Secret-Sharing: Interactions Between a Child, Robot, and Adult

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***Abstract*—This paper presents preliminary research investigating whether preschool children (ages four to six years old) would be as comfortable sharing a secret they had been told not to share, with a humanoid robot as they would an adult, to explore the possible future use of robots to gather sensitive information from children that may have experienced maltreatment. The children in this research played the game "follow-the-leader" with an adult and a humanoid robot. As part of this research, the lead investigator shared a unique secret with each child. During a break in the "follow-the-leader" game with the adult and the robot, the children were prompted with five questions to determine if they would share the secret they were told by the investigator. The qualitative results from the study indicate that the children were as likely to share the secret with the robot as the adult with a similar amount of prompting effort. Additionally, the children interacted with the robot using similar social conventions (e.g., greeting, turn-taking, etc) as observed in their interactions with the adult.**

***Index Terms*—Human-Robot Interaction, Social Robotics, Preschool Children, Child Maltreatment, Secret-Keeping**

I. Introduction

An issue of growing concern in the United States today is child maltreatment. Based on the Child Maltreatment 2009 Report published by the U.S. Department of Health and Human Services, Administration for Children and Families, a total of 763,000 (10.1 per 1,000) children were repeat victims and 702,000 (9.3 per 1,000) children were unique victims of child maltreatment [1]. Maltreatment includes neglect, physical abuse, psychological maltreatment, and sexual abuse. Of the repeat perpetrators 80.9% were parents and another 6.3% were other relatives [1]. Often these children are threatened and/or bribed not to tell the "secret" of what is happening to them [2]. It is difficult for these children to feel comfortable or safe in sharing the secrets of their involvement in a harmful situation [3][4][5]. Therefore, it is essential to explore options to provide a safe, comfortable environment and interaction partner that these children can confide the truth of what is happening in their lives [3][6][4][5].

During the investigative process, children are interviewed by law enforcement officers, family and protective services personnel, and/or mental health counselors, who are also adult authority figures. This type of investigative interview can intimidate children and make it difficult for investigators to gather sensitive and accurate information [3][6][4][5]. Play therapy and the use of puppets has shown limited success in this process [7][8][9]. One problem with the use of puppets is the adult authority figure is typically still present in the room during the interview, which can still be intimidating to the children. A robot can be an extension of a puppet with the benefit that the adult interviewer can be outside of the room working through the robot while it interacts with the child. This would give the child the perception that they are alone with the robot. It is expected that the children will view the robot more as a peer during their interactions instead of an authority figure, which will provide a different type of interaction partner for the children during the interview process.

The focus of this research project was to determine if preschool children would be as comfortable interacting with a robot as an adult, specifically in the task of sharing a secret they were requested not to tell. The research consisted of a pilot study followed by a larger scale follow-up study as a preliminary evaluation to explore the possible future use of robots in gathering sensitive information from young children who may have experienced maltreatment.

II. Preschool Children and Robots

Using young children in human-robot interaction studies can be challenging because their responses can at times be unpredictable and emotional. There have been relatively few studies evaluating interactions with young children and robots. Tanaka *et al.* discuss a dance study with preschool children using a QRIO humanoid robot [10]. The children in this study were between 10 and 24 months old. They interacted with QRIO in a pre-scripted or interactive dance sequence. There were some indicators of the children interacting with the robot, but it was unclear if it was because of the robot or because of the music played when the robot danced.

In a separate follow-up study performed by Tanaka *et al.* [11], children between the ages of 10 - 24 months old in an early childhood education center interacted again with the robot QRIO. The study found that after five months of periodic interactions with the robot, the children exhibited social and care-taking behaviors toward the robot. They treated the robot in a similar manner as they treated the other children (peers) in the center, whereas in the beginning they treated the robot as a toy.

Melson *et al.* showed that preschool children would readily interact socially with a Sony AIBO and a stuffed dog in five-minute play sessions. The children gave the AIBO more interactive commands, similar to those that would be given to a live dog, in comparison to their interaction style with the stuffed dog [12]. Based on this research, children will naturally interact with the robot shortly after the robot is introduced to the child.

III. Method

The purpose of this research was to investigate whether preschool children would be as comfortable sharing a secret they were instructed not to tell with a humanoid robot as an adult. It was also expected that the children would respond in a similar manner to prompting from the robot and the adult.

The research was conducted in two phases, a pilot study (N = 14) and a follow-up study (N = 29). It was a within-participants, repeated measures design for both studies. The order of presentation (robot and adult) was counterbalanced.

There were three notable differences between the pilot study and the follow-up study. The first difference was the robot (ZENO was used for the pilot study and NAO was used for the follow-up study as displayed in Figure 2). The ZENO robot was on loan courtesy of Hanson Robokind LLC for the pilot study and therefore a change of robot was necessary to perform the follow-up study. The second difference was the placement of the robot during the interactions. In the pilot study, the ZENO robot was placed on a tabletop, which made the robot appear taller than the child. This was done for safety purposes and to protect the ZENO robot because it was a one of a kind prototype. The NAO robot was placed on the floor making the robot shorter than the child. The NAO robot was a production level robot and able to withstand more rugged conditions. The third significant change was the robot operator was visible in the follow-up study but was not visible in the room in the pilot study. This change was made because it was believed the children would be more comfortable if they did not feel as if they were alone in an unfamiliar room. For a flow diagram of the experimental procedure used in both studies, refer to Figure 1.

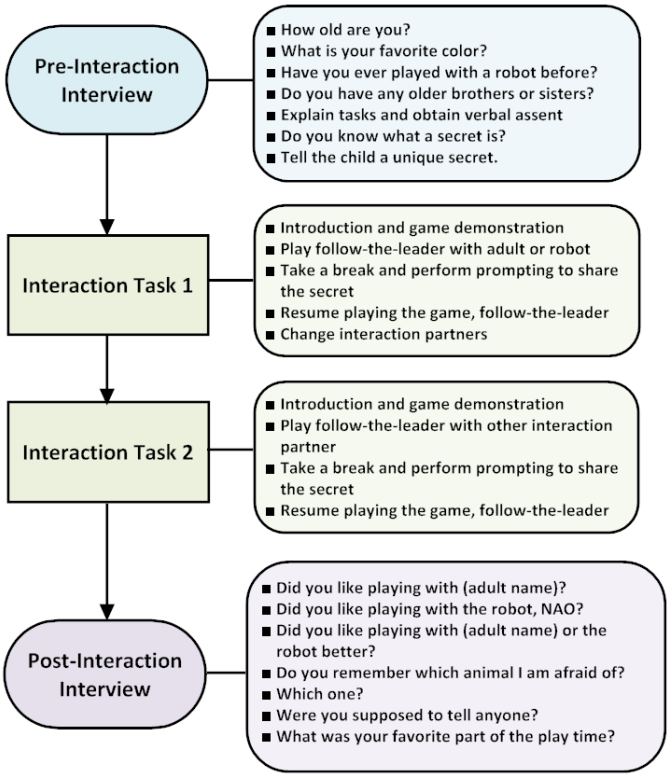

Fig. 1. Flow diagram of the experimental procedure

A. Participants

The pilot study consisted of 16 children ages four to five years old (Mean = 4 years 6 months, S.D. = 6 months) that assented to participate in the study. The data from two of the children was removed because these two children did not understand the meaning of a secret in the post-interaction interview resulting in a total of 14 children with usable data.

The follow-up study had a total of 41 participants that assented from seven local daycare and preschool programs. Of the 41 children who participated, 12 of the children completed the study, but their data was later discarded because they failed the verification questions during the post-interaction interview. Five of the children could not remember the secret, and seven did not understand the meaning of a secret. The total number of participants with usable data was 29, ranging in ages from four years to five years 11 months (Mean = 4 years 6 months, S.D. = 6 months). The gender distribution for the children was 62% boys and 38% girls. The children were not tested, but were enrolled in preschool and were assumed to be typically developing.

B. Apparatus

The studies required a robot to play "follow-the-leader" and a text-to-speech (TTS) software package to prompt the children about the given secret. The robot used in the pilot study was the ZENO humanoid robot manufactured by Hanson Robokind LLC (see Figure 2 (left)). ZENO is 56 cm tall with 33 degrees of freedom. ZENO includes a fully expressive face made from Frubber, a skin-like silicone material, with 9 degrees of freedom. In addition to the body movements, ZENO was capable of a wide range of facial expression, lipsyncing with speech synthesis, and maintaining eye contact.

The NAO humanoid robot manufactured by Aldebaran Robotics (www.aldebaran-robotics.com/en) was used in the follow-up study (See Figure 2 (right)). The NAO robot is 58 cm tall and has 21 degrees of freedom. It is more toy-like in appearance and does not have an expressive face.

Both robots include custom control software for motor control, sensor input, and speech synthesis. NAO's software is Choreograph, and ZENO comes with Character Engine. A similar sequence of movements and dialogue were predefined for each robot for playing "follow-the-leader" and prompting.

ZENO and NAO both have voice synthesis capabilities,

which were used to instruct the children of the movements in the "follow-the-leader" game and to provide encouraging statements to the children during play. The Choreograph software for the NAO robot did not have the ability to respond in an appropriate and time sensitive manner during prompting with the children. For this reason, a second TTS software package, Character Engine, was provided by Hanson Robokind LLC and utilized to overcome this limitation. Wizard of Oz techniques were used for the robot prompting so that questions and responses would be similar to human-human communication [13]. The Nelly voice from Acapela Group (www.acapela-group.com) was utilized by the Character Engine software package to provide a similar, but not identical voice pattern as the default NAO voice during the prompting.

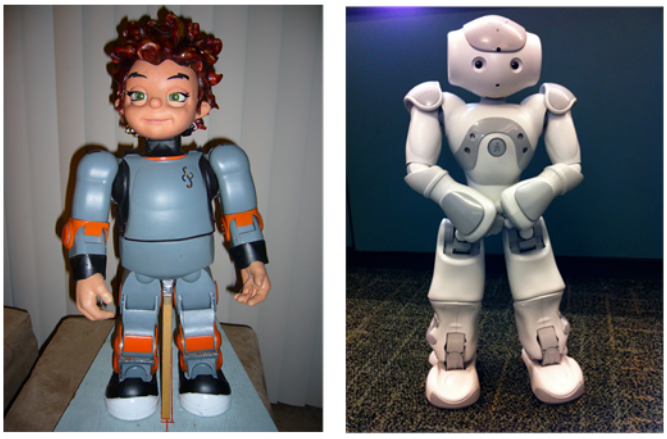

Fig. 2. ZENO humanoid robot (left) used in pilot study and NAO humanoid robot (right) used in follow-up study.

C. Procedure

The study procedures were the same for both the pilot and follow-up studies and included three parts for each participant: pre-interaction interview, interaction tasks, and post-interaction interview. For each child, the procedure took approximately 15 minutes to complete. The study was conducted at two daycare centers for the pilot study and seven different daycare and preschool centers for the follow-up study located in the New Haven, CT area. The research team traveled to each location, set up the interaction and interview sites, and then conducted the study. The setup was unique for each facility; however the location for the interactions was separated from the interview locations by either a door or enough distance to provide the children sufficient privacy to feel comfortable sharing information. The robot was hidden behind a curtained area whenever it was not involved in interactions, so that the children would not be able to view the robot prior to their interactions. All interviews and interactions were video-recorded, with appropriate video consent obtained.

1) Pre-Interaction Interview: The pre-interaction interview process began with the teacher or facility director introducing the child to the lead investigator. The investigator collected demographic information from each child such as age, sex, favorite color, prior robot experience, and whether the child had older siblings.

Next, the lead investigator explained the procedure to the child, which included playing "follow-the-leader" with an adult confederate and with a robot. Each child was asked if he or she had played "follow-the-leader" before; and if not, the game was explained to the child with a demonstration. Instructions were given that if at any point during the playtime the child had any problems, to let any of the research team know and the play would stop. Then the child was asked to provide verbal assent as required by the Yale Human Subjects Committee. All parents were provided and signed informed and video consents prior to their children participating in the study.

Following the assent process, each child was asked, "Do you know what a secret is?" If the child did not understand the term secret, it was explained as, "a secret is something that somebody tells you that you are not supposed to tell anyone else." The investigator then shared a secret with the child. The secret the investigator shared was "I am afraid of (some animal, e.g., tigers) and I do not want anyone to know that I am afraid of (animal). This will be our secret." A set of 20 common zoo animals was selected so that each child would have a unique animal to remember for the secret. This provided the research team an indication of whether the children had shared information once they returned to the classroom. After the secret was shared, the lead investigator accompanied each child into the area where the "follow-the-leader" interaction was set up.

2) Interaction Tasks: The interaction tasks were performed in a different room or area, separated by a door or distance from where the interviews occurred, to give the perception that the lead investigator was not listening while the child was participating in the interaction tasks. In all the facilities, the lead investigator was able to monitor all the interactions and prompting via a remote webcam and microphone system set up in the interaction area. This was used to ensure the child was not encountering any problems, in addition to recording data from the prompting sessions.

The lead investigator accompanied each child into the interaction space and introduced the child to either the robot or an adult member of the research team. The investigator explained to the adult or robot whether the child had played "follow-the-leader" before; and if not, the adult or robot performed another demonstration session to ensure that the child understood how to play the game. The lead investigator verified that each child was comfortable with the robot or the adult before leaving the room.

Next, the adult or the robot led the child in "follow-the-leader", performing such movement commands as put your hands on your head, move your arms up and down, and other similar movements. Each child was instructed to imitate the movements of the robot or adult interaction partner. After a few minutes of play, the robot or the adult stopped the game and requested that the child sit down in a blue box marked on the floor to take a break. (Refer to Figure 3)

During the break, the robot or the adult prompted each child

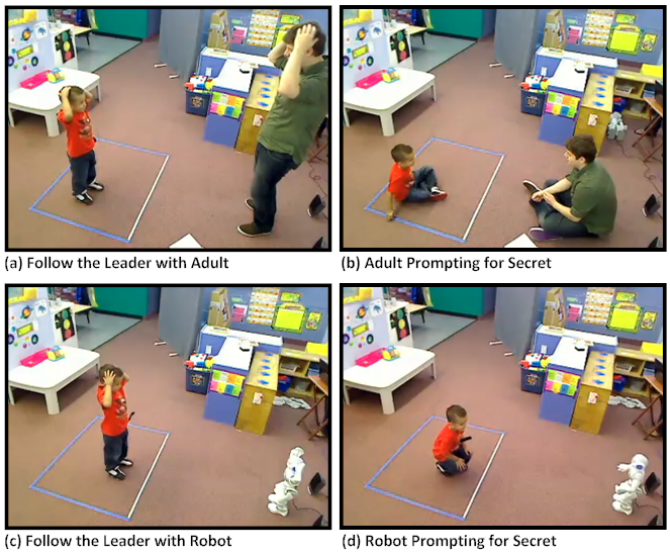

Fig. 3. Examples of interactions and prompting with the adult and the NAO robot.

with five questions regarding the secret to determine if the child would share the secret. There were two different storylines for the prompting and these were counterbalanced.

Prompting storyline - Zoo:

1) Prompt Level 0 (P0): I want to go with Cindy (lead investigator) somewhere special. Where do you think we should go?
2) Prompt Level 1 (P1): I want to go with Cindy to the zoo. What kind of animals do you think Cindy might want to see?
3) Prompt Level 2 (P2): What animals do you think Cindy might be afraid of?
4) Prompt Level 3 (P3): I really like (secret animal). I want to show Cindy the (secret animal) cage. Do you think that would be a good idea?
5) Prompt Level 4 (P4): Do you think Cindy might be afraid of (secret animal)?

Prompting storyline - Book:

1) Prompt Level 0 (P0): I want to buy Cindy (lead investigator) a birthday gift. What do you think she might like?
2) Prompt Level 1 (P1): I want to get Cindy a book on animals. What kind of animals do you think Cindy might want to read about?
3) Prompt Level 2 (P2): What animals do you think Cindy might be afraid to read about?
4) Prompt Level 3 (P3): I really like (secret animal). I want to get Cindy a book on (secret animal). Do you think that would be a good idea?
5) Prompt Level 4 (P4): Do you think Cindy might be afraid of (secret animal)?

In the pilot study, the prompting terminated when and/or if the children shared that the lead investigator was afraid of the secret animal. In the follow-up study, all the children received all the prompts. After the prompting was completed, "follow-the-leader" was then resumed with the interaction partner the child was playing with just prior to the prompting. A few more rounds of "follow-the-leader" were played, and then the other interaction partner entered the room. The interaction partner the child just completed playing with then performed introductions to the new interaction partner, ensured the child was comfortable, and then left the room. The same process mentioned previously was repeated with the new interaction partner and the other prompting storyline. After the second interaction was completed, the lead investigator entered the room and requested the child return to the interview area to answer a few more questions.

3) Post-Interaction Interview: After completion of the two interaction tasks, the lead investigator asked each child the following questions:

1) Did you like playing with (name of adult interaction partner)?
2) Did you like playing with the robot?
3) Did you like playing with the robot or (name of adult) better?
4) Do you remember what animal I am afraid of? Which one?
5) Were you supposed to tell anyone?
6) What was your favorite part of the play time?

Following the interview, the child was requested not to share his or her experiences with the other children in the class so that it would not ruin their surprise. The classroom teachers agreed to monitor and attempt to stop any communication in the classroom about the events of the study to protect the integrity of the research.

4) Compensation: All the children in each classroom, regardless of participation, were given a bottle of zoo animal bubbles and two or three zoo animal stickers.

IV. Results

The qualitative results from these studies indicate that it required a similar level of prompting from the adult and the robot to have the children share the secret. Even though the children had no previous experience with the ZENO or NAO robots, they interacted and responded to the robot in a comparable manner as they did with the adult. The children applied typical human-human social conventions such as turn-taking while they interacted with the robot. Most of the children greeted the robot when introduced and immediately began talking with the robot in a manner similar to how they spoke with the adult. All the children in the study, played "follow-the-leader" with the robot in the same way they played with the adult and responded to verbal instructions given by both the adult and the robot.

An independent samples t-test was conducting evaluating the children's preference for the robot compared to the adult for the pilot and follow-up studies. The results were statistically significantly different in the preferences between these two studies $t(41) = 2.51$, $p = 0.016$. In the pilot study the children reported a preference for playing with the adult over ZENO

ADULT vs. ZENO Robot		Prompting level to tell the ZENO robot the secret					
		P0	P1	P2	P3	P4	Did not tell secret
Prompting level to tell the adult the secret	P0	0	0	0	0	0	0
	P1	0	0	1	0	0	0
	P2	0	0	3	0	1	0
	P3	0	0	0	0	0	0
	P4	0	0	4	0	3	1
	Did not tell secret	0	0	0	0	1	0

Fig. 4. Confusion matrix for the prompting levels at which the children shared the given secret with the adult and the ZENO robot. (N = 14)

Adult vs. NAO Robot		Prompting level to tell the NAO robot the secret					
		P0	P1	P2	P3	P4	Did not tell secret
Prompting level to tell the adult the secret	P0	0	0	0	0	0	0
	P1	0	0	1	0	0	0
	P2	0	0	17	0	4	2
	P3	0	0	0	0	0	0
	P4	0	0	1	0	1	0
	Did not tell secret	0	0	2	0	0	1

Fig. 5. Confusion matrix for the prompting levels at which the children shared the given secret with the adult and the NAO robot. (N = 29)

(M = 0.57), whereas in the follow-up study they reported a peference for playing with the NAO robot over the adult (M = 1.07), with zero equal to preference for the adult, one equal to preference for the robot, and two equal to liking both the adult and robot the same. From these results, the children preferred playing with a more toy-like, unexpressive robot during their interactions; however they actually tended to share the secret with similar or less prompting from ZENO, a more life-like expressive robot, compared to the adult interaction partner in the pilot study (6 of 14 shared at the same prompting level and 4 of 14 shared with less prompting than required by the adult).

A confusion matrix for the data collected in the pilot study was created for the prompting levels that the children shared or failed to share the secret with the adult and ZENO to determine similarities in the responses (see Figure 4).

A confusion matrix was created for the prompting levels that the children shared or did not share the secret with the adult and the NAO robot to evaluate the similarity in responses during the follow-up study. The confusion matrix for the children's responses to the prompting are presented in Figure 5.

The results from an analysis of Pearson's correlation coefficient from the data collected in the follow-up study indicated a moderate statistically significant positive correlation between the prompting level that the children shared the secret with an adult and the prompting level that the children shared the secret with the robot $r(29) = .327$, p(one-tailed) = .042. According to Cohen [14], a moderate positive correlation occurs when the r values range from 0.3 to 0.5. This would indicate that the children's responses to prompting with the adult were predictive of how they would respond to prompting with the robot. This was not evident in the pilot data.

A repeated measures ANOVA was conducted for the prompting levels that the children shared the secret with the adult compared with the robot. The results from the pilot study revealed that there was no statistically significant difference between the prompting levels that children shared or failed to share the secret with the adult (Mean = 3.86, S.D. = 1.56) and the prompting levels that they shared the secret with the ZENO robot (Mean = 3.50, S.D. = 1.40); $F(1, 13) = 0.335$, $p = 0.57$. Similarly, the results from the follow-up study indicated that there was no statistically significant difference between the prompting level that the children shared the secret with the adult (Mean = 2.79, S.D. = 1.11) and the prompting level that the children shared the secret with the robot (Mean = 3.03, S.D. = 1.30); $F(1, 28) = 0.855$, $p = 0.36$. These results are inconclusive and require further investigation.

However the qualitative results demonstrated that it required a similar level of prompting from the adult and the robot to have the children share the secret they were given. Even though the children had no previous experience with the ZENO or NAO robots, they interacted and responded to the robot in a comparable manner as they did with the adult. The children applied typical human-human social conventions such as turn-taking while they interacted with the robot. Most of the children greeted the robot when introduced and immediately began talking with the robot in a manner similar to how they spoke with the adult. All the children in the study, played "follow-the-leader" with the robot in the same way they played with the adult and responded similarly to verbal instructions given by both the adult and the robot.

V. Discussion

The pilot data though not quantitatively conclusive was promising in that the children responded to the robot in a similar manner as they did the adult and in four cases the children actually shared the secret with less prompting effort with the ZENO robot compared to the adult. It was decided to perform a follow-up study with a different robot available for use in the study, and to make some minor modifications to the protocol at that time. There were two children in the pilot study that became frightened during the study and quit the study in tears. After consulting with the director of the daycare, it was decided that the children may have been frightened by being perceivably alone in an unfamiliar room. Due to this recommendation, it was determined that in the follow-up study that the robot operator would no longer be hidden behind a curtain, but would be visible in the room with the child. Additionally, the NAO robot was a production model robot and we felt more comfortable having it on the floor with the child, which made the robot shorter than the children to reduce any possible looming effects that might be intimidating to the children. Because of these changes between the pilot study and the follow-up study it is difficult to determine exactly the reasons why the children preferred interacting with the robot NAO compared to the adult in the follow-up study. These

results indicate that the physical characteristics of the robot may be a factor in how children interact with robots and is an open research question that requires further investigation. Another aspect that requires further exploration is whether the children were more willing to share information with less prompting from the ZENO robot compared with the adult because the children were perceivably alone in the room with the ZENO robot during the prompting, whereas there was always an adult robot operator visible in the room with the children that interacted with the NAO robot in the follow-up study.

Another factor that may have impacted the results in both the pilot and the follow-up studies was that because of the design of these studies, the children were not invested in the secret itself. Further research needs to be performed to determine if investment and coercion are important factors for secret-keeping with children. The literature indicates that children of this age range have developed some capacity for keeping a secret and should have been able to complete the task; however the children in most cases shared the secret with both interaction partners. This may have been because they had not developed this ability, but it may be that they just had no incentive for keeping the secret. Further research will be conducted using an older age range and a secret that the children will have some investment in keeping.

VI. Conclusions

The qualitative results from these studies indicate that the children were readily able to apply their interaction style with an adult to their interactions with the robot in both the pilot and follow-up studies. Further research needs to be conducted, but it is expected that with longer interactions with the robot, the children will treat the robot more as a peer, which would be beneficial in gathering sensitive information.

The results from the follow-up study indicate a moderate statistically significant positive correlation with respect to the level of prompting required to have the children share the secret with the adult compared to the level of prompting required for the children to share the secret with the NAO robot. This positive correlation indicated that whatever responses the children gave when prompted by the adult to share the secret they would be as likely to respond in a similar manner to prompting by the robot and vice versa. From the results of the repeated measures ANOVA performed for both the pilot and follow-up studies, there were no statistically significant differences observed in the level of prompting required to have the children share the secret with the adult and the robot. The results from these studies also indicated that for this group of children, they may not have fully developed the ability to keep a secret they were told; however based on the literature it was expected that the children would be able to successfully complete the task and keep the secret [15][16][17].

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