Interaction between abstract agents: Increasing the readability of causal events with animation principles

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ABSTRACT

In cognitive psychology, causality studies investigate simple causal relations to understand how people perceive a causal relation between agents. In those experiments, geometric shaped characters are used to examine the causal relations only. However, the actions of characters (or agents) in those experiments were not completely described as causal events by many participants, which might be the result of a shortcoming in the design of agents' actions. We believe we can improve the readability of causal events with animation principles. We created *expressive actions* by the use of animation principles of anticipation and reaction, which are used to emphasize the meaning of the main action with expressiveness in pre- and post- actions. To analyze the effect of expressivity and its effect on different embodiments of agents, we conducted a user study with 4 animation clips including expressivity (expressive vs. non-expressive action) and embodiment (object vs. robot embodiment) conditions. We analyzed data from 116 adult participants and the results showed that *expressive actions* significantly increased the readability of interaction between abstract agents in causal events. We also found that the type of embodiment has no effect on readability when we applied expressive actions into their movements.

CCS Concepts

•Human-centered computing→HCI→HCI design and evaluation methods→User studies •Applied computing→Law, social and behavioral sciences→Psychology •Computing methodologies→Computer graphics→Animation

Keywords

Causality; causal perception; body movements; abstract agent; animation principles; multi-agent interaction.

1. INTRODUCTION

The fields of Human-Computer Interaction (HCI) and psychology intersect in many ways. Although HCI researchers have mostly used methods of psychology in their studies, they also contributed to the psychology field through the use of technology in psychological experiments [3, 15, 18]. One of the main topics in psychology that is supported by other fields is the theory of "causal reasoning". In general, causal reasoning studies are video based experiments [6, 7, 22] that illustrate two or more agents to examine the understanding of the relation between cause and its effect [14]. In those experiments, the agent is a character that has features and characteristics to execute causal relations (see Figure 1). One example of a causal event is when an agent hits a second agent, and the second agent starts moving. In this case, the first agent caused the movement of the second agent. The actions of agents can be defined individually, but these actions create some causal relations and the observer should be able to understand these relations.

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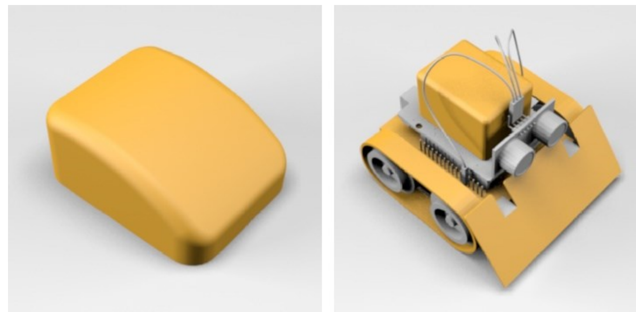

Figure 1. Agents that we used in our study with object appearance (left) and robot appearance (right)

In causality experiments, researchers can evaluate participants' answers by keywords; for example, when one agent pushes another agent to reach its target, causal verbs such as "help", "enable", "support" are expected from participants while they explain this event [7, 8, 27]. However, the actions of agents in those experiments were not fully described as causal events by many participants [7, 8] which can be a shortcoming in the design of agents' actions. Therefore, re-designing the causal events in a more elaborate and exaggerated manner might help in improving the understanding of causal events which is the focus of this paper.

Agents with basic geometric shapes, which were defined as abstract agents, were used to create simple causal events in causality experiments [4, 5, 6, 8, 20, 24]. We believe that the body movement of these abstract agents is one of the features that might help us express the actions of agents. Previous HCI studies noted that applying animation principles [25] on the body movements of an agent is useful to express behavior and present the intention of an agent [2, 19, 23]. However, to our knowledge, there is no previous work that examined the use of animation principles to increase the readability of causal events.

The 12 Animation Principles were introduced in a book from the works of the Disney Animation Studios [25]. There, *Anticipation* is one of the animation principles that prepares an audience for the next action in an animation. An example of anticipation is when a character stretches its arm back before throwing a ball that gives a clue to the observer about its next action. Although researchers ran causal reasoning experiments with animation clips [7, 27], they did not mention or use the animation principles in a structured way to examine the actions of the agents in order to increase the readability of the casual events. For example, in one of the animation clips from George's [7] force dynamics study, one agent tries to climb a hill several times, fails, another agent pushes the first agent to reach home at the top of the hill. Trying to climb the hill several times helps the viewer to understand that the agent wants to go up the hill and the agent cannot do it by itself. However, participants could understand the pushing action of the agent differently. While pushing gently might be perceived as helping, pushing with sudden and powerful moves could be identified as forcing. As anticipation emphasizes the meaning of an action, reaction also helps to understand the intention of an agent. For example, showing a positive reaction after an action emphasizes that the character is pleased with the main action. Animation principles state that every action is important to illustrate the meaning in a scene and to make it understandable for an audience. Thus, if expressive actions are used to design the actions of agents, it might increase the readability of interaction between agents in causal events. In our study, we created expressive actions by applying anticipation and reaction on body movements as their effect on agents found similar in a previous study [23].

Moreover, researchers noted that body movement is a powerful tool to express the intention of agents [1, 6, 12, 22]. Previous studies applied same motion patterns on agents with different embodiments and found that the characteristics of agents were perceived similarly. We want to explore whether motion patterns that we create with the anticipation principles to improve readability of causal interaction have similar results in agents with different embodiments. Thus, in this paper we examine the following hypotheses:

(**H1**) Expressive actions, which are created by the use of the animation principles, will increase the readability of the interaction between abstract agents in causal events.

(**H2**) The type of the agents' embodiment will not change the effect of expressive actions on the readability of interaction between abstract agents.

To analyze our hypotheses, we conducted a user study (N=116) and examined 2 (expressive vs. non-expressive) X 2 (object vs. robot embodiment) conditions with four animation clips in total. In a between subject study, every participant saw one of the videos and their answers were coded by keywords to measure the effect of expressivity and the embodiment on the readability.

In this paper, we mainly contribute to the cognitive psychology field by improving experimental settings with animation principles. In particular, we aim to improve the readability of interaction between two abstract agents in causal events. We also contribute to the HCI field by investigating body movements of abstract agents and interaction between agents. Outcomes of this study might be used in multi-agent systems and kinetic user interfaces.

2. RELATED WORK

2.1 Causality theories

In the field of cognitive psychology, researchers have examined causal reasoning in detail and proposed various theories to explain how we perceive the relation between cause and its effect. Michotte [14] discussed the perception of causality and indicated that simple sequences with geometric shapes create causal events. He found that several parameters such as size, speed, duration and direction of agents could affect the perception of causal events. For example, one big circle that followed a small circle within the same distance was described as "chasing" by participants and when a small ball followed a big ball at a slower speed, participants described the event as "leading" (see Figure 2a). In a popular study by Heider and Simmel [10], they showed an animation clip including a big triangle, a small triangle and a circle that were moving in various directions and at various speeds (see Figure 2b). They found that actions created causal relations between geometric shapes and played a significant role in the organization of the events into a story. Subjects explained interactions between agents as "chasing" and "fighting", and referred to various personalities for agents with different geometric shapes.

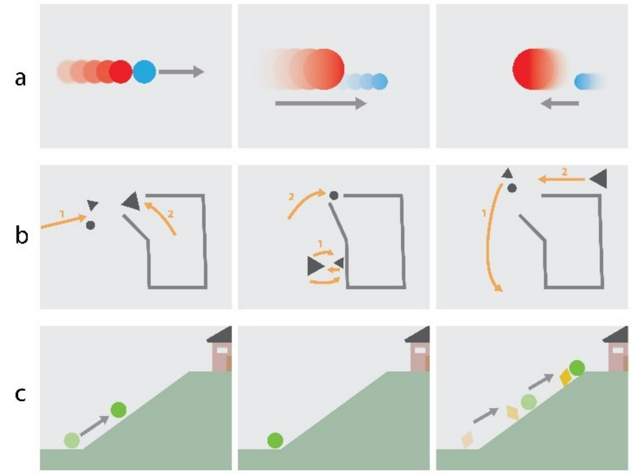

Figure 2. (a) Michotte's demonstration of causality [14]. **(b) Heider and Simmel's experiment** [10]. **(c) "Enable" condition from force dynamics experiments** [7].

Causal events have been investigated by different theories. "Force dynamics", which is defined as an interaction between agents created by multiple forces in space, is one of the semantic models that has been used to explain causal relations [24]. The aim of force dynamics studies is to understand how people define force based causal events in language [7, 8, 27]. To analyze this, researchers present various causal events such as "cause", "enable", "prevent" and "despite". In these causal events, one object is active that applies force and the other object is affected by the force [14]. For example, in an enable event, one agent helps another agent to reach a target and participants are expected to use "enable", "help", "support" or similar verbs to explain this event (see Figure 2c). In the prevent event, one agent tries to reach a target but another agent blocks it and participants should use "prevent", "block", "hold" or similar causal verbs to describe the scene. If participants explain actions of an agent individually or do not use causal verbs to explain the interaction between agents, it would indicate that participants may not have understood the causal event completely. Our study aimed to advance conditions of force dynamics experiments by designing the actions of agents clearly.

Previous studies have shown that motion patterns are useful tools to reveal the intention and purpose of agents [1, 6, 9, 12, 22]. If we can emphasize their intention, for example in the "enable" condition, illustrating that the active agent wants to help and the passive agent needs help, then these causal events might be easier for participants to understand. We aim to reduce errors in the experimental design of causality studies by designing actions of agents properly.

2.2 Expressivity in motion

According to Hoffman and Ju [11], designing movements of an agent is essential and these should be designed before the embodiment of the agent. Several studies in HCI used body movements to express characteristics of agents and communicate with users. Jung et al. [12] developed a robotic torso in an amorphous shape that can bend in three axes. They generated different movements and matched them with product messages in a user study. For example, a stretching movement matched with "charging" and "readying", a surprised movement paired with "warning". Novikova and Watts [17] defined several parameters for creating expressive body movements. These parameters were classified into two categories: the shape and the quality. The "shape" category included body movements such as "transfer body weight", "extend the body", "reduce the body", and "move the body back and forth". Some of these actions were based on additional parts of the body. For example, the agent could raise its head to extend the body. The "quality" category represented qualities of motion such as suddenness, strength, duration and frequency. They also argued that the intentions of the agent depend on its expressive movements. Saerbeck and Bartneck [21] noted that direction and speed parameters are useful to express the characteristics of an agent by body movements. However, these studies mainly used body movements to express an emotion of an agent. There is no previous study that investigated the effect of expressive actions on the readability of interaction between agents in causal events.

Previous studies have shown that body movements are useful to express characteristics of agents. Therefore, actions of agents might be used to emphasize the meaning in causal events. Researchers used animation principles to design the actions of agents and found that it helped to express characteristics of agents [2, 19, 23]. Thus, we aimed to improve the readability of actions by using animation principles on body movements of agents.

2.3 Animation principles

Animation artists have developed experience in giving meaning to a motion for several years. Thomas and Johnston collected works of the Disney Corporation in "The Illusion of Life" and introduced 12 animation principles [25]. These animation techniques were described to help animation artists create believable characters. The *anticipation* is one of the key techniques among these animation principles to prepare an audience for the next action and emphasize the meaning of action. It helps to connect the movements of agents and make the intention of the agent clear. Lasseter [13] applied these traditional animation principles in 3-D computer animation in his influential work and indicated the importance of anticipation as a tool to catch the audience's attention. He explained anticipation with this example: "Before a character reaches to grab an object, he first raises his arms as he stares at the article, broadcasting the fact that he is going to do something with that particular object" [13] (p.38). The *timing* technique is also another key principle to understand actions. Duration of a movement could change the meaning of an action. Lasseter noted timing principle is important for making actions readable. He pointed that enough amount of time should be used for "the anticipation of an action, the action itself, and the reaction to the action" [13] (p.37). Timing is a tool to create the anticipation and reaction. We believe anticipation and reaction are essential elements for an animation and could help to increase the readability of causal events in force dynamics and causality experiments by showing the intention of agents and emphasizing why agents are performing that particular action.

There are various studies that used the 12 animation principles to design actions of agents. Ribeiro and Paiva [19] examined these principles to design facial expressions of agents. They did not specifically focus on the effect of one of the principles. Rather they applied all of the principles to express emotional states. They showed that animation principles are useful to express emotions non-verbally in social agents. Van Breemen [2] applied the timing technique by moving the head of an agent in cat appearance in different velocities. These studies indicate that animation techniques are promising tools to express the behavior of an agent. However, they examined motion with anthropomorphic features such as facial expressions and gestures.

Takayama et al. [23] used the animation techniques to increase the readability of an agent's actions. Participants saw clips of an agent with and without anticipation and reaction. Results showed that anticipation did not increase the readability of actions but increased respondents' confidence in their answers. According to the results, anticipation and reaction made the agent more appealing and approachable. The readability result might be affected by the appearance of the humanoid agent that gave clue about the agent's intention and purpose. This could have decreased the difference between results for expressive and non-expressive actions. We believe the effect of expressive actions might be significant in abstract agents as their appearance does not explain their intentions.

Previous HCI studies mostly applied animation principles to humanoid agents and effect of animation principles on abstract agents have not been investigated. Moreover, these principles were not used to understand the interaction between agents. We advanced the previous literature by applying expressive actions when animating causal events, to increase the readability of interaction between abstract agents.

2.4 Motion and embodiment

Previous studies highlighted that the effect of motion patterns on characteristics of agents is stronger than the embodiment. A causal perception study by Rimé et al. used two animation clips including the same actions of agents, but in a different appearance [20]. Results showed that participants responded similarly to the

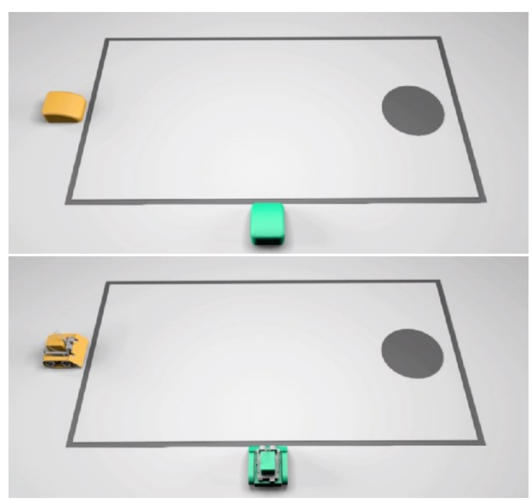

Figure 3. Animation clips that we used in our study with object embodiment (above) and robot embodiment (below)

action of agents in different embodiments. Novikova et al. [16] examined expressive movements through two agents in different levels of abstractness. They found that an agent with a spherical shape and an agent with a head and limbs had similar effects on the perception of agents when they do the same expressive movements. For example, the action of "surprise" defined for sphere agents with "sudden" and "move body forward" parameters and the human-like agent executed the same action with "sudden" "move limbs forward" and "move visible appendages away from the body" parameters. Similar results were found in Saerbeck and Bartneck's study [21] by showing an agent with a cat appearance and a vacuum cleaner which followed the same motion pattern. They discussed that motion design can be used via different embodiments to relate various characteristics with agents.

In comparison to previous studies, we further investigated the effect of expressive actions on two different embodiments in causal events that are animated with expressive actions.

3. USER STUDY

Based on the animation studies by Thomas and Johnston [25] and the work of Takayama et al. [23] on the readability of agents, we hypothesize (**H1**) that expressive actions, which are created by the use of the animation principles, will increase the readability of the interaction between abstract agents in causal events. Previous studies [16, 20, 21] noted that agents with different embodiments were perceived similarly when they have the same motion patterns. Thus, we hypothesize (**H2**) that the effect of expressive actions on readability will not change based on the type of embodiment. A between subject design was used to conduct a study to evaluate four conditions (see Table 1) that manipulated the expressivity level (expressive actions vs. non-expressive actions) and embodiment (object vs robot). To exhibit the four conditions we used a "help" scenario. We then used an online evaluation platform to perform the study, where we recruited 116 adult subjects (66 female) with a mean age of 26.1 years (SD=6.2). Each participant saw only one of the animation clips (see Figure 3). Participants were generally recruited from local mailing lists and contacts and they participated voluntarily. All participants were native Turkish speakers to eliminate any cultural and linguistic factors, and the study was conducted in Turkish.

3.1 Animation Setup

In our experiment, we created animation clips that involve one agent helping another agent as in the "enable" condition from one of the force dynamics experiments [5]. We designed the actions of agents by adding expressive actions. We showed the same "help" scenario to participants with and without expressive actions to examine whether expressive actions will increase the readability of interaction between agents in causal events. For both cases, we used two different embodiments. In total, we presented 4 different animation clips (see Table 1). Animations were rendered with an animation software and each clip was set to play at 30 frames per second in a 450x802 resolution for 28 seconds. The scene was defined in a rectangular area to allow participants to focus on what happened in this area. In the force dynamics experiments, researchers used a house as a goal in animation clips [7]. We also used a circle as a target to highlight the aim of the agent.

Table 1. Four conditions in animation clips

	Expressive actions	Non-expressive actions
Object	EO	NO
Robot	ER	NR

3.1.1 *Agent design*

As we stated before, we used two different type of embodiment to examine the effect of expressive actions on the readability of causal events.

In causality experiments, researchers used agents with geometric shapes to examine causal events only. Thus, we aimed to design an agent with abstract shape and named this appearance of agent *object*. For this purpose, we designed several object forms and refined design alternatives to the last form of the agent. We added slope to the form, to make the agent directional and curves on the edges to prevent the agent from being perceived as a box. We aimed to design an abstract form for the purpose of not creating any bias and analyze the effect of expressive actions only.

For the second embodiment of an agent, we used the 3-D model of a sumo robot kit and named it *robot*. An abstract robot form was used to create simple causal events and examine causality only. We used the robot appearance because a robot is a functional machine that performs its purpose. Thus, the robot appearance is less abstract than the object and we can compare two embodiments in terms of abstractness.

We used the colors yellow and green to differentiate the two agents. We chose these colors to not create any bias on the readability of "help". We asked respondents "How do you infer your answer in Q2/Q3?" item to check if participants would refer to colors. We used these two colors on agents with the same role in robot and object videos. In every clip, green was used on the active object/robot that applies the force and yellow was used on the passive object/robot.

3.1.2 *Scenario*

We created the following scenario to narrate "help" as explained in Table 2. In expressive clips, we designed actions of agents

Table 2. Scenario in animation clips

	Scenario	Expressive actions	Non-expressive actions
1	YA moves slowly to the target	YA sways and limps	YA moves straight
2	GA enters to the area and turns to YA	GA moves, stops, scans the area by turning. When GA sees YA, GA shakes	GA moves with a fixed velocity, turns left without waiting
3	GA moves to YA	GA goes next to YA quickly and examines YA by turning around	GA goes to YA with straight moves and same speed
4	GA goes to the back of YA and starts pushing YA to the target	GA goes the back of YA, stops, goes back a bit, and then pushes YA.	GA goes the back of YA and starts pushing without waiting
5	Both slow down when they reach the target	When they stop, YA starts turning slowly, then turn to GA and shakes, GA shakes back, both turn to viewer side	GA and YA stop when they reach the target

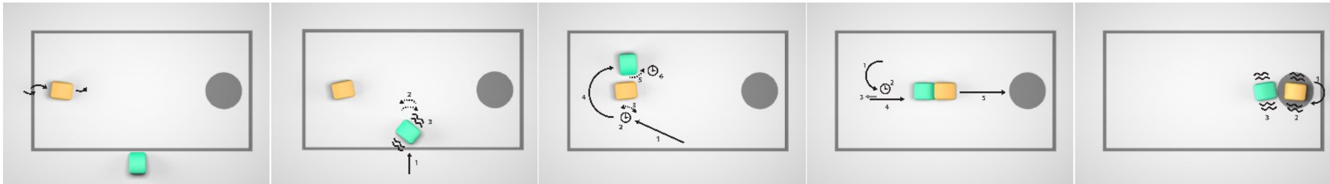

Figure 4. Scenario in the conditions with expressive actions

based on the following story: YA was sick/tired/wounded/old/out of battery and wanted to reach the target area and GA helped YA to reach its goal (see Figure 4).

3.1.3 Design of body movements

Agents in the animation clips were able to go forward, backward and turn 360 degrees. As previous studies stated direction and speed are useful parameters to create characteristics [20], thus, we used these parameters to apply expressive actions on body movements. For example, in expressive actions, the yellow agent was limping (1) and the action was used to indicate that the yellow agent was not capable of moving toward the target or it would take a time to move alone. In that case, the green agent looked around first instead of going toward the yellow agent directly (2). The green agent analyzed the yellow agent by turning around and looking at it (3). At the end, they showed a reaction to success when they reached the target (5). All of these expressive actions were given to emphasize the meaning in the causal event.

We also used the timing technique from the animation principles as a tool to create expressive actions. The timing could change the meaning of the same action by changing its duration. For example, the green agent waited after every movement when it was exploring yellow agent. The aim was to highlight that green agent was thinking and planning what to do. Takayama et al. [23] also applied anticipation, reaction and timing with a similar approach. In their experiments, an agent was looking at its goal and waiting before doing any action.

We used the same motion pattern for objects and robots by changing the 3D model in animation clips. So, the sequence of expressive objects and the sequence of expressive robots were same scenes with different embodiments.

Table 3. Questionnaire in the user study

1. Please describe what is happening in this clip.
2. What is the yellow agent trying to do?
2a. How confident do you feel about your answer in Q2?
2b. How do you infer your answer in Q2?
3. What is the green agent trying to do?
3a. How confident do you feel about your answer in Q3?
3b. How do you infer your answer in Q3?
4. Please rate the yellow agent based on the following parameters: Unintelligent – Very intelligent; Unappealing – Very appealing; Incompetent – Very competent; Unclear intention – Clear intention; Machine-like – Alive-like
4a. What influenced you to make these definitions?
5. Please rate the green agent based on the following parameters: Unintelligent – Very intelligent; Unappealing – Very appealing; Incompetent – Very competent; Unclear intention – Clear intention; Machine-like – Alive-like
5a. What influenced you to make these definitions?

3.2 Study protocol

The online survey started with a consent form. We gathered age, gender and e-mail information, and at the end of the page, there was a notification which warned participants to watch the clip carefully. When participants continued to the next page the video started automatically. There were no control buttons for the video so we know that each participant saw the video twice. We played clips twice to make sure that participants did not miss any actions. Every question was presented on a different page, except for sub-questions.

Subjects then answered the questions in Table 3. Questions 1, 2, 2b, 3, 3b, 4a, and 5a are open ended questions. A 7-point Likert scale was used in questions 2a, 3a, 4 and 5. In question 2a and 3a, the scale is ranging from 7-Absolutely sure to 1-Not sure at all. In Q4 and Q5 range of scales are given in Table 3. We took Takayama et al.'s [23] study as a base for our questionnaire which investigated the readability of agent's actions with animation clips in an online survey. Questions 1, 2, 2a, 3, 3a, 4, and 5 were taken from their study. We excluded questions that were not related to our study. Additionally, we asked the follow-up questions of 2b, 3b, 4a, and 5a to better understand whether participants refer to actions of agents when they explain the causal event and traits of agents. In the Q4 and Q5, we added intention scale to analyze the effect of expressive actions on the intention of agents which was a supportive question for Q2a and Q3a. We added alive-like scale in Q4 and Q5 to see the effect of expressive actions on characteristics of agents.

4. ANALYSIS AND RESULTS

4.1 Analyses

We measured the readability by coding responses in Q1. We coded whether participants used the verbs "help" ("yardım") and "support" ("destek"). If the description of a respondent included one of these verbs we coded it as correct (1) otherwise it was coded as incorrect (0). This Boolean classification was also used in the study of Takayama et al. [23] to measure readability. Moreover, in force dynamics experiments [7, 8, 27] researchers examined whether participants use causal verbs in language. Thus, we only coded the above keywords that cover "enable" scenario in Turkish. Chi-square tests were run to determine the difference in frequencies of the keywords "help" and "support" among 4 conditions. All combinations of the 4 conditions were tested.

We conducted a one-way ANOVA for all 4 conditions to see the difference between the perceptions of agents' personality traits in all cases. The same analysis was also done for the "how confident" item to see whether expressive actions made a difference in participants' confidence in what they believe they observed. After that, we compared videos with and without expressive actions regardless of whether they contained objects or robots (EO+ER / NO+NR). Similarly, we compared object videos with robot videos regardless of their expressivity (EO+NO / ER+NR). Finally, a paired samples t-test was conducted on all cases to see the difference between yellow and green agents' characteristics.

4.2 Results

Overall, there was a significant difference in frequency of the words "help" and "support" when all 4 conditions were compared to each other ($\chi^2(3,116) = 27.15$, $p<0.0001$). Regarding the object embodiment, keyword usage in condition EO (19 - 63.3%) and condition NO (10 - 34.5%), $\chi^2(1,58) = 15.35$,$p<0.0001$ were different as people used keywords in expressive object videos more than in non-expressive object videos. Regarding the robot embodiment, similar results were found and the keyword usage in condition ER (18 - 62.1%) was significantly higher than in condition NR (14 - 50%), $\chi^2(1,58) = 11.8$, $p<0.0001$ (see Figure 5).

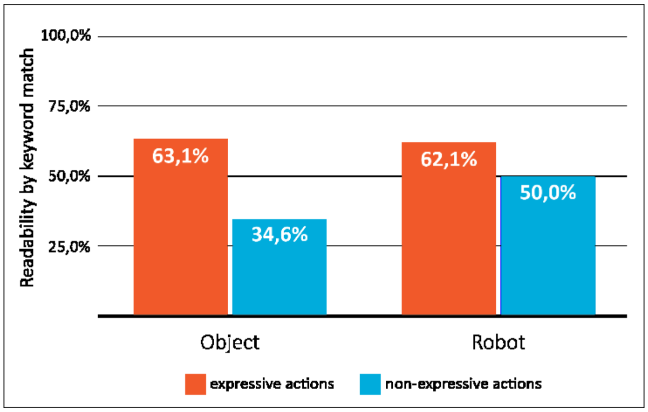

Figure 5. Percentage of correct answers for all conditions

There was a significant difference between the participants' confidence in their answer to question 2a on conditions EO+ER and NO+NR, $F(1, 114) = 4.12$, $p<0.05$. This indicates that people were more confident in their answers for the yellow agent in non-expressive videos (see Figure 6). In contrast to the yellow agent, there was no significant difference in participants' confidence levels for the green agent in their responses to the item 3a between conditions EO+ER and NO+NR, $p>0.05$.

There was no significant difference between the perceived intelligence, competence, and appeal levels of the yellow agent on conditions EO+ER and NO+NR, $p>0.05$. However, the yellow agent's intentions were found clearer in all non-expressive videos (M=5.40, SD=1.14) than it was in all expressive videos (M=4.13, SD=2.07), $F(1, 114) = 12.63$, $p<0.01$. The yellow agent was found to be more alive-like in conditions EO+ER (M=4.36, SD=1.84) and more machine-like in conditions NO+NR (M=3.07, SD=2.02), $F(1, 114) = 12.9$, $p<0.001$ (see Figure 7).

The green agent did not show a significant difference in competence, appealing, and intention clarity scales between videos EO+ER and NO+NR, $p>0.05$. However, it was perceived

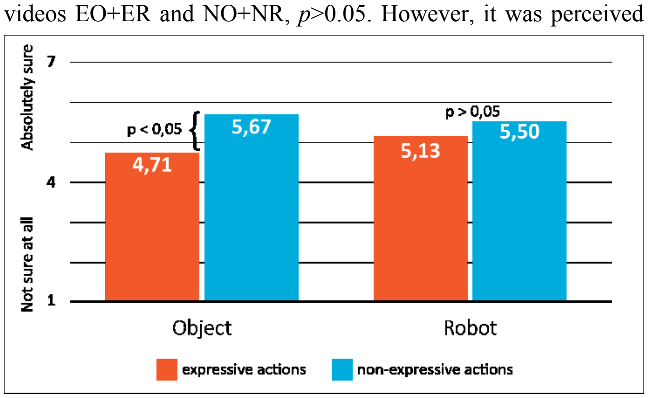

Figure 6. Confidence of participants for yellow agent

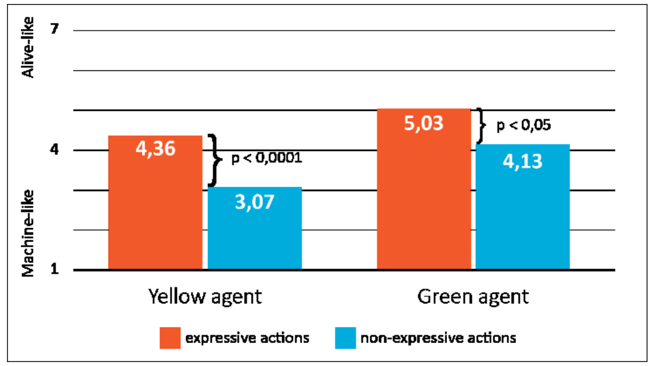

Figure 7. Perceived alive-like rates of agents

to be more intelligent in videos NO+NR (M=5.87, SD=1.14) than in videos EO+ER (M=5.30, SD 1.32), $F(1, 114) = 6.29$, $p<0.05$. In contrast, it was found more alive-like in clips EO+ER (M=5.03, SD=1.82) than in videos NO+NR (M=4.13, SD=2.19), $F(1, 114) = 5.93$, $p<0.05$. (see Figure 7).

On conditions of EO and ER, the yellow robot was perceived more intelligent (M=5.07, SD=1.14) than the yellow object (M=4.06, SD=1.20), $F(1, 59) = 11.05$, $p<0.01$. This effect was also found between conditions NO and NR, $p=0.05$. Between EO and ER, the yellow robot was also found more competent (M=3.83, SD=1.34) than the yellow object (M=3.16, SD=1.13), $F(1, 59) = 4.50$, $p<0.05$ (see Figure 8). There were no significant differences in other personality traits in (EO+NO) versus (ER+NR) for both agents.

We elaborate the qualitative results from open questions in the discussion section.

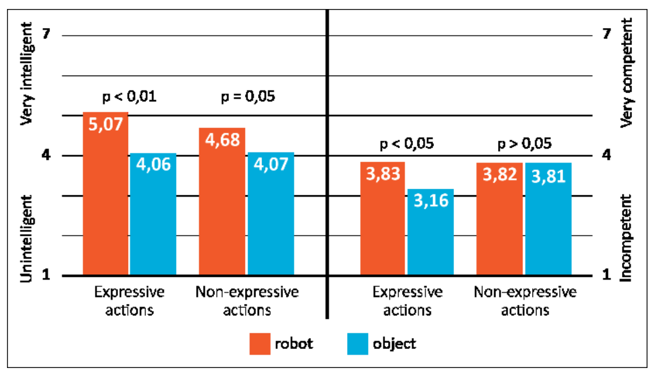

Figure 8. Perceived intelligence (left) and competence (right) of yellow agent

5. DISCUSSION

5.1 Readability of causal events

We found support for our main hypothesis (**H1**). Expressive actions that contain the animation principles of anticipation and reaction increase the readability of causal interaction between two abstract agents. This result indicated that animation principles can help participants to understand causal relations better and they can improve experimental settings. Responses to items 2b and 3b affirm that most of the participants referred to the actions of agents in expressive videos. For question 2b, the answers of participants included "It was not able to move" (P8), "Because of its movements and its hesitation" (P6), and "It was happy when the green agent brought it to the target" (P13). For question 3b, responses included "it was moving around the yellow agent" (P5), and "from its determinant movements" (P74). However, participants who saw non-expressive videos and answered correctly mostly referred to other features in the scene such as direction and the target. Some of these participants were not able to provide an explanation on how they understood the causal relation: "based on what I watched" (P45), "I guessed" (P84) and "I don't know" (P56).

We expanded the study of Takayama et al. [23] by looking at the readability of agents' actions with animation clip. Our results differ from their study, in which they found that expressive actions did not increase the readability of an agent's actions. They stated that the environment helped participants to understand what was going to happen in the non-expressive videos. According to their comments, the presence of a door helped participants to understand that the agent would open the door. Also, they used a robot with human-like features such as arms and hands which was given goal-oriented tasks such as opening a door and this might have helped to understand non-expressive clips. We used abstract agents, which did not include any clues about their purpose, and this might have resulted in increasing the readability of the causal event. According to these results, we believe that expressive actions have a powerful effect on increasing the readability of interaction between abstract agents more than non-abstract agents. Our findings supported this assumption. We found that the difference between correct answers for expressive and non-expressive videos was higher in videos with the object embodiment than those with the robot embodiment.

Another difference from Takayama et al.'s study was that expressive actions increased the confidence of the participants. In contrast, our findings highlight that mean scores for confidence were higher in non-expressive videos (but the difference was significant only in answers for the yellow agent). The agents were moving directly in non-expressive videos. So, there was nothing to guess in the sequences and participants were sure of their answers. However, in expressive clips, agents were doing several actions. Because agents did not have any visual cue for their intention, there was more space for imagination in expressive clips. For example, responses to Q2 – "What is the yellow agent trying to do?" in clips with anticipation included various intentions of the yellow agent such as "it was curious", "it was hesitant", "it was trying to find where to go" and "it did not have self-confidence". Results showed that expressive actions provided a better understanding for participants, but they were not as sure about their answers. Differences between the study of Takayama et al. and our study might be caused because they investigated the goal-oriented actions of one agent and we examined the interaction between two abstract agents.

5.2 Effect of anticipation on different embodiments

The results supported our second hypothesis (**H2**) that expressive actions increase the readability of causal events for different embodiments. However, the effect of expressive actions on readability was more significant for the object appearance than for the robot appearance. Results for expressive videos were similar for robot and object appearance (62.1% and 63.3%, respectively) but the results for the non-expressive robot's clip were higher than the non-expressive object's clip (50% and %34.5, respectively). Although different embodiments of agents had different results in non-expressive clips, results were very close in expressive clips for robot and object embodiments. Previous studies stated that different embodiments of agents did not have any effect on the perception of agents with same motion patterns [20, 21]. We extended this finding by presenting that similar levels of readability in actions of agents with different embodiments were found when motion patterns were identical.

We believe that the level of abstractness was different for each of these two embodiments. Although the agents in the robot form had a machine-like appearance, still a robot is a functional, goal-oriented machine and it completes given tasks. On the other hand, the object form was unfamiliar and it was hard to relate it to any purpose. In contrast to object, robot appearance was definable and this makes the object more abstract in our case. Therefore, the difference in the level of abstractness might cause the effect of expressive actions to be more powerful for agents in the object embodiment than the robot embodiment.

5.3 Trait questions

Following findings in the trait questions are not directly related to our research questions but they are meaningful to discuss. For personality questions, both agents were more alive-like in expressive videos and it was coherent with previous studies which found animation principles to be useful in creating "the illusion of life" in agents [2, 19, 23].

We also found that participants were more confident in their answers for the yellow agent in non-expressive videos. In addition, the intention of the yellow agent was clearer for non-expressive clips compared to expressive clips. This might be due to the fact that there was nothing to guess in non-expressive videos and participants were more confident in their answers. However, we did not find the same result for the green agent. This could indicate that expressive actions might not work for passive agents as they worked for active agents because they were not doing many actions. However, the anticipation technique was described as it creates a thought process for the character and helps the audience to connect all unrelated actions of an agent. For the passive agent (yellow) we applied expressive actions only with a wobbling movement to illustrate that it needs help. In other words, the role of the yellow agent was short and it seems that one motion pattern was not enough to explain its action clearly. Another finding was that the green agent was more intelligent in the non-expressive videos. In non-expressive videos, the green agent (active) was more determined; it was directly going to the yellow agent. However, in expressive videos, the green agent was looking around and thinking before doing the action and it might have shown that the active agent is less intelligent in expressive videos.

5.4 Implications

Our study showed that animation principles are promising for application in other fields, especially in psychology studies. Psychology researchers are mainly focused on their research questions instead of designing visual elements in their experiments. We believe as the psychology field contributes to the other fields, it can also be supported by other fields such as HCI and animation to improve experimental conditions.

In addition to psychology experiments, our study contributes to human-computer interaction and human-robot interaction fields by demonstrating the importance of body movements in communicating with agents. We highlight that it is possible to understand abstract agents' actions by using animation principles. This outcome could be useful in kinetic user interfaces to express behavior in daily objects with their actions. Artificial intelligence (AI) applications have been trending and agents with AI perform a behavior. We believe that showing the intention behind the behavior is crucial. Humanoid body movements not only create appealing characters but also help users to understand the intention of agents. Besides, understanding the communication between agents will be essential when multi-agents systems become common in the future. For example, instant communication is needed in a rescue team of humans, drones, and mobile robots. In this case, human-like body movements can help us to understand the communication between agents. Two agents can transmit data to each other, but this transmission will be invisible for users. Weiser and Brown [26] emphasized the importance of designing "calm technologies" to make these interactions visible by referring to the work of artist Natalie Jeremijenko, the "Dangling String" which is an Ethernet cable that shakes during a data transmission and it vibrates more when the amount of transferred data increases. Studies showed that human-like actions create natural interaction and attract users because humans take themselves as a model to understand their surroundings and often refer to human aspects to explain concepts, artifacts, and non-human beings [4, 5]. Human-robot interaction field mostly focused on humanoid appearance to create this familiarity but humanoid behavior might be much stronger and less uncanny than the appearance to design familiar agents. This initial study speculates the future with moving agents around us and shows the importance of body movements as a communication method in this manner. We should consider the following question to design better body movements: If agents reveal their interactions with body movements in the future, should we imitate the human behavior to design these body movements or can we match their unfamiliar actions with a specific behavior over time?

Another finding of our study was that the effect of expressive actions was higher in object embodiment than in robot embodiment. This showed that the abstractness and expressivity of agents should be considered when applying animation techniques to express actions of agents. We also suggest using animation principles with abstract agents because they do not have any visual cues for their intentions and characteristics. These results could be used in Human-Robot Interaction field to focus on abstract robots instead of humanoid robots in social robotics as we noted expressive actions make abstract agents understandable.

6. CONCLUSION AND FUTURE WORK

This study aimed to examine the effect of expressive actions that involve anticipation and reaction on the readability of interaction between abstract agents in causal events and investigate this effect by using two different embodiments. In order to test the effect of expressive actions and embodiment on the readability, we conducted an online user study with 116 participants. Results showed that expressive actions significantly increased the readability of "help" which proved that animation principles could be used by psychology researchers to design better experiments for causality studies and help participants to understand causal relations. In addition, the effect of expressive actions was found in two different embodiments. However, expressive actions increased the readability of causal events more in abstract agents (object appearance) than in less-abstract agents (robot appearance). These results verify both of our hypotheses (**H1** and **H2**).

We mainly contribute to the cognitive psychology field by animating agents and improving the settings of causality experiments. This study also contributes to the HCI field by investigating the readability of interaction between two abstract agents. Besides, we introduce that understanding non-humanoid abstract agents by only their body movements is possible. Therefore, this study demonstrates the importance of body movements for abstract agents by introducing the effect of an animation principle on readability of actions.

In our study, we investigated motion to emphasize the meaning in the scene. In the future work, it is possible to iterate this research with various causal events other than "help" to examine the effect of context in the scene. Also, the study needs to be conducted in other languages than Turkish for generalizing the results. As causality experiments were done with different age groups and results differ for adults and children [7, 8], the effect of expressive actions on readability could be investigated with children in the future studies.

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