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Physical Media as Active Social Learning Agents

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UPDATE

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Physical Media as Active Social Learning Agents

Future of Content Project Update October 2013

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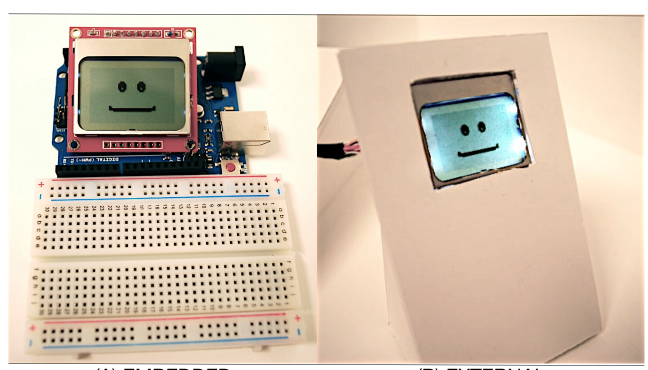
Abstract

What if the thing being created takes the role of an active social agent in the creative experience itself?

The broad, long-term objectives of our study are to develop the theory and principles necessary to design new physical media that can take an active social role in creating highly motivating K-12 learning experiences. Our specific research aim is to explore how the social behavior of mechatronic media affects a creative K-12 mechatronics learning experience. Specifically, we hypothesize that a mechatronic media component exhibiting social back-channeling behavior will lead to improved learning experiences compared to standard non-social media components. To explore this, we developed a 2x2 between-participants laboratory experiment with (N=68) high-school students. We specifically examined how agent expressions of relational interest affected perceptions and learning outcomes depending on the agent's locus of agency. We found evidence that a shift from external to embedded agents can positively influence learning processes and outcomes while not affecting perceptions of the agent.

Introduction

Designing and building mechatronic systems has gradually ceased to be the domain of only highly trained professionals and has become broadly accessible. The desire to make new technology as easily accessible as possible has led to developments such as the Arduino prototyping platform [25], a small microprocessor board with ports for sensors and actuators and a simple programming interface. The introduction of new prototyping platforms is paralleled by an emergence of online communities (e.g.



(A) EMBEDDED (B) EXTERNAL

Figure 1 - The embedded and external learning agent as used in our study.

www.instructables.com) that make new forms of learning content and support for this technology available on demand and with many modalities. The DIY Maker Movement is further evidence of this shift in accessibility of highly sophisticated technology.

In this study we explored whether having the technology itself take an active interest in the prototyping process might provide a unique source of engagement for novice builders. We explored this possibility by observing high-school students with little knowledge of electronics interact with an Arduino electronics-prototyping platform into which we had embedded an animated learning agent (Figure 1A). We contrasted this 'embedded' condition with a traditional 'external' learning agent (Figure 1B). Additionally, we varied whether the agents expressed interest towards the student or not. Consistent with prior research, we found that expressions of positive affect, through interest, increase perceptions of liking and social presence. However, we found evidence that the locus of agency also significantly affects the learning experience. For example, embedding the agent can make the learning task seem less stressful. Finally, our study provoked the question of whether the technology's expressions of interest can be beneficial or harmful, depending on the agent's locus of agency.

Hypotheses

Interest and Agent Perceptions

Expressing interest towards a person is one of the most effective ways of rapidly building positive interactions. Successful negotiators use interest frequently at the beginning of negotiations because interest expressions set a positive tone that flatters and orients the addressed party positively towards the person expressing interest [28]. People expressing interest become more likeable and make the addressed party more susceptible to influence [28]. Interest signaled through attentiveness also plays a critical role in the early stages of building rapport between people [37]. While we could not find research that examined the specific effects of agents expressing interest on learning outcomes, there are indications that animatedness alone is enough to affect learning outcomes positively. For example, Koda and Maes [19] found that people perceived an agent with an animate face more likeable and engaging than a faceless agent. Similarly Baylor and Ryu [4] found an animated learning agent more engaging and socially present ('person-like') than a non-animated learning agent. We therefore expect that:

H1: Agent Likeability – Irrespective of agent location, a learning agent that expresses interest towards the learner will be perceived as more likeable than a learning agent that does not express such interest.

H2: Agent Social Presence – Irrespective of agent location, a learning agent that expresses interest towards the learner will be perceived as more socially present than a learning agent that does not express such interest.

Locus of Agency and Task Perception

Embedding a social agent into the electronic-prototyping medium eliminates the need to split attention between the prototyping medium and an external agent. A traditional external learning agent can distract from the learning task [37, 10]. Distractions by an external question-asker have been shown to increase stress during a problem-solving task [24]. We hypothesize:

H3: Task Stressfulness – Participants will perceive the task as less stressful when interacting with an embedded agent than when interacting with an external agent.

Interest and Subjective and Objective Learning Outcomes

"To be interesting, be interested! [6, p. 88]." This wisdom from the self-help corner of your local bookstore reflects the finding that interpersonal expressions of emotion compel a complementary or reciprocal response [18]. Emotions are contagious – people mimic each other's emotional expressions and converge emotionally [13]. For example Barsade [2] showed that one confederate's expressions are enough to influence the emotional tone of an entire group and thereby group outcomes. It is no surprise that negotiators use interest statements to draw attention towards them in a favorable way [28]. Finally, Hancock and colleagues [3] showed that emotional states are contagious, even over chat media, demonstrating that a full spectrum of behavioral modalities is not required to transfer emotional states. Given that people tend to treat technology as social actors [30], we expect that a learning agent's expression of interest will be contagious as well and induce positive affect in the learner. Feeling more positive can be expected to improve learning performance as felt-positive affect has been shown to favorably influence many learning-relevant processes such as creativity [10], problem-solving [15] and learning motivation [31].

We also expect the locus of the agent's agency affects subjective as well as objective learning outcomes. Students learn better when verbal and visual materials are close together [26]. In line with this finding, a long-standing critique of animated agents has been that they can hamper performance by dividing attention from the task and distracting [10]. This idea is supported by a study in which a learning agent making non-task-related comments was perceived as more memorable but also as more distracting [37]. Embedding a learning agent into the prototyping medium itself guides attention towards the task, is less distracting and therefore can be expected to have a favorable impact on subjective and objective learning outcomes. In summary we hypothesize that:

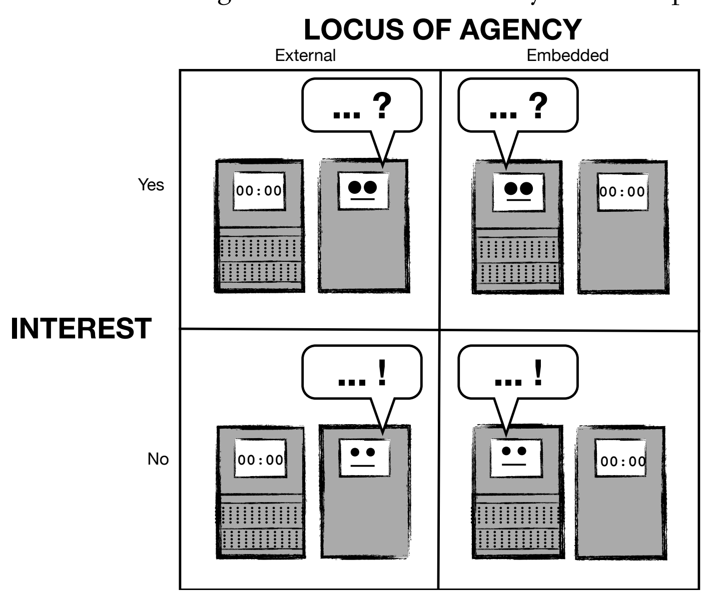


Figure 2 - Experimental setup for all four manipulation conditions with the prototyping platform on the left and the "box" on the right.

H4: Subjective Learning Outcome – Interacting with an interested learning agent will lead to improved subjective learning outcomes (measured by how confident participants feel about their acquired electronics-prototyping skills) compared to interacting with a non-interested learning agent. At the same time, interacting with an embedded learning agent will improve subjective learning outcomes compared to interacting with an external learning agent.

H5: Objective Learning Outcome – Interacting with an interested learning agent will lead to improved objective learning outcomes (measured by the prototyping performance in an open-ended prototyping task) compared to interacting with a non-interested learning agent. At the same time, interacting with an embedded learning agent will improve objective learning outcomes compared to interacting with an external learning agent.

The Experiment

In a 2 (locus of agency: embedded vs. external) x 2 (learning agent interest: interested vs. uninterested) between-participants experiment (N=68), we studied the effects of interested learning agents and their locus of agency on agent perceptions, task perceptions and learning outcomes. Participants were guided through an electronics building and programming tutorial by the learning agent. After participants completed the tutorial and a questionnaire, the learning agent was turned off and participants prototyped on their own for up to 15 minutes.

Participants

68 high school students (35 men and 33 women, balanced across conditions) ages 15 to 18 (M = 16.6, SD = 0.63) participated in our experiment. We recruited all participants from a high- school summer program at Stanford. Each student received a $15 gift certificate for his or her participation.

Manipulations

The expression of interest towards the participant was modeled after a behavioral description of interest as it occurs in marital interactions [8]. Features of interest include: 1) non-verbal attention and positive affect (i.e. eye contact, nodding, smiling), 2) open-ended questions and 3) elaboration and clarification seeking. In conditions where the learning agent was interested in the participant, the agent's face showed attention and positive affect through facial expressions (i.e. nodding when the participant answered a question, smiling when the user lit up the LED). This was done following a Wizard-of-Oz protocol through which an experimenter, viewing the subject from a camera, controlled facial expressions. The learning agent also asked open-ended, interest questions, such as "This looks very interesting. What are you doing right now?" If the participant responded to the question, then the learning agent sought elaboration with a request to know more about the participant's answer.

In uninterested conditions, the learning agent's face moved randomly, without attention, but with similar frequency to interested cases. The learning agent made neutral statements such as "Building electronics can take a lot of time" and did not seek elaboration. Verbal and non-verbal behaviors for each condition are listed in the following table.

	Interest: No	**Interest:** Yes
Non-verbal behavior	Random display of facial movement according to the following distribution: Gaze: 56% Smile : 2% Nod: 5% Confused: 2% Focused: 3% Neutral: 32%	Reactive non-verbal movement according to a specific protocol: A hidden experimenter, who observed the participant's behavior through a camera, controlled the behavior. The non-verbal affective behavior of the agent was mimicking that of the participant. For example if the participant smiled, the agent smiled back.
Verbal behavior	**Five factual statements:**	**Five open-ended questions with follow up:**
	1. "Building a circuit can be very interesting."	1. "You can make pretty much anything with electronics. What's the coolest thing you would like to work on?" Follow up: "Cool! Tell me more."
	2. "Making electronic devices takes a lot of time."	2. "This looks really interesting. Can you tell me what you are building right now?" Follow up: "That is interesting. I'd like to know more."
	3. "Almost all new technologies use electronics."	3. "Building electronics can take a lot of time. What are you working on right now?" Follow up: "Can you tell me more about that?"
	4. "You have three different parts you can use to build this circuit."	4. "You are using all these neat parts. Is there one that you find really interesting?" Follow up: "Can you tell me more about that?"
	5. "Many new devices have complicated electronics."	5. "This looks quite complicated. What's the most complicated thing you have ever made?" Follow up: "Oh! I'd like to know more."

Interest Manipulation

Locus of Agency Manipulation

Locus of agency was manipulated by placement of the LCD face, speaker and foam-core housing in relation to the Arduino and breadboard used by the participant. We built both embedded and external foam-core agents with the same LCD to ensure that we manipulated locus of agency and not other parameters. Additionally, the speaker was placed behind the LCD to link the face and voice as one agent.

In embedded conditions, the learning agent was embodied on the device that participants were building. The LCD face was placed on top of the Arduino with a breadboard underneath, giving the sense that the Arduino and breadboard were part of the learning agent. The external model was programmed to be a digital clock. When it was embedded, spoken instructions referenced the device itself, using phrases such as "Start building the circuit on **my** breadboard." The speaker was placed under the onboard device so that the voice and face were linked. During external conditions in which the social agent was embodied off-device, the external model had a face and the embedded screen was made into a digital clock. The social agent then referenced the Arduino board and breadboard as objects, using phrases such as "Start building the circuit on **the** breadboard." The speaker was placed behind the external model to link the voice and face as one unit.

Procedure

After completing a parental-consent form (if participant was under 18), participants were invited to the lab. Upon arriving, participants signed an assent form and filled out an online pre-task questionnaire, collecting information on their personal and academic backgrounds. After completing the questionnaire, participants were asked about their experience with building electronics and programming. The researcher then reminded students that no experience was required and that the participant would be completing a tutorial with the learning agent. The experimenter gave a brief tutorial on the components used during the task, such as the Arduino, breadboard and programming environment. The experimenter then went into another room to control the learning agent, unbeknownst to the participant.

The tutorial began when the learning agent spoke, saying "Let's learn how to light up a light emitting diode (or LED) using my/a [depending on condition] microprocessor board and a breadboard." Participants were either guided through the task by the agent embedded in the Arduino board itself or by the external agent, depending on the locus of agency manipulation. During the task, the learning agent guided the participant through building and programming a blinking-light circuit, using a guide sheet with illustrations. The agent asked open-ended interest questions or made factual statements, dependent on whether people interacted with an interested or uninterested learning agent, respectively. An example of an interested, embedded interaction would be as follows:

Agent: Are you ready to get started?
Participant: Yes.
Agent: My microprocessor board has numbered pins or little holes in black boxes that we can plug wires into to control electronic components. Lets get started by grabbing some components. Grab your favorite color LED, a 220 ohm resistor, and 3 short wires from the box. Do you have all the parts?
Participant: Yes.
Agent: OK, Lets start building the circuit. Start with picture 1 and let me know when you are done.

Participant: OK, I'm done.
Agent: You can make pretty much anything with electronics. What's the coolest thing you would like to work on?
Participant: Flashing lights.
Agent: Cool! Tell me more!
Participant: I'm interested in concert experiences and I like it when, uh, when concerts, when lights start flashing to the beat of music, and I'm interested in seeing how that works and how I can improve that technology.

If an issue arose or a participant became stuck on a step during the experiment, a researcher would enter the room and help the participant complete the step. Once the participant completed the task, a researcher entered the room and instructed the participant to complete a questionnaire. At this time the social agent was turned off and all continuing prototyping activity was unmediated by the agent. After completing the questionnaire, the researcher instructed the participants to build anything of their choosing. Participants could use more electronics components, the programming environment and additional craft supplies (paper, scissors and markers) to create a device. Participants were told that they could take as much time as they wanted but that the researcher would stop the participant after 15 minutes. Participants were then debriefed and discussed the study with researchers.

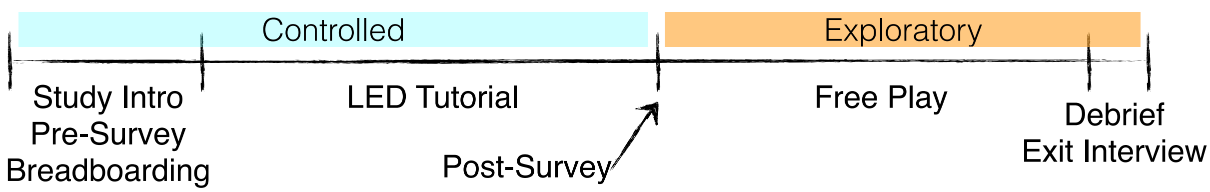


Figure 3 - Various phases of the study.

Materials and Measures

Learning Agent Design

The learning agent was comprised of an Arduino UNO, a Nokia 5110 LCD display, a small speaker and a foam-core housing. The learning agent was designed to interact both non-verbally and verbally with the participant. Non-verbal expression of interest was accomplished by displaying a stylized face with various emotional expressions and by moving it on an LCD display. We designed a palette of expressions that could be used to signal interested engagement non-verbally: making eye contact with the speakers, gazing, smiling, frowning and nodding during a conversation. The LCD backlight was lit during each facial transition to attract the participant's attention. During neutral states the LCD cycled in brightness in a periodic 'breathing' pattern to evoke a sense of presence. Facial movement was controlled by one of the researchers or randomly via a Processing script. To allow the learning agent to communicate verbally, a small speaker was placed behind the LCD screen and foam-core housing. We used this verbal communication to give tutorial instructions and to either ask interested questions or neutral statements. The Mac OSX 'Apple Alex' voice with a U.S. English linguistic style was used at normal speed.

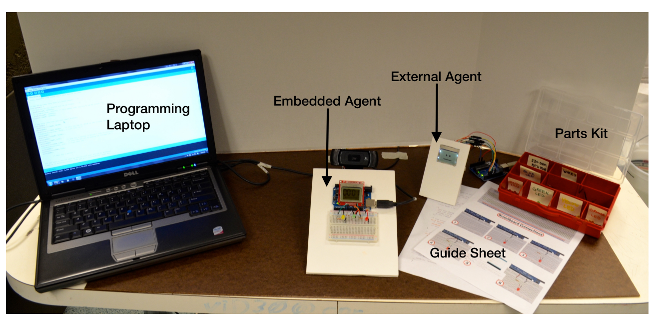


Figure 4 - Setup as participants saw it. Learning agent with LCD, Arduino, foam-core housing, programming computer, guide sheet, and parts kit.

The tutorial prompts and questions were pre-written and triggered by one of the researchers during each experiment.

The learning agent was embodied in a simple, white, foam-core box. This allowed for the faces to be the most prominent feature of the device and keep a consistent aesthetic between both the embedded and external agents. To control the devices having screens, both the embedded and external models were present among all conditions with the unused agent displaying a digital clock.

Electronics Prototyping Task

The experimental protocol included two types of prototyping interactions. The first was a scripted, tutorial-like prototyping exercise. The second was an open-ended prototyping exercise. During the experiment the participants completed a short electronics and programming tutorial modeled after the introductory activity in Getting Started with Arduino using the Arduino UNO development board [1]. The learning agent guided participants on how to make a light-emitting diode (LED) blink using a numbered Arduino pin as an output. The task included circuit-building and short programming sections. Participants used a breadboard, wires, LEDs and resistors to create their circuits. Participants programmed the Arduino using a laptop computer and a modified version of the 'Blink'-example source code in the Arduino IDE. After completing the tutorial, students were given 15 minutes to explore the Arduino prototyping environment using more electronics components, without the aid of the learning agent.

Measures

Measures of 1) liking of agent, 2) agent social presence, 3) task stressfulness, 4) electronics prototyping confidence and 5) prototyping performance were collected during this study. Liking of agent, agent social presence, task stressfulness and prototyping confidence were collected using 10-point, Likert-questionnaire items given directly after the guided tutorial. Objective learning outcome was measured through video analysis of the 15-minute unguided exploratory activity. In addition to these exploratory measures, we also had manipulations checks for the participant's perception of agency location and interest.

Agent Perception

Agent perception was assessed by measuring Liking of Agent and Agent Social Presence. Liking of Agent was operationalized as a three-item index. We asked participants if they thought the device that guided them through the task was Friendly, Likeable and Fun. Items were rated on a 10-point Likert scale, ranging from "describes very poorly" (1) to "describes very well" (10). This index was reliable (Cornbach's $\alpha = 0.71$).

The Social Presence measure was operationalized using a standard seven–item social presence measure from Lovell [22]. Items were rated on 10-point Likert scales ranging from "not at all" (1) to "absolutely" (10). The index was reliable ($\alpha = 0.70$).

Task Perception

We assessed task perception by measuring how stressful participants perceived the task to be. Task stressfulness was operationalized as a three-item index. Participants rated on a 10-point Likert scale, ranging from "describes very poorly" (1) to "describes very well" (10) how much the task experience could be described as Stressful, Afraid, and Made Me Nervous. The index was reliable ($\alpha = 0.70$).

Learning Outcomes

Subjective and objective learning outcomes were assessed by measuring prototyping confidence as well as prototyping performance, respectively. Our prototyping confidence measure was operationalized as a four-item index adapted from a study on evaluating self-efficacy during a soft-circuits curriculum [23]. The following items were based on a 10-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (10): i.) I am confident that I can draw a diagram of a simple circuit, including a light and a battery, ii.) I can easily build a simple circuit from a light and a battery, iii.) I am confident in my ability to explain what I built today to a friend, and iv.) I can easily learn how to make electronic devices that are more complex. The index was highly reliable ($\alpha = .89$).

The objective prototyping-performance measure was operationalized by coding the video records made during the open-ended prototyping phase. We coded three dimensions – hardware, software and aesthetics of the student's prototype on a three-point scale (1 = small attempt to change device, such as moving the LED to 3 - impressive attempt to change the device, such as adding three LEDs and making a stop light). These three scores were summed to create an overall prototyping-performance score.

Results

All measures were analyzed using two-way analysis of variance (ANOVA). Agent perception, task perception, learning outcomes and manipulation checks were analyzed with Agent Interest and Locus of Agency as independent variables. All analyses were performed with 62 participants. Six participants (three from each of the embedded and external interested conditions) did not respond to all initial questions of the agent and were removed from the final analysis as their non-responsiveness led to a different experimental treatment from the other participants.

Manipulation Checks

To confirm the intended manipulation of the agent's locus of agency, we asked participants to select where the image of the agent that interacted with them was located (1:External, 2: Embedded). As expected, participants in embedded conditions recognized the agent as embedded in the prototyping board ($M=1.97$, $SD=0.041$) and participants in external conditions recognized the agent as external ($M = 1.06$, $SD=0.039$), $F(1,62)=259.9$, $p<0.001$.

To confirm the intended manipulation of expressed interest by the agent, we asked participants "The talking device was interested in me." on a 10-point Likert Scale, ranging from "describes poorly" (1) to "describes well" (10). As intended, participants of interested conditions rated the learning agent as more interesting ($M=7.9$, $SD=0.366$) than in uninterested conditions ($M=6.29$, $SD=0.331$), $F(1,62)=10.7$, $p<0.002$.

Agent Perception

As expected from H1, participants rated the interested learning agent (M=7.8, SD=1.6) more likeable than an uninterested learning agent (M=6.7, SD=1.4), $F(1,62)=4.95$, $p<0.05$. (Figure 5A).

We found a significant main effect in agreement with H2. Participants perceived the interested agents as having more social presence (M = 6.9, SD = 1.3) than the uninterested agents (M = 6.0, SD = 1.3), $F(1,62)=6.506$, $p<.05$. (Figure 5B).

Task Perception

As expected in H3, we found a main effect for agent location on perceived task stressfulness, with participants rating the task as more stressful when the agent was external (M=3.5 SD=1.7) than when it was embedded (M=2.7, SD = 1.4), $F(1,62)=4.19$, $p<0.05$. There was also a marginally significant difference with participants reporting more stress during the interested condition and less stress during the uninterested condition for external conditions, $F(1,32)=2.855$, $p<0.01$ (Figure 5C).

Learning Outcomes

H4 was not supported. We found no significant main effects for agent locus or agent interest on prototyping confidence. However, we found a significant interaction effect for agent locus and agent interest $F(1,62)=5.17$, $p<0.05$. There was also a marginally significant difference between participants reporting higher confidence with the interested embedded agent over the uninterested embedded agent, $F(1,30)=3.50$, $p<0.10$. (Figure 5D).

H5 also received no support. We found no significant main effects for agent locus or agent interest on participant's prototyping performance. Instead, we found a marginally significant interaction between agent locus and agent interest, $F(1,62)=3.16$, $p<0.10$. Participants also performed significantly better during uninterested, external conditions over uninterested, embedded conditions, $F(1,32)=4.04$, $p<0.05$. (Figure 5E).

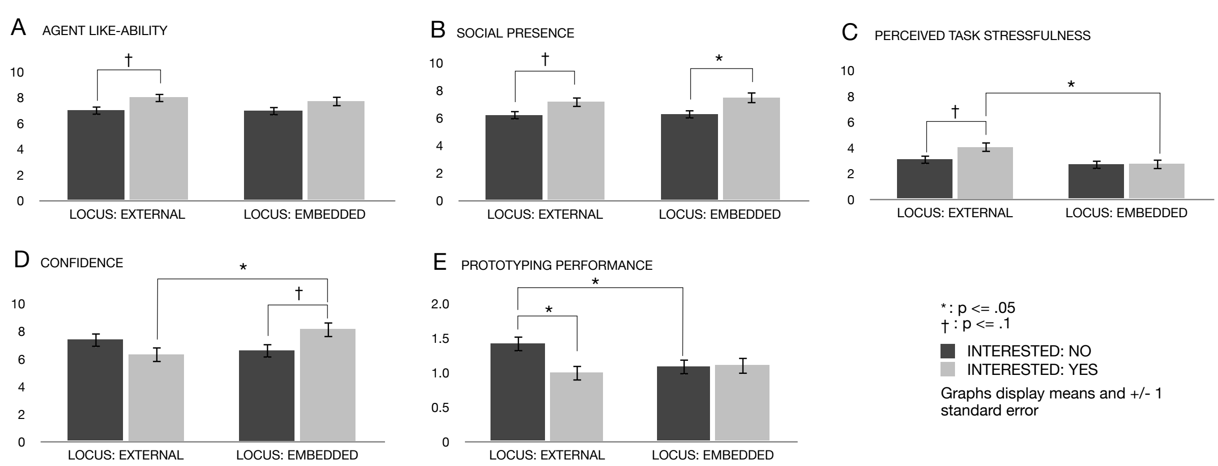


Figure 5 - Results for agent like-ability, social presence, perceived task stressfulness, confidence, and prototyping performance.

Discussion

When one discusses participatory design, one usually considers the end users. In this study, we bring the notion of 'participatory design' to the technology itself. That is, we ask whether it makes a difference whether a technology is engaged and involved in its own creation. While the results are preliminary, we found evidence that embedding an agent into a prototyping medium can have definite advantages over the use of traditional external agents. In particular, an embedded agent was perceived as more socially present and likeable than an external one, and it reduced task stressfulness.

Hypotheses 4 and 5 received no support, but more interestingly we found significant cross-over interactions for interest and locus of agency on prototyping confidence and prototyping performance. The post-hoc analyses revealed that although the agent looked identical in all conditions, having the agent speak about itself had powerful effects. In combination, these results could indicate that interest affects learning processes differently, depending on its expression by an external or an embedded agent. More specifically, interest could have negative learning consequences when expressed by an external agent and positive impact when expressed by an embedded agent.

An explanation consistent with these observations is that interest led to increased attention towards the learning agent as it was involved in highly engaged and lengthy 'conversations.' In the external-agent condition, interest expressions might therefore have guided attention away from the task, making the agent seem distracting and interruptive. The negative impact of the distractiveness might have outweighed the positive impact of interest on the learning process. On the other hand, in the embedded-agent condition, interest expressions might have guided attention towards the task, letting the user fully harness the positive effects of interest without pulling attention from the task. In line with this idea, Thrun and colleagues [37] demonstrated that behaviors associated with the expression of interest, such as smiling, looking at people and positive emotional speech content, can be highly effective behaviors for robots to compel the attention and engagement of museum visitors. Given that some positive emotions have different relational effects and some are more attention-grabbing than others, these findings could also explain why some researchers reported animated learning agents to have negative impact on learning outcomes by being distractive [10, 37] while others found no such distracting effects [19].

Limitations

An important limitation must be addressed. We do not know if the effects we found are mediated by role-perceptions of the agent. Expression of interest and locus of agency could both influence the perception of the agent's status, or role. For example, when the agent was external it might have been perceived as a teacher, higher in status and therefore more dominant than when the agent was embedded. An external agent asking questions might be perceived as more controlling and expert than an embedded agent – which was talking about itself – doing the same.

Embeddedness might have led to a perception of the agent as more of a peer and therefore resulted in different learning outcomes. However, we did not find any qualitative evidence that participants referred to the agent differently under our various experimental conditions. In support of this, our manipulation check confirmed that a question-asking agent was perceived as genuinely interested independent of its locus of agency. Additionally we asked participants to rate on a 10-point Likert scale, ranging from "Not at All" to "Absolutely," as to "How much did you feel as if you and the talking device were a team?" We found no significant differences for this measure of the participant's perception of the agent as a teammate between either the non-interested (M = 5.29, SD = 000) and interested (M = 6.16, SD = 000) F(1,62)=0.834 p=.21 conditions nor between the external (M = 5.38, SD = 2.78) and embedded (M = 6.00, SD = 2.93) F(1,62)=0.834, p=.34 conditions.

Qualitative Observations

One of the most striking outcomes of our study was how powerful the interest manipulation was shown to be in engaging the students in short, meaningful conversations with the agent. Many students shared personal stories with the agent:

Agent: This looks quite complicated. What's the most complicated thing you have ever made?

Participant: The most complicated thing I have ever made was trying or attempting to work an electromagnetic induction system, and it worked, but it took a lot of time.

Agent: Oh! I'd like to know more.

Participant: So me and my friend, as I told you earlier, were working on this self-sustainable engine, and we worked a lot on it, and we were using electromagnetic induction to create the energy we need, and so we spend a lot of time developing this technology, and that was the most sophisticated or complicated thing I have ever worked on, but it is not the only complicated thing that I have ever worked on. (OI-04).

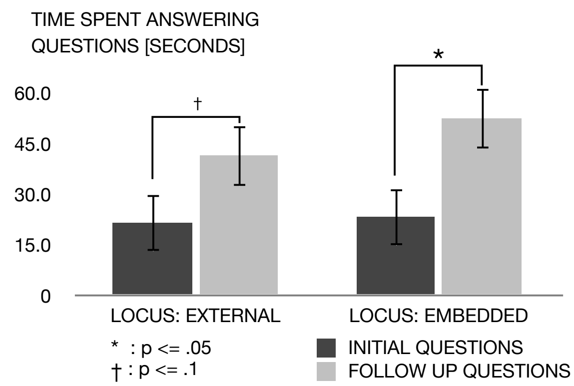


Figure 6 - People spent on average twice as much time answering the follow up questions than the initial questions.

The follow-up question in particular seemed to have been effective in encouraging interactions. An ANOVA with question type (initial vs. follow-up) and agent locus (external vs. embedded) as independent variables and the average time spent to answer all five question as dependent variable showed that follow-up questions provoked significantly longer answers (M=46.5, SD=42.8) than the initial questions (M=22.2, SD=17.1), F(1,56)=2.804, p<.01.

Interestingly, students responded differently when the agent was on-board than when it was off-board. For example, when interacting with an external interested agent, eight participants responded with "I don't know" when being asked a question. When interacting with an embedded interested agent, only one participant reacted in that seemingly defensive way, a highly significant difference, p<.001, suggesting that a device talking about itself elicits more engagement.

Finally, our research provides initial insight into the use of relational emotional expressions such as interest on learning performance. Past research on affective learning agents has primarily focused on using positive affect as a feedback mechanism and to increase the believability of the agents. Employing interest as a way to regulate the emotional quality of the interactions between student and agent is novel and shows promising effects.

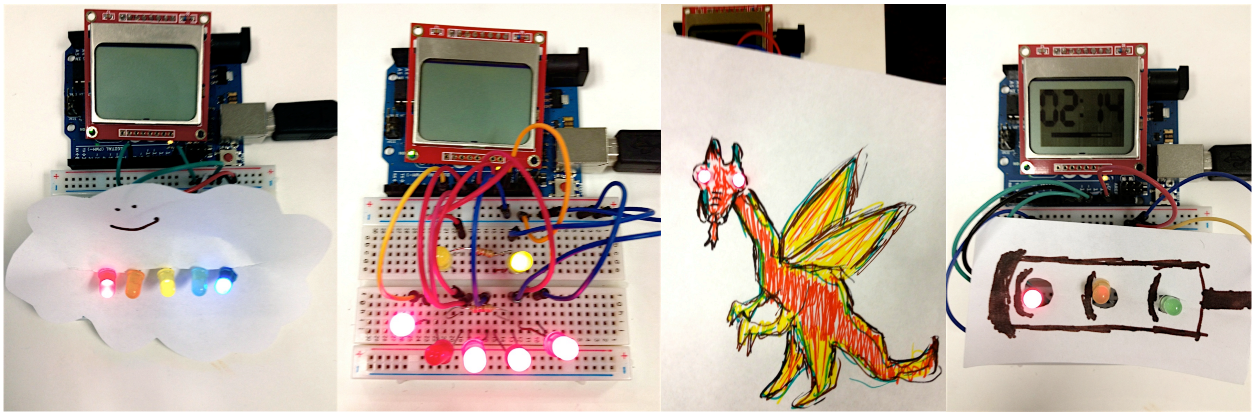


Figure 7 – Sample designs created during the free play activity

Future Work

We believe that the results of our study suggest that creating social-active and interested devices can improve learning activities. This study has helped us to develop a basic set of ways to create social-active devices. One interesting application for this in the education space would be as a mentor or guide during a massively online, open course (MOOC). The social-active device could provide emotional support for a student working alone. This may provide a critical, missing component to many MOOC's today, by supplying the student with the social component of the learning process. More broadly, we feel that creating interested devices can aid in improving design activity. We imagine new prototyping systems that interact with a design team, providing both technical and social content. With specifically crafted social interactions we may be able to further a team's design process, helping them to be more productive during idea-generation tasks and more convergent during technical-prototyping tasks. Further studies should explore how a social agent can influence and support team activities. Additionally, developing new social interaction, beyond interest, would help to improve and enrich these interactive experiences.

Acknowledgement

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