No evidence for enhanced likeability and social motivation towards robots after synchrony experience

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A wealth of social psychology studies suggests that moving in synchrony with another person can positively influence their likeability and prosocial behavior towards them. Recently, human-robot interaction (HRI) researchers have started to develop real-time, adaptive synchronous movement algorithms for social robots. However, little is known how socially beneficial synchronous movements with a robot actually are. We predicted that moving in synchrony with a robot would improve its likeability and participants' social motivation towards the robot, as measured by the number of questions asked during a free interaction period. Using a between-subjects design, we implemented the synchrony manipulation via a drawing task. Contrary to predictions, we found no evidence that participants who moved in synchrony with the robot rated it as more likeable or asked it more questions. By including validated behavioral and neural measures, future studies can generate a better and more objective estimation of synchrony's effects on rapport with social robots.

Keywords: social robots, human-robot interaction, embodied interaction, interpersonal synchrony, social motivation, Pepper, Godspeed questionnaires

Introduction

In his book *Deep Thinking*, former chess grandmaster Gary Kasparov (2017) recounts the story of his failure against the IBM super-computer Deep Blue in 1997. Contrary to what one might expect, he emphasizes that the triumph of the machine is ultimately the triumph of its human makers, and in order to thrive, humans must learn to live together with intelligent machines. Beyond chess playing devices, disembodied algorithms, and fully automatized factory

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lines, the present time is very much shaped by the rise of *social* robots. These robots have the potential to provide society with economical care, company and therapy (Eriksson, Matarić, & Winstein, 2005; Prescott et al., 2012; Robins, Dautenhahn, Boekhorst, & Billard, 2005). While robots are now deployed in various social contexts where they are framed as companions rather than tools (Darling, 2015; Duffy, 2000), roboticists and stakeholders are faced with the seemingly impossible challenge of making robots “truly social” (Duffy, Rooney, Hare, & Donoghue, 1999). Researchers describe this as a grand challenge with a vast problem space (Riek, 2014; Sandini et al., 2018). However, by endowing an artificial agent with socialness, patients as well as healthy individuals might benefit greatly from improved learning, companionship and therapeutic outcomes (Fasola & Matarić, 2012; Feil-Seifer & Matarić, 2011).

Wiese and colleagues (2017) suggest that the best way to make robots appear more social is to use the toolbox provided by neurocognitive research methods to implement empirically supported behaviors that give “socially awkward” robots better “people skills”. Hence, psychological research methods will be crucial in engineering engaging, long-term and motivating interactions between humans and artificial agents (Broadbent, 2017). But how can we solve the problem of designing truly social robots (Duffy & Joue, 2005)? One approach may be to examine a kind of “lowest common social denominator” that helps establish common ground in human-human interaction: namely, interpersonal synchrony. Defined as movements matched in time (Hove & Risen, 2009), interpersonal synchrony has been established as an indicator of social closeness between two individuals, and also a causal factor in enhancing rapport between people (Berniere, Reznick, & Rosenthal, 1988; Hove & Risen, 2009).

Researchers in human-robot interaction have started taking advantage of the fact that synchrony with another agent may foster rapport (Hove & Risen, 2009). In their proof of concept study, Mörtl, Lorenz and Hirche (2014) equipped a robot with the ability to synchronize its movements to those of human participants during a joint-action pick-and-place task. The authors report that 11 out of 12 participants recognized the adaptability of the robot and 10 participants liked this about the robot. Relatedly, Shen and colleagues (2015) used an information distance algorithm to generate real-time, adaptive motor coordination with the KASPAR2 robot. While the main goal of the experiment was to test the success of the synchrony-promoting algorithm, they also distributed a questionnaire to their 23 participants, inquiring about which of the games (adaptive condition versus non-adaptive baseline condition) they preferred. While most participants preferred the adaptive robot, there was no significant pre- to post- rating difference for their single-item measure of the robots’ social capabilities. However, results by Lehmann and colleagues (2015) suggest that movement synchrony of a non-anthropomorphic robot significantly improved participants' ratings of the robot's likeability and perceived intelligence.

As Irfan and colleagues (2018) emphasized, when implementing concepts from social psychology to human-robot interaction studies, it is important to establish how reliable and robust these effects are in humans. A recent meta-analysis by Mogan and colleagues (2017) investigated the effect size of interpersonal synchrony on pro-social attitudes and behavior. The authors included 42 independent studies that experimentally manipulated synchrony. The researchers found that moving in synchrony had a medium effect on increasing prosocial behaviors ($M_{ES} = 0.28$), small to medium effects on perceived social bonding and cognition ($M_{ES} = 0.17$) and a small effect on increasing positive emotions ($M_{ES} = 0.11$). However, Mogan et al. (2017) did not take into account a potentially problematic methodological artefact: experimenter bias. In fact, a meta-analysis conducted by Rennung and Göritz (2016) reports that the effect of interpersonal synchrony (here they define synchrony both as 'synchronous motor movement and sensory stimulation', p. 169) on prosocial behaviors can be *entirely* explained by a lack of experimenter blinding. They found that the effect of interpersonal synchrony on prosocial attitudes and perceived social bonding was greatly reduced when controlling for experimenter blinding but remained significant.

Similar to the abundance of synchrony manipulations used in the field (see Cross, Wilson, & Golonka, 2016, for an overview), no underlying mechanism is generally agreed upon (Mogan et al., 2017). However, Rennung and Göritz (2016) remark that all potential explanations share a common trait: '[interpersonal synchrony] is a rewarding experience' (p. 169). Wheatley and colleagues (2012) hypothesize that moving in sync with another individual may engage the brain's reward system, which in turn may incentivize further social interactions. This idea is closely related to the theory of social motivation, as proposed by Chevallier and colleagues (2012). These scientists highlight two main components of social reward: liking and seeking of social cues. Empirical support for the theory that interpersonal synchrony may be connected to reward comes from Kokal and colleagues' (2011) study on synchronized drumming. For participants who acquired the drumming rhythm easily before the scanning session, activity in the caudate nucleus was enhanced during synchronous drumming, which furthermore predicted later prosocial behavior towards the experimenter (who was blind to the manipulation). All in all, a possible underlying social reward mechanism may be what promotes the positive interpersonal effects of synchrony, thus highlighting the need to investigate interpersonal synchrony in conjunction with social motivation.

The goal of the present double-blind study was to investigate whether interpersonal synchrony with a robot improves social motivation towards the robot.

We hypothesized that moving in sync with the robot would improve its likeability, analogous to the findings of Lehmann and colleagues (2015), and, based on Chevallier's social motivation theory, would increase the motivation to interact with the robot, as measured by the number of questions participants chose to ask the robot during a free interaction.

Methods

Data statement

We report all measures in the study, all manipulations, any data exclusions, and the sample size determination rule. The data and the R analysis script are publicly available via the OSF [https://osf.io/c7jwy/].

Participants

We aimed to recruit the highest number of participants within the testing period (February to April 2018). Initially, the sample consisted of 71 participants. Four participants were excluded from further analysis due to large error rates (losing the metronome more than 30 times, see experimental procedure below) on the task, and four more had to be excluded due to missing data on the Godspeed questionnaires. Two participants were excluded because they reported studying computer science, and one participant was excluded due to reporting a diagnosis of Autism Spectrum Disorder. Eleven participants were excluded, as they failed the manipulation check of correctly perceiving synchrony or asynchrony. Four additional participants were removed after completing statistical checks before analyses (see data analysis, below). The final sample consisted of 45 participants. The subjects' ages ranged between 18 and 31, with an average of 20.51 years ($SD = 2.69$). Of the 45, 30 were female. Ethical approval was obtained from the Bangor University ethics review board (2018–16221). All subjects provided written informed consent prior to taking part and were reimbursed for their participation either by payment or course credit. Participants were naïve to the goal of the experiment.

Robotic platform

For the experiment, a Pepper robot was used. Pepper is a 1.2 m tall, commercially available humanoid robot from SoftBank Robotics (Tokyo, Japan). Pepper features 20 degrees of freedom and runs a Linux operating system programmable using NAOqi libraries with Python or C++. The robot can run in an automatic animation mode and a controlled animation mode. For the experiment, the controlled mode was used (sometimes referred to as the 'Wizard of Oz' mode). The controlled mode allows full command over movement and speech, where it only acts as instructed by the experiment program, rather than by its inbuilt AI.

Dependent measures

Participants were asked to assess likeability, anthropomorphism and perceived intelligence of the robot via the three Godspeed subscales of the same name (Bartneck, Kuli, & Croft, 2009). The items were presented in a scrambled order, as recommended by the authors. All subscales consist of 5 items, which are structured as a 5-point semantic differential scale (for example: like-dislike). The behavioral measure of social motivation was a list of questions provided to the participants, including such questions as "How are you?", "Are you a boy or a girl?" and "Are you intelligent?" (Appendix C). The number of questions asked was used as a proxy for social motivation.

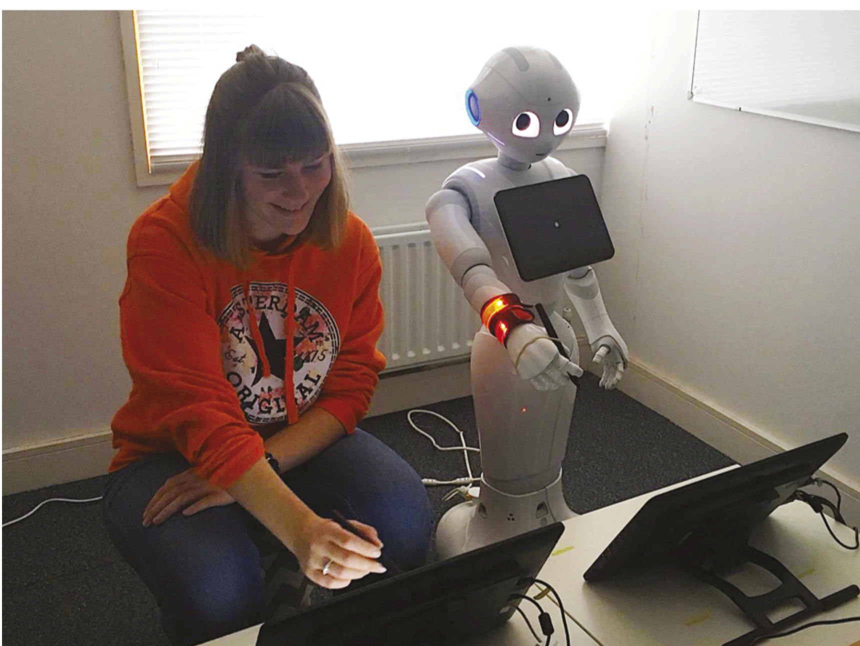

Figure 1. The set-up for the drawing task.

Experimental procedure

Upon arrival, participants received information about the experimental task and provided informed consent. Next, they filled out questionnaires relating to their demographic information and trait attitudes towards robots (Nomura, Kanda, & Suzuki, 2006; Syrdal, Dautenhahn, Koay et al., 2009). Then they met Pepper, the robot, who introduced itself as a member of the University research department and invited participants to take a seat next to it. Importantly, the experimenter was blind to which condition the participant was randomly assigned to. The blinding was ensured via a room divider, hence, at no point during the synchrony manipulation could the experimenter see the movements of the robot or the participant.

The two between-subjects experimental conditions involved drawing either in sync or out of sync with Pepper. We modelled our task after Hove and Risen (2009). In their study, participants were following a visual metronome (a rising and dropping bar), which resulted in them tapping either in synchrony or out of synchrony with a confederate (Hove & Risen, 2009). Similarly, we used a visual metronome (a small circle moving along a larger circular trajectory) and instructed participants to follow its movement with a pen. The practical reason for choosing this task was that it gave us a high degree of control of the participants' movement, without explicitly asking them to synchronize with the robot, a potential confound. In the synchrony condition the metronome was linked to the movement of the robot, whereas in the asynchrony condition the robot was moving approximately 2.5 times as fast along the circle shape as the participant. Participants received the instruction from the experimenter that the goal of the task was to follow the moving target as closely as possible and deviate from it as little as possible. While participants followed the moving target with the drawing pen on the tablet, the robot (due to the technical constraints of it not being able to hold a pen), performed the drawing motion with some distance to the screen (Figure 1). The tablet in front of the robot was always turned off- participants were told that a film on the screen was used to prevent them from getting distracted from their task. When using the drawing pen, participants could see that the pen has indeed a wireless function, but they were always encouraged to keep the pen on the tablet, to minimize the chance of losing the visual metronome.

After an initial practice round was completed, participants received the additional instruction of monitoring an LED strip on Pepper's right arm, similar, but not identical, to the one seen in Figure 1. They were told that the LED lights would change colors randomly and they would be probed to report the color changes. However, due to technical difficulties with controlling the LED lights via a remote control, we only report a descriptive graph (Appendix A). Each experimental block consisted of four repetitions around the circle shape, resulting in four circular arm movements per block. After three experimental blocks of the drawing task, the participants filled out the three Godspeed subscales (Bartneck et al., 2009), which were presented to them via the drawing tablet screen. They proceeded with three more experimental drawing blocks.

Finally, they received the instruction via their tablet that the main part of the experiment was over, and they now had the chance to get to know the robot better. They were also informed that this part of the study was optional and that they would not be compensated by research credits or money for the time spent talking to the robot. Then they picked up the piece of paper containing the questions, took a seat opposite to the robot and asked the robot questions, whose answers were Wizard-of-Oz controlled by the experimenter behind the room partition. Then, participants filled out a manipulation check probing them for suspicion and asking about perceived synchrony. Overall, the task took 12 minutes to complete (2 minutes per experimental drawing block) and completing the entire study took roughly 45 minutes.

Data analysis

We conducted a MANOVA on the Godspeed subscales, as this analysis accounts for the relationship between the outcome variables. Before the analysis, multivariate assumption checks were conducted. The Mardia skewness and kurtosis tests confirmed multivariate normality. Via Malanobis distance, four multivariate outliers were identified and removed. Moderate correlation between dependent measures was confirmed after running pairwise correlations. Bartlett's test was not significant, indicating homogeneity of variances. Furthermore, a non-significant Box's M test suggested homogeneity of the covariance matrices. A one-way multivariate analysis of variance (MANOVA) was conducted to investigate the effect of synchrony on the robot's likeability, anthropomorphism and perceived intelligence. Furthermore, Welch's Two Sample t-test was used to examine how the synchrony manipulation affected the participants' social motivation. However, the manipulation check showed that a rather large proportion of the participants in the asynchrony condition had perceived to be in sync with the robot ($n=10$) and one participant in the synchrony condition had failed to perceive this ($n=1$). Based on this insight, participants who had failed to correctly perceive the manipulation were excluded, resulting in $N=45$ participants. A second group split based on perceived synchrony was performed, and within the context of exploration, the above analyses were repeated ($N=56$).

Results

Original group split

The one way MANOVA showed no significant differences between groups on the dependent measures: Pillai's $V=.07$, $F(3,41)=.96$, $p=.42$. There was no significant difference between the groups on the measure of social motivation: $t(41.49)=-.45$, $p=.67$, $d=-.13$. These results are visualized in Figure 2. Synchrony did not lead to increased liking or social motivation towards the robot.

Perceived groups

The second one way MANOVA showed also no differences, when the groups were split on perceived synchrony: Pillai's $V=.11$, $F(3,52)=2.05$, $p=.12$. In addition, there was no significant difference between the perceived groups in social motivation towards the robot: $t(39.24)=-.26$, $p=.60$, $d=-.15$. Likeability ratings and social motivation of the perceived groups are depicted in Figure 3. Perceived synchrony did not lead to an improved perception of Pepper or towards an increased motivation to ask the robot questions.

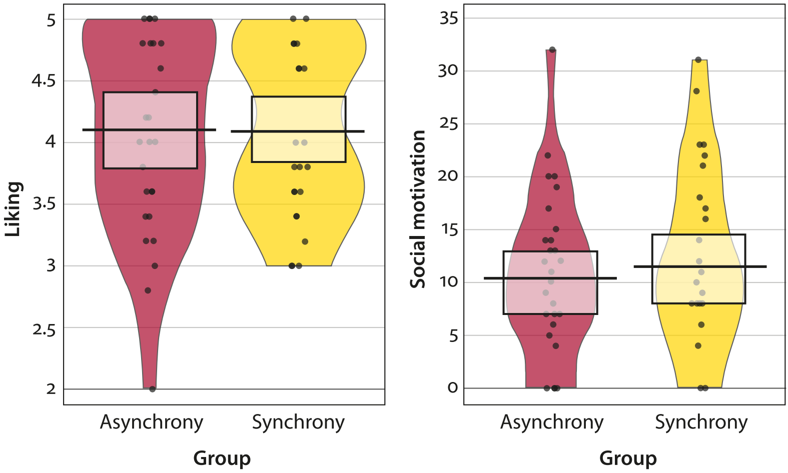

Figure 2. The plot on the left-hand side depicts the groups' ratings on likeability of the robot. The graph on the right depicts the distribution of number of questions participants asked the robot ($N=45$, $n=19$ in the asynchrony group, $n=26$ in the synchrony group). The plots depict the raw data, the central tendencies and densities, and the 95% highest density intervals.

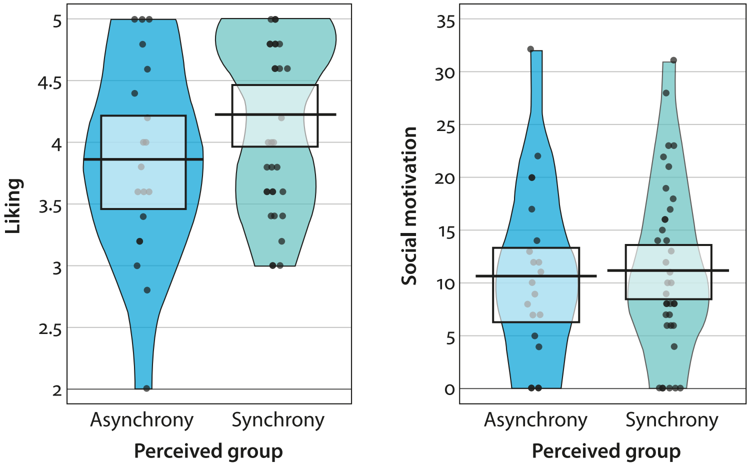

Figure 3. On the left, the likeability ratings are shown for subjectively perceived synchrony with the robot. Individuals, who were in the asynchrony condition, but reported to have been in sync with Pepper were combined with those, who were objectively in sync with the robot. On the right, again the number of questions asked are shown, this time for perceived groups ($N=56$, $n=20$ in the asynchrony group, $n=36$ in the synchrony group). The plots depict the raw data, the central tendencies and densities, and the 95% highest density intervals.

Discussion

In this study, we investigated the effect of experiencing interpersonal synchrony with a humanoid robot on its likeability and participants' social motivation towards the robot. Contradictory to our hypotheses, participants who moved in sync with the robot Pepper did not rate the robot as more likeable, intelligent or humanlike than participants who performed the task out of sync with it. Participants in the synchrony condition did not show stronger social motivation towards the robot … either, as indexed by the amount of questions they asked the robot in a voluntary interaction after completion of the main task.

One critical but interesting observation were the differences in experimentally manipulated and subjectively experienced synchrony. One third of the participants who were assigned to the asynchrony group reported that they believed they were moving in sync with Pepper. Given this finding, it may be that the experimental manipulation of synchrony was either too subtle or too short to fully immerse participants in the experience and to produce the hypothesized beneficial effect on rapport between synchronizing agents. Indeed, findings reported by Lehmann and colleagues' (2015) suggest that movement synchrony should positively impact self-reported likeability of a synchronous robot. However, an important difference between the study reported here and their experiment was that in their videos, the robot was making goal-direct movements towards a person. They defined "positive synchrony" as the robot shifting its "gaze" towards the movement of a human agent, who was arranging flowers in a vase. In contrast, in our experiment, Pepper was making goal-directed, synchronous movements reacting to the task, and not the participant. Hence, this was a markedly less social context, than reacting to the movements of the other interaction partner.

In addition to the potential necessity of adaptivity in synchronous interpersonal movement, Lorenz, Weiss and Hirche (2016) argue that in order to reap the benefits of synchrony in social interactions with robots, the human interaction partner needs to attribute a mind to the robot. This idea is consistent with research by Wiese and colleagues (2012), which shows that top-down beliefs about an agent's intentional stance can influence basic attentional mechanisms. Even though we assessed trait negative attitudes towards robots, we did not include a self-report or behavioral measure of mind attribution. While Pepper introduced itself before starting the drawing task, it remains unclear how much mind and intention the participants attributed to the robot. In addition to these factors that could have adversely affected the hypothesized positive influence of interpersonal synchrony, we saw a ceiling effect of likeability of the robot – in both groups, Pepper was rated as very likeable.

More questions remain regarding why the synchrony manipulation did not impact participants' social motivation towards Pepper. One possible explanation for this result could be that counting the amount of questions the participants chose to ask the robot may have been too crude a measure to pick up any small to medium sized effect we expected from a synchrony manipulation. Stronger motivational factors, such as the desire to finish an already long experiment, may have interfered with subjects' desire to spend time with the robot. In addition, previous experiences with the robot might have influenced their behavior, with participants lacking any experience perhaps showing stronger curiosity to interact with Pepper or a lack of familiarity affecting the mind perception of the robot (Müller et al., 2011). This lack of sensitivity of the behavioral measure highlights an important gap in readily available, objective, dependent measures in social robotics. Behavioral and neuronal measures offer objectivity, which self-report measures are not able to provide, due to inherent reporting bias and social desirability effects. Drawing on established and validated measures from cognitive (neuro)science might help us to bridge this gap (Wiese et al., 2017). Future research in interpersonal synchrony with robots should invest in the implementation of these behavioral and neuroscientific dependent measures, to complement the limitations of self-report and enable more precise triangulation of the mechanisms and consequences of social affiliation via synchrony. Future experiments should further include a positive control to ensure the synchrony manipulation works as expected in human-human interaction and additional loops of control to ensure that the synchrony manipulation is sufficiently immersive and salient. A final limitation we would like to highlight is the fact that given the rather high number of participants we had to exclude, the sample size may have been too small to show the expected small to medium effect size of a synchrony manipulation on perception of and behavior towards the robot.

Following the tenets of the recent HRI'18 workshop "What Could Go Wrong: Lessons Learned When Doing HRI User Studies with Off-the-Shelf Social Robots?", below we summarize the insights gained as psychologists conducting experiments with commercially available robots, such as Pepper.

The Pepper robot as an experimental confederate: Lessons learned

Our initial motivation was to use the most natural, and most autonomous robotic behavior available. However, we quickly noticed in preceding pilot experiments that even little robotic movements away from the participant (due to it orienting to the experimenter's voice behind the room partition), were interpreted as rejection, and especially the faulty behavior of the robot during the free interaction period (due to volume or accent issues), would obstruct the question asking scenario significantly. As such, we used an experimenter-controlled, Wizard-of-Oz setting with gaze lock implemented, to ensure it would always face the participant during the introduction and free interaction period. Furthermore, we found it useful to use Pepper's "alive and breathing" mode between experimental drawing blocks, as the change from complete stillness to the drawing motions might have been perceived as too uncanny.

In conclusion, we did not find that orchestrated synchrony, here induced via a drawing task with a physically present embodied robot, improved the rapport between participants and the robot. Future experiments will help to further elucidate the relationship between synchronous behavior and social affiliation toward robots by including both behavioral and neural measures of social motivation.

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Appendix

A. *Objective manipulation check: LED bracelet colour changes*

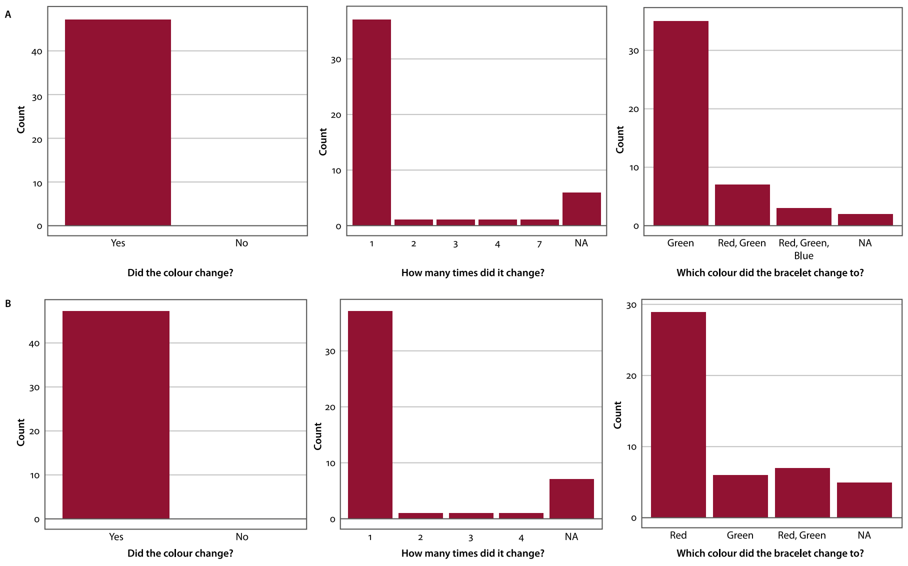

Figure 4. Descriptive visualisation of the LED bracelet based attention check. Participants were asked to report potential colour changes of the LED bracelet on Pepper's arm. There were two colour checks, one after the first three drawing blocks and one after the final three drawing blocks. Participants first had to report if they noticed any colour change (the correct answer is yes, there was one colour change), then how many changes they observed, and which colour the bracelet changed to. In the first check, the correct colour the bracelet changed to was green, in the second round the bracelet changed to red. Due to technical difficulties with the remote control of the LED lights, it is however not informative to interpret these results beyond the obvious fact that a majority of the participants reported the correct answers on all six checks.

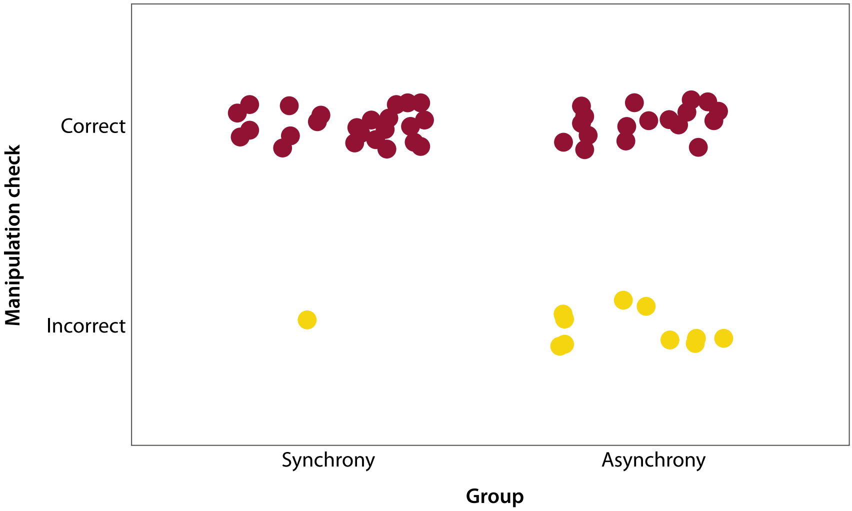

Figure 5. Descriptive visualisation of the subjective manipulation check. To probe perceived synchrony, we asked the participants "Did the robot draw … in synchrony with you? …out of synchrony with you?" 10 participants in the asynchrony group reported to have been in sync with Pepper on the drawing task, whereas one participant in the synchrony condition reported to have been out of sync with Pepper.

B. *Table specifying the group compositions*

Participant numbers in the planned analysis		
Asynchrony	Synchrony	Total
19	26	45
Participant numbers in the exploratory analysis		
Perceived asynchrony	Perceived synchrony	
20	36	56

C. *List of questions participants could choose from*

QUESTIONS YOU CAN ASK PEPPER	
Hello!	Do you eat?
How are you?	Do you have a family?
Why is your name Pepper?	Do you have friends?
Who made you?	What is your friends' name?
Where were you made?	Can we be friends?
When is your birthday?	Are you kind?
Are you a robot?	Are you cool?
What is a robot?	Are you intelligent?
What is a humanoid robot?	Can I trust you?
Are you a boy or a girl?	Will robots replace humans?
Are you human?	Do you know the laws of robotics?
Can you think?	Can you say goodbye?
Can you feel emotions?	
How do you detect emotions?	

Figure 6. The maximum amount of questions participants could ask Pepper was 28 (the two additional questions resulting from participants being able to ask for the second and third law of robotics after Pepper cites the first one. However, since this was a free interaction, some participants chose to either ask zero questions or asked more than 28, in which case we had programmed the robot to be able to answer "I don't know", "Maybe", and "Yes" or "No". Thus, individual participants would end up with a score higher than the number of questions provided by us.

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