Swarm UIs: Impact of Assistance on Users' Sense of Agency

OPHÉLIE JOBERT, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, France
AMINA KORGHLOU, YELLI COULIBALY, and THIBAUT LEONE, Univ. Grenoble Alpes, France
ALIX GOGUEY, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, France
BRUNO BERBERIAN, ONERA, DTIS/ICNA, France
JULIEN BOURGEOIS, Université Marie et Louis Pasteur, institut FEMTO-ST, CNRS, France
CELINE COUTRIX, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, France

Swarm UIs provide assistance to support users in their tasks and are increasingly explored in HCI. This paper studies the extent to which this assistance impacts users' sense of agency. A reduced sense of agency can lead to non-use of the interface or a diminishing sense of responsibility regarding the consequences of users' actions. We conduct three experiments studying the impact of three factors on the sense of agency: the level of assistance, the task difficulty, and the predictability of modules. Our nine assistance levels vary in system autonomy and module coordination (proxy vs. no proxy). We find that higher assistance reduces users' sense of agency, and this effect is not impacted by task difficulty. Predictability only impacts the least assistive interaction techniques. Our results will foster users' acceptance, responsibility, and use of swarm UIs. This workshop position paper is a summary of a CHI'26 paper [18].

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**.

Additional Key Words and Phrases: Swarm UI, Sense of Agency, Autonomy, Assistance, Proxy

ACM Reference Format:
Ophélie Jobert, Amina Korghlou, Yelli Coulibaly, Thibaut Leone, Alix Goguey, Bruno Berberian, Julien Bourgeois, and Celine Coutrix. 2026. Swarm UIs: Impact of Assistance on Users' Sense of Agency. In *Proceedings of AutomationXP26 Workshop of the 2026 CHI Conference on Human Factors in Computing Systems, April 14, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 7 pages.

1 Introduction and related work

Swarm UIs are interfaces made up of several modules that can move independently, without needing to be physically connected to one another. They operate collectively and respond to user commands as a group [22]. The actuation allows swarm UIs to provide assistance to users. Assistance is the degree of autonomy left to a system to help the user perform a task. In this context, swarm UIs can be considered as physical multi-agent systems, with each module capable of making a decision independently or based on the decisions of others and the user's decisions. We currently do not know the effect of such assistance on users' sense of agency (SoA) –that is, the feeling of controlling an action and its effects in the environment [15]. Additionally, the SoA may be influenced by two other factors: (1) users' task

Authors' Contact Information: Ophélie Jobert, ophelie.jobert@univ-grenoble-alpes.fr, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, Grenoble, France; Amina Korghlou; Yelli Coulibaly; Thibaut Leone, Univ. Grenoble Alpes, Grenoble, France; Alix Goguey, alix.goguey@univ-grenoble-alpes.fr, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, Grenoble, France; Bruno Berberian, bruno.berberian@onera.fr, ONERA, DTIS/ICNA, Salon de Provence, France; Julien Bourgeois, julien.bourgeois@univ-fcomte.fr, Université Marie et Louis Pasteur, institut FEMTO-ST, CNRS, Montbeliars, France; Celine Coutrix, celine.coutrix@univ-grneoble-alpes.fr, Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, Grenoble, France.

performance [17, 26, 44, 45] and (2) the predictability of the response of the swarm [7, 8, 36, 37, 46]. This position paper addresses the following research question: *To what extent does the assistance provided by swarm UIs lower the users' sense of agency and how task performance and system predictability modulate this effect?* Answering this question is crucial, as a reduced SoA can lower users' perceived responsibility for the outcomes of their actions [6]. This is especially critical for high-stakes applications –such as surgery [39] or search-and-rescue coordination [16]– where users must retain a sense of control to make informed decisions taking into account any potential consequences. Moreover, user's ability to maintain control over a system impacts its acceptability [35].

Previous work showed a reduced SoA when the system behaves unexpectedly [7, 8, 36, 37, 46]. However, no prior work studied the combined impact on users' SoA of the predictability (e.g., trajectory errors or bugs) and the level of assistance. Conversely, prior work showed that performance can affect the SoA [17, 26, 44, 45]: e.g., the higher the performance, the stronger the SoA [44]. The SoA tends to increase with better performance, regardless of the assistance level [45]. However, prior work suggests that high levels of assistance may reduce the SoA [12, 24, 43, 47, 48], even if performance remains high [43]. This implies that an optimal balance must be found between automation, performance, and SoA [2, 3, 43]. These studies were conducted in the context of graphical interfaces. Direct physical manipulation of modules may increase users' SoA. Moreover, these studies considered the system as a tool rather than as a cooperative partner.

Cooperation happens when "two or more individuals work together toward the attainment of a mutual goal or complementary goals" [1]. Prior work studied the impact of cooperation between humans [28, 40] and between humans and machines [10, 11, 14, 29, 32, 33], on SoA. Particular SoA emerges whenever the consequences of users' actions are linked to those of a partner [38]. *We-Agency* [28, 29] suggests that individual SoA dissolves into a joint SoA when actions are performed cooperatively. However, this dissolution lacks empirical support [21]: when pursuing a common goal, studies show that joint SoA does not replace individual SoA, but supplements it through the development of (1) a *shared* SoA [21] and (2) a *vicarious* SoA for the partner's actions [28, 40]. The SoA for the co-agent's actions appeared when the partner was human, but not when it was a computer [29, 34]. S

Another hypothesis is the distribution of SoA among partners: individual SoA tends to decrease during joint action, being redistributed to other human partner [4, 25, 31, 49] or to robotic partner [10]. Such distributed and joint SoA can only emerge in synchronous tasks, i.e., when the behavior of other agents aligns with one's expectations [23, 31]. However, on the contrary to the systems considered in these studies, swarm UIs can physically move in space to perform an action, creating a sensory effect similar to human actions [32]. Most prior work investigating the SoA when cooperating with robots [10, 11, 14, 32, 33] shows a negative effect of the robotic partner on the SoA compared to the absence of a partner [10, 11, 14, 33]. However, humans show a *vicarious* sense of agency when the robotic partner physically performs the task, while it decreased when the robotic partner performs the task without physical motion [32]. Similarly, there is a significant difference in SoA between three types of partners [33]: human > humanoid robot > servomotor. This suggests that the type of autonomous system involved in the cooperation task has an effect on the SoA.

However, in these studies, partners did not interact with each other when cooperating. On the contrary, in existing swarm UIs, users can directly interact with the modules to achieve their goal (e.g., [19, 22, 41]). Moreover, as opposed to swarm UIs, prior studies focused on a single robot.

We explore the impact of the assistance on users' sense of agency when interacting with a swarm UI (Experiment 1), and how this is further impacted by performance (Experiment 2) and predictability (Experiment 3).

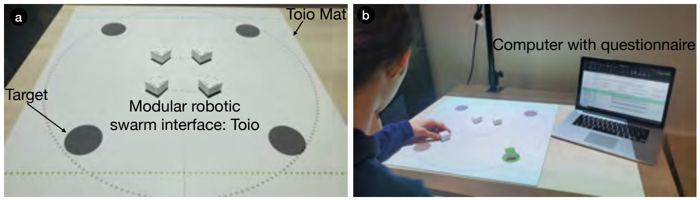

Fig. 1. Experimental setup: (a) Swarm UI consisting of 4 Toios modules, in a square starting position, in front of their gray target vertex, (b) Participant dragging a module, before they answer our sense of agency questionnaire on the right.

2 Experiments

Our three experiments follow the same protocol. Participants performed a drag-and-drop task to resize a circle made of robots. They dragged robots initially arranged in a circle at the center of a platform, and dropped them into a circular target (6 cm in diameter) positioned 15.5 cm away (center to center) in front of each robot (Figures 1) For each experiment we recruited 35 participants (resp. 18/12/12 self-identified as women, 17/23/23 as men, M = 29.26/23/27.66 y.o., SD = 7.57/4.5/9.02). We used four rectangular Toio™ robots [42] (3 cm × 3 cm, height of 2 cm), controlled by Bluetooth via the *Toio SDK* for Unity [27]. We used Unity 2021.3.0f1 on a MacBook Pro M1 Max. The robots and their mat were placed on a table in front of the participants (Figure 1). We project the targets onto the mat with a video projector above the mat.

For each experiment, we used a within-subjects design, with two independent variables and one main dependent.

Independent Variables XP1: Autonomy and Proxy. Our XP1 involves two independent variables controlling the assistance provided by the Toios: Autonomy –the participants drag-and-drop the robots into their targets in five different ways– and Proxy –the robots imitate or not the movements of a leader, called *Proxy*. A combination of both is called Type of assistance.

The Autonomy has 4 levels and 1 baseline level: Inert (A_{INERT}), which corresponds to a level without robots' autonomy ; Snapping (A_{SNAP}) and Stoppable (A_{STOP}), which correspond to semi-autonomous levels ; Triggered (A_{TRG}), which corresponds to a high level of autonomy ; and Complete (A_{CMPLT}), which corresponds to the full level of autonomy and there is no control of participants, this is the baseline level [18].

The Proxy has 2 levels and 1 baseline level: Without Proxy ($P_{W/O}$), the participants interact with each robot ; With Proxy (P_{WITH}), the participants interact *only with the proxy robot* to drag and drop *all of them* into their targets, the others robots are called satellites ; Observation (P_{OBS}), the participants do not interact with any robots, this is the baseline level [18].

Independent Variables XP2: Autonomy and Difficulty. Our XP2 involves two independent variables:

The Autonomy refers to the same levels as in XP1. However, we did not test the Proxy variable in this 2nd experiment and set it to the P_{WITH} and baseline Autonomy levels. There were therefore 5 Autonomy levels.

The Difficulty has 2 levels: the *Harder*, targets have the same size and were at the same position as in the first experiment: Size = 6 cm, Distance = 15.5 cm (Fitts' ID = 3.3) ; and the *Easier*, targets were bigger and closer to Toios: Size = 12 cm, Distance = 9.5 cm (Fitts' ID = 1.2).

Independent Variables XP3: Autonomy and Predictability. Our XP3 involves two independent variables:

The Autonomy refers to the same level as in the XP2.

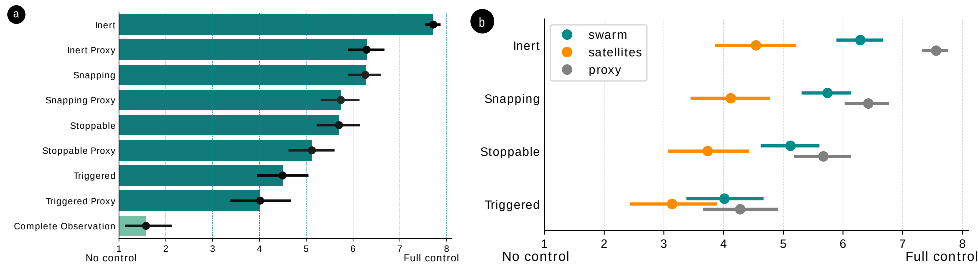

Fig. 2. (a) SoA depending on Type of assistance. For more condensed writing, Types of assistance $P_{W/O}$ are named only by the name of the Autonomy. (b) SoA depending on Autonomy and the role of modules in movement coordination (proxy module vs. satellite modules). For both, error bars represent *bootstrapped* 95% confidence intervals.

The Predictability, refers to the noise in the modules' trajectory, and has 2 levels: the *Straight*, the modules' trajectory is not affected by vibrations and is very predictable; and the *Noisy*, the trajectory is affected by a random vibration of the Toio.

Dependent Variable. Our dependent variable is participants' Sense of Agency (SoA) on the modules' movement. We measure the overall SoA (i.e., for the swarm), the SoA on both proxy and satellites for each Type of assistance using 8-point Likert scales [10, 11].

Results of XP1: Effect of the Type of assistance on SoA. We found (a) a decrease in SoA when the Autonomy increases, but with no difference between the two semi-autonomous levels, A_{SNAP} and A_{STOP} (Figure 2), (b) a higher SoA for $P_{W/O}$ than P_{WITH} (Figure 2a), but no interaction effect between Autonomy and Proxy (Figure 2a), and (c) a higher SoA for the proxy module than for the satellites modules and this gap is even greater when the Autonomy is low (Figure 2b).

Results of XP2: Combined effect of task Difficulty and Autonomy With Proxy on SoA. We found no significant effects of Difficulty on SoA for each level of Autonomy and between the proxy module and the satellite modules (Figure 3a).

Results of XP3: Combined effect of Predictability and Autonomy With Proxy on SoA. We found (a) a small but significant difference between *Noisy* Predictability and *Straight* Predictability, with a SoA weaker for *Noisy*, (b) a small but significant decrease of Predictability effect on SoA when the Autonomy increases, and (c) a small but higher effect of Predictability on SoA for the proxy module than for the satellites modules. This last effect is not impacted by Autonomy (Figure 3b).

3 Discussion and Conclusion

What type of SoA is felt when interacting with a proxy? First, a human *leader* (through the proxy module in our case) develops vicarious SoA for the actions of those humans under their command (satellite modules in our case) [5, 9, 20], lower than their individual SoA [5, 20]. Furthermore, during a joint action, a shared SoA appears [20] (swarm in our case), lower than the individual SoA. We, therefore, propose three types of SoA involved when interacting with a swarm UI through one of its modules acting as a proxy: (a) **Leader SoA** felt for the proxy module, impacted by autonomy (≈ individual SoA), (b) **Follower SoA** felt for the satellite modules, little impacted by autonomy and with a fairly low level (≈ vicarious SoA), (c) **Shared SoA** felt for the whole swarm, impacted by autonomy. Users might be more likely to attribute an error in the satellites to a system malfunction rather than to their own input –regardless of the system

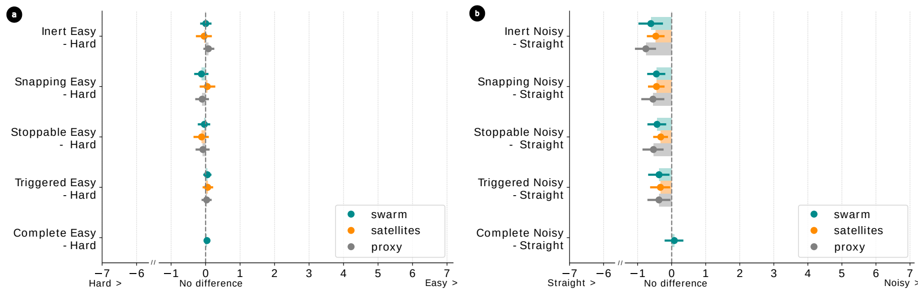

Fig. 3. (a) SoA for XP2 Autonomy × Difficulty(b) SoA for XP3 Autonomy × Predictability For both, the graph represent pairwise differences in SoA for the swarm, the satellite modules and the proxy module, according to Autonomy. The difference is between the SoA score for the *Easier* Difficulty (resp. *Noisy* Predictability) and the *Harder* Difficulty (resp. *Straight* Predictability). Error bars represent *bootstrapped* 95% confidence intervals.

autonomy. Moreover, users are more inclined to feel responsible for an error of the proxy module or for the swarm, unless the system exhibits a high level of autonomy, in which case responsibility is again attributed to the system. Designers should foster users' responsability and therefore consider lower autonomy or introducing a proxy.

Second, users could distribute their SoA among modules, due to the synchronous aspect of our task (i.e., the concordance of the satellites movements with those of the proxy). Users would perceive the satellite modules as having their own SoA, and the SoA would be distributed among proxy and satellite modules. However, the creation of distributed SoA and diffusion of responsibility only happen in the case of synchronous tasks –as in XP1 and 2– and not in the case of asynchronous tasks [23, 31]. Our XP3 (predictability) partially supports this analogy: the effect of predictability on the SoA seems weaker for the satellites (≈ vicarious) and the swarm (≈ shared) than for the proxy (≈ individual). Moreover, when comparing the level SoA between XP1 and 3 (Figure 2b and 3b), experiencing unpredictability seems to impact users' proxy's and satellites' SoA. This suggests that an asynchronous, unpredictable task tends to cancel the difference between the three types of SoA in swarm UIs (Leader, Follower, and Shared SoA). In the case of a search and rescue scenario, imagine that robots make a decision (autonomy), failing to take users' input into account (unpredictability), and lowering all SoA They might therefore attribute the outcomes to the system and disengage from its use. On the contrary, if robots take users' input into account and become predictable, designers should be aware that users' responsibility for the actions of the proxy and satellites will increase, but depart from each other.

Sense of agency beyond swarm UIs. Assistive systems will no longer be seen merely as tools for completing tasks, but as partners with whom we collaborate to achieve a common goal [30]. Among these, swarm robotics gained attention and are now actively studied. Beyond swarms, robotics systems with a collective behavior –even when modules are attached to each other– can also benefit from our results. Among other assistive systems, human-robot multi-agent systems [13] could draw on our results. Humans should not be expected to react in the same way depending on the type of assistance granted to the agents they interact with. For example, if the goal is for humans to retain a sense of responsibility while still benefiting from robots' autonomy, using proxies could provide them with agency. Conversely, if responsibility is not a major issue while autonomy is crucial (e.g., to save time), designers should anticipate the consequences on human behavior.

References

[1] APA dictionary - cooperation definition 2018. https://dictionary.apa.org/cooperation.

[2] Bruno Berberian. 2019. Man-Machine teaming: a problem of Agency. *IFAC-PapersOnLine* 51, 34 (2019), 118–123.

[3] Bruno Berberian, Patrick Le Blaye, Nicolas Maille, and Jean-Christophe Sarrazin. 2012. Sense of Control in Supervision Tasks of Automated Systems. *Aerospace Lab* 4 (2012), p–1.

[4] Frederike Beyer, Nura Sidarus, Sofia Bonicalzi, and Patrick Haggard. 2017. Beyond self-serving bias: diffusion of responsibility reduces sense of agency and outcome monitoring. *Social cognitive and affective neuroscience* 12, 1 (2017), 138–145.

[5] Emilie A Caspar, Axel Cleeremans, and Patrick Haggard. 2018. Only giving orders? An experimental study of the sense of agency when giving or receiving commands. *PloS one* 13, 9 (2018), e0204027.

[6] Emilie A Caspar, Salvatore Lo Bue, Pedro A Magalhães De Saldanha da Gama, Patrick Haggard, and Axel Cleeremans. 2020. The effect of military training on the sense of agency and outcome processing. *Nature communications* 11, 1 (2020), 4366.

[7] Valerian Chambon, Elisa Filevich, and Patrick Haggard. 2014. What is the human sense of agency, and is it Metacognitive? In *The cognitive neuroscience of metacognition*. Springer, 321–342.

[8] Valerian Chambon and Patrick Haggard. 2012. Sense of control depends on fluency of action selection, not motor performance. *Cognition* 125, 3 (2012), 441–451.

[9] Thierry Chaminade and Jean Decety. 2002. Leader or follower? Involvement of the inferior parietal lobule in agency. *Neuroreport* 13, 15 (2002), 1975–1978.

[10] Francesca Ciardo, Frederike Beyer, Davide De Tommaso, and Agnieszka Wykowska. 2020. Attribution of intentional agency towards robots reduces one's own sense of agency. *Cognition* 194 (2020), 104109.

[11] Francesca Ciardo, Davide De Tommaso, Frederike Beyer, and Agnieszka Wykowska. 2018. Reduced sense of agency in human-robot interaction. In *Social Robotics: 10th International Conference, ICSR 2018, Qingdao, China, November 28-30, 2018, Proceedings 10*. Springer, 441–450.

[12] David Coyle, James Moore, Per Ola Kristensson, Paul Fletcher, and Alan Blackwell. 2012. I did that! Measuring users' experience of agency in their own actions. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 2025–2034.

[13] Abhinav Dahiya, Alexander M Aroyo, Kerstin Dautenhahn, and Stephen L Smith. 2023. A survey of multi-agent human–robot interaction systems. *Robotics and Autonomous Systems* 161 (2023), 104335.

[14] Ouriel Grynszpan, Aïsha Sahaï, Nasmeh Hamidi, Elisabeth Pacherie, Bruno Berberian, Lucas Roche, and Ludovic Saint-Bauzel. 2019. The sense of agency in human-human vs human-robot joint action. *Consciousness and cognition* 75 (2019), 102820.

[15] Patrick Haggard and Valerian Chambon. 2012. Sense of agency. *Current biology* 22, 10 (2012), R390–R392.

[16] Maria-Theresa Oanh Hoang, Niels Van Berkel, Mikael B Skov, and Timothy R Merritt. 2023. Challenges and requirements in multi-drone interfaces. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–9.

[17] Kazuya Inoue, Yuji Takeda, and Motohiro Kimura. 2017. Sense of agency in continuous action: Assistance-induced performance improvement is self-attributed even with knowledge of assistance. *Consciousness and cognition* 48 (2017), 246–252.

[18] Ophélie Jobert, Amina Korghlou, Yelli Coulibaly, Thibaut Leone, Alix Goguey, Bruno Berberian, Julien Bourgeois, and Céline Coutrix. 2026. Swarm UIs: Impact of Assistance on Users' Sense of Agency. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Barcelona, Spain) *(CHI '26)*. Association for Computing Machinery, New York, NY, USA. doi:10.1145/3772318.3790663

[19] Lawrence H Kim, Daniel S Drew, Veronika Domova, and Sean Follmer. 2020. User-defined swarm robot control. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[20] Solène Le Bars, Alexandre Devaux, Tena Nevidal, Valerian Chambon, and Elisabeth Pacherie. 2020. Agents' pivotality and reward fairness modulate sense of agency in cooperative joint action. *Cognition* 195 (2020), 104117.

[21] Alexis Le Besnerais, James W Moore, Bruno Berberian, and Ouriel Grynszpan. 2024. Sense of agency in joint action: a critical review of we-agency. *Frontiers in psychology* 15 (2024), 1331084.

[22] Mathieu Le Goc, Lawrence H Kim, Ali Parsaei, Jean-Daniel Fekete, Pierre Dragicevic, and Sean Follmer. 2016. Zooids: Building blocks for swarm user interfaces. In *Proceedings of the 29th annual symposium on user interface software and technology*. 97–109.

[23] Marin Le Guillou, Laurent Prévot, and Bruno Berberian. 2023. Bringing together ergonomic concepts and cognitive mechanisms for human—AI agents cooperation. *International Journal of Human–Computer Interaction* 39, 9 (2023), 1827–1840.

[24] Hannah Limerick, David Coyle, and James W Moore. 2014. The experience of agency in human-computer interactions: a review. *Frontiers in human neuroscience* 8 (2014), 643.

[25] Janeen D Loehr. 2022. The sense of agency in joint action: An integrative review. *Psychonomic Bulletin & Review* 29, 4 (2022), 1089–1117.

[26] Janet Metcalfe and Matthew Jason Greene. 2007. Metacognition of agency. *Journal of Experimental Psychology: General* 136, 2 (2007), 184.

[27] Morikatron. 2024. DATAtab: Online Statistics Calculator. https://morikatron.github.io/toio-sdk-for-unity/docs_EN/ Last retrieved: 2024-08-27.

[28] Sukhvinder S Obhi and Preston Hall. 2011. Sense of agency and intentional binding in joint action. *Experimental brain research* 211 (2011), 655–662.

[29] Sukhvinder S Obhi and Preston Hall. 2011. Sense of agency in joint action: Influence of human and computer co-actors. *Experimental brain research* 211 (2011), 663–670.

[30] Marine Pagliari, Valérian Chambon, and Bruno Berberian. 2022. What is new with Artificial Intelligence? Human–agent interactions through the lens of social agency. *Frontiers in Psychology* 13 (2022), 954444.

[31] Paul Reddish, Eddie MW Tong, Jonathan Jong, and Harvey Whitehouse. 2020. Interpersonal synchrony affects performers' sense of agency. *Self and Identity* 19, 4 (2020), 389–411.

[32] Cecilia Roselli, Francesca Ciardo, and Agnieszka Wykowska. 2019. Robots improve judgments on self-generated actions: an Intentional Binding Study. In *Social Robotics: 11th International Conference, ICSR 2019, Madrid, Spain, November 26–29, 2019, Proceedings 11*. Springer, 88–97.

[33] Aïsha Sahaï, Emilie Caspar, Albert De Beir, Ouriel Grynszpan, Elisabeth Pacherie, and Bruno Berberian. 2023. Modulations of one's sense of agency during human–machine interactions: a behavioural study using a full humanoid robot. *Quarterly journal of experimental psychology* 76, 3 (2023), 606–620.

[34] Aïsha Sahaï, Andrea Desantis, Ouriel Grynszpan, Elisabeth Pacherie, and Bruno Berberian. 2019. Action co-representation and the sense of agency during a joint Simon task: Comparing human and machine co-agents. *Consciousness and cognition* 67 (2019), 44–55.

[35] Ben Shneiderman and Catherine Plaisant. 2004. *Designing the user interface: strategies for effective human-computer interaction.* Pearson Addison-Wesley éd.

[36] Nura Sidarus and Patrick Haggard. 2016. Difficult action decisions reduce the sense of agency: A study using the Eriksen flanker task. *Acta psychologica* 166 (2016), 1–11.

[37] Nura Sidarus, Matti Vuorre, Janet Metcalfe, and Patrick Haggard. 2017. Investigating the prospective sense of agency: Effects of processing fluency, stimulus ambiguity, and response conflict. *Frontiers in Psychology* 8 (2017), 545.

[38] Crystal A Silver, Benjamin W Tatler, Ramakrishna Chakravarthi, and Bert Timmermans. 2021. Social agency as a continuum. *Psychonomic Bulletin & Review* 28, 2 (2021), 434–453.

[39] Metin Sitti, Hakan Ceylan, Wenqi Hu, Joshua Giltinan, Mehmet Turan, Sehyuk Yim, and Eric Diller. 2015. Biomedical applications of untethered mobile milli/microrobots. *Proc. IEEE* 103, 2 (2015), 205–224.

[40] Lars Strother, Kristin A House, and Sukhvinder S Obhi. 2010. Subjective agency and awareness of shared actions. *Consciousness and cognition* 19, 1 (2010), 12–20.

[41] Ryo Suzuki, Clement Zheng, Yasuaki Kakehi, Tom Yeh, Ellen Yi-Luen Do, Mark D Gross, and Daniel Leithinger. 2019. Shapebots: Shape-changing swarm robots. In *Proceedings of the 32nd annual ACM symposium on user interface software and technology*. 493–505.

[42] Toio (official website) 2018. https://www.sony.com/en/SonyInfo/design/stories/toio/.

[43] Sayako Ueda, Ryoichi Nakashima, and Takatsune Kumada. 2021. Influence of levels of automation on the sense of agency during continuous action. *Scientific reports* 11, 1 (2021), 2436.

[44] Robrecht PRD van der Wel, Natalie Sebanz, and Guenther Knoblich. 2012. The sense of agency during skill learning in individuals and dyads. *Consciousness and cognition* 21, 3 (2012), 1267–1279.

[45] Wen Wen, Atsushi Yamashita, and Hajime Asama. 2015. The sense of agency during continuous action: performance is more important than action-feedback association. *PloS one* 10, 4 (2015), e0125226.

[46] Dorit Wenke, Stephen M Fleming, and Patrick Haggard. 2010. Subliminal priming of actions influences sense of control over effects of action. *Cognition* 115, 1 (2010), 26–38.

[47] Debora Zanatto, Mark Chattington, and Jan Noyes. 2021. Human-machine sense of agency. *International Journal of Human-Computer Studies* 156 (2021), 102716.

[48] Debora Zanatto, Mark Chattington, and Jan Noyes. 2021. Sense of agency in human-machine interaction. In *Advances in Neuroergonomics and Cognitive Engineering: Proceedings of the AHFE 2021 Virtual Conferences on Neuroergonomics and Cognitive Engineering, Industrial Cognitive Ergonomics and Engineering Psychology, and Cognitive Computing and Internet of Things, July 25-29, 2021, USA*. Springer, 353–360.

[49] Laura Zapparoli, Eraldo Paulesu, Marika Mariano, Alessia Ravani, and Lucia M Sacheli. 2022. The sense of agency in joint actions: A theory-driven meta-analysis. *Cortex* 148 (2022), 99–120.