SitBot: A posture-mimicking robot to reduce slouching

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Abstract. Poor posture is a common issue in modern sedentary lifestyles and can lead to long-term musculoskeletal problems. This study explores whether a robot can improve human posture through mimicry. We designed a teddy bear robot that mimics people's slouching behaviour, and alerts the person to return to an upright posture. The prototype was tested in a controlled user study involving 20 participants. Results indicate that the inclusion of slouch mimicry tends to make people correct their posture and increases their posture awareness, without being perceived as more distracting than a baseline condition. These initial results suggest that slouch mimicry can be an effective solution to improve people's posture while working at a desk.

Keywords: Human-Robot Interaction (HRI) · Posture · Mimicry

1 Introduction and Related Work

The increasing use of technology and prolonged sedentary behaviours have been linked to poor postural habits and musculoskeletal issues [10], as well as emotional disturbances including stress, anxiety and depression [8]. Given the central role of technology in education, such issues are increasingly common among university students [3]. Various technological solutions have been proposed to help people maintain a healthy posture, such as reminder systems, wearables to monitor posture, and other desktop tools (e.g., [13,1]). While effective to some extent, these systems are often perceived as intrusive or easy to ignore, thus limiting their long-term engagement. Design research suggests that more embodied, interactive technologies such as robots may offer a more engaging and acceptable alternative [18]. In particular, Socially Assistive Robotics (SAR) has shown promise in encouraging healthy behaviours in sedentary contexts. For example, robots that prompt users to take breaks have been found to be more engaging and motivating than traditional alarms [20,18,7]. However, most robotic applications rely on explicit cues or predefined prompts (e.g. [7]).

To the best of our knowledge, little has been done to integrate human social norms, such as mimicry, into an embodied technology as a motivator to improve one's posture while working or studying. Mimicry, or alignment, is a widespread phenomenon in human-human interaction, whereby people tend to unconsciously imitate each other's gestures, facial expressions, speech patterns, mannerisms, and more, to signal affiliation and promote positive rapport [4]. This phenomenon has been studied in the field of Human-Robot Interaction (HRI), both in terms of whether people mimic a robot, thus unconsciously signalling that they are positively aligned towards it (e.g. [12]), and in terms of robots mimicking people, with the aim of improving the interaction. Researchers have studied the effect of robots mimicking e.g. human speech features [9], gestures [15], and facial expressions [17]. Robot mimicry has generally been shown to have positive effects on people in several aspects, including mood improvement [2] and likeability [14]. However, the question of whether mimicry can be used to nudge people to change an undesired behaviour remains underexplored within the context of HRI. Kucharski et al.[7] developed a robot that encourages office workers to take breaks by slowly changing its posture; however, in this case the robot did not mimic the workers' posture, but simply changed posture at pre-defined intervals.

We propose a novel solution to support individuals sitting at a desk by developing a social robotic platform that encourages proper sitting habits through subtle mimicry-based embodiment cues. With this social robot, we investigate the following research question: How does a robot's posture-mimicking behaviour affect a user's sitting posture during desk work? Here, we present a study that addresses this question by examining whether robots, by mimicking people's slouching behaviours, can improve people's posture and posture awareness.

2 Method

We used a rapid prototyping process [5] to develop a teddy bear-shaped robot that mimics slouching. The animal-like form was chosen to encourage empathy [5], and the teddy bear specifically due to its anatomical similarity to humans, particularly the ability to sit upright with a bent back, enabling posture mimicry.

Robot Prototype: Given the intended use case (a robot companion for desk work), we incorporated soft textures and a friendly appearance to enhance user acceptance. The prototype was built using a 28 cm tall IKEA stuffed teddy bear and a custom skeleton composed of three foam segments representing the head, chest, and lower body. These segments were connected via servo motors to enable posture control. Figure 1 illustrates the design stages of the prototype. The waist servo could shift between two positions (100° and 50°), representing upright and slouched postures. A speaker was used to play a sighing sound when the robot slouched. This was meant to alert people to pay attention to the robot. All the code and data are available `here`.

Study Setup and Procedure: To test the effect of robot posture mimicry, we conducted a between-subjects study with two experimental conditions: one where the robot would slouch and sigh (condition SM), and one where the robot would only sigh (condition S) whenever the participant slouched at the desk [1].

[1] `Link to a video showcasing the teddy bear robot's movement and sound.`

(a) Skeleton (b) Structure (c) Appearance

Fig. 1: Final teddy bear robot prototype. (a) shows the foam skeleton, (b) the structure inside the bear, and (c) the completed appearance.

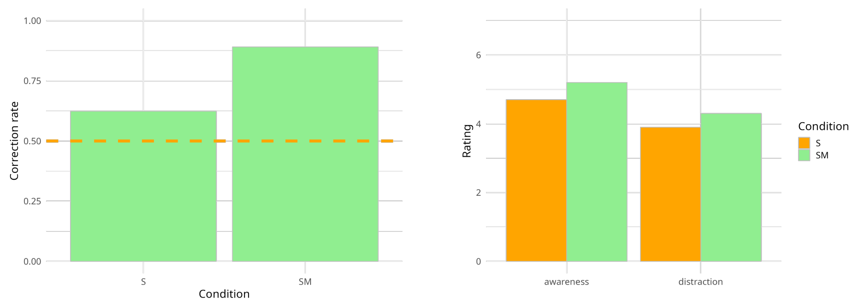
Participants were asked to read a long technical research paper while seated on a tall chair at a high table. Each session began with signing an informed consent form and reading a cover story describing the robot as a "companion teddy bear". Participants were told to "keep posture in mind" without revealing the role of the robot. The robot's response was triggered through Wizard-of-Oz: a researcher prompted the robot to react whenever a participant was observed to be slouching (here, we defined slouching as leaning forward with a bent back or drooping shoulders, based on previous field observations). Participants' posture was noted down throughout the reading task. After 10 minutes of reading, participants were asked to complete a short survey with two 7-point Likert questions on robot awareness and perceived distraction, and a semi-structured interview assessing people's general perceptions of the robot, and how they interpreted the robot's nonverbal communication. Each session lasted approximately 20 minutes.

Participants: We recruited 20 participants (age = 19-58; 12 women, 7 men, 1 preferred not to say), who were randomly assigned to one of the conditions. The experiment followed ethical guidelines from Chalmers University of Technology.

3 Results

Descriptive statistics of the ratings and posture corrections can be seen in Figure 2. A Bayesian ordinal regression model was fitted for both robot awareness and perceived distraction to estimate the effect of mimicry, using the `rethinking` R package. Compared to Frequentist methods, Bayesian models provide full uncertainty estimates and allow intuitive probability statements about effects. They are particularly well suited for small samples and ordinal data, making them ideal for analysing the subjective ratings and behaviour in this study. For behavioural observations, a separate Bayesian logistic regression model was used, where each slouch event was treated as a trial and each posture correction as a binary outcome. All code, data and equations used in this study are publicly available at the project's GitHub repository linked earlier.

Regarding robot awareness, people in the SM condition reported slightly higher ratings than in the S condition. The posterior probability that SM rated higher awareness was 70.3%, with a mean group effect b = 0.30 and a 90% credible interval of $[-0.62, 1.22]$. For perceived distraction, the posterior probability that SM found the robot more distracting was 65.3%. The estimated mean group effect b = 0.21, with a 90% credible interval of $[-0.68, 1.12]$.



(a) Correction Rate (b) Awareness & Distraction

Fig. 2: Comparison between conditions. (a) shows correction rates (dashed line = 50% chance). (b) shows awareness and distraction ratings.

The effect on posture was analysed by looking at whether people corrected their posture after the robot alerted or mimicked them. The Bayesian model estimated a posterior probability of 97.4% that posture correction was more likely in the SM condition compared to S. The estimated group intercept was $a = 1.37$, corresponding to a baseline correction rate of approximately 80% for S ($\text{logit}^{-1}(1.37) \approx 0.80$). The group effect was $b = 0.91$, which translates to an increase in correction rate of about 91% in the SM group ($\text{logit}^{-1}(1.40 + 0.91) \approx 0.91$). The 90% credible interval for b was $[0.13, 1.72]$.

To facilitate comparisons within the HRI community, we also fitted corresponding frequentist regression models to both the Likert scale ratings and the posture correction data. For the ratings, an ordinal logistic regression found small, non-significant group effects for robot awareness ($b = 0.35 \pm 0.80$, $t = 0.44$, odds ratio = 1.43) and perceived distraction ($b = 0.64 \pm 0.82 t = 0.77$, odds ratio = 1.89). For the posture correction, a binomial logistic regression model estimated the baseline correction rate for the S condition as 80% ($\text{logit}^{-1}(1.42)$), with a significant intercept of 1.42 ($p < 0.001$), meaning that people in the S group corrected their posture significantly more than chance. The group effect was estimated at $b = 1.00$, corresponding to an odds ratio of 2.72 ($p = 0.12$), meaning that there was no statistically significant difference in the posture correction rates between the two groups.

Finally, we conducted a thematic analysis on the open-ended questions . The results revealed four key themes: participants generally considered the robot's behaviour as either posture-corrective or emotionally expressive. In the SM condition, the participants understood the corrective function better than in the S condition. The robot sounds were effective in drawing attention to the robot, but five people found them distracting. Mimicry was reported to increase posture awareness (one participant saw it as a "mini version" of themselves). Lastly, two participants wished for personalisation in the robot's embodiment.

4 Discussion and Conclusion

We developed and evaluated a prototype robot that mimics users' posture to encourage them to sit correctly at a desk. Our preliminary results provide initial evidence that mimicking tends to increase people's posture correction and posture awareness, compared to simply drawing attention with auditory cues, as demonstrated by both the Bayesian analysis of participants' behaviour and thematic analysis of the post-interaction interviews. Interestingly, this behavioural change occurred with a very small, not-significant increase in perceived distraction or awareness of the robot. On the contrary, the interview data suggest that the auditory cue alone was sometimes confusing to participants, whereas posture mimicry appeared to clarify the robot's intended message.

To our knowledge, this is the first study in HRI to explore posture-mimicking as a form of implicit feedback to promote behaviour change. While mimicry has been studied in social affiliation and imitation in HRI (e.g. [12,15,14]), its use to signal (un)desired behaviour is novel and holds promising results.

Another interesting finding is that adding mimicry to the auditory cue did not significantly increase perceived distractions or awareness of the robot as shown in figure 2. This suggests that postural mimicry can enhance behavioural compliance without introducing additional cognitive load. This also aligns with previous research showing that multimodal cues are more effective at conveying information than unimodal cues (e.g. [16]). Previous studies suggested that embodied agents such as robots should be more engaging and effective than disembodied computer applications [18], and smartphone-based applications are also known for inducing distractions [6]; still, an experimental comparison between a robot application such as ours and, for example, a mimicking virtual avatar remains to be conducted. In sum, we suggest that posture mimicry is most effective when used as part of a multimodal feedback system rather than as a standalone cue.

While our study did not directly measure perceived engagement or likeability, it is possible that the mimicking gesture contributed to a greater sense of affiliation with the robot, as this is one of the goals of unconscious mimicry [4]. Although our data cannot confirm this interpretation, the increased posture correction observed in the SM condition may reflect increased affiliation with the robot. This can also be linked to participants' comments indicating a desire for more robot personalisation. Previous work on desktop companion robots allowed people to personalise their robot, and this was found to be a positive design feature [7]. Future studies should explicitly measure perceptions such as likeability and engagement, and investigate how personalisation and mimicry might jointly contribute to the effectiveness of socially assistive robots. Another open question for future work is what other human behaviours could be mimicked by robots to support or nudge positive change. Researchers have begun to explore ideas such as yawn contagion in HRI [11], and mirroring or contrasting user behaviour at a desk to influence attention and productivity [19].

Our findings should be viewed in light of some limitations. First, the small sample size (N = 20) limits generalisability and statistical power. While frequentist analyses found no significant effects, Bayesian analyses suggest tentative support for postural mimicry. These results are preliminary and require validation with larger, more diverse samples. Second, the study used a Wizard-of-Oz setup, with manually controlled robot behaviour. Though this ensured consistency, it may not reflect real-world responses to an autonomous system. Future studies should include an autonomous version to assess ecological validity. Third, we did not test a mimicking-only condition without sound, due to pilot results showing that movement alone often went unnoticed. Still, future work should include this for completeness. Fourth, the robot's ability to mimic posture was limited to a single slouching pose, although bad sitting posture can vary between individuals. More advanced prototypes with a more sophisticated anatomy should replicate a wider range of postures and use sensors and cameras for autonomous and real-time detection. Fifth, while our results show promising positive results of using mimicry as a way to make people slouch less, mimicry might actually also have the reverse effect of making people slouch more. This is an ethical concern that should be investigated before similar persuasive technologies are adopted more widely. Lastly, we did not measure other aspects of user perception, such as engagement, likability, or long-term adherence, which should be explored in future work to better understand the persuasive robot's overall impact.

In sum, with our teddy bear prototype, we suggest that posture-mimicking by a robot is a novel and promising strategy to implicitly encourage users to correct their posture, without adding cognitive load or being perceived as distracting.

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