Implications of Robot Backchannelling in Cognitive Therapy *

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Abstract. The social ability of humans to provide active feedback during conversations is known as backchannelling. Recent work has recognised the importance of endowing robots with such social behaviour to make interactions more natural. Nonetheless, very little is known about how backchannelling should be designed in order to be detected and whether it can have an impact on users' behaviour and performance in cooperative tasks. In this article, we aim at evaluating the legibility of robot's backchannelling behaviour on Persons with Dementia (PwDs) and its effect on their performance when playing cognitive training exercises. Aiming to do so, a TIAGo robot was endowed with backchannelling behaviour generated by combining verbal and non-verbal cues. To evaluate our system, two user studies were carried out, in which the social signal was provided first by a human therapist and later on by a robot. Results indicate that patients were capable of identifying such kind of feedback. Nonetheless, our findings pointed out a significant difference in terms of performance between the two studies. They reveal how patients in the study with the robot overused the feedback to obtain the correct answer, putting in place a cheating mechanism that has led them to significantly worsen their performance. We conclude our work by discussing the implications of our findings when deploying robots in sensitive roles and possible solutions to address such unexpected behaviours.

Keywords: Backchannelling Cues · Socially Intelligent Behaviour · Socially Assistive Robotics · Cognitive Training Therapy.

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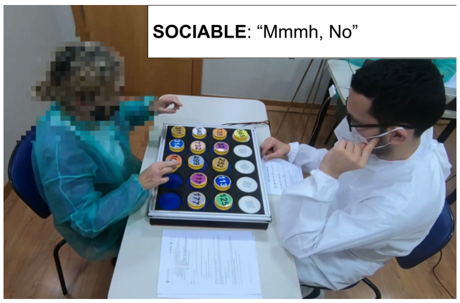
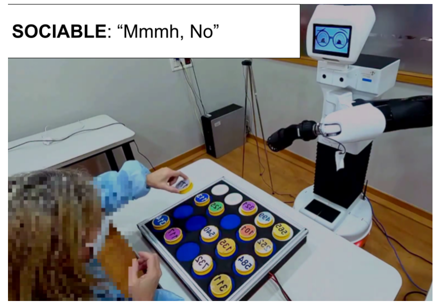


(a) Patient-Therapist



(b) Patient-Robot

Fig. 1: Examples of backchannelling behaviour during the interactions between a patient and the therapist (a), and between a patient and the robot (b).

1 Introduction

Nowadays, robots are increasingly employed in contexts in which they are requested to interact socially with humans. The social robotics field has grown consistently in the last decades, having expanded to domains such as education [8], healthcare [23] and entertainment [1]. In such contexts, robots are expected to have high communication skills almost equivalent to those of humans [7].

Communication in human-human interactions is complex and multi-modal. Our everyday communication is a constant mix of verbal and non-verbal message sending and receiving. Backchannelling in linguistics refers to the cues provided by the listener to the speaker during a conversation without the intent to take a turn, but only to provide feedback. In general, backchannel can be classified by content in: non-lexical ("Hu hu"), phrasal ("Yeah") and substantive ("Come on") [17]. Mimicking such behaviour on robots would make interaction with humans more fluid and natural, which, in turn, would contribute to increasing humans' overall engagement [16].

Despite its importance, very few works in social robotics have explored how to implement such behaviour on robots [2, 10, 13, 15, 20, 22] and its impact on humans' acceptance and performance in assistive tasks [12, 16]. Ding *et al.* [10] describes how an agent can be endowed to elicit conversations with older adults for delivering cognitive training. Similarly, Hussain *et al.* [14] presented a method that learnt to produce non-verbal backchannels, and demonstrated how such feedback had an impact on participants' engagement. Inden *et al.* [16] modelled five different strategies for feedback behaviour in a conversational agent and evaluated their effectiveness in a user study, showing that when the robot took into account the interlocutor's utterance and pauses, participants rated that strategy as more adequate than the others. Likewise, Park *et al.* [22] developed a backchannelling prediction algorithm that detected speaker cues in children's speech and produced backchannelling responses. The results showed that children preferred the robot endowed with such behaviour.

In our preliminary work presented in [2], we modulated a kind of backchannelling behaviour, called SOCial ImmediAcy BackchanneL cuE (SOCIABLE), which was proved to be effective for its immediacy and responsiveness. The system was validated with healthy participants playing a cognitive game. In this work, we go a step further, deploying it in a social robot designed to deliver cognitive training therapy to Persons with Dementia (PwDs) [6]. Indeed, from a set of observational studies conducted with healthcare professionals of Ace Alzheimer Center Barcelona (Fundació ACE), we noticed that patients when playing cognitive training exercises tended to look for the therapist's feedback after each move. On their side, therapists usually respond to such requests by providing positive or negative backchannelling behaviour by combining verbal and non-verbal cues.

Therefore, in this work we are interested in addressing the following research question: *To what extent, if any, would PwDs recognise the robot's backchannelling behaviour, and what would be the impact on their overall performance?*

With the purpose of answering our research question, we evaluated the **legibility** of SOCIABLE and its impact on patients' **performance** during a cognitive training task. Specifically, we designed two user studies in which the therapist was firstly a human, namely, the human-therapist study, and later on a robot, namely, the robot-therapist study (See Fig. 1).

To the best of the authors' knowledge, this is the first work that has evaluated backchannelling social cues with PwDs. With this effort, we aim to shed some light on the implications of using such social signals with vulnerable populations in sensitive contexts in which humans might be inclined to take shortcuts.

2 The personalised RACT system

The Robot-Assisted Cognitive Training (RACT) system has been presented in detail in [6]. We developed aCtive leARning agEnt aSsiStive bEhaviouR (CARESSER), a personalised framework capable of being customisable by therapists and of adapting to patients' individual needs. In the following, we describe the robot's assistive behaviour. Focusing on the verbal and non-verbal social cues that have been implemented on the robot to provide the robot with backchannelling behaviour.

2.1 Socially Assistive Behaviour

The robot could provide assistance in a multi-modal fashion by combining verbal and non-verbal social cues before any patient's movement. The seven incremental levels of assistance are the following: i) turn-taking, ii) reminding, ii) encouragement, vi) suggesting line, v) suggesting subset, vi) suggesting solution, and finally, vii) offering token. These levels were learnt by the robot using Learning From Demonstrations (LfD) through Inverse Reinforcement Learning (IRL) by combining the therapist's demonstrations and expertise [6]. Besides that, the robot is also endowed with an empathic self-comparative personality in order to be more engaging. For instance, it never compares the performance of the current patient to the other, and it celebrates them when they move the correct token and reassures them when they commit mistakes [3]. These supportive behaviours were provided before and after the patient's move, while SOCIABLE, the backchannelling behaviour object of this study, is provided as soon as the patient makes a move.

2.2 SOCIABLE

SOCIABLE [2] is a kind of backchannelling behaviour that is defined as a combination of verbal and non-verbal cues resulting in an instantaneous response to the user's move. Specifically, SOCIABLE is based on phrasal, non-lexical and substantive backchannelling [17]. When the patient picks the incorrect token, the robot firstly makes a confused / surprised / sad face reproducing a sound like "Mmmh", "Huhu", "Naaa" (non-lexical). Then, if the patient carries on picking wrong tokes, the robot might say "Nope", "Incorrect" (phrasal), "Are you sure?" or "Really want to move this?" (substantive). On the contrary, when the patient picks the correct token, the robot would make a happy /excited face and reproduce sounds like "Yep" (non-lexical), "Ok", "Good", "Wow" (phrasal), "Well done", "Carry on" (substantive). In both cases, the facial expressions and the verbal utterances are reinforced by the robot nodding its head. Here[3], we show a snapshot of a session in which the robot endowed with backchannelling behaviour delivers cognitive training therapy to a patient.

3 Experimental Design

The study was set up as a within-subject design, in which the same patient played the cognitive training therapy session first with the human therapist and later on with the robot therapist. It is worthwhile mentioning that the order of the sessions was fixed due to our experimental design [6]. However, we believe there was no learning effect as between the two studies there was almost a month (M=26 days).

Each session consisted of two batteries of three trials. In one battery, the therapist (human or robotic) provided backchannelling behaviour and in the next one, the therapist did not offer any social feedback. To avoid any learning effect, the order in which the batteries were delivered was randomised.

In both studies, we manipulated SOCIABLE (independent variable). To demonstrate the presence or the absence of an effect, we analysed the data using regression analysis.

3.1 Experimental Setting

The experiment was carried out in a room where patients were used to receiving their cognitive training therapy at one of the healthcare centres of Fundació ACE.

[3] https://youtu.be/a2Ktz6ADlwo

The therapist, either a human or a robot, was sit in front of the patient and the board was placed on the table. Cameras were installed to record audiovisual data and monitor the interactions during the session. Only the therapist (human or robotic), the experimenter and the patient were present in the room. Figure 1 shows the experimental setup for both studies.

3.2 Cognitive Exercises

The cognitive exercises delivered by the therapist (human or robotic) were designed by the professional staff according to the well-known Syndrom-Kurztest (SKT) [21].

The board consists of 5x4 cells, on which ten/fifteen tokens are randomly located in the second, third, and fourth rows (see Fig. 2a). The goal of the exercises is to place five of the ten or fifteen tokens in the first line of the board, according to a given criterion (sorting ascending / descending order, only even / odd numbers).

The dynamics of the proposed cognitive task is simple. The patient waits for the robot's assistance at each turn (see Sec. 2.1). Next, the patient is requested to move the token. At this stage, only if SOCIABLE is enabled, the robot provides the backchannelling cue as soon as a token is picked. If the token is placed in the correct location, the robot congratulates the patient. On the contrary, if the patient moves the incorrect token, the robot reassures the patient and provide further assistance. After a predefined number of consecutive mistakes, the therapist moves the correct token on behalf of the patient, as a demonstration. Finally, in the case the patient does not move any tokens for more n secs, the therapist intervenes and offers additional assistance.

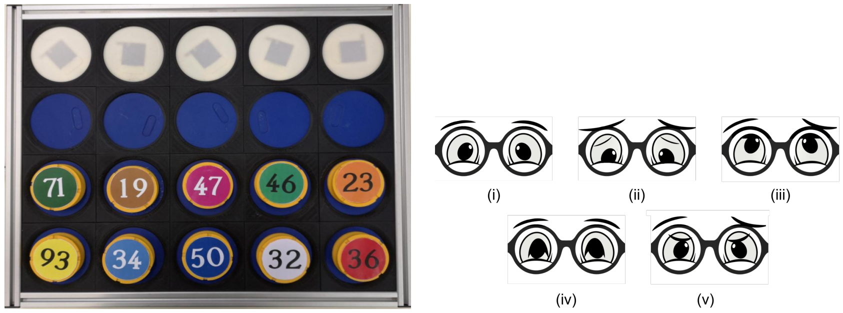
3.3 Participants

Sixteen PwDs (10 male and 6 female, with age distribution of M=75.9 and SD=8.2) were selected by the healthcare professionals. Seven of them were diagnosed with mild cognitive impairment, while the remaining nine had mild dementia. None of the patients had prior experience interacting with the robot.

3.4 Apparatus

The cognitive exercises were administered using an electronic board described in [5]. In order to detect when patients pick a token, the entire board is equipped with RFID antennas and each token with its unique RFID identifier (See Fig. 2a). We improved the previous implementation in [2], guaranteeing the triggering of the backchannelling behaviour in less than 0.2 sec. As a robotic platform, we employed the TIAGo[4] robot. The robot was customised with a new head including an LCD screen to provide affective responses as shown in Fig. 2b. These facial expressions were designed in collaboration with the care providers

[4] https://pal-robotics.com/robots/tiago/



(a) (b)

Fig. 2: Cognitive exercise (a), robot's facial expressions from [6] (b).

of Fundació ACE. Furthermore, the robot's gestures and speech were included as additional interaction modalities.

3.5 Evaluation Measures

At this stage of our work, we decided to employ only objective measures to assess our system in both the human-therapist and the robot-therapist studies. To do so, we measured patients' performance in terms of (i) completion time, i.e., the time they took to complete the task, (ii) number of mistakes, i.e., the number of times a wrong token was picked, or it was placed in the wrong location, (iii) ratio of SOCIABLE, i.e., the number of times SOCIABLE was grasped by patients normalised on the overall number of attempts, and finally, (iv) reaction time, i.e., the time they took to pick a token and place it in a given location after one of the levels of assistance was provided by the robot (see Sec. 2.1).

It should be noted that when the backchannelling behaviour was provided on a correct token, whether the patient detected it was not automatically recorded in our system because the robot was not able to infer if the social feedback was recognised. Therefore, the experimenter took note of whether the patient looked at the robot for getting confirmation feedback. On the contrary, detecting when patients picked a wrong token was done thanks to the electronic board as if SOCIABLE was recognised the patient would move the token back to its original position.

3.6 Protocol

The two user studies were carried out during a two-month period. In the first one, we conducted the human-therapist study and in the second one the robot-therapist one. Sessions were carried out once a week (4 patients) because of the COVID-19 restrictions.

Upon arrival, the experimenter greeted the patient and explained the purpose of the study together with the therapist. At this stage, members of the family

	R^2	**F**	β	**p**
# mistakes	0.11	0.17	-0.26	0.68
reaction time	0.08	2.69	-1.15	0.14
completion time	0.09	1.18	-3.66	0.28

(a) human-therapist

	R^2	**F**	β	**p**
# mistakes	0.26	10.98	2.56	0.002
reaction time	0.28	5.78	-2.64	0.006
completion time	0.02	0.6	0.93	0.8

(b) robot-therapist

Table 1: Results of the linear regression analysis when the backchannelling behaviour was provided by the human therapist (a) and the robot therapist (b). It is important to note that R^2 defines the coefficient of determination, β indicates the magnitude of the effect that the independent variable has on the dependent variable, and the sign defines the direction of the effect, finally F and p-value are the value of the distribution and the significance value, respectively.

were also allowed to attend. If the patient agreed to participate, the experimenter asked them to sign an informed consent form, which included the authorisation to collect data for scientific purposes. Next, a warm-up session was arranged for the patients in order to get accustomed to the board, the nature of the instructions and the kind of exercises.

The patients received instructions to play two test batteries of three trials. Between one trial and the other, a 5-min break was offered to the patients. After each trial, a new sequence of tokens was arranged by the experimenter. This is to avoid the patients memorising the tokens. After completing the first battery, patients were offered a break of 30 min in which they could relax a bit and have informal conversations with the therapist.

4 Evaluation

4.1 Human-Therapist Study

The objective of this first study was to evaluate the patients' performance when the social feedback was provided by the human therapist.

In order to validate whether the backchannelling behaviour of the human therapist had an impact on patients' performance, we formulate the following research hypothesis:

H1: When patients interact with the human therapist, their performance does not change whether the therapist provides them with SOCIABLE or not.

H1 was stated according to previous observational studies carried out with PwDs. From these studies, we noticed that patients when not provided with any backchannelling behaviour tried to solve the task anyway without altering their strategy.

To evaluate the impact of SOCIABLE on patients' number of mistakes, reaction time and completion time (dependent variables), we ran a simple linear regression. The results of the statistical analysis are reported in Table 1a. Overall, we did not find any statistical significance.

Specifically, with respect to the number of mistakes, findings showed that there was not a significant effect ($p = .68$) between when the human therapist provided patients with SOCIABLE ($M = 10.73$, $SD = 1.96$) and when the therapist did not offer it ($M = 11.04$, $SD = 1.63$).

Concerning the average reaction time, results suggested that the difference between patients' reaction time when interacting with the human therapist who provided SOCIABLE ($M = 4.86$, $SD = 2.66$) and when the therapist did not offer it ($M = 3.2$, $SD = 1.83$) was not significant ($p = .14$).

Finally, regarding the impact of SOCIABLE on patients' completion time, results showed that there was not a significant effect of SOCIABLE ($p = .28$) on patients' completion time (with $M = 48.8$, $SD = 9.5$; and without $M = 52.53$, $SD = 6.4$).

4.2 Robot-Therapist Study

The objective of the second study was to evaluate the legibility of the backchannelling behaviour and its impact on patients' performance when it was provided by the robot. We formulated the following research hypotheses:

H2: When patients interact with a TIAGo robot, capable of providing SOCIABLE, they recognise the social feedback and leverage it during the exercise.

H3: When patients interact with a TIAGo robot, their performance does not change whether the robot provides them with SOCIABLE or not.

With H2 we aimed at assessing the legibility of the backchannelling behaviour of the robot. On the other hand, we formulated H3, according to the main findings of the previous study, in which we expected that SOCIABLE would not alter patients' performance.

Concerning the legibility of SOCIABLE, we computed the percentage of times it was detected by the patients. It seems that, in average, patients leveraged the social feedback 78.4% of the time. We noticed that the remainder 21.6% of the time, they did not detect it for two main reasons: they were still discovering it (early stages of the first trial) or because they were at the end of the trial and did not need any confirmation from the robot.

Given those results, we then evaluated whether the social feedback had any impact on the patients' performance. To do so, we ran a simple linear regression, with SOCIABLE as a predictor, controlling for patients' number of mistakes, reaction time and completion time. The results of the statistical analysis are reported in Table 1b.

Regarding the number of mistakes, results highlighted that the difference was significant ($p = .002$), indicating that patients when provided with SOCIABLE ($M = 10.43$, $SD = 1.67$) committed on average 2.56 mistakes more than when they were not provided with any social feedback ($M = 9.59$, $SD = 2.08$).

Similarly, we found a significant effect of SOCIABLE on patients' reaction time ($p = .006$). Indeed, when the robot was endowed with SOCIABLE participants took less time to pick up the next token to move ($M = 4.625$, $SD = 1.31$) than when they interacted with a robot that did not provide any feedback ($M = 7.25$, $SD = 1.56$).

Finally, we did not discover any significant difference in patients' completion time ($p = .8$), that is the robot's backchannelling did not have any impact (with $M = 84.3$, $SD = 8.23$, without $M = 87.26$, $SD = 10.31$).

4.3 Discussion

The results from the human therapist study confirmed our research hypothesis H1. Indeed, patients' strategy and attitude toward the task were the same regardless of the social feedback provided by the therapist. On the other hand, from the robot therapist study, only H2 was supported by our findings, while H3 was only partially confirmed.

The 16 PwDs involved in the study were capable of detecting the backchannelling behaviour of the robot and leveraging it during the interactions (H2). Nonetheless, the impact of SOCIABLE on their performance (H3) was significant on some dimensions: the number of mistakes and reaction time.

Regarding our initial research question, we can conclude that when the backchannelling behaviour was detected by patients, it did impact their performance. We observed that when the robot replaced the human therapist, and it provided social feedback, patients' strategies to solve the task completely changed. Indeed, most of the patients started to pick up tokens randomly and very quickly without paying attention to the number of mistakes but only waiting for the robot's social feedback to decide whether the token was the correct one or not. While not all of them implemented this strategy, by analysing the recording, we can conclude that it was a kind of pattern that we observed. This is also reflected in the significant differences we found in the number of mistakes and reaction time.

From this study, two important aspects of Human-Robot Interaction (HRI) emerged and merit comment: the role ascribed by patients to the robot and the cheating mechanism. We speculate that patients did not fully buy the legitimacy of the TIAGo robot as a therapist. Indeed, humans when interacting with other humans behave differently than when they interact with robots in the same context [4]. Such differences might be the result of applying different social [9] and moral norms [19] to humans and to robots. Another aspect related to the robot's role is its personality and communication style. Indeed, a human therapist would have lambasted the patient for having such behaviour by: (i) telling them to be more concentrated; (ii) gazing at them and making a negative facial expression; (iii) refusing to provide any feedback. In our context, the robot was endowed with an empathic and self-comparative personality, resulting in a very supportive and reassuring behaviour which was not programmed to tackle such lambasting behaviours. Considering switching to a more authoritarian personality might be a valid solution to face such situations. This idea is further supported by the findings of Maggi *et al.* [18] whereby a more authoritarian robot could be more suitable for tasks that require high cognitive demand than a polite one.

Concerning the "cheating" behaviour of patients when provided with SOCIABLE, we interpret it as a coping mechanism given the mental workload required by the task and to prevent negative feelings that they might experience during the session such as anxiety, pressure, or frustration for a negative evaluation [11, 25]. We hypothesised that patients, by realising that the robot was not capable of detecting their behaviour, felt authorised to use it as a shortcut to solve the exercises. This interpretation is consistent with the findings of Petisca *et al.* [24] who found in their study that when participants were alone in the room with the robot (no other human was present) with no chance at all to get caught, participants were more keen to cheat.

5 Limitations and Future Work

Although the present results clearly support our research question, it is appropriate to recognise several potential limitations, both methodological and experimental. With respect to the methodological ones, we can include the limited sample size, which does limit the power of our findings. Given the promising preliminary results, in the future we aim at evaluating the system with a wider population. An additional limitation is the lack of subjective evaluation. It would be interesting to analyse the patients' perception in terms of cognitive workload, user experience and robot's capabilities. A follow-up study will be focused on this specific aspect.

Concerning the developmental limitations, we can mention the lack of adaptivity of the backchannelling. Indeed, we did not learn the "when", i.e., when to provide it, and the "what", i.e., what to say. Future work should explore the possibility to learn the backchannelling behaviour that best fits the patients' individual needs, similarly to [10]. A further limitation was the lack of detecting unexpected situations such the ones reported in this study. On the one hand, we could leave the final decision of reprimanding the patients to the human therapist. On the other hand, as mentioned before, we could integrate the current personality with a more authoritarian one that can tackle such edge situations and study whether the robot is better recognised as a reliable entity. The personalisation framework presented in [6] could be extended in a way to integrate both these two functionalities.

6 Conclusion

In this work, we aimed at evaluating the legibility of robot's backchannelling behaviour (SOCIABLE) and its impact on patients' performance during a cognitive training session. Towards such goal, we designed two within-subject studies: one in which the social feedback was offered by the human therapist and the other, in which it was provided by the robot. We found that patients were capable of detecting SOCIABLE. However, their behaviour and attitude towards the task in the two studies was quite different, leading us to speculate that patients (i) did not ascribe the robot the same authority they assigned to the human therapist, (ii) put in place cheating mechanisms without being worried to get caught when the backchannelling was provided by the robot.

Since robots in the near future are expected to be employed in sensitive roles, it is very important to be sure that they are prepared to tackle some of these situations. While these results are very preliminary, we believe that they can provide food for thought for the social robotics community about the implications that a given behaviour, designed for offering a better human-like experience, may trigger such unexpected behaviour.

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