Universiteit Leiden

Coordinating with Machines

The effects of a pre-task coordination exercise on collaborative task performance in human-computer interaction

by

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Abstract

When humans are instructed to perform a collaborative task, e.g. a puzzle or multiplayer video game, they perform better when having carried out a coordination exercise beforehand, which can for example involve clapping or chanting in rhythmic synchrony with their interaction partner. This improved collaborative performance can include increased task performance, short-term memory performance and prosocial effects such as increased liking towards their interaction partner. Whether these effects on task performance are forthcoming in collaborative human-computer interactions as well, remains largely unexplored. Hence, this research aimed to investigate how a pre-task coordination exercise influences collaborative task performance in human-computer interaction, when compared to human-human interaction. Experiments were conducted in which participants were instructed to collaboratively play a two-player video game with either a human or an AI interaction partner and, in either condition, with or without performing a coordination task beforehand. Participants in the human-human conditions scored significantly higher than those in the human-computer conditions, which can be attributed to the observed non-verbal communication in the human-human conditions and the inefficient AI agent in the human-computer conditions. On average, the participants that performed the coordination exercise were able to score higher than those that did not, in both human-human and human-computer conditions. However, no statistically significant effect of the coordination exercise on collaborative task performance was found. In order to get a clear answer to the research question, further research with a larger number of participants is needed to achieve statistical significance in the results and to investigate the effects more extensively. Moreover, the specific representation of the AI interaction partner could be improved upon to generate a more familiar and relatable interaction partner.

1. *Introduction*

In today's society, interactions between humans and computers have become somewhat indispensable and they continue to increasingly intertwine with everyday life. As a result, computer systems are more frequently being implemented in environments that can have a significant impact on the lives of humans. Examples of this include the application of social robots in elderly care and educational computer programs being applied in learning environments for children (Movellan et al., 2009; Chen et al., 2020; Hersch, 2015). Consequently, interactions between humans and computers have become common in modern day lives and there is a vast body of scientific research on these human-computer interactions.

Since the specific capacity in which the term 'human-computer' is being implemented in literature differs (e.g. refers to human-computer, human-machine, human-robot or human-AI), it is applied in this research as an overarching term, referring to interactions between a human and a mechanical partner. Many of the existing studies on human-computer interactions encompass back-and-forth interactions, meaning interactions in which a human often utilizes a mechanical partner in alternating interactional turns to achieve a certain goal (e.g. navigating a smartphone's user interface in order to make a phone call (Petrovcic et al., 2018; Harris, 2015)). However, there is a scarce body of knowledge to be found on collaborative human-computer interactions, i.e. interactions in which a human has to collaborate with a mechanical partner towards a certain goal. To illustrate, in research on human-human interactions, extensive studies have been done on collaborative interactions between two or more humans, often categorized by terms such as 'joint action' and 'cooperative action'. Particularly, the collaborative task performance of humans, i.e. the extent to which a task is successfully completed together, is often investigated under various circumstances and conditions. An example of such a condition is the execution of a pre-task coordination exercise prior to the actual joint action task, which has been shown to induce certain results.

When humans are instructed to perform a collaborative task, e.g. a puzzle or multiplayer video game, they perform better when having carried out a coordination exercise beforehand, which can for example involve clapping or chanting in rhythmic synchrony with their interaction partner. This improved collaborative performance can include improved task performance, short-term memory performance and prosocial effects such as increased liking towards their interaction partner (Richardson & Von Zimmermann, 2016; Lysander, 2018; Garrod & Pickering, 2004). Whether these effects on task performance are forthcoming in collaborative human-computer interactions as well, remains largely unexplored. Hence, this research aims to investigate how a pre-task coordination exercise influences collaborative task performance in human-computer interaction, when compared to human-human interaction.

Since it has been shown that human-computer interaction, when compared to human-human interaction, can improve affective engagement (Movellan et al., 2009; Chen et al., 2020), we hypothesize that similar effects may be found when comparing the effects of a pre-task coordination exercise in human-computer interaction with human-human interaction.

2. *Background*

2.1 Coordination & Collaborative Task Performance

Coordination and synchronization of interpersonal human action has virtually always played an intrinsic part in human civilization (McNeill, 1995). All human cultures have some incorporated ritualistic aspect involving rhythmic coordination, for example in the form of dancing, marching or chanting together. This synchronous movement and human action is indicated to be inherent in human nature (Marsh et al., 2009). It creates a foundation for interpersonal human affinity and it stimulates reciprocal cooperation between humans (Richardson & Von Zimmermann, 2016; Valdesolo et al., 2010). Moreover, human beings have a tendency to automatically coordinate their movements with one another. For instance, visually coupled humans synchronize their movements in a rocking chair (Richardson et al, 2007) and they coordinate their body posture and movements during conversation (Shockley et al., 2009).

Synchronized movement in human-human interaction induces prosocial effects, such as feelings of connectedness and increased liking towards the interaction partner (Richardson & Von Zimmermann, 2016; Valdesolo & DeSteno, 2011). Furthermore, the effects of coordinated human movement have been shown to influence collaborative task performance. When jointly working on a task towards a certain goal, prior rhythmic movement coordination stimulates cooperation, enhances rapport and increases functional collaborative performance (Marsh et al., 2009; Richardson & Von Zimmermann, 2016; Valdesolo et al., 2010). These effects are clearly extant and have been indicated to occur in human dyads as well as in larger groups. However, whether they can also occur in interactions between a human and a mechanical partner remains largely unexplored.

2.2 Human-Computer Interaction

Interactions between humans and computers have been studied extensively over the last decades. Many of these involve the design and functioning of user interfaces with which a human often utilizes a mechanical partner to achieve a particular goal (Petrovcic et al., 2018; Harris, 2015). Additionally, the effects of robots in learning environments for children (Chen et al., 2020; Movellan et al., 2009) and in elderly care (Hersch, 2015) have been studied, indicating improvements in affective engagement and short-term memory tasks, when compared to human-human interactions. Artificial agents have been developed to anticipate chaotic human movement and synchronize with these movements, similar to the inherent synchronization in human-human interactions (Washburn et al., 2019). This indicates the potential of human-computer interactions for study on collaborative tasks.

Nevertheless, these interactions under study are generally not of a collaborative nature, as one interaction partner deploys the other as a functional tool. However, collaborative human-computer interactions have been a point of study to some degree. For example, human-aware artificial agents have been studied for their potential as synthetic teammates for humans in performing collaborative tasks (Nalepka et al., 2021), specifically in a two-player video game. Human team interactions were explored and the artificial agents indicated to be adaptive in interaction flexibility. Humans collaborating with a human-aware agent even demonstrated that they could perform better than human-human teams (Carrol et al., 2019). Even so, there remains an unexplored area of study regarding these collaborative human-computer interactions.

2.3 Anthropomorphism

An important aspect to be considered when discussing human-computer interaction is anthropomorphism. Anthropomorphism is the attribution of human-like characteristics to non-human entities, such as animals, objects, or computer programs. In the context of human-computer interaction, anthropomorphism refers to the tendency of humans to attribute human-like characteristics to computers and other digital devices or programs, such as emotions, intentions, or personality traits.

Anthropomorphism can have both positive and negative effects on human-computer interaction. On the positive side, it can help users to understand and interact with digital devices more easily, by making the devices seem more familiar and relatable (Waytz, Heafner, & Epley, 2014). For example, a chatbot with a human-like personality can make the interaction feel more natural and engaging. On the negative side, anthropomorphism can lead to unrealistic expectations and misunderstandings. Users may assume that a computer program understands their intentions and feelings in the same way that a human would, leading to frustration and disappointment when the program fails to deliver the expected response (Waytz et al., 2014). In addition, anthropomorphism can lead to privacy concerns, as users may feel uncomfortable sharing personal information with a machine that seems too human-like.

Thus, it is important to consider the potential risks and benefits of anthropomorphism, when incorporating human-computer interactions. One should carefully consider how to incorporate human-like characteristics into their interactions in a way that enhances usability and user experience, without creating unrealistic expectations

3. *Methods & Materials*

In order to investigate how a pre-task coordination exercise influences collaborative task performance in human-computer interaction compared to human-human interaction, the following experiment design was set up.

Four experiment conditions were devised, two of which included a pre-task coordination exercise as well as a main task and two of which only included a main task. Each of these two sets of conditions was constructed as follows. They contained one condition in which two participants were instructed to collaboratively play five 90-second rounds of the Onion Soup Game, adapted from Carrol et al. (2019), and one condition in which one participant was instructed to collaboratively play five 90-second rounds of the Onion Soup Game with a computer partner (AI agent (Carrol et al. (2019)).

As mentioned, one of these two sets of two conditions included a pre-task coordination exercise. For this exercise, the participants were instructed to jointly listen to a metronome beat and continue the rhythm by clapping together as soon as the metronome ended, for 1 minute. In the condition in which a participant worked together with a computer partner, the participant was instructed to clap together with their computer partner (depicted as the metronome), in which the metronome consisted of a generated beat with slightly modulating tempo to stimulate engagement in the participant and induce the experience of an actual collaboration partner.

3.1 Participants

For this study, 52 participants (*M* age = 20.17, *SD* age = 3.80, *N* females = 49, *N* males = 3) were recruited through the SONA recruitment system of the department of Psychology at Leiden University, who were imbursed for participating with course credit. The human-computer conditions comprised 10 participants each and the human-human conditions comprised 16 participants each. All participants were informed on the goal of the research and on the experiment procedure.

Ethical approval was obtained from the Media Technology Ethics Committee at Leiden University. All participants consented to taking part in this experiment and were fully debriefed upon completion.

3.2 Apparatus & Stimuli

For the main task, the Onion Soup Game, as adapted from the ‘Overcooked’ environment developed by Carroll et al. (2019), was implemented (Figure 1). Participants were given instruction on how to play this two-dimensional two-player game, after which they were instructed to play five 90-second rounds of the game with either their human partner or with an artificial intelligence agent (Carroll et al. 2019).

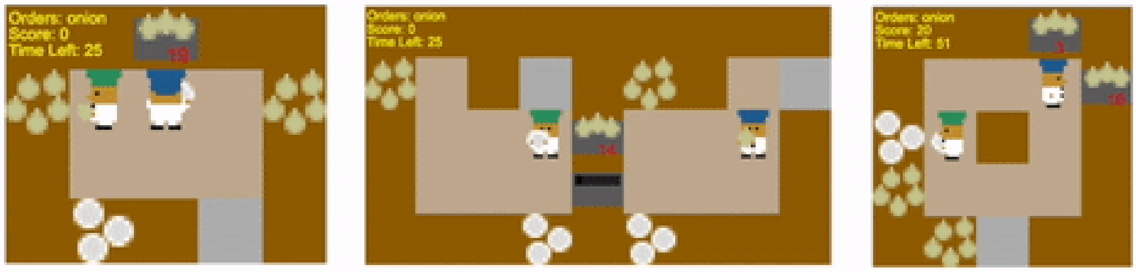

Figure 1. Screenshots from the Onion Soup Game.

When played by two participants, the game was played on two juxtaposed computers connected to the same internet. When played by one participant with their computer partner, the game was played on one computer. In the game, participants saw a simple two-dimensional kitchen with two controllable avatars. These avatars were unable to move though the same location and had to be maneuvered around each other. Using the arrow keys on the computer keyboards, the participants were able to move their respective avatar across the kitchen floor. On the side of the kitchen, onions, plates and a soup pan would be placed on the kitchen counters. Using the spacebar on the computer keyboards, participants were able to pick up an onion or a plate and put them back down in a different location. By putting three onions in the soup pan, the soup would start cooking, which would take around 2 seconds. By taking a plate and interacting with the full soup pan (by using the spacebar again), the soup would be placed on the plate, which could then be served out at the gray counter. Each plate of soup served out would earn the team 20 points. The goal of the game for the participants was to earn as many points as possible within a 90-second round, by maneuvering around their interaction partner and collaboratively cooking and serving out soup.

For the pre-task coordination exercise, a metronome was constructed in Pure Data. A standard metronome at 80 beats per minute was used in the condition in which two participants collaborated. The two participants were asked to listen to the metronome, clap along to it together for 5 beats and then keep clapping the rhythm for 1 minute after the metronome was stopped. For the condition in which one participant was instructed to collaborate with their computer partner, a metronome with slightly modulating tempo (around 80 bpm) was constructed. In this condition, the participant was asked to clap along with the metronome, which was introduced as their computer partner. It had a visual representation on the computer screen of a circle shrinking and growing accordingly with the beat. The slightly modulating tempo was aimed at engaging the participant and inducing the feeling of an actual imperfect interaction partner.

3.3 Procedure

Participants were randomly and exclusively assigned to one of the four experiment conditions. In all conditions, participants were asked to read the instruction and information sheets and to sign the informed consent form (Appendix A) after which they played one 90-second test round of the Onion Soup Game. During the test round, participants were allowed to talk and able to ask for further clarification regarding the game if necessary.

In the two conditions with the pre-task, after finishing the test round, participants were instructed to perform the coordination exercise with their interaction partner. Thereafter, they were instructed to perform the main task of five 90-second rounds of the Onion Soup Game. During the main task, there was no verbal communication. The game scores for each game were recorded.

In the two conditions without the pre-task, after finishing the test round, participants were instructed to immediately perform the main task, again with no verbal communication during the task.

In all four conditions, after finishing the main task, participants were instructed to fill in a questionnaire (Appendix A) aimed at evaluating participants' positive feelings towards their interaction partner. The questionnaire contained the following statements, to which participants responded on a 7-point Likert scale from 'strongly disagree' to 'strongly agree':

1. I felt that my teammate and I performed well.
2. I enjoyed playing the game with my teammate.
3. I felt that my teammate and I worked together like a team.
4. During the game I experienced a feeling of connectedness with my teammate.

Finally, participants were asked to sign the de-briefing from (Appendix A) before leaving.

Figure 2. Participants playing Onion Soup Game in human-computer condition (left) and human-human condition (right).

4. *Results*

4.1 Task performance

When analyzing the acquired experiment data (Appendix C), the following results were obtained regarding the game scores and overall task performance. For every participant or participant dyad, the average of their five game scores was calculated and the average score within each condition was calculated. Participants in the human-human conditions scored significantly higher than participants in the human-computer condition, as shown in the distributions in Figure 3 and in Appendix B.

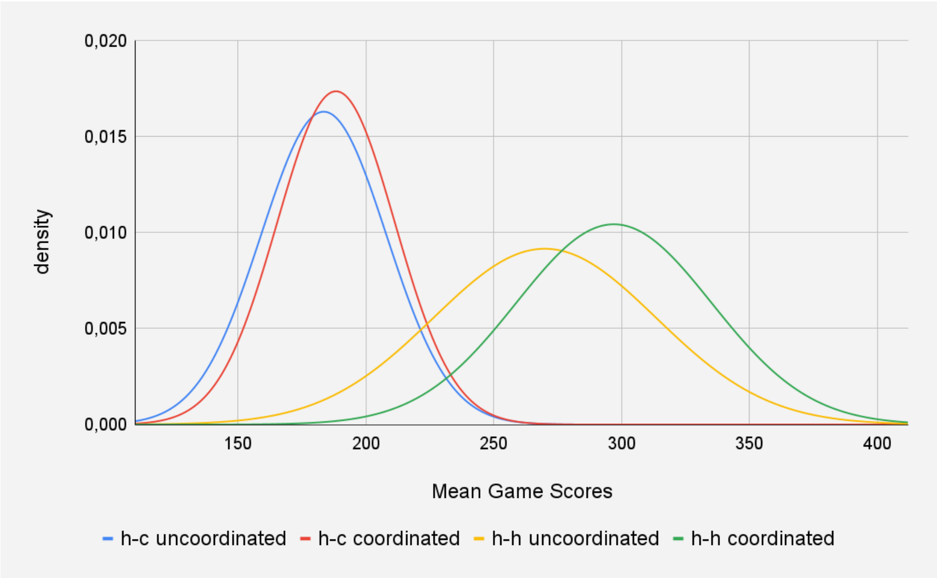

Figure 3. Distribution plots of mean game scores of all four experiment conditions.

However, whether or not participants performed a pre-task coordination exercise had no significant effect on the average game scores [p = 0.087], although the average scores were slightly higher in the coordinated conditions. This was calculated by running a two-way ANOVA in JASP (Appendix B).

Given that the average game scores were slightly higher in the coordinated conditions than in their respective uncoordinated conditions, but without a statistically significant effect of the pre-task, the existing data set was multiplied to assess whether an indication of statistical significance would be found with a higher number of participants. With a twice as large set of participants (n = 104), a statistically significant effect [p = 0.013] of the pre-task on the average game score was calculated (Appendix B). Nevertheless, this remains speculative unless investigated in the experiment setup with a larger number of participants.

Moreover, analysis was performed to investigate whether a learning curve was present during the five games each participant or participant dyad played. The average of each separate game was calculated for each experiment condition and the percental difference in score between Game 1 and Game 5 was computed (Appendix B; Figure 4). In the human-computer condition without pre-task coordination exercise, an increase in game score of 28% was found. In the human-computer condition with pre-task, an increase in game score of 14% was found and in both human-human conditions, an increase of 5% was found.

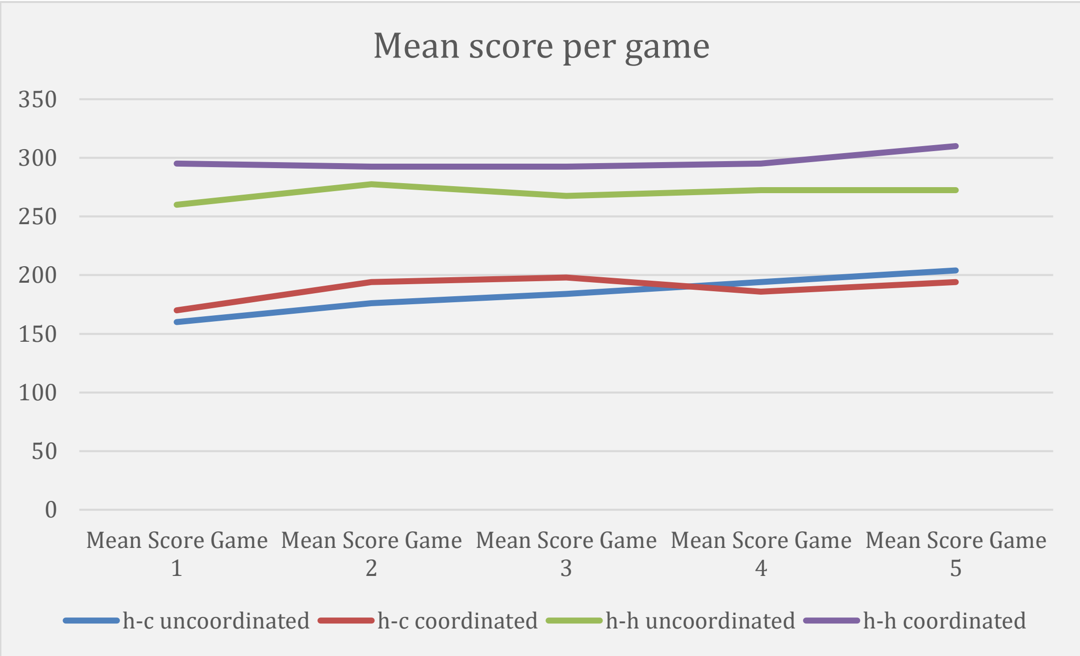

Figure 4. Learning curve comparison of all four conditions.

4.2 Affiliation

Further results were acquired by analyzing the questionnaire responses in all four conditions. This was computed by implementing two-way ANOVAs in JASP on the questionnaire responses (Appendix B). Overall, participants reported slightly higher levels of affiliation with their interaction partner in the human-human experiment conditions [$p = 0.008$; $p = 0.676$; $p = 0.010$; $p < 0.001$].

In the human-computer conditions, participants reported that they felt they performed better when having done the pre-task, than without having done the pre-task, although no statistical significance was found [$p = 0.939$]. In the human-human conditions, however, this was reported to be marginally lower when having performed the pre-task.

Participants reported higher perceived levels of teamwork in the human-human conditions when coordinated, compared to uncoordinated, which was reported to be the opposite in the human-computer conditions, albeit without statistical significance [$p = 0.630$].

Furthermore, increased feelings of connectedness with their interaction partner were reported in the coordinated conditions in both human-human and human-computer conditions, compared to their respective uncoordinated conditions, again without statistical significance [$p = 0.122$].

In the human-human conditions, participants reported higher levels of enjoyment playing with their interaction partner in the condition with the pre-task than without. However, in the human-computer conditions, this was reported to be the opposite. In both cases, no statistical significance was found [$p = 0.135$]. Additionally, a statistically significant interaction [$p = 0.047$] was found between the condition state (human-human or human-computer) and whether or not the pre-task was performed, when examining the perceived levels of enjoyment. Yet, the interpretation of this significance remains unclear.

5. *Discussion*

With this study, the main goal was to investigate how a pre-task coordination exercise influences collaborative task performance in human-computer interaction compared to human-human interaction. Since studies have shown the potential for improvements in performance and affective engagement in human-computer interactions, when compared to human-human interactions (Carrol et al., 2019; Chen et al., 2020; Movellan et al., 2009), we hypothesized that similar effects would be found in this study.

The results indicate that participants in the human-human conditions scored significantly higher than those in the human-computer conditions, which could be considered to have multiple reasons. Firstly, even though participants were not allowed to talk during the task, non-verbal communication was often still observed. This ranged from sighs or laughs to nudges given to the fellow participant. This non-verbal communication was not possible in the human-computer condition, since there was no physical mechanical partner next to the participant and the AI was not able to produce or react to any non-verbal cues. Secondly, the AI agent was far from perfect and it would sometimes make a mistake or become temporarily stuck in place while playing the game, more so than a human would. This could lead to frustration in the participant and a loss in efficiency regarding the game score. Moreover, this may tie into the increased learning curve observed in the human-computer experiment conditions. Participants may have needed additional time in their first games to get acquainted with the imperfect AI partner and with how to collaboratively play the game with it, leading to lower scores. Then, when better acquainted in their last games, participants were able to score much higher. Additionally, the aspect of anthropomorphism may have played a role in these results. For instance, if the AI interaction partner was given more human-like traits such as an actual physical body or personality, it may have been more familiar and relatable to the participants, which in turn could have aided in understanding and interacting with the AI partner (Waytz et al., 2014). A simpler and more accessible way of improving upon the AI partner's representation would be to, for example, provide it with an improved in-game representation, such as an additional on-screen avatar that is seen playing the game. If the participant would see an avatar next to the game screen that appears to be controlling the AI's in-game avatar, then this could already provide the participant with a more relatable interaction partner.

Even though the average game scores were slightly higher in the coordinated conditions, the pre-task coordination exercise had no significant effect on task performance in any of the experiment conditions. By multiplying the existing data to twice the amount, this effect was found to be significant. Since this remains speculative, no evidential arguments can be made from this. However, this does indicate the need for further research to investigate the effects of pre-task coordination exercises in this setting on a larger number of participants and to explore the implications of these findings.

Furthermore, the results from the questionnaire responses, which were implemented to measure perceived levels of performance, teamwork, connectedness and enjoyment of playing with their interaction partner, indicated the following. The participants reported higher overall levels of affiliation with their interaction partner in the human-human experiment conditions, compared to human-computer conditions. Similarly to what was mentioned above, this could be attributed to the imperfect AI's performance, its lack of human-like traits or the absence of non-verbal communication. Participants reported higher perceived levels of teamwork in the human-human conditions when coordinated, compared to uncoordinated. Additionally, increased feelings of connectedness with their interaction partner were reported in the coordinated conditions in both human-human and human-computer conditions. This may indicate a positive impact of a pre-task coordination exercise on affiliation in these interactions. Participants reported that they felt they performed better in the human-computer conditions when having done the pre-task coordination exercise. In contrast, in the human-human conditions this was reported to be marginally lower. Nevertheless, no statistical significance was found in these results concerning the questionnaire responses and all these findings remain speculative. A larger number of participants may be needed to gain further insight.

An additional remark can be made on the specific demographics of the participants. Since participants were recruited through the SONA system of the department of Psychology at Leiden University, most participants were first-year Psychology students, which are largely female. This resulted in only having 3 male participants out of a total of 52. In addition, these male participants were able to attain the highest average game scores in their respective experiment conditions. What this can be attributed to is another topic of study, but it can be annotated that the acquired participant set might not be the ideal random sample.

To summarize for future research, the following would be advised. The number of participants should be increased in order to possibly achieve statistical significance in the results. For these experiments, a minimum of 100 participants would be recommended. Furthermore, the representation of the AI interaction partner could be improved upon, by for example providing it with more human-like traits such as a physical body or personality. This may also be achieved by providing it with an on-screen representation that is seen playing the game with the participant. The AI's in-game performance capabilities could be improved, so that it is less likely to get stuck or make an error. It may also be interesting to investigate this research from another angle. For example, by taking the human-human interaction as a starting point and systematically altering the components of that interaction towards the human-computer interaction. To illustrate, the human-human experiment condition could be altered by first removing the participants' ability to physically reach each other, then by removing their ability to see each other, then by falsely informing them that their interaction partner is an AI agent and so on until the human-computer experiment condition is reached. These alterations are simply examples, further research into the effects of each alteration would be needed to devise such an experiment setup. By performing such experiments, insight may be acquired into the large differences in scores between the human-human and human-computer experiment conditions and into where the tipping point lies between both types of interactions.

6. *Conclusion*

Performing a coordination exercise before engaging in a collaborative task, such as a puzzle or multiplayer video game, can lead to better performance in human-human interactions. This exercise involves rhythmic synchrony with their interaction partner, such as clapping or chanting together. In addition, the benefits of this improved coordination can include an increase in prosocial effects towards their interaction partner. The extent to which these advantages in task performance and prosociality can be observed in collaborative interactions between humans and computers is still an area that has not been extensively studied. Hence, the objective of this study was to examine how a pre-task coordination exercise affects collaborative task performance in human-computer interaction, as opposed to human-human interaction. The acquired experiment results yielded no significant effect of a pre-task coordination exercise on task performance or prosociality in either human-computer or human-human interaction, which rejects our hypothesis. This may, however, be attributed to a lack of participants or the unideal AI agent. Hence, for future work, a larger number of participants should be utilized to investigate the hypothesis with more efficacy. Additionally, the AI interaction partner may need to be improved upon. This can be achieved by improving its in-game performance capabilities and by providing it with human-like traits such as a physical body.

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Appendix A: Forms

Information Sheet

Name of the Student:	Thijs van Vliet
Affiliation:	Media Technology MSc, Leiden University
Name of the Supervisor:	E.F. van der Heide
Research Title:	Coordinating with Machines: The effects of a pre-task coordination exercise on collaborative task performance in human-computer interaction

Introduction
My name is Thijs van Vliet, I am conducting this research as part of my Media technology MSc thesis. I am inviting participants to take part in this research in order to collect data for answering my research question.

Purpose of the research
The research question of this research is as follows: How does a pre-task coordination exercise influence collaborative task performance in human-computer interaction, when compared to human-human interaction? This research aims to indicate how that synchronization with your partner influences your collaborative performance and how two human partners compare to a human and computer partner.

Voluntary Participation
Participation in this research is completely voluntary and it is possible to stop at any time.

Right to Withdraw
You have the right to withdraw your consent to use the personal data within one month after providing it. You do not have to justify your decision to withdraw your consent and there are no consequences for withdrawing your consent.

Procedures
You will be asked to play five 90-second rounds of the Onion-Soup Game (instruction will be provided) with your partner, either with or without performing a coordination exercise beforehand. The coordination exercise will involve rhythmically clapping your hands for roughly 1 minute. You can always ask for additional clarification during the research. After the research, you will be asked to fill in a short questionnaire regarding your experience. In total, the tasks will not take longer than 10 minutes, however, 30 minutes have been made available for any additional clarification or adjustments.

Potential Risks and Discomforts
There is very little risk for your safety in this research. You will be in a save environment.

Reimbursements
There will be no monetary compensation for your participation. Coffee or tea can be provided before the start of the research.

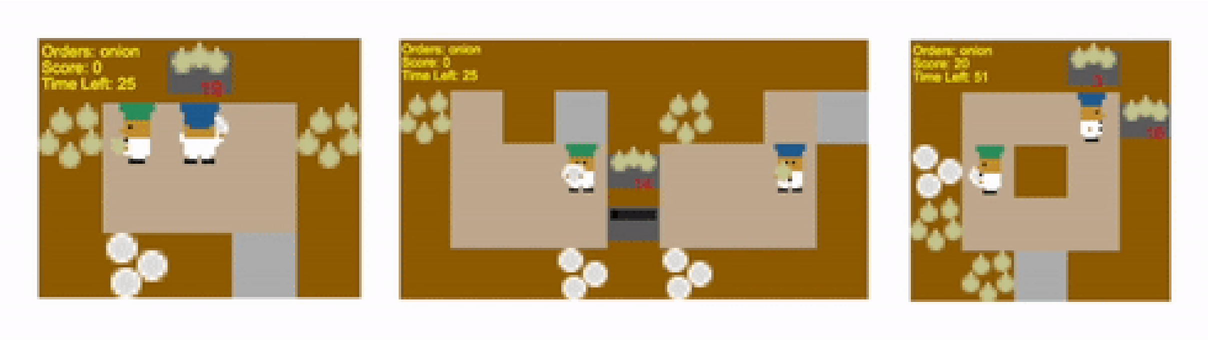
Privacy
All data collected will be anonymous. Your name will not be collected. Audio/photo/video material will only be collected when explicitly agreed upon, face will be made unrecognizable. Any such material will be stored safely and detached from info that can be used to identify you.

Retaining and Sharing data
All data will remain anonymous after completion of the project and transferred to the Media Technology archive. The data might be shared with other researchers for follow-up work when needed for publication of a paper, always in anonymized form.

Sharing the Results
The findings of the research will be communicated to scientific peers as a thesis in scientific paper format.

Who to Contact
Thijs van Vliet (email: t.b.vanvliet@gmail.com; telephone: 0627370842)
Edwin van der Heide (email: e.f.van.der.heide@liacs.leidenuniv.nl)

The Onion-Soup Game



- You will see a two-dimensional playing field as depicted in the image above (multiple options depicted).
- The goal of the game is to serve as many bowls of soup as possible.
- Your avatar can move around the middle light-brown part of the map, using the arrow keys or the wasd-keys on the keyboard (depending on your teammate, this will be instructed by the research team).
- On the counter, the dark-brown sides of the map, you can see onions, white plates and an iron pot.
- In order to make soup, your avatar has to walk over to the onions and face the onions, press Enter or Spacebar (depending on your teammate, this will be instructed by the research team) to pick up an onion. While holding an onion, your avatar has to walk over to the iron pot and press Enter or Spacebar again to drop the onion in the pot. Once 3 onions are in the pot, soup will start cooking, indicated by a short timer on the pot. Once the soup is finished, your avatar needs to have picked up a plate from the counter (the same way you picked up the onions) and face the pot while you press Enter or Spacebar. Your avatar will pick up the finished soup, after which your avatar needs to walk towards and face the light grey part of the counter, press Enter or Spacebar again to drop the soup off and earn 10 points.
- You and your teammate's avatars cannot stand in the same spot, so you will need to coordinate around each other.
- The more soup you and your teammate can serve within 90 seconds, the higher your score will be.

Informed Consent Form

For participating in Media Technology MSc graduation project research conducted by Thijs van Vliet supervised by Edwin van der Heide at Leiden University.

I confirm that I have been clearly informed about the nature and method of the research, as described in the information sheet. My questions have been answered satisfactorily.

I agree to participate in this research freely. I know that I can stop my participation at any time. If my research results are to be used in scientific publications, or made public in any other way, this will be done completely anonymously, unless I give my consent to exceptions below by marking the checkboxes..

Quotes
I hereby consent to having my answers quoted in research publications. When quotes are used, my (real) name and other direct identifiers will not be mentioned. ☐

If I would like any further information about the study, now or in the future, I can contact Thijs van Vliet (telephone: 0627370842; e-mail: t.b.vanvliet@gmail.com) or Edwin van der Heide (e-mail: e.f.van.der.heide@liacs.leidenuniv.nl).

If I have any complaints about this research, I can contact the supervisor of this research (Edwin van der Heide, e-mail: e.f.van.der.heide@liacs.leidenuniv.nl) or the secretary of the Ethics Committee for Mathematics and Natural Sciences of Leiden University (ethicscommittee@science.leidenuniv.nl).

Age: ……………………….

Gender: ……………………….

Location and date: ……………………………………………………………………….

Signature

Post-Experiment Questionnaire

Participant information:

Age:
Gender:

Please answer the following statements regarding your experience of the research, by circling you preferred opinion:

	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
1. I felt that my teammate and I performed well.	1	2	3	4	5	6	7
2. I enjoyed playing the game with my teammate.	1	2	3	4	5	6	7
3. I felt that my teammate and I worked together like a team.	1	2	3	4	5	6	7
4. During the game I experienced a feeling of connectedness with my teammate.	1	2	3	4	5	6	7

De-briefing Template

Thank you for your participation in this research. This research aims to indicate how that synchronization with your partner influences your collaborative performance and how two human partners compare to a human and computer partner.

Right to withdraw data

You may choose to withdraw the data you provided during the research. If that is the case, please contact me not later than 1 month after participating in this research.

If you have questions

The main researcher conducting this study is Thijs van Vliet. This research is supervised by Edwin van der Heide at Leiden Institute for Advanced Computer Science (LIACS), Leiden University. Please ask any questions you have now. If you have questions later, you may contact Thijs van Vliet at t.b.vanvliet@gmail.com or at 0627370842.

If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the supervisor Edwin van der Heide (e.f.van.der.heide@liacs.leidenuniv.nl) or secretary of the Ethics Committee for Mathematics and Natural Sciences of Leiden University (ethicscommittee@science.leidenuniv.nl).

If you would like to receive a copy of the final report of this study or a summary of the findings when it is completed, please feel free to contact the student.

Your signature below indicates that you have been debriefed, and have had all of your questions answered.

Name of Researcher	Signature	Date
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Appendix B: Statistical Analyses

2-Way ANOVA: Main hypothesis

ANOVA - GScoreMean

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Coordination	3683.569	1	3683.569	3.045	0.087	0.021
NumHumans	113664.123	1	113664.123	93.950	< .001	0.644
Coordination ✻ NumHumans	1158.031	1	1158.031	0.957	0.333	0.007
Residuals	58072.000	48	1209.833			

Note. Type III Sum of Squares

This does not confirm our hypothesis, but the number of humans significantly impacts the score.

Descriptives

Descriptives - GScoreMean

Coordination	NumHumans	N	Mean	SD	SE	Coefficient of variation
No	1	10	183.600	24.473	7.739	0.133
	2	16	270.000	42.079	10.520	0.156
Yes	1	10	191.200	25.072	7.929	0.131
	2	16	297.000	36.936	9.234	0.124

2- Way ANOVA: Data multiplied by two, Main hypothesis

ANOVA - GScoreMean

Cases	Sum of Squares	df	Mean Square	F	p
NumPlayers	227328.246	1	227328.246	195.730	< .001
Coordination	7367.138	1	7367.138	6.343	0.013
NumPlayers ✻ Coordination	2316.062	1	2316.062	1.994	0.161
Residuals	116144.000	100	1161.440		

Note. Type III Sum of Squares

Descriptives

Descriptives - GScoreMean

NumPlayers	Coordination	N	Mean	SD	SE	Coefficient of variation
1	N	20	183.600	23.820	5.326	0.130
	Y	20	191.200	24.404	5.457	0.128
2	N	32	270.000	41.395	7.318	0.153
	Y	32	297.000	36.335	6.423	0.122

2-Way ANOVA: Questionnaire Q1

ANOVA - Q1

Cases	Sum of Squares	df	Mean Square	F	p
Coordination	0.004	1	0.004	0.006	0.939
NumHumans	5.712	1	5.712	7.737	0.008
Coordination ✻ NumHumans	0.081	1	0.081	0.110	0.742
Residuals	35.438	48	0.738		

Note. Type III Sum of Squares

Descriptives

Descriptives - Q1

Coordination	NumHumans	N	Mean	SD	SE	Coefficient of variation
No	1	10	5.300	1.252	0.396	0.236
	2	16	6.063	0.680	0.170	0.112
Yes	1	10	5.400	0.699	0.221	0.129
	2	16	6.000	0.816	0.204	0.136

2-Way ANOVA: Questionnaire Q2

ANOVA - Q2

Cases	Sum of Squares	df	Mean Square	F	p
Coordination	1.062	1	1.062	2.308	0.135
NumHumans	0.081	1	0.081	0.177	0.676
Coordination ✻ NumHumans	1.908	1	1.908	4.147	0.047
Residuals	22.088	48	0.460		

Note. Type III Sum of Squares

Descriptives

Descriptives - Q2

Coordination	NumHumans	N	Mean	SD	SE	Coefficient of variation
No	1	10	6.000	0.816	0.258	0.136
	2	16	5.688	0.602	0.151	0.106
Yes	1	10	5.900	0.738	0.233	0.125
	2	16	6.375	0.619	0.155	0.097

2-Way ANOVA: Questionnaire Q3

ANOVA - Q3

Cases	Sum of Squares	df	Mean Square	F	p
Coordination	0.174	1	0.174	0.235	0.630
NumHumans	5.300	1	5.300	7.169	0.010
Coordination ✻ NumHumans	1.250	1	1.250	1.691	0.200
Residuals	35.488	48	0.739		

Note. Type III Sum of Squares

Descriptives

Descriptives - Q3

Coordination	NumHumans	N	Mean	SD	SE	Coefficient of variation
No	1	10	5.600	0.699	0.221	0.125
	2	16	5.938	0.929	0.232	0.156
Yes	1	10	5.400	1.265	0.400	0.234
	2	16	6.375	0.500	0.125	0.078

2-Way ANOVA: Questionnaire Q4

ANOVA - Q4

Cases	Sum of Squares	df	Mean Square	F	p
Coordination	3.154	1	3.154	2.485	0.122
NumHumans	26.100	1	26.100	20.559	< .001
Coordination ✻ NumHumans	1.154	1	1.154	0.909	0.345
Residuals	60.938	48	1.270		

Note. Type III Sum of Squares

Descriptives

Descriptives - Q4

Coordination	NumHumans	N	Mean	SD	SE	Coefficient of variation
No	1	10	4.100	1.287	0.407	0.314
	2	16	5.250	0.931	0.233	0.177
Yes	1	10	4.300	1.767	0.559	0.411
	2	16	6.063	0.574	0.143	0.095

Learning curve comparison

	h-c uncoordinated	h-c coordinated	h-h uncoordinated	h-h coordinated
Mean Score Game 1	160	170	260	295
Mean Score Game 2	176	194	277,5	292,5
Mean Score Game 3	184	198	267,5	292,5
Mean Score Game 4	194	186	272,5	295
Mean Score Game 5	204	194	272,5	310
% increase	28%	14%	5%	5%

Appendix C: Raw data

ID	Age	Gender	NumHumans	Coordination	CondGroup	GScore1	GScore2	GScore3	GScore4	GScore5	GScoreMean	Q1	Q2	Q3	Q4
1	22	F	1	N	1N	120	180	220	200	200	184	6	7	6	5
2	20	F	1	Y	1Y	120	120	140	200	180	152	5	6	7	6
3	18	F	1	Y	1Y	180	220	240	200	200	208	6	5	6	4
4	19	F	1	N	1N	180	140	240	220	240	204	6	6	6	5
5	19	F	1	Y	1Y	180	180	180	180	220	188	5	6	6	6
6	19	F	1	N	1N	140	140	100	180	220	156	5	6	7	5
7	25	F	1	Y	1Y	160	160	180	180	180	172	5	6	4	2
8	24	F	1	Y	1Y	220	220	200	260	200	220	6	6	3	1
9	18	F	1	N	1N	180	200	200	220	220	204	5	6	6	4
10	28	M	1	N	1N	220	240	200	260	240	232	2	4	5	1
11	20	F	1	N	1N	120	200	220	180	160	176	6	7	5	5
12	23	F	1	Y	1Y	160	220	220	140	160	180	4	5	4	3
13	20	F	1	N	1N	160	180	180	200	200	184	6	6	5	5
14	19	F	1	Y	1Y	200	240	240	240	260	236	6	7	6	6
15	19	F	1	N	1N	180	200	180	140	200	180	5	6	5	3
16	18	F	1	N	1N	160	140	120	160	180	152	6	6	5	4
17	24	F	1	Y	1Y	140	220	200	220	220	200	6	5	6	5
18	21	F	1	Y	1Y	180	180	180	200	180	184	5	6	6	5
19	20	F	1	Y	1Y	160	180	200	140	180	172	6	7	6	5
20	18	F	1	N	1N	140	140	180	180	180	164	6	6	6	4
21	18	F	2	N	2N	180	220	200	240	220	212	6	5	7	6
22	19	F	2	N	2N	180	220	200	240	220	212	5	6	7	6
23	21	F	2	Y	2Y	240	220	220	220	220	224	6	5	6	6
24	19	F	2	Y	2Y	240	220	220	220	220	224	6	7	6	7
25	20	F	2	Y	2Y	300	300	280	280	320	296	6	7	6	6
26	18	F	2	Y	2Y	300	300	280	280	320	296	6	7	7	6
27	19	F	2	N	2N	300	320	300	300	280	300	6	6	7	4
28	18	F	2	N	2N	300	320	300	300	280	300	7	6	7	6
29	20	F	2	N	2N	320	340	360	360	340	344	7	6	7	5
30	18	F	2	N	2N	320	340	360	360	340	344	7	7	7	7
31	20	M	2	Y	2Y	360	320	360	360	360	352	7	7	7	7
32	18	M	2	Y	2Y	360	320	360	360	360	352	7	7	7	7
33	20	F	2	N	2N	260	260	260	240	240	252	6	6	6	7
34	19	F	2	N	2N	260	260	260	240	240	252	6	6	6	5
35	20	F	2	N	2N	200	220	200	240	220	216	5	6	5	5
36	18	F	2	N	2N	200	220	200	240	220	216	6	6	5	5
37	19	F	2	Y	2Y	280	280	240	260	280	268	6	6	7	6
38	43	F	2	Y	2Y	280	280	240	260	280	268	4	6	6	6
39	19	F	2	Y	2Y	300	320	320	300	340	316	6	7	7	6
40	18	F	2	Y	2Y	300	320	320	300	340	316	6	6	6	6
41	20	F	2	Y	2Y	320	320	340	300	320	320	5	6	6	6
42	20	F	2	Y	2Y	320	320	340	300	320	320	5	7	7	6
43	20	F	2	N	2N	280	300	280	260	280	280	6	5	5	5
44	18	F	2	N	2N	280	300	280	260	280	280	5	5	5	4
45	19	F	2	N	2N	240	260	260	300	300	272	7	6	6	5

46	20	F	2	N	2N	240	260	260	300	300	272	6	5	5	5
47	18	F	2	Y	2Y	260	280	300	320	300	292	6	6	6	6
48	18	F	2	Y	2Y	260	280	300	320	300	292	7	6	6	5
49	19	F	2	Y	2Y	300	300	280	320	340	308	7	6	6	6
50	20	F	2	Y	2Y	300	300	280	320	340	308	6	6	6	5
51	18	F	2	N	2N	300	300	280	240	300	284	6	5	5	4
52	21	F	2	N	2N	300	300	280	240	300	284	6	5	5	5