger is difficult for many individuals [15]. Considering previous indications that robots can facilitate HHI, it is possible that integrating robots in opening-encounters between strangers would assist in overcoming the challenges associated with such interactions and lead to positive experiences. However, a robot may alter the human-human nature of the interaction by becoming an additional active participant [18]. Previous studies indicated that robots integrated in HHI may actively lead the interaction or become mediators between the humans [17]. This suggests that integrating a robot into HHI may capture the humans' attention and divert it from the subtle social cues that are required for establishing positive opening-encounters.

In an effort to preserve the human-human nature of the interaction, several studies employed non-humanoid robots [5, 21, 27] that are not perceived as an additional participant in the interaction [5, 27]. As opposed to humanoid robots that take an active role within the interaction, non-humanoid robots leverage simple physical gestures as their primary communication modality. Such simple robotic gestures have been shown to influence and enhance the interaction between humans without becoming part of the interaction itself [9]. However, despite the peripheral nature of robotic objects, they are not embedded as a natural part of the HHI environment.

To preserve the natural environment of human-human opening-encounters, there is an underexplored opportunity in adding autonomous capabilities to everyday objects. Previous studies have already evaluated interactions with furniture and various household objects. These studies typically evaluate interactions between one robot (i.e., autonomous furniture) and one human. Their findings indicate that participants attribute intent to the robotic furniture and perceive the interaction as a positive experience [10, 14, 23–25]. Only a few projects explored the integration of autonomous everyday objects in the context of HHI. For example, Kinch et al., (2014) and Grönvall et al., (2014) evaluated the effects of an autonomous bench that was designed to change its shape once two strangers sit on it. The exceptional and unexpected movements of the bench initiated a conversation between strangers. However, the movement did not provide grounding for a broader social interaction on topics that were not related to the movement of the bench [8]. Similarly, Takeuchi and You (2014) presented a design concept of facilitating social interactions in an urban setting using kinetic furniture with adaptive affordance. They suggested that the furniture's position can impact interactions between humans [26]. Such experiences and design concepts were consolidated by Mitchell and Olsson (2019) into three design guidelines for supporting opening-encounters : (1) Automating the first move; (2) Ambiguity of first move; and (3) Deflecting from the first move [16].

In this study, we explored if autonomous furniture can facilitate an opening-encounter between two strangers. Specifically, we fabricated a pair of robotic bar-stools that were naturally embedded in the HHI environment (see Figure 1). We used the opening-encounter guidelines suggested by Mitchell and Olsson (2019) [16] to design their autonomous behavior that involved a minimal rotation movement (either clockwise or counterclockwise). Participants without previous acquaintance were asked to take a seat on the bar-stools while waiting for an experiment. The bar-stools' movement was designed to serve as a cue for initiating HHI, without becoming the center of interaction. We evaluated participants' experience when the bar-stools slightly rotated them towards one another or away from one another.

2 RELATED WORK

Relevant work includes the impact of robots on HHI and opening-encounters in HRI (where one human interacts with one robot).

2.1 The Impact of Robots on HHI

Previous studies indicate that integrating robots in HHI can have both positive and negative influences on the humans' perception of one another and on their interpersonal communication [5, 11, 12, 21]. For example, Tennent et al. (2019) introduced Micbot, a non-humanoid robot designed as a microphone and integrated into a group discussion. The robot's movements towards passive group members increased engagement and improved the group's problem-solving performance [27]. Another positive influence was indicated by Rifinskli et al. (2021) that implemented a non-humanoid robot in the context of a human-human conversation. The non-verbal gestures of the robot raised participants' attentiveness towards the other participant, resulting in higher ratings of interpersonal communication and perception of the conversation quality [21]. Similarly, in the context of intimate HHI, Erel et al. (2021) showed that the same robot enhanced the quality of an emotional support interaction when designed to perform empathy-related gestures [5]. Studies have also indicated that integrating a robot in HHI can lead to negative effects. Jung et al. (2018) integrated a robotic arm in an HHI that involved a collaborative task (building a wooden tower). The robotic arm was responsible for distributing resources (wooden blocks). When the robotic arm distributed the blocks unequally, participants' evaluation of one another was significantly lower despite the collaborative nature of the task [11]. More generally, Palinko et al. (2018) indicated that a robot's non-verbal gestures are perceived as appropriate communication cues when integrating a robot in an HHI [19].

We extend this line of studies by testing the influence of robotic furniture in the specific context of opening-encounters between strangers, an important yet challenging human-human social interaction.

2.2 Opening-encounters in HRI

Previous studies indicated that opening-encounters are also important when one human interacts with one robot. These studies suggest that it is possible to design opening-encounter experiences even with simple non-humanoid robots that communicate via non-verbal gestures. For example, Anderson et al. (2018) showed that an abstract non-humanoid robot designed as a ball rolling on a dome was successful in communicating positive and negative social cues in the context of an opening-encounter between a human and the

robot. Participants interpreted the robot's movements (direction of the ball on the dome) as indicating the robot's willingness or unwillingness for interaction [1]. Similarly, Sirkin et al. (2015) showed that the movements of a mechanical ottoman were perceived by participants as social cues. Their findings suggest that indirect and curved movements towards the participants were perceived as intent to interact [23].

While these studies show that it is possible to design opening-encounters with robotic objects and everyday objects, in the current study we explore the possibility of leveraging the movement of such robots for facilitating opening-encounters between two humans (and not between a human and a robot).

3 DESIGN AND IMPLEMENTATION

Following the approach of designing robotic movement into everyday objects and specifically furniture [14, 23, 24], we augmented a pair of bar-stools with the ability to rotate participants' sitting orientation. In each stool, we integrated a stepper motor that was connected via a chain to a gear that was attached to the stool's sitting area. We chose a 4:1 gear ratio to enhance the torque of the motors. In addition, we integrated a microcontroller to control the stepper motors at a predefined speed and acceleration towards the designated direction. The motors were hidden underneath the sitting area (see Figure 2) to maintain their natural look as bar-stools. The bar-stools' movement was triggered through a wireless connection using a Wizard-of-Oz (WoZ) technique, a common method in HCI (e.g., [17, 20]. The researcher sent commands to the microcontrollers and directed the movements of the autonomous bar-stools to the designated direction, according to the experimental condition.

We designed the bar-stools' movement to follow the principles presented by Mitchel and Olsson's (2019) for facilitating human-human opening-encounters: Automating the first move and Ambiguity of the first move. The third principle, Deflecting from the first move, was less relevant due to the wish to maintain a natural environment. To automate the first move, the bar-stools were designed to perform two types of synchronized rotations, Approach and Avoid. In the Approach movement, the bar-stools rotated towards one another (right bar-stool rotates counterclockwise and left bar-stool rotates clockwise). The rotation direction was designed to mimic humans' natural movement indicating willingness for interaction in the context of an opening-encounter. In the Avoid movement, the bar-stools rotated in an opposite direction from one another (right bar-stool rotates clockwise and left bar-stool rotates counterclockwise). The rotation direction was designed to mimic humans' natural movement indicating unwillingness for interaction in the context of an opening-encounter. In both cases the movement was designed to be gradual and lasted 4-seconds, which was indicated in a pilot study as fast enough to be noticed without intimidating the person seated. To maintain ambiguity, we decided to use bar-stools with no backrests, allowing participants to resist the bar-stools' movement and easily return to the original position. In addition, the final angle of the bar-stools was determined in the pilot study at 45°, which was perceived as a *suggestion* for initiating (or terminating) an interaction rather than forcing one.

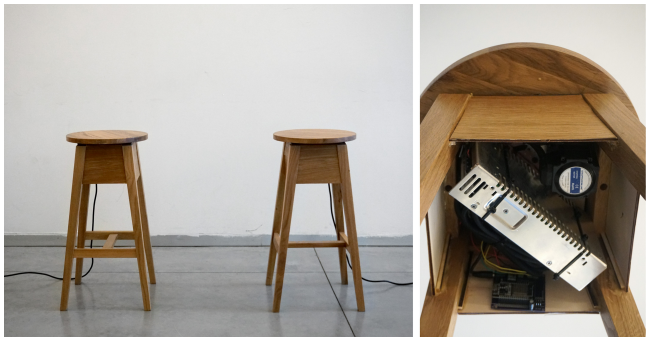

Figure 2: Left: A pair of robotic bar-stools. Right: The motors, gear, and microcontroller hidden within the inner side of the bar-stools

4 METHOD

To enhance an opening encounter, we leveraged common non-verbal cues indicating willingness for social interaction. In the specific situational context we created, the relevant social cues involve participants turning towards one another. In order to gain preliminary insight into the impact of the robotic bar-stools' movement on opening-encounters between strangers, we conducted a study with nine pairs of participants. The study was held under strict COVID-19 safety regulations and was approved by the university's ethics committee.

4.1 Participants

18 undergraduate students from the university participated in the study (9 males, 9 females, mean age = 22.4, SD =2.5). They received bonus course points for their participation. We verified in advance that participants had no previous acquaintance. Participants were randomly assigned to one of the three conditions and to either single gender pairs or mixed gender pairs (in each condition: male-male; female-female; female-male).

4.2 Experimental Design

The between-participant experimental design included three conditions with varying bar-stools movements. In the *Inward* condition the bar-stools performed the Approach movement turning the participants towards one another. In the *Outward* condition the bar-stools performed the Avoid movement turning the participants away from one another. In the *Baseline* condition the bar-stools did not perform any movement (see Figure 3).

4.3 Measures

4.3.1 Observation. Two variables were coded for identifying trends in the participants' behavior:

Social interaction: The number of participants who engaged in verbal and non-verbal social interaction was coded based on a strict protocol and included behaviors related to interpersonal communication (e.g., smile towards the other person and direct conversation) [4].

Acceptance of the bar-stools' movement: The number of participants who accepted the bar-stools' movement was coded based on a strict

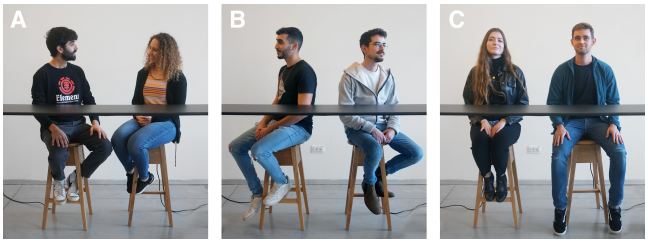

Figure 3: The experimental conditions: Sitting orientation following the autonomous movement of the robotic bar-stools

protocol and included the participants' willingness to move with the bar-stools, in comparison to participants that resisted the bar-stools' movement (i.e., returned to the original sitting orientation).

4.3.2 Interview. The semi-structured interview allowed for flexibility during data collection while remaining grounded in a particular framework [7]. The interview included general questions evaluating the experience (e.g., *"Please describe the experience?"*), specific questions concerning the interaction with the bar-stools (e.g., "*What did you think about the bar-stools?"*), and questions evaluating the perception of the other participant (e.g., *"What did you think about the other participant?"*).

4.4 Procedure

Participants arrived at the lab and were reminded that the experiment is recorded for later analysis and that it is possible to quit without consequences. They were asked to sign a consent form and complete a demographic questionnaire in a "waiting room", before the actual experiment took place. The "waiting room" (see Figure 4) was set up with a bar table and the two bar-stools that were placed next to it. The distance between the bar-stools was set at 76 cm, as this is considered a comfortable 'conversation distance' [3]. A set of questionnaires was placed on the table in front of each bar-stool. Each participant took a seat on one of the bar-stools and began to complete the questionnaires. The participants were not introduced to each other and had no time for a conversation before entering the room. The researchers viewed the experience from a control room through a camera and used the WoZ application to trigger the bar-stools' movement according to the conditions: *Inward*, *Outward*, and *Baseline*. In the experimental conditions, one of the two movements (Approach or Avoid) was triggered after both participants completed the questionnaire. In the *Baseline* condition no movement was triggered. In all conditions, the researcher entered the room 5-minutes after the participants completed the questionnaires. Then, a semi-structured interview was held with each participant separately in a different room. At the final stage of the experiment, the researcher debriefed the participants and verified that they left with an overall positive experience.

5 ANALYSIS

The interviews were analyzed using thematic coding [2] that included 5 stages: (1) Interviews were transcribed and read several times to develop a general understanding of the data; (2) Initial themes were identified separately by two coders and discussed until inconsistencies were resolved; (3) A list of mutually-agreed themes was defined; (4) The raters used these themes to analyze half of the data independently, verifying inter-rater reliability (kappa=87.5%); (5) The rest of the data was analyzed. The observations' variables were coded from the videos based on a strict protocol that focused on the interpersonal communication between the participants and their social interactions.

Figure 4: Experimental room with a bar table and the two robotic bar-stools

6 FINDINGS

6.1 Observation

The variables coded in the observation indicated the influence of the robotic bar-stools' movement on the HHI in the opening-encounter. Due to the preliminary nature of the work and the low number of participants, we did not conduct significant tests that should be conducted in future work (i.e., Chi square analysis).

6.1.1 Social interaction. All participants (6/6) in the *Inward* condition engaged in a social interaction that was initiated by the bar-stools' movement. The interactions involved non-verbal cues (e.g., smiles) and verbal conversations. All social interactions lasted until the researcher entered the room. In the *Outward* condition only 2/6 participants engaged in a social interaction. In both cases the interaction was initiated before the bar-stools' movement and was interrupted as a result of their movement. In the *baseline* condition 2/6 participants engaged in a social interaction. The interactions ended when the researcher entered the room. The rest of the participants (4/6 in the *Outward* condition and 4/6 in the *baseline* condition) did not interact with one another and remained silent until the researcher entered the room.

6.1.2 Acceptance of the bar-stools' movement. In the *Inward* condition all of the participants (6/6) accepted the bar-stools' movement and remained in the final orientation of the bar-stools (facing each other). In the *Outward* condition only 2/6 participants accepted the bar-stools' movement and remained in their final orientation.

6.2 Interview

The interview analysis revealed three themes: "Social interaction between participants", "Perception of the other participant", and "Bar-stools' intent".

6.2.1 Social interaction between participants. In all conditions participants discussed the presence or the lack of social interaction with the other participant. Their description varied between conditions. All (6/6) of the participants in the *Inward* condition described the interaction as a positive experience: *"We had a small talk. It was nice"* (P.15; Male). 4/6 participants also explicitly mentioned how the rotation of the bar-stools changed the nature of the interaction: *"After the bar-stools moved I felt encouraged to talk, it was easier to start a conversation"* (P.7; Male). They described how the movement motivated conversation: *"I didn't pay attention to her at first but when the bar-stools moved we laughed and started talking"* (P.2; Female) and served as an "ice breaker": *"Two strangers sitting in a room, its embarrassing. As soon as the bar-stools moved us toward one another we started to talk and it was really nice"* (P.7; Male). One participant also emphasized a sense of connection: *"When you look into someone's eyes, something special happens. No matter who was sitting next to me, even if it was my enemy, you feel a sort of a connection. It frames the situation as something you can't ignore. You have to either look or talk and we choose to talk"* (P.8; Female).

Only 2/6 of the participants in the *Outward* condition mentioned the interaction with the other participant. One participant described the interaction as a positive experience: *"We spoke a little, it was nice"* (P.11; Male). The same participant mentioned how the rotation of the bar-stools changed the nature of the social interaction: *"It was a gentle movement. It took out the eye contact. It switched the conversation subject"* (P.11; Male). Another participant mentioned that the movement of the bar-stools terminated the social interaction: *"When the chair moved it stopped"* (P.6; Male).

4/6 of the participants in the *Baseline* condition mentioned the interaction with the other participant. All of those participants described minimal social interactions: *"There wasn't much interaction"* (P.18; Female). Other participants mentioned the awkwardness of the situation: *"We started talking because it was quiet and awkward"* (P.9; Male); *"In the beginning it was a bit weird until one of us started talking"* (P.13; Female).

6.2.2 Perception of the other participant. Participants in all conditions described their thoughts about the other participant. Their description varied between conditions.
3/6 of the participants in the *Inward* condition described the other participant in a positive manner: *"He was nice"* (P.16; Female); *"She is very cute and seems like a really nice person* (P.7; Male); *"He was very friendly and nice"* (P.8; Female).

4/6 of the participants in the *Outward* condition shared their perception of the other participant. One of them described the other participant in a positive manner: *"She was very cute"* (P.11; Male), two others described the other participant in a neutral manner *"I didn't think anything of him"* (P.5; Male), and one participant described the other participant in a negative manner: *"He was on his own. Very focused on himself"* (P.3; Female).

3/6 of the participants in the *Baseline* condition shared their perception of the other participant. One of those participants described the other participant in a positive manner: *"She was nice"* (P.14; Female). The other two participants described the other participant in a neutral manner: *"He is fine. Nothing really to say"* (P.18; Female).

6.2.3 Bar-stools' intent. In the *Baseline* condition there was no mention of the bar-stools' intention.
3/6 of the participants in the *Inward* condition described the movement of the bar-stools as an entity trying to facilitate an interaction between the participants: *"It moved me towards the other person. It wanted us to interact"* (P.16; Female); *"It wanted us to face each other"* (P.15; Male).

4/6 of the participants in the *Outward* condition described the movement of the bar-stool as an entity trying to diminish or prevent interactions: *"I felt like it was trying to make us avoid one another and stop the conversation"* (P.6; Male). They perceived the movement of the bar-stool as explicit intent: *"I was thinking maybe I should stop the conversation because I felt that this is what the bar-stool wanted"* (P.11; Female); *"It felt like someone is putting me back to back with another person and it's not my intention"* (P.12; Female).

7 DISCUSSION

In this study, we explored the possibility of facilitating an opening-encounter between strangers by augmenting everyday furniture with an autonomous movement. We specifically chose robotic bar-stools that can be naturally embedded in an HHI and evaluated if their movement can assist in overcoming the challenges associated with opening-encounters between strangers. We leveraged the stools' movement and created a social context that indicates willingness for interaction, by turning the participants towards one another at the exact same time. Our findings indicate that the robotic bar-stools have the potential to increase the frequency of opening-encounters and lead to a positive experience. Specifically, in the *Inward* condition, where the bar-stools rotated participants towards one another, the movement was perceived as a cue for initiating HHI which reduced the situation's awkwardness and served as an *"ice breaker"*. In the *Outward* condition, where the bar-stools rotated participants away from one another, the movement was perceived as interrupting or preventing the interaction. The baseline condition revealed only minimal and "awkward" interactions between the participants.

These preliminary findings indicate that robotic bar-stools performing minimal movement have the potential to impact opening-encounters. Our findings support Mitchell and Olsson's (2019) design principles: Automating the first move and Ambiguity of the first move. Implementing an automated first move (by the bar-stools) promoted participants to engage in a social interaction and led to a positive experience. Moreover, participants mentioned that the rotation of the bar-stools shifted a challenging and sometimes awkward situation into a fun social experience. In addition, implementing ambiguity and merely suggested cues for social interaction (by lack of backrest and a mild rotation angle of 45 °) enabled participants to resist the stools' movement when needed.

Interestingly, while participants described the movement of the bar-stools as representing intent, the observed social interaction between participants did not focus on the bar-stools, or their movement. In fact, only once the interview started, participants realized that the movement of the stools was the core of the experiment. In

some cases, the bar-stools were not even mentioned in the social interaction that was initiated following their movement: *"By the way, what's your name?"* (P.7; Male; *Inward* condition). In addition, none of the participants in the experimental conditions stood up or felt uncomfortable sitting on the bar-stools during or after the movement.

Taken together, our findings suggest some insights for practitioners and designers. First, when designing autonomous everyday furniture for enhancing natural HHI in the context of opening-encounters, there is an opportunity in leveraging everyday objects that are perceived as an integral part of the social context (e.g., bar-stools, benches, and table-maps). Such objects are inherently embedded in opening encounters that are often characterized by awkwardness. Second, there is an opportunity in integrating autonomous behavior of such objects that trigger social cues indicating willingness for interaction (e.g., turning people towards one another, leading to mutual eye gaze, etc.). Importantly, opening-encounters with strangers can be also ethically sensitive. In some cases people may wish to avoid interactions with strangers and even a minimal suggestion for initiating an interaction can be perceived as intrusive and forceful. Future studies should further explore the acceptance and likeability of such minimal encouragement for interaction by autonomous everyday objects.

Several other aspects should be further investigated. First, various characteristics of the movement of the robotic bar-stools, including the timing of the movement (when they begin to rotate), their speed, final position, and synchronization (i.e., both robotic bar-stools rotation together vs. one robotic bar-stool rotates while the second robotic bar-stool is fixed). Second, the characteristics of the participants' including their personality, mood, and need for social interaction. Third, the characteristics of the social context, including situations where there is a need for initiating a social interaction (e.g., when people are interested in an interaction but are too shy to initiate it) and situations where the social interaction should be interrupted (e.g., when there is a need to take a time-out in an escalating conflict).

8 CONCLUSION

In this study we explored the potential of autonomous furniture in facilitating a social interaction between two strangers in the challenging context of an opening-encounter. Our findings suggest that the autonomous movement of the bar-stools, rotating participants towards one another, resulted in positive encounters that preserved the human-human nature of the interaction.

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