"I'll just Repeat the Rules one more Time": An Analysis of Interactional Repair and its Impact on Engagement in HRI

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***Abstract*— In this paper I present a microanalytical sequential analysis of people's interactions with a small humanoid robot, in which they play a word formation game together. The analysis reveals two ways of engaging with the robot and suggests that the robot's response to user-initiated repair during an interaction can lead to more engaging behaviors in people interacting with it.**

I. INTRODUCTION

Social robots are fast entering class rooms and other teaching contexts [1], [2], [3]. Indeed numerous studies report on positive learning gains in areas such as math [2], logic problem solving tasks [4], learning English as a foreign language [5], learning English native-like prosody [6], and elementary science [7]. However, in many learning contexts, be it with robots or humans, an important precondition is that the student is engaged with the learning material and/or with the teacher or tutor mediating said material. While introducing a robot into a learning scenario may increase students' engagement on the short term it is often the case that engagement drops once the novelty effect of the technology wears off. Thus, there is need to identify behaviors in educational robots that increase students' engagement, a need that is also recognized in the call for this workshop.

Engagement is defined by Sidner et al. as "*the process by which interactors start, maintain and end their perceived connection to each other during an interaction.*" [8]. Engagement is in HRI often studied and measured using non-linguistic factors such as gaze and proxemics. For example, in their 2016 HRI Conference paper Lemaignan et al. offer a literature review of a series of metrics evaluating engagement, in which gaze is predominantly represented [9]. Relying solely on gaze to measure engagement poses three potential problems. First, most models that measure engagement in HRI assume that an interaction consists of a robot, a human, and a set of objects which are manipulated by either the robot, the human or both. However, some teaching contexts, such as some language learning tasks, do not necessarily require any tangible objects, but can rely solely on the verbal interaction between speaking partners. Second, gaze can be a useful metric for measuring when a person is displaying engaging behaviors, but is less useful for uncovering what causes these behaviors. Third, gaze behavior is subject to a high degree of interpersonal variation and is contingent upon the communication partner's gaze behavior [10]. Thus, an analysis of gaze behavior may prove difficult in an interaction where one part does not have equal or similar abilities to signal gaze as the other.

To explore how engagement can be investigated using only the verbal interaction between a person and a robot I present a study in which people play a word game with a small social robot, a game played without any tangible objects. Rather than relying on gaze and proxemics the investigation, relies on detailed and sequential analyses of the verbal interactions between a person and a robot. Such an analysis focus on tertiary objects only if participants orient to these, and may point to how an engaging behavior has come to into action. The analysis points to specific indicators of engagement and shows what behaviors can lead people to perceive the robot as being engaging.

An important feature in interactions between people is their ability to respond contingently to their communication partner. This is important in order to be able to answer questions, signal attention, and to signal trouble in the interaction. The latter is referred to as interactional repair, and describes the process by which communication partners deal with problems with hearing, speaking or understanding utterances during the interaction [11]. For example, repair can be initiated by asking one to repeat an utterance. In this paper I argue and demonstrate that the robot's timely and appropriate response to user-initiated repairs lead users to be more engaged with the robot.

II. PREVIOUS WORK

Engagement in HRI has been much studied by Sidner and colleagues. In one study, they investigate peoples's gaze behavior during a tour of their lab and find that a robot tracking tracking a user's gaze is the best way to maintain engagement, verbal feedback can also fulfill this role [12]. In a different study they investigate how gestures affect users' engagement with a robot [8]. Here their analysis relies on subjective measurement through the use of a questionnaire, analyses of participants' gaze behavior, and analyses of participants' verbal behavior. However, the latter deals only with quantitative factors such as duration of interaction, length, and numbers of utterances. One of their key findings is that people more often look back at the robot when the robot uses gestures than when it is not. In other work, Baxter et al. consider gaze as a proxy for engagement [13], Castellano et al. consider gaze and smiles as indicators of engagement [14], and Hall et al. measure engagement by using post experiment questionnaires after users interacted with a robotic head [15]. Rather than dealing with the somewhat fuzzy concept of 'engagement' Lemaignan and colleagues introduce a concept

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they refer to as "with-me-ness" [9]. That is, the extent to which a human is "with" the robot in an interaction. Here, they consider a human to be "with" the robot if attention is focused on the robot or to an object to which the robot directs its attention. Pitsch et al. show that people are more likely to be engaged in an interaction with a robot whose responses are contingent upon users' actions [16]. Unlike most other studies, they base their analysis not solely on gaze and other non-verbal behaviors, but use a conversational analytical approach, i.e. they carry out a sequential analysis of peoples' verbal and non-verbal conduct with their robot. Finally, Szafir and Mutlu (2012) [17] measure engagement using EEG signals. Potential problems using this method are that it is relatively complex to set up and requires users to wear special equipment.

III. METHOD AND DATA

A. Robot

The interactions were carried out with a JD EZ-Robot (see figure 1). The robot is 31.8 centimeters tall with 16 degrees of freedom. The robot's speech was produced with MaryTTS [18] with a US English voice (cmu–bdl–hsmm–en_us).

Figure 1: Experimental Setup

The robot was controlled remotely, using the Wizard-of-Oz methodology (WoZ) from an adjacent office and followed a semi-set script. However, the controller was also able to respond to spontaneous prompts from the user using a direct link between MaryTTS and the robot. Under optimal conditions the robot would be fully autonomous and would not have to rely on a human controller to time and produce its actions and utterances. However, this is not currently technically feasible. Even with robust and precise speech recognition (which we do not have) robots will need to be able to respond in socially appropriate ways. This requires the robot to place any given utterance and its meaning (literal or metaphorical) in the local interaction history. Without going into a larger discussion of the future of AI, the point with doing a WoZ study with a robot that is not autonomous is that once the technology is available for a robot to engage in rich social interactions there will already be data on how people respond to such technology. One might fear when using WoZ that people are not really interacting with the robot, but rather use it as a proxy to interact with another human [19]. However, during the debriefing all eight participants expressed that they were surprised that the robot was human operated.

B. Procedure

Participants were first asked to fill out a questionnaire in which they were asked questions about their demographics, how they perceive robots in general, and the extent to which they have worked with robots before. They were then seated at a table facing the EZ-robot, and as the experimenter left the room, the robot initiated a greeting using the participants' name and welcomed the participant to the study. The robot then explained the rules of the game that they were to play, and said that it would help the robot if they could play at least three rounds of the game. After having played five rounds, the robot said it was tired and needed to rest. In each round the robot would say something off-topic to display that it was situationally aware of its surroundings. I will refer to these utterances as odd-messages. This is strategy is in part influenced by a study by Sirkin et al. who show that people's trust in a simulation of an autonomous car is increased when the car comments on events and objects in the simulated world [20]. First, the EZ-robot would make a comment about the whiteboard hanging on one of the walls (not visible in picture). Second, it would say that it liked the participants' shirt. Third, it would comment on the picture on the wall. Fourth, it would ask to be moved a bit to the left, and thank the participants once he or she did this. In the fifth and final round it would say that they had played four rounds already. After the game had finished the robot thanked the participant for playing and bid them farewell.

C. Game Rules

The game is a relatively simple word formation game. Players take turns choosing a letter, and the player who is first able to form a word using this exact list of letters wins the game. Players can then challenge each other if they suspect that the word formed does not exist or is not a real word. Whoever wins this argument wins the game.

D. Data

Eight interactions were in total recorded for this study. Interactions each lasted 10-15 minutes, which were then transcribed using the Jefferson transcription notation system [21] for later analysis. The transcripts are analysed using conversation analysis [11], a method that seeks to uncover recurrent and systematic social phenomena in interaction, through sequential and microlevel analysis.

E. Participants

Participants were students or staff members who work at the University of Southern Denmark, campus Sonderborg. Participants have a mean age of 36 (ranging from 20 to 56 years). Because of the large number of international students and staff members on this campus the study was conducted in English. Participants self-report an English listening proficiency of 4.75 (SD=0.7) and English speaking proficiency of 4.38 (SD=0.7) on a 5-point semantic differential scale, where 1 is beginner and 5 is proficient. The study has an even number of men and women (4/4). One participant indicates he works regularly with robots, while the others only know robots from media or have played or worked with a robot once or twice. However, none of them have ever seen or worked with the robot used for this study before.

IV. ANALYSIS

Initially, all participants reacted in very similar ways to the robot, and follows a structure similar to that of excerpt 1 below.[1]

```
1.    Robot:  okay let's start to play
2.    Robot:  you go first choose a letter from
              the english alphabet
3.            (0.5)
4.    Par08:  dee:
5.    Robot:  okay (.) let me think.
6.            (1.0)
7.    Robot:  i choose o:.
8.            (1.5)
9.    Robot   so (.) now it's your turn again.
10.           (0.5)
11.   Par08   u::hm (0.5) a:.
```

Excerpt 1

A pervasive feature of all the participants' verbal conduct is that they align linguistically with the robot's utterances on both the structural and lexical level. For example, initially all participants select the next letter in the game simply by saying the letter without prefacing or suffixing the utterance with any other lexical items. An example of this is seen in excerpt 1 in line 11, where Par08 says the letter "a" prefacing it only with a hesitation marker ("u::hm"). However, within a few turns participants align their utterances with the robot's and use the structure shown in line 7 of excerpt 1 above.

Another example of this kind of alignment is also seen in excerpt 2 below, where the robot up until this point has been selecting letters by just saying the letter or using the structure reported in 1 above. The robot uses a different structure in line 7 of excerpt 2, displaying its awareness of its previous action. In turn the participant copies this behavior in line 11.

```
1.    Robot:  tee (T).
2.            (0.7)
3.    Par15:  ( ).
4.            (5.0)
5.    Par15:  a::nd a:
6.            (8.0)
7.    Robot:  tee (T) again.
9.            (1.0)
10.   Par15:  tee again?
11.   Par15:  the::n a again.
```

Excerpt 2

Halfway through the interactions two distinct interaction patterns emerge; one (referred to as engaging) in which participants engage with the robot playfully and where participants themselves act proactively by for example raising off-topic questions, and produce more linguistically complex and varied utterances (5 participants), and another one (referred to as non-engaging) in which participants engage with the robot only reactively and respond only minimally to the robot's utterances (3 participants). An example of a participant engaging proactively is seen in excerpt 3 where the participant initiates a repair sequence in line 1 to better understand the rules of the game.

```
1.    Par15:  and we should use [all these
              letters,
2.    Robot:                    [and eye (I).
3.            (4.0)
4.    Par15:  and we should use all these letters
              to create a word?
5.            (2.5)
6.    Par15:  should we?
7.    Robot:  yes yes we must form a word
9.    Par15:  with all of them?
10.           (4.5)
11.   Par15:  with [all,
12.   Robot:       [yes.
```

Excerpt 3

The participant's utterance is cut off by the robot's overlap in line 2, after a long (four second) gap the participant restarts the sequence in line 4. When the robot does not immediately respond she attempts to re-elicit a response from the robot in line 6 using a short reformulation, to which the robot immediately responds. The participant therefore displays that she expects the robot to understand full linguistic phrases, and is able to respond to these in a timely fashion. In normal human-human interactions a 'timely' response is considered to be no more than 300 msec, with some cultural variation [22]. Structurally, this excerpt is also quite complex. Besides the basic adjacency pair (question/answer) found in line 1 and 12, it also features embedded adjacency pairs (adjacency pairs within adjacency pairs), for example in line 4 and 7, and post-expansions ("should we?") as in line 6.

In comparison, the participant in excerpt 4 responds with just one-word utterances throughout the dialog. The dialog itself is also structurally simple; line 1 is the first pair part of an adjacency pair to which line 5 is the second pair part. Line 5 is followed by a long gap of more than 16 seconds where the participant does nothing but wait for the robot to respond. When it does respond in line 7 it is with a repair initiator (tomato?), which is treated by the participant as a confirmation check that she in fact said "tomato", which she then restates in line 9. There is no indication in the excerpt that the participant expects the robot to be able to understand more than simple utterances, nor is there any indication that she holds the robot accountable to adhere to the rules of interaction in the same extent she would a human. This is displayed in particular in her acceptance of the 16.8 second gap in line 6. This excerpt is indicative of not only her interaction with the robot but also with the other participants who engage with the robot reactively, and is thus representative of several participants in the study.

Excerpts 3 and 4 differ quite significantly and represent two very different ways of handling the interaction with the robot. The interesting question here is of course what leads people to adopt different communication strategies in interactions that on the face of it should be very similar. As seen in excerpts 1 and 2 participants use the robot's

[1] See appendix for a list of transcription symbols used.

```
1.   Robot:  i choose e.
2.           (2.0)
3.   Par10   .hh
4.           (0.5)
5.   Par10:  tomato.
6.           (16.8)
7.   Robot:  tomato?
8.           (4.5)
9.   Par10:  tomato.
```

Excerpt 4

speech as a resource for their own production. This is as such not surprising; people have been shown to align in interaction with other people [23], with computers [24], and with robots [25]. It is therefore sensible to assume that the more of its ability and vocabulary a robot is able to display the more resources do its communication partners have at their disposal, which should in effect directly affect how they interact with it. There is some truth to this argument; a common nominator for the participants who interact with the robot in an engaging way is that they enter into a repair sequence early on in the interaction, in which the robot displays its ability to respond to spontaneous requests, respond in a (somewhat) timely fashion, and is able to understand and produce different utterances. This is demonstrated in excerpt 5.

```
1.           (3.0)
2.   Robot:  o:kay (.) i'll just repeat the rules
             one more time.
3.   Par11:  no it's fine it's fine
4.   Robot:  are you ready to play?
5.   Par11:  i am ready to play
6.           (1.5).
7.   Par11:  [yes
8.   Robot   [let's start to play.
```

Excerpt 5

In the lines preceding the excerpt the robot explains the rules of the game. When the participant does not respond (line 1) the robot initiates repair by offering to restate the rules. The participant immediately declines this offer in line 3, which prompts the robot to confirm that the participant is indeed ready to play, which he confirms in line 5. After a 1.5 second gap in 6 the participant expects an action from the robot, which is displayed by his second confirmation to play the game in line 7. Thus, the fact that the robot displays its ability to initiate repair and respond to the participant with human-like timing shapes the participant's expectations of the robot's abilities which is observable in lines 6 and 7, and in the interaction that follows.

A. *Effect of Odd-Messages*

Despite their intended function, the odd-messages uttered by the robot to signal its situational awareness did not seem to have any interactional effect. Instead, the way in which participants engage with the robot seems to have an effect on how they respond to some of the odd-messages. Two of the odd-messages (“Have you ever seen such a big whiteboard before?" and “This picture is a bit big and intimidating, don't you think?") are assessments. Assessments in interaction between people are special in the sense that they can be agreed or disagreed with, and assessments can be down- or upgraded. In general, there is a preference for agreement displayed by a quick response (for example “yes"") without hesitation or other prefixing [26]. Disagreement (down- and upgrades are essentially also disagreements) on the other hand are interactionally more strenuous in the sense that they are prefixed with hesitation markers, pauses, and accounts. While disagreement may in some cases be preferred (such as in self-deprecating assessments) the preferred response in the two assessments uttered by the robot is to agree. This is displayed by those participants labelled as engaging as seen in excerpt 6 (preferred response) and in excerpt 7 (dispreffered response). Excerpt 6 is interactionally quite simple; the robot makes an assessment and the participant accepts the assessment.

```
1.   Robot   this picture is a bit big and
             intimidating, don't you think?
2.   Par02:  hhh yeah yes.
```

Excerpt 6

Excerpt 7 is in comparison more complex; the robot makes an assessment which is followed by a 5 second pause, which again is followed by only a partial acceptance of the the assessment (line 3). The disagreement ("it's nice") in line 5 is prefixed with a 3.1 second pause and the hedge marker "i think", which is used to minimize the impact of the disagreement.

```
1.   Robot   this picture is a bit big and
             intimidating, don't you think?
2.           (5.0)
3.   Par15   it's big.
4.           (3.1)
5.   Par15   i think it's nice.
```

Excerpt 7

However, those participants labeled as non-engaging do not display same attention to the preference structure, which is demonstrated in excerpt 8:

```
1.   Robot   this picture is a bit big and
             intimidating, don't you think?
2.   Par08   no:
```

Excerpt 8

The different responses to these assessments display participants' very different understandings of the robot as an engaging communication partner. There is no interactional differences in how participants react to the other three odd-messages.

V. DISCUSSION & CONCLUSION

In summary, this preliminary and inherently qualitative analysis points to several tendencies. First, people take the robot's utterances as a point of origin for their own speech production. Second, as a result of this the more of its abilities the robot is able to "show off" the more do people expect of it in terms of interactional competence. Third, one strategy for doing so that seems to work well is by initiating repair sequences. Thus, from a communication design perspective, conversing robots should be equipped with the ability to detect whether an utterance is a potential trouble source, and be able to initiate repair if that is the case. This will in turn show the human communication partner that the robot is situationally aware, responds contingently (as also recommended by Pitsch et al. [16]), and will contribute to humans' understanding of the robot as a competent communication partner, and thus make the interaction more engaging.

In the larger picture, this paper showed that engagement can be measured and analyzed through other means than by gaze and proxemics alone. While this approach cannot directly be used in a robotic system to monitor people's engagement online the same way gaze can, it may influence the communication design of robots used in learning contexts.

A. Future Work

As seen in the transcripts presented throughout the paper participants respond quite differently to the same or very similar stimuli. I have argued that the difference in people's behavior is accounted for by the robot's opportunities for responding to user-initiated repair. The data presented here seem to support this hypothesis. However, there may be other variables that factor in as well. For example, Fischer has found interpersonal differences to have an effect on the extent to which people respond to a robot as a social actor or as a tool [25], while Clark [27] suggests that when communicating with virtual partners people enter into a joint pretense, engages in a role-play so to speak. That is, people may, rather than understanding the robot as a social engaging communication partner, simply be 'making believe' and respond accordingly. Further work should investigate how personal variation interact with the verbal behavior exhibited by robots, and how these variables affect people's engagement.

With regard to the analyses presented in this paper future work will involve adding analyses of people's gaze behavior, increasing number of participants, and correlating behavioral observations with subjective assessments. Furthermore, for this p aper I adopted the definition of engagement as defined by Sidner et al. (2005). However, future work should distinguish between task engagement, social engagement, and social-task engagement as addressed by Corrigan et al. (2013) [28].

APPENDIX

What follows is a list of the transcription symbols used in the paper, based on Jeffersons transcription notation system [21].

:	Lengthening of a syllable
(.)	Micropause (below 0.2 seconds)
(0.0)	Pause in seconds
(T)	Transcriber's indication of what letter is being uttered
?	Rising turn-final intonation contour
.	Falling turn-final intonation contour
[	Beginning of overlapping speech
.hhh	Audible in-breath
hhh	Audible out-breath

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