Demonstrating Virtual Teamwork with Synchrobots: A Robot-Mediated Approach to Improving Connectedness

Yuna Watanabe
yuna-watanabe1923@g.ecc.u-tokyo.ac.jp
University of Tokyo
Tokyo, Japan

Xi Laura Cang, Rúbia R. Guerra, Devyani McLaren, Preeti Vyas
{cang,rubiarg,devyanim,pv}@cs.ubc.ca
Computer Science, University of British Columbia
Vancouver, Canada

Jun Rekimoto
rekimoto@acm.org
Interfaculty Initiative in Information Studies, The University of Tokyo
Tokyo, Japan

Karon E. MacLean
maclean@cs.ubc.ca
Computer Science, University of British Columbia
Vancouver, Canada

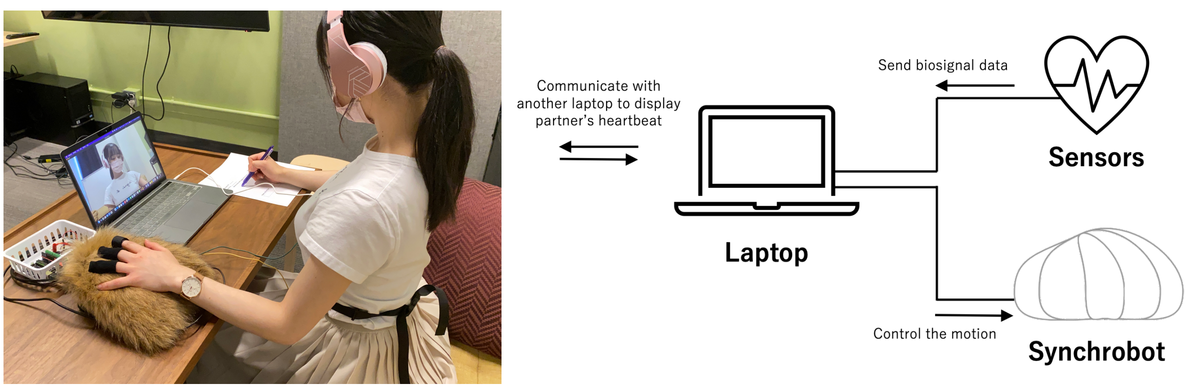

Figure 1: Left: Robot presence being felt during online collaboration. Right: System schematic of biosignal sensors, robot display (Synchrobot), and video conferencing computer.

ABSTRACT

The increased prevalence of online collaborative work, through necessity or preference, is accompanied by measurable drops in satisfaction, creativity and energy, often termed "zoom fatigue." As loss of physical co-presence and associated nonverbal communication are identified as contributors, we introduce Synchrobots – robots designed to channel human biophysiology for group connectedness. We propose an Interactivity demo wherein two participants perform an online problem-solving task while wearing physiological sensors and holding a Synchrobot as it physically renders a translation of their partner's heartrate. The setup involves two stations, each with a laptop running Zoom, a set of wearable sensors recording heart rate, respiratory rate, and electrodermal activity, and a Synchrobot. After the problem-solving task, we will invite participants to reflect on how connected they felt with each other as well as their satisfaction with the collaboration quality. Participants may consent to release this data for later inclusion as part of a study.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative interaction**; **Haptic devices**.

KEYWORDS

robot haptic display, physical co-presence during online collaboration, team connectedness, biosignal display

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1 INTRODUCTION

While tools such as Zoom, Google Suite, and Microsoft Teams significantly improve access to online collaboration by facilitating synchronous verbal communication, they bring new problems, including virtual or 'Zoom fatigue' [14]. Impacts of zoom fatigue include impeding creativity in terms of idea generation [4], leading to dissatisfaction in collaboration [20], and making it challenging to reach a consensus [9], as well as difficulty establishing prosocial behaviours like mutual trust, balancing competitive-cooperative culture, motivation by and awareness of team members [12]. This Interactivity session will showcase a haptic robot display aimed at increasing participants' sense of closeness and collaboration quality in online interactions. We begin by describing the ideal collaboration interaction in terms of a team 'flow state', and how research has shown that physical presence contributes to efficient cooperative work. Robots exhibiting breathing are explored as a display of 'liveliness' and a proxy for teammate physical presence.

1.1 Team Flow and Synchrony

Periods of deep immersion, high productivity, and elite performance are desirable states of being in *flow* [13]. *Team flow* refers to this condition being shared within group collaboration [19]. The process for getting into such a state is not yet well understood, but is recognized to involve physiological and even neurological synchrony between team members [18]: intensely focused pairs experienced significantly higher synchrony in electrodermal activity (EDA) and heart rate than low collaboration pairs even during sit-down cerebral tasks [1, 8, 11]. While physical presence seems to facilitate synchronous collaboration, recent studies of gaming teams found that physical co-presence may not be required to enter physiologically synchronized flow states [10, 21]. This has been seen, for example, when a virtual environment supports real-time joint coordination, *e.g.*, in cooperative online gaming [21]. However, sharing physiological signals in communication such as visual, auditory, and haptic feedback of others' physiological signals in the form of heartbeat [3, 15], respiration [16], and EDA [15], increases mutual awareness [3], perceived empathy [16], and enjoyment [15]. We propose that re-introducing these elements of physical co-presence may increase team flow and improve the collaborative environment.

1.2 Robot Physiological Impact

Breathing behaviours in small furry robots have demonstrated an impact on human physiology and emotion response (e.g. slow relaxed breathing aiding in feelings of calm along with reductions in human heart rate [17]). Even simple robots (*e.g.*, the easy-to-build CuddleBit [5]) can portray a variety of expressive motions, that are human-interpretable to be of complex origin and to have anthropomorphized motivations [6]. We posit that a similarly expressive robot performing dynamic breathing behaviours may evoke human physical co-presence in a virtual teamwork environment.

1.3 Approach

Synchrobots are simple, furry robots actuated with a one degree-of-freedom breathing motion, based on the CuddleBit blueprint [5]; but now with their breathing behavior linked to a team member's sensed heart rate. Since heart rate synchrony is reported to correlate with better teamwork, we adopted heart rate as a Synchrobot control signal. Given that speech is prominent in the task, heart rate may be a more stable measure than respiration rate.

In a virtual collaborative problem-solving environment, each individual holds a Synchrobot which displays their partner's signals. This Interactivity is an opportunity for CHI-goers to personally and physically experience and ask: *How does feeling my teammate's heartbeats through a robot proxy, change our joint problem-solving?* Should participants consent, we will record their interaction as well as their answers to a short questionnaire about their problem-solving experience and how they regard the mutual collaboration quality with their partner after experiencing the robot breathing.

2 SYNCHROBOT

Synchrobot is a furry, animal-like robot designed to be used during communication, particularly online communication. Users place their hands on the robot during communication, and the robot simulates breathing-like movements (see Fig. 1).

2.1 System Overview

The robot is controlled by a microcomputer, ESP32 DevKitC [1]. The ESP32 controls a servo motor, which allows the robot to simulate breathing movements. The ESP32 is connected to a laptop via a cable and receives signals from a Python program running on the laptop to control the robot. Three types of physiological sensors are connected to a microcomputer (Arduino Uno [2]): heartbeat sensor, respiration sensor, and EDA sensor. While only heart rates are used to control Synchrobot, respiration and EDA data are also collected for future analysis. Arduino reads sensor signals in real-time, detects heartbeats, and sends the data to the Python program. When launched, the Python program receives biosignals from Arduino, stores them in CSV (comma-separated values) files, and calculates beats per minute (BPM) of heartbeats. Motion signals are sent to the ESP32 and the robot moves according to pre-defined input modes. Figure 2 illustrates the system.

2.2 Robot Design

The body of a Synchrobot is made of flexible plastic binder sheets cut to a CAD-designed pattern, configured as a spring that is stretched and released by a servo motor, largely mimicking the design of [5]'s Flexibits. The plastic sheet strips are connected to a base sheet with machine screws, to form a shape like the petal of a flower. A servo motor is fixed in the center of the base sheet using another plastic sheet and machine screws. The plastic sheets are brought together at the top and fastened with another screw. The horn of the servo motor is connected to the top screw with a fishing line, which allows the entire robot to expand and shrink according to the servo movement. The servo motor is connected to the ESP32 and thence to the laptop. The bot body and ESP32 controller are covered with a fur cover. The Synchrobot assembly, including the fur cover, is about the size of a large grapefruit and sits comfortably in most users' hand.

[1]Link: https://www.espressif.com/en/products/devkits/esp32-devkitc/overview
[2]Link: https://store.arduino.cc/products/arduino-uno-rev3

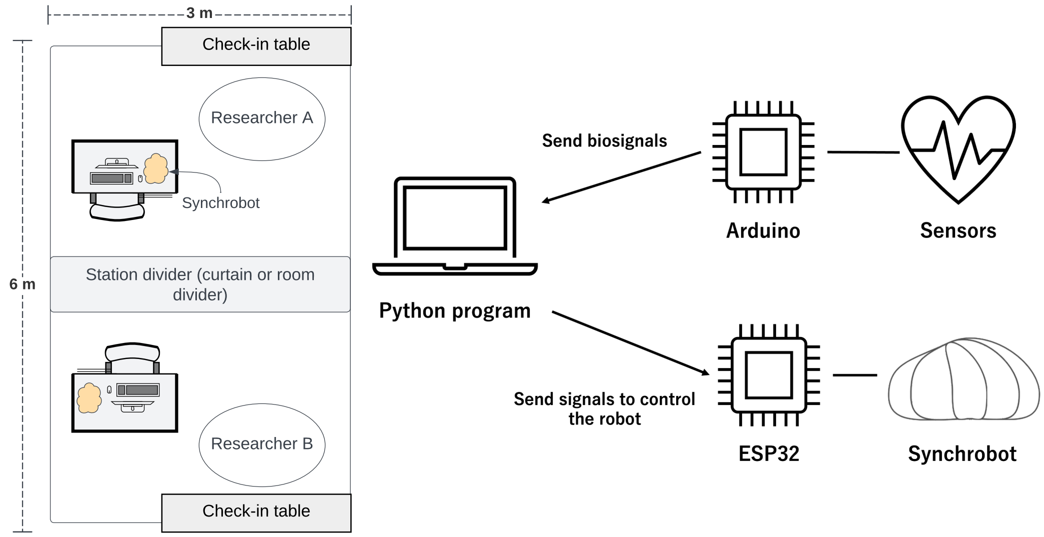

Figure 2: Physical space setup (left) and device configuration overview (right). Sensors and Synchrobot are connected to a laptop.

We adopted a furry robot and breathing-like motion based on previous research suggesting that vibration feedback may induce negative feelings in participants. Previous work comparing visual, audio, and haptic feedback of breathing [7] indicated that nine out of fourteen participants expressed negative feedback toward vibrotactile stimuli, and three participants linked the vibrations to phone notifications. Since we did not want to make the feedback itself stressful for participants, we adopted breathing-like behavior, rather than vibrations. As a pilot for this setup, we have run a short lab study based on this protocol and are now eager to substantively increase the dataset and get audience feedback while simultaneously contributing to the CHI experience.

2.3 Translating the Heart Rates into Robot Motion

Piloting showed that subtle changes in raw heartbeat are imperceptible so we perform a transformation of the partners' heartbeat, amplifying the deltas and translating to breathing rate. Robot breathing motion is calculated by Eq. (1) where *threshold* is the average interval of the partner's first fifteen beats, *interval* represents the current interval between the partner's heartbeats, and $interval_{rev}$ represents the calculated interval between Synchrobot's motion peaks. $Coef$ is 1 when the interval is close to the threshold (average bpm at the beginning). However, the shorter the interval is, the smaller the coefficient becomes (movements become faster), and the longer the interval is, the larger the coefficient becomes (movements become slower).

$$\begin{aligned} x &= interval - threshold \\ coef &= (\frac{1}{1+e^{-2x}} + 0.5)^3 \\ interval_{rev} &= interval * coef \end{aligned} \tag{1}$$

3 DETAILED WALKTHROUGH

Each Interactivity session will run two participants at a time. The dyad can be either strangers or in any kind of relationship. While in line, they will be asked a few questions about their collaboration style. Participants will enter from two separate sides of a demo station, each with a dedicated demo administrator. Should participants provide informed consent to experience the demo, their administrator will introduce the procedure and Synchrobot. Participants will be asked to touch the robot to ensure their comfort with the robot without being told the differences or meanings of any haptic stimuli the robot may or may not display. Participants will wear a heartbeat sensor and EDA sensor on their fingers and a respiration sensor around their waist. To prevent participants from being distracted by the servo motor noise of Synchrobot, they will be provided with headphones playing pink noise during the experiment (all equipment will be cleaned between sessions). Participants will meet their partner on Zoom and work on a randomly assigned problem while experiencing a randomly assigned robot condition (regular breathing or partner-reflecting).

Both participants will keep their non-dominant hand in contact with Synchrobot with audio/video on. Each will be given a paper with a problem to solve and they will be able to discuss their thought processes with their partners and take notes on the paper. Interactivity administrators will limit the problem-solving session to 7 minutes to maintain audience throughput. While previous participants fill out a reflection questionnaire, administrators will prep the next set of participants. We anticipate the activity to take a total of 12 minutes but with the previous session's reflection interleaved with the next session's prep so as to run 8 - 10 dyads (or 16 - 20 individuals) in 60 minutes.

3.1 Pre-Task Collaboration Style Survey

While waiting in line, participants will be debriefed about the Interactivity task and should they consent to data collection, they will be asked to answer a short questionnaire on their personality, collaboration style, and what they deem to be important for effective collaboration before participating in the Interactivity.

3.2 Task

As a cooperative task in our user study, we will use Fermi problems, which involve making educated guesses about uncertain quantities – a reasonable problem-solving task for exploring mathematical and collaboration competencies [2]. These types of problems require dissection into smaller parts and making guesses based on experience and knowledge (for example, "*How many words does a person speak per day?*"). We evaluate the effects and perceptions of Synchrobot in a real-life, collaborative setting that requires communication. Although there is no previous research on physiological synchrony during problem-solving tasks like Fermi problems, we select this task for our early application study.

3.3 Post-Task Questionnaire

After completing the Interactivity task, participants will leave the robot station to answer some questions on a separate tablet. We will ask participants about their overall satisfaction with the collaboration and how they perceived their partner. To measure satisfaction, we have developed questions about collaboration quality, desire to work again with the partner, level of enjoyment during the collaboration, satisfaction with the answer, and perceived closeness with the partner. Participants will rate these elements on a 10-point Likert scale. For measuring perceived closeness, we will use the Inclusion of Other in the Self (IOS) scale [22]. Administrators will set up for the next participants including preparing equipment, wiping down surfaces, and providing hand sanitizer while the last pair reflect on the questionnaire.

4 POST-CHI EVALUATION

As a by-product of this Interactivity, we will collect valuable participant reflections on the two robot movement styles (with approval from our institution's Ethics board). This material can be mined to determine the effectiveness of Synchrobots in improving physical connectedness and reducing virtual fatigue. After the conference, we will investigate the self-reported levels of connection between partners in the partner-matching group to the control (regular breathing) group. We also plan to compare participants' physiological states using heart rate, respiratory rate, and EDA data collected. We plan on reporting the outcomes from the Interactivity data and discussing implications for the use of Synchrobots in online collaborative work in a future publication.

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