Perceived autonomy of the co-agents: Sense of agency in human- versus robot-*intended* actions

Zeynep Barlas

Social Cognitive Systems - Cluster of Excellence Cognitive Interactive Technology (CITEC)- Bielefeld University, Bielefeld, Germany

BACKGROUND

CONCEPTS

❖**Sense of agency (SoA)** refers to the sense that one has control over their actions and the outcomes of these actions[1-2].

❖**Intentional binding** refers to the perceived temporal attraction between voluntary actions and their outcomes[3], and has been used as an implicit measure of the SoA. Shorter estimations of the interval between actions and outcomes indicate stronger intentional binding.

❖**Judgment of control (JoC)** is the subjective report of the degree of control experienced over actions or outcomes.

ACTION CHOICE and SoA

❖Previous research showed that sense of agency is weakened when actions are performed as instructed by another human or virtual stimuli compared to when freely selected[4-8].

❖Increased use and engagement of AI technology and robots in human life poses the question how autonomous they are perceived by humans and how one's SoA would alter when acting with a robot compared to when acting with another human.

PRESENT STUDY

❖**The goal of the present study** was to assess the sense of agency when actions (right or left key press) were either freely selected or instructed by a human or a humanoid robot. Crucially, the belief about the autonomy of the robot (Fig. 1) was manipulated such that participants (Table 1) were told either that the robot instructed pre-determined actions (*machine-like*), or it could autonomously determine an action by modeling how humans choose their actions (*human-like*).

DESIGN

❖**Independent measures {4x4x2}:**

- **-Choice** {blocked, Fig. 2}:
  Baseline, free, robot-instructed, human-instructed
- **-Key press-tone interval** {mixed}:
  200 ms, 400 ms, 600 ms, 800 ms
- **-Perceived autonomy** {between subjects}:
  Human-like, machine-like

❖**Dependent measures:**

- **-Interval estimations,**
- **-JoC ratings,**
- **-Post-experiment questionnaire**
  Anthropomorphism, Likeability, Intelligence, Intentionality, Decision making

METHODS

Participants

Human-like (n=30)	Machine-like (n=30)
14 male; M_{age}=24.93 years; *SD*=4.55	13 male; M_{age}=24.73 years; *SD*=4.86
"Zora is implemented with an AI module that mimics how humans choose their actions. On each trial, Zora will actively determine which key you should press."	"Zora is programmed to passively tell you a pre-determined action on each trial."

Table 1. Demographic data of the two groups and corresponding descriptions of Zora given to each group.

POST-EXPERIMENT QUESTIONNAIRE[9]

Q1) Please rate your impression of the robot on these scales:

Anthropomorphism

1. Fake	1	2	3	4	5	Natural
2. Machinelike	1	2	3	4	5	Humanlike
3. Unconscious	1	2	3	4	5	Conscious
4. Artificial	1	2	3	4	5	Lifelike
5. Moving rigidly	1	2	3	4	5	Moving elegantly

Likeability

1. Dislike	1	2	3	4	5	Like
2. Unfriendly	1	2	3	4	5	Friendly
3. Unkind	1	2	3	4	5	Kind
4. Unpleasant	1	2	3	4	5	Pleasant
5. Awful	1	2	3	4	5	Nice

Perceived Intelligence

1. Incompetent	1	2	3	4	5	Competent
2. Ignorant	1	2	3	4	5	Knowledgeable
3. Irresponsible	1	2	3	4	5	Responsible
4. Unintelligent	1	2	3	4	5	Intelligent
5. Foolish	1	2	3	4	5	Sensible

Q2) The robot appeared to be intentional[10].

1 2 3 4 5

Q3) The robot appeared to be able to make its own decisions[11]

1 2 3 4 5

Fig. 1. Nao, named "Zora" in the present study, is a humanoid robot produced by Aldebaran Robotics. "Zora" was programmed using NAOqi Python API, integrated with PsychoPy[12,13] that was used to develop the experiment software.

Procedure

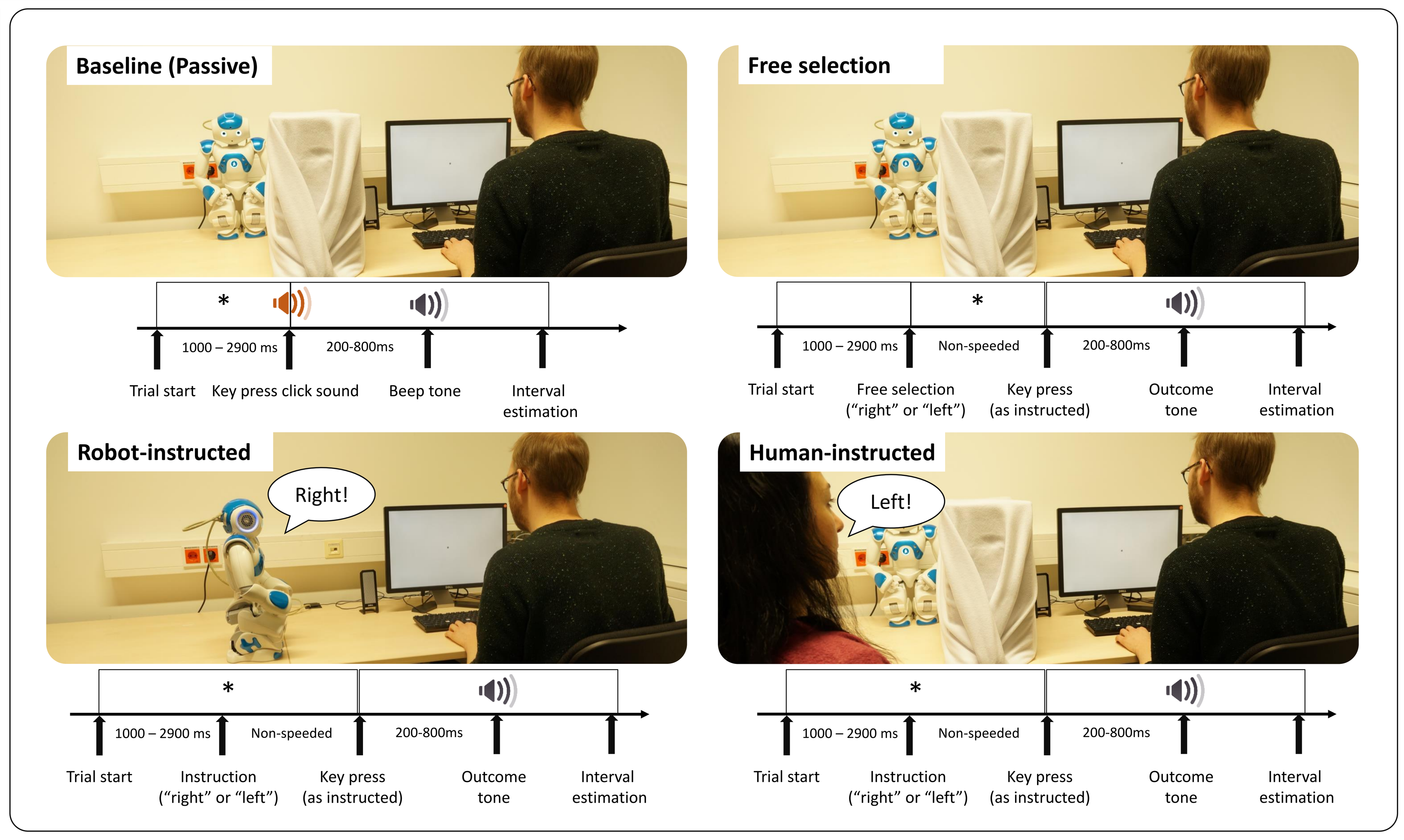

Fig. 2. Illustration of each condition and corresponding trial procedure. In the baseline condition, participants estimated the delay between two passively heard sounds (a key press click sound and a beep sound). In the free condition, they freely chose between the right and the left key while in the human and robot-instructed conditions, they pressed the instructed key. At the end of each trial, they estimated the delay between their key press and the beep sound. At the end of each block (80 trials), except the baseline condition, they indicated how much control they experienced over the beep sound on a 6-point scale (1:very weak; 6:very strong). Additionally, participants completed a post-experiment questionnaire that assessed the robot in terms of anthropomorphology, likeability, perceived intelligence, and whether it appeared intentional and able to make its own decisions.

RESULTS

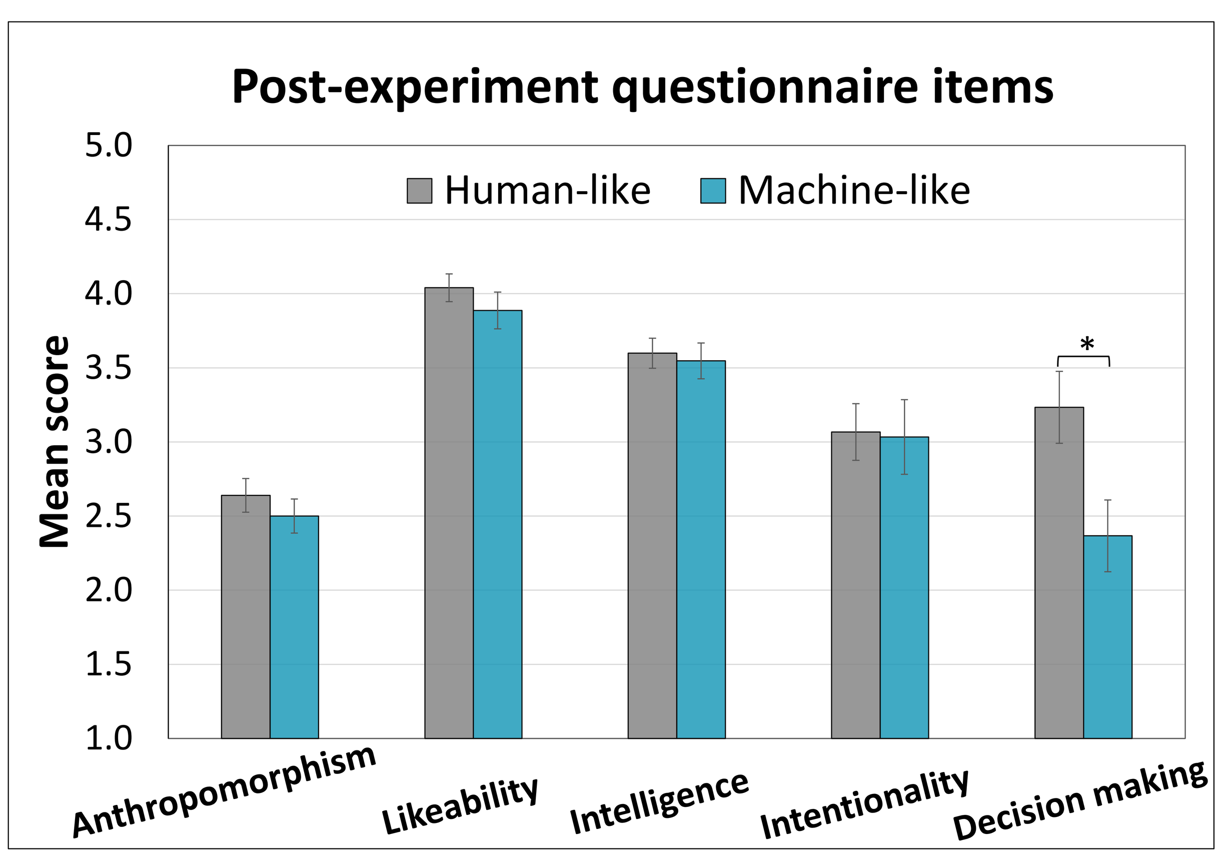

Fig. 3. Mean scores for each questionnaire item and group. (t(58)=2.53, p=.014). Error bars are *SE*.

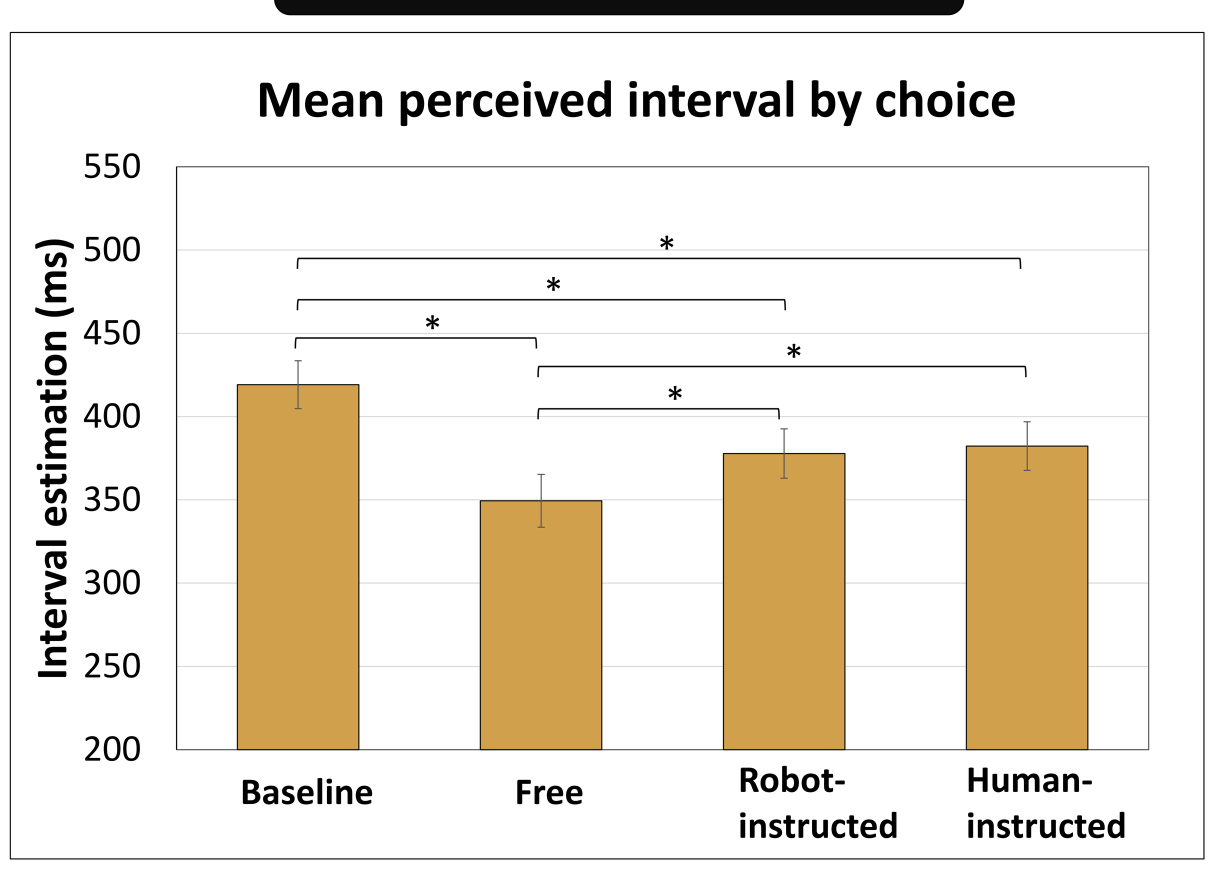

Fig. 4. Mean interval estimations across all groups for each choice condition (F(3,174)=11.88, η^2_p=.17, p<.001; *p<.05 [Newman-Keuls]). Shorter estimations indicate stronger binding. Error bars are *SE*.

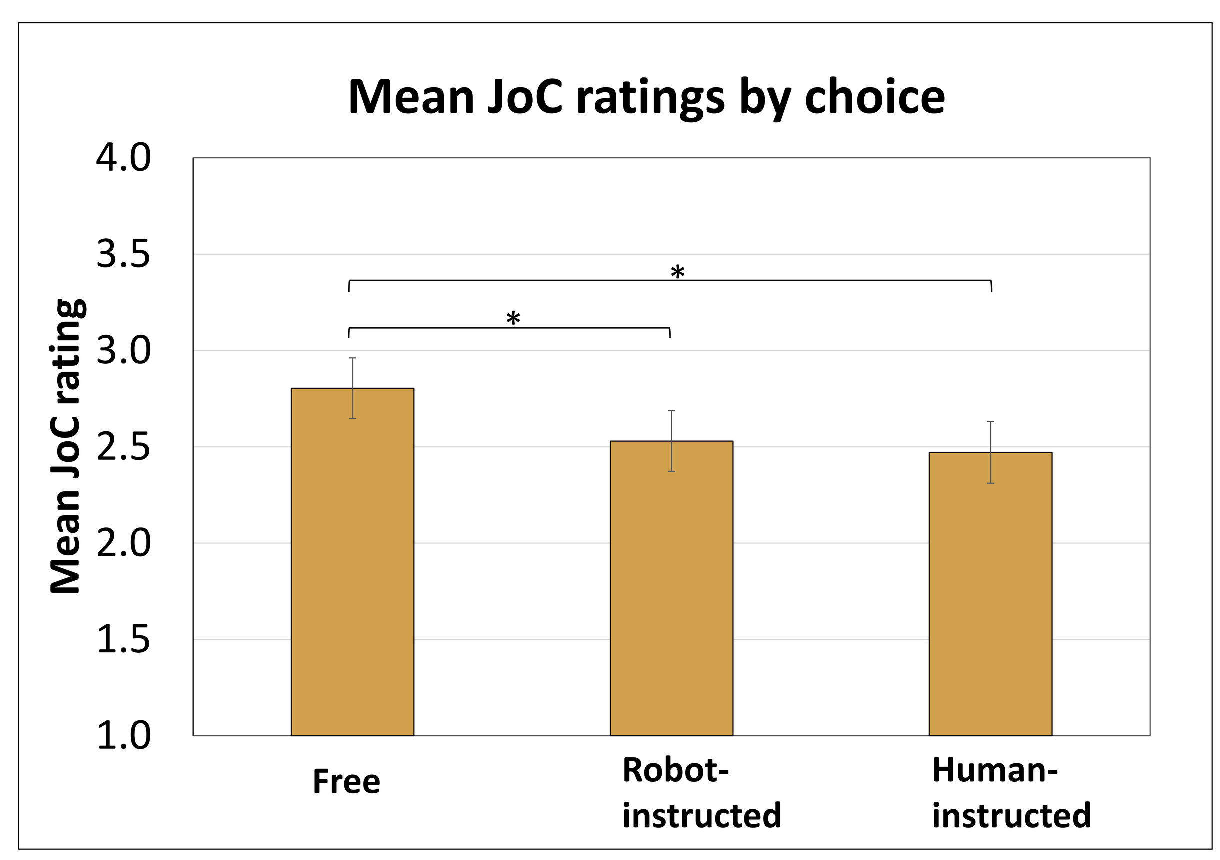

Fig. 5. Mean JoC ratings across all groups for each choice condition (F(2,116)=4.05, η^2_p=.06, p=.024; *p<.05 [Newman-Keuls]). Error bars are *SE*.

Questionnaire item	Intelligence	Intentionality	Decision making
Anthropomorphism	r=.47 p<.001 95% CI=0.24-0.65	p>.05	r=.42 p=.001 95% CI=0.19-0.61
Intelligence	p>.05	r=.49 p<.001 95% CI=0.27-0.66	r=.45 p<.001 95% CI=0.21-0.63
Intentionality	p>.05	p>.05	r=.47 p=.000 95% CI=0.24-0.65

Table 2. *Pearson correlations among the questionnaire items.*

CONCLUSIONS

❖Anthropomorphism was positively related to perceived intelligence and decision making ability of the robot. Perceived intelligence was also found to be related to the perceived intentionality and decision making ability. Finally, perceived intentionality positively correlated with the robot's ability of autonomous decision making (Table 2).

❖SoA, measured by intentional binding and subjective judgment of control, was stronger when actions were freely selected as compared to when instructed by a human or by a humanoid robot (Fig.4 and Fig. 5).

❖SoA was found to be independent of whether the external source of action selection was a human or a humanoid robot and whether the robot was perceived to be autonomously selecting its own actions or not.

❖A follow-up experiment is planned to test whether the SoA would be independent of the external source of actions (i.e., human vs. robot) when action-outcomes bear an emotional or moral value.

References

[1] P. Haggard and M. Tsakiris, "The Experience of Agency: Feelings, Judgments, and Responsibility," *Curr. Dir. Psychol. Sci.*, vol. 18, no. 4, pp. 242–246, Aug. 2009.

[2] S. Gallagher, "Philosophical conceptions of the self: implications for cognitive science.," *Trends Cogn. Sci.*, vol. 4, no. 1, pp. 14–21, Jan. 2000.

[3] P. Haggard, S. Clark, and J. Kalogeras, "Voluntary action and conscious awareness.," *Nat. Neurosci.*, vol. 5, no. 4, pp. 382–5, Apr. 2002.

[4] E. A. Caspar, J. F. Christensen, A. Cleeremans, and P. Haggard, "Coercion Changes the Sense of Agency in the Human Brain," *Curr. Biol.*, vol. 26, no. 5, pp. 585–592, Mar. 2016.

[5] Z. Barlas and S. S. Obhi, "Freedom, choice, and the sense of agency.," *Front. Hum. Neurosci.*, vol. 7, no. August, p. 514, Jan. 2013.

[6] Z. Barlas, W. E. Hockley, and S. S. Obhi, "The effects of freedom of choice in action selection on perceived mental effort and the sense of agency," *Acta Psychol. (Amst).*, vol. 180, no. September, pp. 122–129, Oct. 2017.

[7] Z. Barlas, W. E. Hockley, and S. S. Obhi, "Effects of free choice and outcome valence on the sense of agency: evidence from measures of intentional binding and feelings of control," *Exp. Brain Res.*, vol. 236, no. 1, pp. 129–139, Jan. 2018.

[8] Z. Barlas and S. Kopp, "Action Choice and Outcome Congruency Independently Affect Intentional Binding and Feeling of Control Judgments," *Front. Hum. Neurosci.*, vol. 12, no. April, pp. 1–10, Apr. 2018.

[9] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *Int. J. Soc. Robot.*, vol. 1, no. 1, pp. 71–81, 2009.

[10] A. Stenzel, E. Chinellato, M. A. T. Bou, Á. P. del Pobil, M. Lappe, and R. Liepelt, "When humanoid robots become human-like interaction partners: Corepresentation of robotic actions.," *J. Exp. Psychol. Hum. Percept. Perform.*, vol. 38, no. 5, pp. 1073–1077, 2012.

[11] S. van der Woerdt and P. Haselager, "When robots appear to have a mind: The human perception of machine agency and responsibility," *New Ideas Psychol.*, no. November, pp. 0–1, 2017.

[12] J. W. Peirce, "PsychoPy—Psychophysics software in Python," *J. Neurosci. Methods*, vol. 162, no. 1–2, pp. 8–13, May 2007.

[13] J. W. Peirce, "Generating stimuli for neuroscience using PsychoPy," *Front. Neuroinform.*, vol. 2, 2008.

Correspondence:

zbarlas@techfak.uni-bielefeld.de

https://www.techfak.uni-bielefeld.de/~zbarlas/

zeynepbarlas

SOCIAL COGNITIVE SYSTEMS
AG Kognitive Systeme und soziale Interaktion

Acknowledgements:

I am thankful to Thorsten Schodde and Cognitive Systems Engineering group for their technical support. This work was supported by the Cluster of Excellence Cognitive Interaction Technology "CITEC" (EXC 277) at Bielefeld University, funded by the German Research Foundation (DFG).