International Journal of Social Robotics
https://doi.org/10.1007/s12369-018-0509-0

Multiple Communication Roles in Human–Robot Interactions in Public Space

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Accepted: 30 November 2018

Abstract

This study looks at robots as media and aims to explore the multiple communication roles that they can play in public space. We have analyzed three scenarios: European Researchers' Night in Pisa; the inauguration of the University of Udine's 39th academic year; and the official video of the inauguration in Udine. These three scenarios represent three types of media interactions. The first is a human–robot interaction based on a one-to-one or circular communication model; the second is a robot–human interaction based on a one-to-many communication model in-presence; and the third is a robot–human interaction, based on the classical one-to-many communication model mediated through a television screen. Results show that public patterns of behavior toward the robot tend to replicate the ritualization of encounters between humans in the one-to-one model, and audience rituals in public events toward human characters in the one-to-many model. Second, greater proximity and familiarity with the robot increases the respondents' positive evaluations of all the aspects of the interactions. These results are in line with results coming from research on Information and Communication Technologies (ICT) use.

Keywords Human–robot communication · Robot–humans communication · Robots as public figures · Public interaction with social robots · Robots in public space · Robots' multiple communication roles

1 Introduction[1]

The industrialized world is shifting from industrial to social robotics. While industrial robots were limited to operating in private and regulated spaces (e.g., factories with specialized workers), social robots are expected to become part of private and public spaces (e.g., dealing with human care, domestic tasks, or entertainment) [1]. Research on robot acceptance shows that people view robots as animal-like in many ways [2], expect them to engage humans in the future [3], or expect them to lack affect and be outside human control [4]. Since actual encounters with social robots have so far been limited, Stafford and colleagues concluded that people's ideas about robots "may originate from exposure to robots in the media, including books, television, film, and news reports, which often exaggerate the capabilities and dangers of robots" [5, p. 28, 6].

In the present study, we take a different stance and consider robots as embodied media, which are already used in movies, television programs, and in public spaces, which nurture our expectations, understanding, and evaluation of robots, as well. Extending what Zhao pointed out—that robots "are not a medium through which humans interact, but rather a medium with which humans interact" [7, p. 413]—this paper posits that robots are media that serve many interactive purposes in public spaces. First of all, robots can interact with other robots. Second, they are already able to trigger communication with humans in multiple ways. Third, they

[1] An early version of this study was presented at the conference Foritaal (Italian Forum 2017: Ambient Assisted Living) 14–15 June 2017, Genova.

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enable people (and are used) to interact and communicate with other humans in the public arena. Furthermore, robots can communicate with a large audience or even convey mass communication through television or radio channels, or new media like the Internet, depending on their features. Their presence in public spaces thus requires going beyond one-to-one communication models to consider one-to-many models.

Few studies have addressed the use of robots in the public space [8–11], with a focus on their use in museums or shopping malls. The present study contributes to this field by exploring three communicative uses of robots in public contexts. We examined two occasions in which robots have been used in public: a scientific exhibition in a public square and a ceremony in an institutional building. As a third element of comparison, a video of the ceremony including human–robot interaction was displayed to a restricted audience, similar to what happens on television.

This study was inspired by previous research we carried out, funded by the Robot-Era project (http://www.robot-era.eu), in which three robots—DORO, CORO and ORO—were designed and developed to provide assistance to elderly people from the street to the home with the deployment of a domestic, condominium, and outdoor robot [12]. In the present study, we brought one of these domestic robots, "DORO", to two different public events occurring in Pisa and Udine. These events in Pisa and Udine concerned academic and scientific life and thus they may have been biased in terms of audience involvement and expectations. Nevertheless, they provided contexts for observation, which could help to reflect on how robots are perceived "outside the lab" and what potential they have for communication. In the next section, we present the theoretical reflections that guided the analyses of the three communicative contexts examined.

2 Theoretical Perspective on Human–Robot Interaction and Communication

Human–robot interaction is generally studied through a one-to-one model between a human and a robot. Höflich [13], drawing on Max Weber, posited that, differently from human–human interaction, human–robot interaction cannot take upon to be based on "reciprocal meaningful behavior". Thus, this interaction can be defined as based on a quasi-interpersonal and quasi-social relationship or, as proposed by Krotz [14], on a pseudo-social relationship. In this interaction, the robot, as second interlocutor, is not seen as a sensomotoric or autonomous machine, but as a communication agent. We add that, in contrast to the dyadic model that involves two humans and represents basically the most equal and democratic form of communication between individuals, the model that involves a human and a robot denotes a less equal form of communication. A robot usually has less advanced communication abilities than a human being (e.g. less language competence and lack of non-verbal language), whereby the power relationship between them is disproportionately in favor of the human (also in the present research a robot is seen by some children as a child younger than them or as disabled). However, as in any master–servant relationship, the one who has less power (the robot) does express some forms of power toward humans, as it obliges them to reshape their language and attitude in the interaction. As Krotz [14, p. 160] argues, the efficacy of communication between a human and a medium is achieved when human beings are willing to adjust their behaviors to the inadequacies of the medium.

In order to grasp this dynamic, we argue with Höflich [13] that the theory of media equation, which suggests that people treat media as if they were real people [15], is applicable also to robots. Several studies have shown that people tend to treat social robots as if they were people [16]. This theory has also inspired some recent juridical elaborations. In 2016, a resolution of the European Parliament (A8-0005/2017) established that it is necessary to create "a specific legal status for robots in the long run, so that at least the most sophisticated autonomous robots could be established as having the status of *electronic persons* responsible for making good any damage they may cause, and possibly applying electronic personality to cases where robots make autonomous decisions or otherwise interact with third parties independently" [17, p. 18] (our emphasis) [18]. Another step in the normalization of treating social robots as true persons is the fact that on October 25, 2017 at the Future Investment Summit in Riyadh, the social robot named Sophia was granted Saudi Arabian citizenship. Sophia has become the first robot ever to have a nationality. Although this decision aroused several controversies in the media [19, 20], here it suffices to stress the importance of this decision in strengthening the concept that social robots are increasingly assimilating to the category of people.

However, for this study Höflich's model is even more interesting. Höflich proposes to widen the usual dyadic model of human–robot interaction with a triadic model, which considers social robots to be mediators "between two persons or between a person and his or her environment" [13, p. 36]. Such a triadic model implicitly accords to social robots the status of a real or imagined "other", which is able to shape humans' perception of the environment, including other human beings or themselves. The triadic model allows us to shed new light on the impact that social robots will have on our societies, as was expressed in the definition proposed by Fong et al. [21, p. 144], who regard social robots as "embodied agents that are part of a heterogeneous group: a society of robots *or* humans" (the italics are ours). The more social robots live within human societies, the more these will become hybrid, insomuch as they will include artificial agents. Thus, we propose to modify the last part of Fong et al.'s definition, and to revert to an even older vision of "a society of robots *and* humans" [22, p. 366].

The triadic model of human–robot–environment interaction, and the inclusion of robots in the public arena, introduces new issues that require a further expansion of Höflich's model in order to consider more comprehensively the various forms of human–robot interaction and to take better advantage of the theories elaborated so far on communication in the public arena. Examining robots in the public space thus requires to illustrate some of the social and communicative features of the public sphere itself.

Scholars sharing the social representations theory have largely theorized on the triadic self-other-object relationship and on the intertwining between communicative encounters and the public sphere. Drawing on this theoretical tradition, Jovchelovitch and Priego-Hernández [23, p. 164] suggested considering the political, spatial, and social psychological dimensions of the public spheres. The political dimension plays a role in the public arena for the exercise of institutionalized debates and critical opinions. Spatially and psychosocially, public arenas are "public places where people come together mediated by the natural and/or built environment, which operate as enablers of physical circulation and communication" and "spaces of mediation and communication, where self and other come together in a variety of forms to create identity, representations and imaginations".

Other sociological traditions stress that the public space is the social arena in which encounters take place and where people expose themselves to others. To use a theatrical metaphor, the place constitutes the front stage [24], where people present and represent themselves to the others, play social roles, communicate, and provide information about themselves and their intentions, but also convey other information unintentionally. Public life implies a network of expectations and actuations regarding social practices as well as controlled and formal actions, which correspond to socially defined etiquette and behavioral appropriateness [25]. Public space is also regulated by laws, norms, and institutionalized values, by daily routines and rituals, by cultural, social and political content, and meanings. Public places, moreover, are relevant for defining citizenship and belonging. "Public spaces are the natural arena of citizenship, where individuals, groups, and crowds become political subjects. They are socio-physical settings where public life occurs on the basis of open visibility, scrutiny, and concern, supporting public interest and citizens' well-being" [26, p. 124]. In this sense, we may also say that public space has a particular feature of safety, because it conveys a sense of protection from the risks of the unexpected [27].

If robots have to enter our social and public arena, political, spatial, and communicative features have to be considered, and their role should be examined taking into account roles, power, and intergroup relationships that shape our everyday public interactions. From a communicative perspective, it means that Höflich's proposal [13] can be further expanded by including other models of communication: one-to-many, intra-group, and many-to-many. Robots, in fact, can address a live audience or via a media source. For example, robots can become the protagonists of a television show, as the robot iCUB did April 27, 2016 in the Italian version of the program "Got Talent", or of a theatrical piece, such as Robo Thespian in "Spillikin", addressing large audiences in the theater and watching the show on television. This model of communication is more similar to the mass media communication model for antonomasia than, for example, the interactive communication model typical of the Internet. Group communication and many-to-many models are also necessary to analyze the penetration of social robots in the reproduction sphere [28], where they inevitably mediate the life of the family group. Other examples are when a social robot enters a classroom, a health service, or in a rescue operation in which it becomes a member of the team [29]. The interaction here takes place within a group including a robot and some humans. In other circumstances, the interaction can take place between a human and several robots. This could be the case if a human interacts with a series of networked robots, as will probably be the case in homes of the future combining domotics and robotics. Concerning the new many-to-many communication model, this can help us to explain the flow of communication that takes place between bots and Internet users [30]. More recently, Bicchi and Tamburrini [31] introduced another model of communication regarding robot–robot interaction, in which the communication takes place only among robots. This can include, for example, a group of robots introduced in a museum or in a shopping mall to patrol the buildings during the night and that has suggested to these two scholars the metaphor of a society of robots.

In sum, social robots should be seen as complex and mobile communication hubs [13, p. 37], who—entering public space—have to deal with the complex, communicative, and relational *dispositif* of public space.

This raises several questions: How can the robot enrich the communicative settings offered by the public space? Do different degrees of physical distance implicate different forms of interaction between people and the robot? And if yes, what are the features that characterize each situation in terms of communication? How should the robot be experienced so as not to undermine the sense of safety that the public space conveys? In order to explore these questions in the present study we examined them in two different contexts: the square in Pisa and the University auditorium in Udine. These had not only different spatial features, but also the stages of different typologies of interactions (i.e. the political and psycho social components of public spheres): an open encounter between science and citizens happened in the former, whereas a highly ritualized ceremony involving authorities and cultural elites was held in the latter. Furthermore, we also explored the situation in which people were separated from the robot by a screen, thus equating to the television public.

3 Aims and Methods

3.1 Aims

The aim of this paper is to conceptualize the different forms of human–robot interactions by exploring them in the public space. In particular, drawing on our conceptualization of social robots as media and on the extension of Höflich's proposal [13], our operational objective is to collect, examine, and compare results emerging from one-to-one, one-to-many, and mediated one-to-many communication between humans and a social robot (DORO).

3.2 Method

3.2.1 The Social Robot DORO

The robot used during the events is DORO (Fig. 1), which presents the following dimensions: (for $W \times L \times H$) $610 \times 735 \times 1550$ mm, a weight of 65 kg, can reach a maximum speed of 1.4 m/s, and has an autonomy of 16 h. DORO was previously developed and tested for domiciliary social assistance in active and healthy aging applications [32]. This robot was developed on a SCITOS G5 platform (Metralabs, Germany) and safely navigated in the environment with the use of front (SICK S300) and a rear (Hokuyo URG-04LX) laser scanners. The navigation stack relied on CogniDrive, a proprietary software of MetraLabs, and it was linked to ROS middleware, used for the development of all the software. DORO was also conceived to provide support to people with an integrated robotic arm (Jaco, Kinova, Canada) for object manipulation, a tray for the transportation of objects, and a handle for walking support. Furthermore, both visual and auditory feedback were provided to the user via multicolor LEDs mounted on the robot's eyes, speakers, and graphical user interface (GUI) on a removable tablet. Particularly, the human–robot interaction capabilities were implemented by means of a Multi-Modal User Interface (MMUI), composed of two main modules: the Web Interface Server that included the graphic user interface (GUI) and the text-to-speech (TTS) software; the Dialog Manager that implemented the Speech User Interface (SUI) with the Automatic Speech Recognition (ASR) software (Nuance SDK) [33].

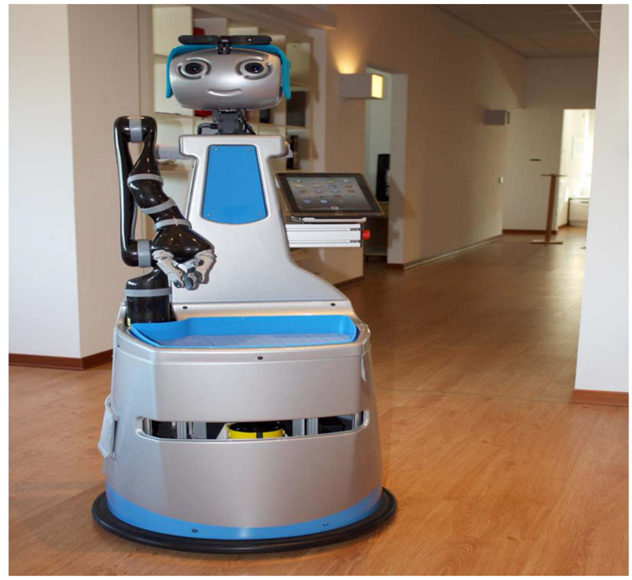

Fig. 1 The social robot DORO

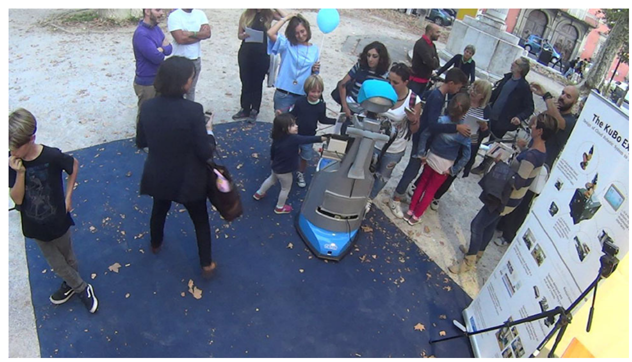

Fig. 2 DORO at the European Researchers' Night in Pisa

3.2.2 Participants and Procedure

Three studies were conducted live in Pisa and in Udine and in an ecological setting in Pordenone.

Each situation corresponded to one form of human–robot communication in a public space:

- *One-to-one* The European Researchers' Night is an event that universities in Europe organize every year in order to communicate to citizens about, and involve them in, the scientific discoveries they produced. In this case, we brought DORO in the Martiri della Libertà square in Pisa (Italy), a mid-sized city in central Italy, where Sant'Anna School prepared a display counter with the robot DORO. The robot was programmed to perform two actions: gently take a bottle of water and hand it to bystanders (it is a very simple and repetitive gesture) and manage some dialogues with those who tried to talk to it (Fig. 2).

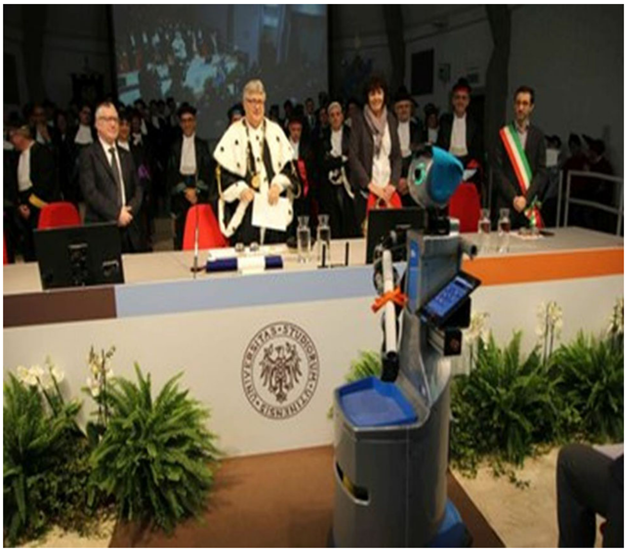

Fig. 3 DORO in the opening ceremony of the 39th anniversary of the academic year, in Udine

- *One-to-many in co-presence* DORO was brought into the opening ceremony of the 39th anniversary of the academic year in Udine, which took place in a public building. In this context, the researchers did not foresee interactions with the entire audience, but only with the authorities on the stage. DORO interacted with the vice-chancellor of the University of Udine, bringing him the text of his inaugural lecture and then exchanging a short dialogue with him, while a large audience viewed this interaction (Fig. 3).
- *One-to-many, mediated* The video of the opening ceremony was shown on screen to a heterogeneous group of people in a different location, Pordenone, a city near Udine.

The participants in Pisa consisted of all individuals who approached the stand with the robots, organized by the Scuola Sant'Anna, in the 3 h in which it remained open, while in Udine they consisted of all the people who attended the ceremony. In Pordenone, the convenience sample was selected with a snowball technique and these participants did not receive any reward for their time. In the three contexts, we conducted semi-structured interviews, which were integrated by observation of the direct interaction with the robot in Pisa, the reaction of participants watching the on-stage interaction in Udine, and the reactions of spectators while watching the video in Pordenone.

3.2.3 Semi-Structured Interviews

In Pisa, everyone who approached the stand with the robots in the 3 h in which it remained open were asked if they would like to participate to a small interview. In Udine, participants who assisted in the ceremony were approached at the exit. People who agreed were submitted to a short semi-structured interview. In Pordenone, interviews were conducted with a convenience sample of university students to whom the video of the inauguration was shown. Interviews were conducted by trained research assistants.

Interviewees were N = 49 in Pisa, N = 51 in Udine, and N = 74 in Pordenone. As to gender, in Pisa males were 24 and females 25 (49.0% vs. 51.0%); in Udine, males were 23 and females were 28 (45.1% vs. 54.9%); and in Pordenone 34 and 40 (45.9% vs. 54.1%), respectively. Age (range from 8 to 80 years) was recoded into three broad categories: youth (8–24 years, N = 61, 35.1%); adults (25–49 years, N = 60, 34.5%); and elderly (50 and more, N = 52, 29.9%). As to education, the majority of participants had college or higher degrees (often a PhD) in Pisa and Udine, compared with Pordenone, where participants were university students. However, the application of the Chi square test did not show significant differences regarding these socio-demographic variables among the three groups of participants (as to gender: $\chi^2 = .170$, df = 2, $p =$ n.s.; as to age: $\chi^2 = 6.345$, df = 4, $p =$ n.s.; as to education: $\chi^2 = .997$, df = 2, $p =$ n.s.).

All interviewees declared interest in scientific discoveries, when asked on a ten-point Likert scale: "How much are you interested in scientific discoveries?" Answers were polarized, and respondents were categorized into three groups: those very interested (rates 9–10, 45.1% of respondents), those moderately interested (rates 4–5, 43.0% of respondents) and respondents' not at all interested (rate 0, 9.8% of respondents). Respondents in Pisa and Udine showed higher interest than those in Pordenone. The number of those very interested was 38 versus 19 versus 7; the number of those moderately interested was 5 versus 7 versus 49; finally, those who were not interested were only among the Pordenone respondents (N = 17).

Almost all respondents were also Information and Communication Technologies (ICT) users: 90.8% used smartphones and 93.7% used the Internet.

The areas explored in the interviews are the following:

(1) *Expectations* Discrepancy between the expectations towards robots and the actual robot was investigated by means of a single item, "Did DORO meet your expectations?" (ten-point scale) and the open-ended question, "What did DORO look like compared to the idea you had of robots?"
(2) *Interaction* Quality of the interaction with DORO was investigated with the open-ended question, "What did the dialogue with DORO look like?" and with the single item, "I had the feeling that DORO looked at me in my eyes/at the vice-chancellor in his eyes" (ten-point scale).

(3) *Movements* Quality of the movements performed by DORO was investigated through the open-ended question, "What effect did the movements performed by DORO provoke in yourself?"
(4) *Safety* Perceived safety was explored through an open-ended question, "What would you need to feel safe about a robot moving in public space?" and a single item, "I felt safe about DORO" (ten-points scale).
(5) *Emotions* Emotions toward DORO were investigated with an open-ended question, "What are the three most important emotions felt during the interaction with DORO?"
(6) *Evaluation* Evaluation of robots moving in public space was explored by means of an open-ended question on the expected effects, "What effect would it make a robot moving in the public space?" and by four evaluative items about DORO, including, "How much did you appreciate the presence of DORO in the public space?", "Could it be useful to have a robot that gives information in public space?", "Could it be useful to have a robot that entertains people in public space?", and, "Could the robot be an attraction in the public space?" (ten-point response scale).
(7) *Behavioral intentions* Finally, we investigated behavioral intentions through a single item, "Would you take home a robot like this?" (yes/no).

Data from the closed question were submitted to analysis of variance (post hoc multiple, pair-wise comparisons were performed using the Bonferroni test) and Chi square analysis (and assessment of standardized residuals[2]) in order to examine the role of communication models and socio-demographic characteristics of respondents for each of the examined themes.

Open-ended answers from the interviews were submitted to thematic content analysis in order to identify and compare across groups a few main themes emerging from the data for each of the investigated issues. The analysis was performed by three trained judges. First, the judges acted independently and reduced the open-ended answers to keywords or short sentences, which they thought could represent the perspectives of respondents. These bottom-up categories and expressions were then listed and a comparative effort was jointly conducted by the three judges in order to further categorize the data into a few shared macro categories.

[2] Standardized residuals have been considered in the interpretation of significant differences across conditions in contingency tables (i.e. s.r. > |2|).

3.2.4 Observation and Video

Self-assessment was integrated in Pisa and Udine by non-participant observation of the interactions with the robot (in the robot's presence and supported by video recording). In Pisa, we recorded videos of 39 people (17 males and 22 females) who had an interaction with DORO. By estimation, these people belonged to all the age groups, with a certain concentration of children between 5 and 10 years old. The research team coded the first reactions people had when they found themselves face-to-face with DORO (i.e., the action that took place in the first few seconds), and the subsequent interactions (up to three) that people had with DORO. We also transcribed and qualitatively considered the dialogues that some people undertook with DORO.

In Udine, due to the disposal of the camera, the video we made recorded the reactions of 64 spectators (30 males and 34 females) sitting in the first two rows of the auditorium. Here, the interaction was one-to-many in the robot's presence, and the camera had been positioned for recording the global reactions of the audience.

In Pordenone, participants were not video-recorded due to technical reasons and thus we could limit to non-participant observation of reactions noted while participants were watching the video on a screen.

4 Results

4.1 Semi-Structured Interviews

Semi-structured interviews examined the expectations, perceived quality of interaction and movements, perceived safety, emotions, overall evaluation of the social robot, and intention to bring it home across the three contexts.

4.1.1 Expectations Toward Robot

When asked to express from 1 to 10 to what extent DORO had satisfied their expectations, participants in Udine, Pisa, and Pordenone gave positive ratings: Mean = 7.33 (SD = 1.849), without any significant difference among the three samples or any socio-demographic variables. What is more significant is that their answers to open-ended questions confirm this evaluation and provide further insight into human–robot interaction. Four macro categories were built on the basis of the answers to the question, "What did DORO look like in respect to the idea you had of robots": Similar, More, Less, Different. About 40% of participants in Pisa, Udine, and Pordenone declared that DORO confirmed their idea about robots and everywhere the participants who stated that DORO was more advanced than they believed were more numerous than those who found that this robot was less advanced than they had expected.

In particular, in Pisa, more than one-third of the interviewees found a correlation between the ideas that they had about robots and DORO. Only six people found DORO different from their expectations and 14 clearly stated it overcame their expectations. Their answers gave interesting insights into the type of "other" that robots may become in the public space. DORO was perceived as different, either because it was "more humanoid than I expected" and "more alike human-beings than expected" or because it appeared infra-humanized like "an innocent and asexual child". More than a quarter of the respondents said that DORO overcame their expectations since they found DORO "magic", "genial", and "interesting", but also "a companion" and "funny", suggesting that evaluations were based on relational features. A fifth revealed a delusion regarding DORO's utility, being "rudimentary", "slow", "stupid", and "yet limited in its evolution".

In Udine, answers showing that DORO was "more than expected" were quite numerous and rich in meanings; respondents stated that DORO was "more sympathetic, humanized", "advanced robot autonomous-like, fluid in movements and words," and one person explicitly appreciated its voice. Negative answers confirm its perception as "static", "less technological advanced than robots present on the web", and "not yet evolved".

In Pordenone, the responses were similar to those expressed in the one-to-one communication scenario. It is worth reporting, however, that DORO was compared with objects and cartoons. DORO appeared, for example, different since, "it seems to me a distributor with wheels and audio", "it seems to me to be a beverage distributor", and "it appeared more than expected because it seemed more Bender of Futurama".

According to the Chi square test, however, the differences among the three groups of participants were not significant ($\chi^2 = 10.7$, df = 6, p = n.s.). This means that the expectations about robots are not associated with the communication model.

4.1.2 Perception of the Dialogue with DORO

The perception of the quality of the dialogue with DORO was investigated with the question: "What did the dialogue with 'DORO' look like?" and with the single item, "I had the feeling that 'DORO' looked at me in my eyes/at the vice-chancellor in his eyes".

By analyzing the content of the answers to the first question we built three macro categories: quite satisfactory; unsatisfactory; and ambivalent. Nearly 50% of answers could have been included in the first macro category, with almost a third of the respondents still unsatisfied with the quality of the dialogue and almost a fifth showing ambivalence.

More specifically, results show that almost half of the interviewees in the three contexts perceived their dialogue with DORO in a satisfactory way. These respondents described it as "impressive", "funny", enjoying the dialogue with the robot, appreciating its "naturalness" and "efficacy". In the one-to-many mediated condition in Pordenone, the dialogue was perceived as satisfactory and also unsatisfactory by a higher percentage (N = 45, 60.8% and N = 27, 36.5%, respectively) of the respondents. Respondents in this condition were the only ones who described the dialogue as "friendly" and who noticed the "embarrassment of the vice-Rector". It should be noted that in Udine, on the contrary, the same dialogue between DORO and the vice-chancellor was rated as satisfactory by less than half of the respondents (N = 25, 46.9%).

In each of the three scenarios, nearly a third of the interviewees focused on the defects that are still present in the dialogue, such as the "lack of true interactivity", its "poverty", and "basic nature". It can be noted that in all three situations it was the "lack of fluency" that made the dialogue be perceived as "programmed" and thus not real. Lastly, for almost a fourth of the respondents, the dialogue was ambivalent: "strange but also amusing", "slow but also interesting", "a bit surreal but nice", "positive, but unrealistic", and "interesting but without emotions". This means that, although generally interviewees were aware that automation and programming were implicated in the dialogue, the results were judged overall quite acceptably. However, the differences among the three groups of participants with these concerns were significant ($\chi^2 = 16.9$, df = 4, $p < .01$). This means that the satisfactory evaluation of the dialogue with DORO was associated with the communication model. While in the one-to-one and one-to-many models, this was much more satisfactory than unsatisfactory; in any case, it was distributed in the three categories of answers—satisfactory, unsatisfactory, and ambivalent—in the one-to-many mediated model in Pordenone, where the distance between the robot and humans was the largest. This evaluation was much more polarized between satisfactory and unsatisfactory.

Regarding the perceived eye-to-eye interaction, which can be considered as a proxy of perceived naturalness of the interaction between the actors, a univariate ANOVA ($F_{(2,158)} = 13.258$, $p < 0.0001$) showed significant differences among the three contexts. Post-hoc comparisons (Bonferroni) confirmed that in the one-to-many, in-presence communication (M = 2.90, SD = 2.77) the scores are significantly lower ($p < .01$) than those in the one-to-many mediated (M = 5.37, SD = 2.28) and even more in the one-to-one (M = 5.67, SD = 3.32) contexts. An explanation for this result is that in Udine the larger distance could not provide sufficient details to judge the effective capability of DORO to look into the vice chancellor's eyes. In that situation, respondents answered on the basis of their positive prejudices towards robots' capabilities to perform as humans, which were also supported by the higher percentage of positive evaluations of the dialogue itself.

4.1.3 Quality of DORO's Movements

According to the content analysis of the answers to the question "How did you feel about the movements performed by DORO?", only two macro categories emerged: improvements and limitations. It is worth noting that in Pisa (one-to-one model) and Udine (one-to-many, in-presence model) more than half of participants found that the movements performed by DORO improved compared with the past. In Pordenone, (one-to-many mediated model) the majority of participants stressed the limitations of DORO's movements.

Overall, the respondents spontaneously evaluated the quality of DORO's movement along a single dimension—fluidity. Those who showed appreciation underlined the "improvements compared to the past", the "fluidity of gestures", and their "precision and coordination". On the contrary, negative evaluations stressed the fact that the robot gestures appeared "artificial", they "imitated human gestures" without being such, showed "lack of fluidity", "lack of spontaneity", and a lack "of naturalness". Someone even felt these were "piloted", whereby the effect was strange (e.g., "too clicking", "mechanical", "unnatural", "non-fluid", "clumsy", and "disturbing").

Looking at the different contexts, the more direct the interaction (one-to-one communication) the more respondents felt unexpected improvements in the robot's gestures. In the shift from the one-to-one model to the one-to-many, in-presence, and the one-to-many mediated models, the evaluation of the quality of DORO's movements decreased, whereas the percentage of those who stressed the limitations of its movements increased. According to the Chi square test, these differences among the three groups of participants were significant ($\chi^2 = 19.2$, df = 2, $p < .0001$), confirming that the evaluation of DORO's movements is associated with the communication model.

4.1.4 Perceived Safety

Perception of safety is fundamental if robots are expected to become part of our public space. Despite the mean evaluation being positive, our results show that one-to-one interaction produced a greater sense of safety than the one-to many, in-presence and one-to-many mediated communication conditions. A univariate ANOVA ($F_{(2,166)}) = 45.442$, $p < 0.0001$) with Bonferroni post hoc comparisons shows significant differences ($p < .01$) between groups: those who had a direct interaction with the robot gave higher ratings (M = 9.18, SD = 1.56) than those who saw the robot acting on the stage (M = 7.94, SD = 2.41), and the latter rated significantly higher than those who saw the video (M = 5.78, SD = 1.95).

The answers to the open-ended question add further details to this picture. Even in this regard, a progressive increase of concerns is noticed in relation to an increase in the distance from the robot.

After being exposed to one-to-one communication, about half (44.9%) of our respondents answered that they would not need anything else in order to feel safe. The rest of the respondents (55.1%) expressed needs that essentially regard the materiality of the robot (e.g., "good sensors" and "recognize obstacles") and its body (e.g., "it shouldn't be metallic, it should be made of gel in case of errors"). Several respondents also stressed the need to have control over the robots (e.g., "knowing that it obeys the laws of robotics", "having the possibility to turn it off", and "it must be slow") or over the space where the robot moves (e.g. "a bounded space" and "it must be in a separated space"). Lastly, respondents in one-to-one interaction hoped for a better interaction with robots, and for two respondents the most important thing was that "it does not hurt children and the elderly" or "does not suddenly go crazy".

One-third (28.6%) of those who were exposed to the robot in the one-to-many communication context said that they did not need anything else because they already felt safe with a robot. The majority explained they would need a robot with "good and safe software" and that was "interactive". Again, control is a major issue: respondents asked for robots that can be "easily controlled", "easily turned off", and "switched off". They felt they need for the presence of "someone who controls the robot" and wanted to be sure that their "use occurs in a delimitated space" and that their "force and intelligence has been limited". Information seems to be relevant in this regard, as respondents asked that, in order to be sure they needed to be "carefully and preventively informed about safety measures in place", to "precisely know for which purposes it has been programmed", "to know how it works", or even "to know who programmed it".

Those who looked at the interaction through a screen agreed that current robots were not safe enough, and respondents in this group focused only on their needs for increased safety. This can be achieved through "better interactivity", "safety distance", "improved controls", "on–off switch", "presence of technicians who can control it", and "small dimensions of robots" (N = 11). Interestingly, in order to be safe, a number (N = 6) of respondents in this group also ask for "more human-like robots".

4.1.5 Emotions

A total of 108 expressions were counted from the free answers collected on emotions after one-to-one interaction.

Overall, 84 expressions indicating positive emotions and 15 negative were gathered. The most frequent positive emotions were empathy, curiosity, wonder, fun, and pleasure. The most frequent negative words concern fear, apprehension, and coldness. Both positive and negative emotions were characterized by medium/high levels of arousal.

In the one-to-many communication, in-presence context, a total of 120 expressions of emotions were collected. Overall, 95 words indicating positive emotions and 23 expressing negative emotions were counted. The most frequent emotions in Udine were curiosity, wonder, empathy, surprise, and fun, with an emotional texture a little different from those expressed by Pisa respondents. The most frequent negative words included embarrassment, indifference, fear, and concern. Again—apart from fear—it is possible to notice concepts like indifference or embarrassment, which express a different nuance of arousal from the negative expressions indicated by the previous sample.

The group who looked at the interactions with DORO through the television screen reported 222 expressions: 185 positive emotions and 37 negative. The most frequent positive words included amazement, happiness, and interest, while the negative ones include sadness, anxiety, and distrust; these were again quite different from those indicated by the previous samples.

4.1.6 Evaluation

To complete the picture, we investigated the general evaluation of a robot moving in public space, and the specific evaluation of its functions.

A robot moving in public space is expected by the majority of respondents to cause a positive effect associated with feelings of "companionship", and positive reactions and emotions such as "pleasure", "novelty", "interest", "curiosity", "surprise", "astonishment", "support", and "security". These emotions are actually more varied than the ones reported by respondents on DORO's movements. In less than one-fifth of cases, a robot moving in public space is expected to cause essentially "fear" and "strangeness".

The content analysis of the open answers to the question "What effect would it make a robot moving in the public space?" led to two macro categories: positive feelings and negative feelings. Again, some differences related to the different modes of interaction and communication have to be acknowledged. In the first two contexts, the large majority of respondents expected that a robot moving in public space will have a positive emotional impact. In the third context, the responses were half positive and half negative. The mediation, not unexpectedly, seems to worsen the emotional impact expected by respondents. The Chi square test shows that among the three groups of participants the differences are significant ($\chi^2 = 35.4$, df = 2, $p < .0001$), and thus that the evaluation of DORO's movements were associated with the communication model. The positivity of the emotions decreased from the Pisa group to the Udine group, and to the Pordenone group.

Four items were then used to look further inside the appreciation of DORO in public space and the functions that respondents would appreciate in social robots. We report them in descending order regarding the overall convenience sample: its mere presence (N = 173); being an attraction (N = 144); entertaining people (N = 136); and giving information (N = 128). The three models of communication with a robot were associated significantly to participants' appreciation of these functions, except for the robot as attraction ($\chi^2 = 5.928$, df = 2, p = n.s.). With respect to the other three functions regarding the evaluation of DORO's presence ($\chi^2 = 20.662$, df = 2, $p = .0001$), the evaluation of a robot giving information ($\chi^2 = 16.658$, df = 2, $p = .0001$) and of a robot that entertains people ($\chi^2 = 10.376$, df = 2, $p = .05$), the most vivid appreciation was always expressed by the participants in Pisa (98.0, 100.0 and 65.3%), while the participants in Udine were almost in the middle (74.0, 77.1 and 54.9%), and the most lukewarm appreciation was registered almost among the participants in Pordenone (62.2, 70.3, and 59.5%).

As to the intensity of this evaluation, we report the average scores obtained by the four functions on a ten-point scale: regarding DORO's presence M = 7.92 (SD = 1.610); regarding a robot giving information M = 8.04 (SD = 1.475); a robot as an attraction M = 7.96 (SD = 1.858); and a robot entertaining people M = 6.87 (SD = 2.381).

With regard to the appreciation of DORO, gender, age, and education did not produce significant differences, while the typology of the event was significantly related to the appreciation of DORO in public space. According to a univariate ANOVA ($F_{(2,125)} = 8.459$, $p < .0001$), in the one-to-one interaction context (M = 8.63) respondents appreciated the presence of DORO more than in the one-to-many mediated (M = 7.61) and the one-to-many, in-presence contexts (M = 7.35). Post-hoc tests confirmed that the scores of the one-to-many models were not significantly different.

With respect to the evaluation of a robot that gives information in the public space, again a univariate ANOVA ($F_{(2,133)} = 13.870$, $p < .0001$) with Bonferroni's post-hoc revealed that, after one-to-one interaction with DORO (M = 8.87), respondents appreciated the usefulness of a robot in public space significantly more than after being exposed to one-to-many, in-presence (M = 7.76) and to one-to-many mediated communication (M = 7.50).

Related to the evaluation of a robot entertaining people in public space, the only significant difference involved education: a univariate ANOVA ($F_{(2,101)} = 8.366$, $p < .0001$) showed that those with a higher level of education appreciated this potential role of social robots significantly less (M = 5.75) than people with low (M = 8.14) levels of education.

Answers by participants with medium levels of education were in the middle and did not differ from the mean scores of the other two groups (M = 7.03).

Finally, regarding the evaluation of a robot as an attraction in public space, again a univariate ANOVA ($F_{(2,141)} = 5.451, p < .01$) revealed that after one-to-one interaction (M = 8.05), respondents appreciated the robot in the public space as an attraction more than after being exposed to one-to-many mediated communication (M = 7.93) and one-to-many, in-presence communication (M = 7.29). Post-hoc test confirmed significant differences among the mean scores.

4.1.7 Behavioral Intention

To our question: "Would you like to bring DORO home?" 32.8% of the respondents answered yes, 63.2% said no or were uncertain. There were no significant differences by gender, education, or attitude toward scientific.

Age affects answers: adults are the least ready to bring a robot like DORO home, while younger individuals (z = 4.1) and the elderly (z = 2.2) are more likely to do so ($\chi^2 = 8.280$, df = 2, $p < .05$). This study confirms results from the Eurobarometer survey that highlighted a need expressed by the elderly to be helped by a social robot [34].

The perceived establishment of a direct relationship through non-verbal cues seems to be an influential variable; a univariate ANOVA showed that those who would be available to bring DORO home are also convinced more than the others who stated that DORO looked in their eyes (M = 5.42 vs. M = 3.33, $F_{(9,146)} = 2.071$, $p < 0.05$).

This is also confirmed by the fact that the type of public event had significant effects on interest in bringing the social robot home, which was higher in Pisa (s.r. = 3.9) than in Udine (s.r. = 0.0), and especially in Pordenone (s.r. = − 3.0) ($\chi^2 = 36.627$, df = 2, $p < 0.0001$). The more the human–robot interaction acquires physical distance and even the mediation of a screen, the less people intend to bring DORO home.

4.2 Observation and Video

The results emerging from the self-assessment were integrated by the non-participant observation and the observations of video recordings in Pisa and Udine.

4.2.1 European Researcher's Night in Pisa

In the one-to-one communication context, the majority of participants first shook hands with DORO. Of this group, however, only 10 participants then continued the interaction by taking the bottle from DORO's hand; the remaining 21 participants stopped interacting with the robot.

Eight participants avoided any contact at the beginning, but two of these participants then moved to taking the bottle. No one, at first, attempted to take the bottle that DORO was offering.

This behavior is very interesting because it shows that people tend to replicate with robots the same rituals, such as to "shake hands", that they perform in public encounters with humans. At the beginning of an encounter, people greet each other, shake hands, and then go on to perform some other action.

As the interaction continued, a series of actions were performed by bystanders in sequence. Regarding their first action, eight bystanders limited themselves to waving at DORO, whereas more than half of the bystanders tried to have a conversation with the robot. In a second moment, participants seemed to be waiting for DORO to start the interaction; the majority of bystanders performed no action and five bystanders moved their hands in front of DORO to elicit a reaction from it. The third scenario expressed more curiosity, since the majority of people looked at DORO in the third action.

As to the dialogues with DORO taking place between bystanders and the robot, particularly interesting are those between children and the robot. DORO approached people by saying, "I am pleased to meet you. My name is DORO". Several children answered by saying their names. Also in this interaction, there was a replica of the ritualization of encounters between humans. Children answered DORO's opening the conversation by introducing themselves.

A strong empathy toward DORO emerged in several cases. A child (F, 5–10 years) answered DORO's greeting by saying, "I love you. Hello". Another, "I like you". Others said, (F, 5–10 years) "you are very kind", (F, 5–10 years), "you are very sweet and cute", (F, 5–10 years), "you're like a good little soldier", (F, 5–10 years), "ooh DORO, I adore you! You are so cute", and "you're so funny and cute". Regarding children's appreciation, on the one hand, there was immediate enthusiasm; and on the other, they imitated how adults expressed their appreciation toward children.

A child was asked by DORO, "What do you think about robots?" The child answered, "you are marvelous". Then, he asked DORO, "Do you know SIRI?" This question is revelatory of how this child immediately thought of other robots, and he tried to investigate possible relationships that DORO could have.

Children—who are used to receiving approval and encouragement by adults when they behave well—replicated this behavior with DORO. In fact, when DORO gave them a battle of water they said, (F, 5–10 years) "thanks, little one", or (F, 5–10 years) "you have been very good".

The assimilation of DORO to humans by these children brought them to ask the robot about its love relationship. One (M, 5–10 years) asked, "Do you have a boyfriend?" Other children's questions explored different plans related to DORO's assimilation to humans. One (M, 5–10 years) asked, "what is your favorite food?" and said, "DORO, sing a song". In children-DORO interactions, there was even the assimilation of the robot to an artificial waiter. A child (M, 10–15 years) said to DORO, "prepare me a sandwich".

A woman (40–50 years) was asked by DORO: "What is the most beautiful thing you saw today?" She answered, "It is you, DORO". Then, this woman said "DORO, look at me, I want to take a picture of you". DORO answered, "Let us do a selfie together".

4.2.2 The Opening Ceremony of the Academic Year in Udine

Observation of the audience's behavior during the ceremony shows that the majority of the audience expressed great interest, some were puzzled, and only one person was very indifferent. It was a girl who, when DORO began to move, continued to read a book.

The first reaction of the audience was to smile, showing a positive attitude toward the communication happening onstage. Then, a behavior involving the audience in all of the sequences was applause, thus conforming to the audience's role, as if the ceremony was the performance of two actual actors. It is worth noting that applause was the second action for more than half of the audience. Fourteen people commented about the presence of the robot with their neighbors, thus showing the necessity of interacting with others in order to make sense of the technological novelty. It is surprising that very few people took a picture of the robot. This could be because, as it was a ceremony inaugurating the academic year, it was considered inappropriate to take a picture. As a third action, applause still remained a relevant behavior. Whereas from the fourth action onward, the absence of action, except for a few who pointed to the robots, became highly prevalent.

5 Discussion and Final Remarks

Overall, our respondents expressed a positive attitude toward robots in public space through their gestures, smiles, and applause.

The results of this study bring all in the same direction: the model of human–robot interaction one-to-one was the most satisfactory and thus the most promising model of communication and interaction; this can have implications for future diffusion and direct adoption of social robots by individuals.

In respect to our research question "How can the robot enrich the communicative settings offered by the public space?", this study supports the idea that robots are a mature technology that can be used in public space, at least for purposes of attraction and information [35, 36]. As for the automata, it is still the illusion and the unexpected that fascinate our participants. The expansion of Höflich's model that we proposed [13] in this study to explore the human–robot interaction in the public space has revealed to be very effective. Also, including the one-to-many communication model in two different contexts—in the presence of a live audience and in a mediated situation—was fundamental in grasping the features of human–robot interactions in public and understanding the extent to which social robots can be considered complex communication hubs [37]. With respect to the other research questions, "Do different degrees of physical distance implicate different forms of interaction between people and the robot? And if yes, what are the features that characterize each situation in terms of communication?", the Pisa study—where the physical distance between the robot and humans was the smallest—shows that DORO was an entity with which people could speak and entertain a direct conversation. In this case, DORO played the role of a medium with which humans interacted, to borrow again Zhao's expression. But if DORO can be equipped also with a mobile phone, the social robot can become a medium through which humans interact, to again borrow Zhao's expression [7]. The Udine study—where the physical distance between the robot and humans was bigger—shows that DORO was able to become a source of communication addressing many people at the same time, that is, a public. This suggests that DORO played the role of a public character but also that DORO potentially can play the role of a mass medium (television and radio) (one-to-many). Through the tablet that DORO wears in front, people could watch television programs or listen radio programs. The Pordenone study—where the physical distance between the robot and humans was the largest—confirms that DORO became a protagonist of videos or television programs, as it happened several times. The present study indicates that social robots can be complex communication hubs that convey flows within a system based on three different levels of distance in human–robot interaction and communication.

The analyses of interactions with the robot show that public patterns of behaviors tend to be a replica of the ritualization of the encounters between humans. However, the contextualization of robots in the public space makes human–robot interaction and the related communication structure more complex, since it introduces further issues regarding ostensibility and authenticity. As Ferrari [38, p. 225 and following] points out, automata in Hellenistic times were not only mere objects of entertainment but also "ostensible equipment". That is, they were general instruments of application and demonstration of mechanical principles, and particularly pneumatic ones. DORO, like the ancient automata, in its public exhibitions performs this ostensible role of scientific and technological wonder [39–41]. Overall, the videos of the two events show that in the one-to-one model of interaction and communication the audience is involved in rich behavioral and communicative participation, while in the one-to-many model of communication, the audience had an individual reaction (smile), followed by interactions with other humans (talk). This behavior was mostly coherent with the script of the situation they were in, accepting the robot as one of the two performers on the stage in the ceremony. When exposed to a setting based on the one-to-one model of human–robot interaction, participants tended to greet DORO and shake its hands, whereas it was mainly the children who showed intimacy toward the robot. Children are more accustomed than adults in cultivating a fictional world populated by puppies and toys in general, whereby they are more comfortable with the simulation expressed by the robot. When exposed to a setting built around the one-to-many, in-presence communication model, the audience smiled at DORO, talked to their neighbors in order to make sense of the technological novelty, and applauded. This behavior was mostly coherent with the script of the situation they were in, accepting the robot as one of the two performers on the stage of the ceremony. Also here the ritualization that occurred in public events toward human characters was replicated toward DORO. In the Udine ceremony, the choice of using a moderately anthropomorphized robot such DORO did not pose serious problems of "authenticity [42] in the flow of communication and social interaction between DORO and the public, because DORO was easily perceived as a robot. A different impact on the issue of authenticity would have had the use of an android or gynoid robot. Hence, robots having anthropomorphic shapes bring further elements inside the question of the possible role that social robots can play in contemporary societies. As Baron points out [42], the problem of infringing on authenticity conveyed by android or gynoid robots depends on the fact that their purpose is not only to surprise but also to trick the public.

Even if at an exploratory level, these observations are supported by self-reports collected by interviews. The change in the communicative format between DORO and respondents across the three contexts shaped participants' evaluations of the robots, expectations towards DORO, perceptions of the dialogue with DORO, emotions, and the other examined dimensions.

The evaluation of the quality of DORO's movements indicates that the more direct the interaction (one-to-one communication) the more respondents focused on the unexpected improvements concerning the robots' gestures. In other words, from one-to-many to one-to-many mediated contexts, the percentage of those focusing on improvements decreases whereas the percentage of those who stress the limitations of movements increases.

Perceived safety shows a progressive increase of concerns according to increased distance from the robot, too. In the same vein, as the distance from the robot grows, positive emotions decrease and negative ones increase. With respect to the evaluation of DORO and its functions in the public space, it emerges that in the one-to-one interaction model respondents appreciate the presence of DORO, itself. Moreover, in the one-to-one interaction model respondents appreciate the function of information and attraction more than in the one-to-many in-presence and mediated models. Finally, as to the behavioral intentions of respondents, results show again that as human–robot-interaction acquires physical distance, and even the mediation of a screen, the less people intend to bring a robot like DORO home.

In conclusion, the results show that in Pisa and Udine direct interaction with the robot caused respondents to positively evaluate all the features of the robot and their interaction with it. These results are in line with results consistently coming from research on ICT use: the more people have familiarity with and use communication and information technologies, the more they appreciate them and feel positive emotions toward them [43]. However, the overall results emerging from research on technology (robots and ICT) contradict the emotional model of consumption, which indicates that the pleasure we feel when we consume a certain product usually blunts over time [44]. The data collected in this research confirm research regarding ICT use [45], and suggest that our relationship with this new medium may instead follow the opposite pattern. This probably depends on the particular dynamism that is embodied in digital devices, making it difficult to reach the addiction level and the peak of the curve of satisfaction. Despite these interesting results, we need to say a final word about the limitations of the present study. This is a qualitative study that has been carried out at an exploratory level. Its purpose was to provide insights into the structure of human–robot interaction, the potential roles that robots can play in the public space, and to develop ideas or hypotheses for a theoretical elaboration. Like many qualitative research studies this study is characterized by convenient samples of participants who are limited in number, whereby it is impossible to generalize its results. It limits itself to present the pros and cons connected with correlational research conducted in real settings.

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