Experiments with a Robotic Computer: Body, Affect and Cognition Interactions

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ABSTRACT

We present RoCo, the first robotic computer designed with the ability to move its monitor in subtly expressive ways that respond to and encourage its user's own postural movement. We use RoCo in a novel user study to explore whether a computer's "posture" can influence its user's subsequent posture, and if the interaction of the user's body state with their affective state during a task leads to improved task measures such as persistence in problem solving. We believe this is possible in light of new theories that link physical posture and its influence on affect and cognition. Initial results with 71 subjects support the hypothesis that RoCo's posture not only manipulates the user's posture, but also is associated with hypothesized posture-affect interactions. Specifically, we found effects on increased persistence on a subsequent cognitive task, and effects on perceived level of comfort.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences

General Terms

Human Factors, Experimentation

Keywords

Human-Robot Interaction, User Studies, Affect, Embodiment

1. INTRODUCTION

In this paper we present RoCo, a novel robotic computer designed with the ability to move its monitor in subtly expressive ways that respond to and encourage its user's own postural movement. The design of RoCo is inspired by a series of Human Robot Interaction studies that showed that people frequently mirror the posture of a socially expressive robot when engaged in a social interaction [3]. It is interesting to consider whether a more computer-looking robot with the capability to adjust its "posture" can elicit similar postural mirroring effects during interaction. One potential benefit of introducing increased postural movement into computer use is reduced back pain, where physical movement is recognized as one of the key preventative measures.

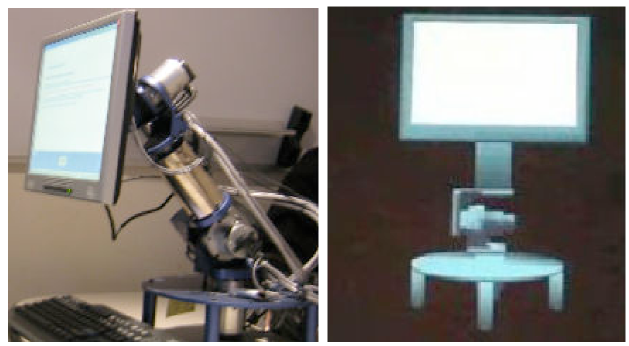

Figure 1: RoCo: A robotic computer (left) and its graphical simulator (right).

It is also possible that reciprocal physical movement of human and computer, and its interaction with the user's affective and cognitive states during task performance, could be designed to improve the efficacy of computer use. We believe this is possible in light of new theories that link physical posture and its influence on cognition and affect. A number of psychology studies have also explored the effect of body posture on affect and cognition [20],[19],[6],[24]. An example is the theory in Riskind's "stoop to conquer" research [19, 20], where it was found that slumping following a failure in problem solving and sitting up proudly following an achievement, led to significantly better performance outcomes than crossing those conditions.

In this paper, we adapt Riskind's "stoop to conquer" experiment where the "posture" of RoCo is used to manipulate the posture of the human user. We report our initial results with respect to posture-affect interaction effects on the user's level of persistence on a subsequent task, and their perceived comfort while using RoCo during the experiment.

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This paper is organized as follows. First we present a description of the new RoCo robotic computer platform. Next we offer a summary of relevant psychological literature with respect to body, affect, and cognition interaction effects that informs and guides our work. We then present a novel user study adapting Riskind's experiment to the RoCo platform. Our initial results show promise that a robotic manipulation can successfully elicit human body, affect, cognition interactions with respect to task measures (such as persistence in problem solving) as well as along ergonomic dimensions, such as comfort.

2. ROCO: A ROBOTIC COMPUTER

The physical RoCo robot has five degrees of freedom that manipulate a mechanical "neck" with a LCD screen as its "face" and "head." See Figure 1. Two DoFs move the mechanical neck (base yaw and base pitch) and three DoFs (head yaw, head pitch, and head roll) move the LCD display. It is interfaced to a MEI motion controller to drive the motors.

Character animators appreciate the importance of body posture and movement (i.e., the principle axes of movement) to convincingly portray life and convey expression in inanimate objects. Take Pixar's animated desk lamp, Luxo Jr., as a case in point. Special attention was paid to RoCo's design for producing smooth backlash-free movement, quiet operation, and the ability to move with velocities and accelerations necessary to convey expressive states and animations. RoCo's five degrees are sufficient to perform a wide variety of expressive and communicative motions. High-level motion trajectories are generated by the C5M behavior engine developed at the MIT Media Lab [2, 4] to control interactive characters (both animated and robotic). This codebase can generate real-time expressive behavior either from hand-crafted source animations or using procedural techniques [21].

The primary use of the LCD screen for the purposes of this experiment is to display task relevant information. However, this does not preclude the ability to display facial animations graphically on the LCD screen, or other sorts of graphical information to support other experiments or applications with RoCo. It is also equipped with camera input, microphone input, and speaker output (although they were not used in the study presented in this paper). The computer can also express itself through non-linguistic auditory channels, although this does not preclude the use of speech synthesis if the task demands it.

3. AFFECT, BODY, AND COGNITION INTERACTIONS IN PEOPLE

3.1 Evidence of Affect-Cognition Interactions

Everyone knows that how you feel can influence what you think and do, usually because of personal observation of how extreme emotions inspire negative thoughts, actions, and more. However, many people do not know that there is a growing body of findings from psychology and neuroscience where more subtle affective states have been shown to systematically influence cognition. For example, in an overview chapter of the influence of positive affect, Isen points to dozens of experiments showing that positive affect "has been found to promote creativity and flexibility in problem solving and negotiation, as well as both efficiency and thoroughness in decision making, and other indications of improved thinking" [12]. The effects have not just been found in psychology students, but are robust across many different groups, ages, and positive affect manipulations. Other specific influences of affect on cognition have also been found for subtle negative affective states, e.g., Schwartz argues that being in a sad mood enables better performance on certain kinds of analytic tests [23].

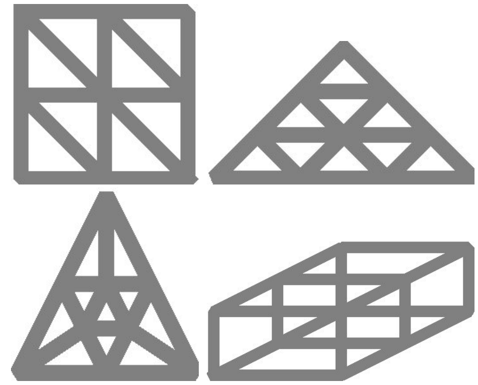

Figure 2: Two solvable and two unsolvable puzzles

The effects can be significant even in rational decisions that people do not think of as being influenced by emotion. For example, Lerner et al. [14] have shown that different kinds of negative feelings – disgust and sadness – had significantly different effects on the prices people would accept to get rid of an item, or pay to acquire an item. These emotions significantly changed people's economic decision making behavior. In the case of disgust, even reversing the classic endowment effect whereby people want to sell things for more than they want to buy them for.

Emotion not only influences cognition, but it also interacts with information in the environment in ways that can enhance or hinder your ability to perform. Nass and colleagues [16], while trying to decide if a voice in the automobile driver's environment should sound subdued and calm or energetic and upbeat, ran an experiment trying both kinds of voices. Importantly, they also looked at the two conditions where drivers were either upset or happy (having just viewed disturbing or funny films). In a total of four conditions, the happy or upset drivers drove in a simulator with either an energetic voice or a subdued voice talking to them and asking them questions. On multiple measures of driving performance and cognitive performance, happy drivers did better overall than upset drivers. But there was also an important and interesting interaction, highly relevant to the work in this paper. When the voice was matched suitably to the driver's state (energetic/upbeat with happy drivers, subdued/calm with upset drivers) then performance was significantly better than in the crossed conditions. The worst performers of all four conditions occurred when the upset drivers had to listen to the energetic and upbeat voice.

3.2 Evidence of Body-Affect Interactions

The congruence effect in the Nass et al. study was originally found in an entirely different domain by Riskind [19]. In Riskind's [19] "stoop to conquer" study, he showed that physical posture, like facial expressions [6], can not only in-

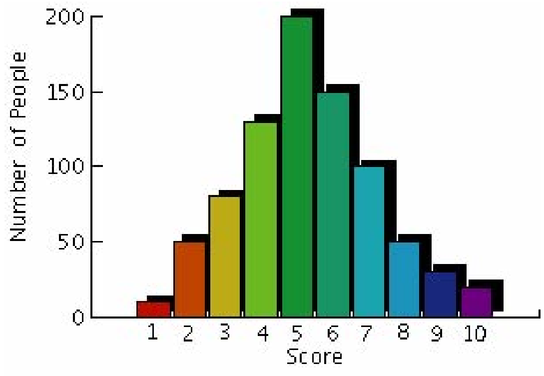

Figure 3: Performance chart.

dicate mental state but may also affect mental state and behavior. The results suggest that "incongruous" postures, such as slumping after a success, can negatively affect subsequent performance, while "congruous" postures, such as slumping after a failure, help to mitigate the effects of failing. His findings suggest that it is therefore not beneficial to sit with chin up, acting proud, after failing, despite that people often tell children to do that.

In Riskind's original experiment, the subjects were first asked to perform a cognitive task in whatever posture they chose (e.g., a tracing puzzle task). The affective manipulation was handled by the experimenter who informed the subject of their "score" on the task. A high score (success) elicits a positive mood in the subject, while a poor score (failure) elicits a negative mood. After this first task, the subjects were taken to a different room and asked to either sit slumped or sit upright in a particular manner under the false pretense of a biofeedback experiment. The subjects were required to hold this posture for 8 minutes before performing a subsequent cognitive task (e.g., additional puzzle tracing tasks) in whatever posture the subject desired. Riskind found that people in the conditions that used incongruous postures (stooped/slumped upon success, upright upon failure), felt like they had less control, showed less motivation in persistence tasks, and reported higher depression than subjects in congruous positions.

4. HYPOTHESIS AND PREDICTIONS

These studies are evocative, and reveal the importance of designing technologies that can appropriately respond to a user's affective state as he or she performs cognitive tasks. This is a particularly interesting domain to explore with robotic technologies because their physical embodiment and dynamic movement can influence how a person moves his or her body, and thereby allows us to explore body-affect-cognition interactions. The key question, therefore, is how do we design robotic technologies that beneficially influence the interactions between a human user's body, affective, and cognitive states to foster healthful computer usage and improved task outcomes.

Our experiment expands on the *appropriateness hypothesis* [20] which predicts that congruous posture guides an individual towards self-regulating behaviors while incongruous posture leads to self-defeating behavior. Taking advantage of the unique RoCo research platform, this experiment introduces a different posture manipulation method that allows the subject to perform dependent measure tasks while in the manipulated posture. Thus, while Riskind measured the effect of a prior posture on a subsequent cognitive task, we can now measure the effect of the posture concurrent with the task. The expectation is that RoCo will be an effective agent for manipulating posture and inducing the "stoop to conquer" effect.

5. EXPERIMENT METHOD

This experiment measures persistence on a helplessness task, creativity on a word association task, and general spatial cognition on a puzzle task as a function of congruous and incongruous postures following affect manipulation.

5.1 Subjects

Seventy-one naive subjects (31 females, 40 males) were recruited from MIT and the surrounding area. Subjects were given a $10 gift certificate to Amazon.com as compensation for their participation in the study.

Subjects were assigned to one of six conditions based on the order that they signed up to participate in the study. The six conditions correspond to all possible pairings of the mood manipulation (success or failure) with the posture manipulation (slumped, neutral or upright) as shown in Table 2 and Table 3. The first subject was assigned to condition one (success: slumped), the second to condition two (success:neutral), etc. Randomness was achieved through the signup process which was done through postering, mailing lists, and boston.craigslist.org.

5.2 Preliminaries

When subjects arrived they were first greeted by the experimenter and then led to a standard PC. The experimenter read the following standard set of instructions aloud to the subject:

"Please be seated. In front of you is a standard computer setup with mouse, keyboard, monitor and a pen tablet for use in the tracing puzzles. You may arrange these components on the desk any way you like. Please read the instructions carefully as you go. The height of the chair is adjustable with a lever underneath the seat. I will be outside the curtains, if you have any questions or get confused, but in general, please try do as much on your own as possible."

The experimenter then left the area while the subject was shown a two minute video clip previously shown to induce neutral affect [22].

5.3 Mood Manipulation

Half of the six conditions involved inducing a feeling of success (positive mood), while the other half involved inducing a feeling of failure (negative mood). This was accomplished as follows. Subjects were given a series of four tracing puzzles to solve. They had two minutes to solve each puzzle. To solve a puzzle, the subject must trace over the design without lifting a pen from the puzzle or retracing any lines. In this case, the puzzles were presented on a standard LCD screen and pen tracing is done with a computer pen and tablet input device. The puzzles used are the same set used by Riskind [19] in his studies as well as by Glass and Singer [9]. Examples of the puzzles are shown in Figure 2.

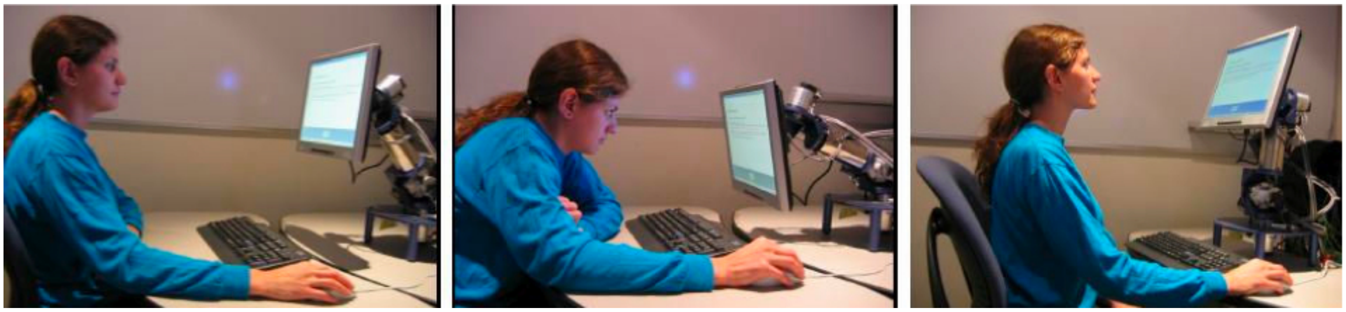

Figure 4: RoCo's postures: neutral (left), slumped (center), and upright (right).

To create a success condition, all four puzzles were solvable. Generally each subject was able to solve at least three out of the four. Unsolved puzzles were usually the result of not carefully reading the instructions beforehand or having difficulty using the pen and tablet interface. Regardless of how the subjects in the success condition actually performed, they were shown a results chart (Figure 3) and told they scored an 8 out of 10.

For the failure condition, the first and last puzzles were unsolvable. The sense of failure was further reinforced by displaying the same results chart and the subjects were told they scored a 3 out of 10.

5.4 Posture Manipulation

Following the success-failure mood manipulation, the subject's chair was rolled over a few feet to RoCo – its "posture" preset to either slumped, upright, or neutral as shown in Figure 4. The subject was seated in the same calibrated chair and asked to perform another series of puzzles, this time on RoCo. The subject was video taped as a posture manipulation check (see Figure 5).

5.5 Dependent Measures

The experiment examined three dependent measures: creativity, spatial cognition, and persistence. Subjects were administered these tests in a random order to minimize any effect the order of the tasks might have.

Unsolvable Tracing Task to Test Persistence -

The subject was given four mathematically unsolvable tracing puzzles with a time limit of two minutes for each. This task assumes that the fewer the number of tries in the allotted time, the lower the subject's tolerance for a frustrating task. Some of the puzzles are the same as those used in Riskind's original study. Additional puzzles were created by transforming some solvable into unsolvable. Debriefings showed that only people who knew the mathematical rule ahead of time for solvability were able to distinguish solvable from unsolvable puzzles (and data from such people was not included in the results).

Remote Associates Test - The subject was asked to complete 14 items of the Remote Associates Test (Table 1) that ranged from easy to hard. Past research has shown that performance on the Remote Associates Test improves with positive affect, although negative affect does not have an adverse effect [13].

Prompt	Answer
shelf,read,end	book
keel,show,row	boat
cookies,sixteen,heart	sweet
athletes,web,rabbit	foot
walker,main,sweeper	street
car,swimming,cue	pool
soap,shoe,tissue	box
desert,ice,spell	dry
inch,deal,peg	square
chamber,staff,box	music
base,show,dance	ball
jump,kill,bliss	joy
shopping,washer,picture	window
bass,complex,sleep	deep

Table 1: Remote Associates Test. The subject is prompted with words in the left hand column, and is asked to come up with a word that associates them as shown in the right hand column.

Tangram Puzzle - The subject was given seven minutes to try to solve as many (up to seven) tangram puzzles as possible. Good performance on tangrams has been linked with good spatial cognition. A maximum of seven was chosen since it would be difficult to complete all puzzles in seven minutes even if the solutions were known beforehand.

5.6 Debriefing Procedures

Following the dependent measure tests the subject was given a full debriefing. As a check on the success-failure mood manipulation, the subject was asked how well they thought they performed on the first part. All subjects in the failure manipulation responded with answers like "not well", "below average", and "ok", suggesting that the manipulation was sucessful. Similarly, most subjects in the success case responded with answers such as "well" and "above average". Four subjects in the success condition who had trouble with the tracing puzzles in part one did report that they did not do well. Their results were discounted given the mood manipulation was not successful for them.

Following the mood manipulation check, the details of the study were disclosed including the impossibility of some of the tracing puzzles and the fabricated test results in the first part of the experiment. Four subjects also reported at this

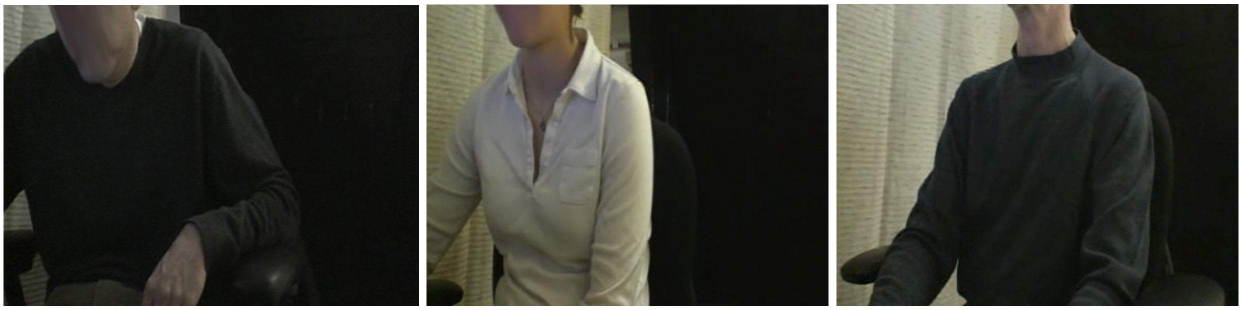

Figure 5: Video analysis. Sample of human subject postures (with faces blurred out) in response to Roco's "posture" corresponding to slumped (left), neutral (center), and upright (right).

time that they knew the tracing puzzles were mathematically impossible. Their results for the tracing puzzles were similarly discounted.

6. RESULTS

6.1 Persistence on task

A two-way analysis of variance (ANOVA) on the persistence on insolvable puzzles data (summarized in Table 2) showed no main effects for either the success-failure or the posture manipulations, $F(2, 57) < 2, p < 0.2$ and $F(2, 57) < 3, p < 0.07$ respectively.

As predicted, the analysis did reveal a statistically significant interaction effect, $F(2, 57) = 4.1, p < 0.05$. Further simple effects analysis by success-failure outcome revealed that success subjects exhibited more persistence when they used RoCo in its upright position ($M = 11.97$) after their success than when they used RoCo in its neutral position ($M = 8.32$), or in its slumped position ($M = 8.15$), $F(2, 57) = 7, p < 0.01$. However, unlike in Riskinds study, failure subjects showed no statistical difference across postures, $F(2, 57) = 0.1$. We address this in the discussion in light of the video analysis of the subjects' posture.

6.2 Perceived Comfort

ANOVA analysis of self-reported comfort levels shows a significant posture main-effect, $F(2, 62) = 4.12, p < 0.02$ (See Table 3). As one would expect, slumped postures are rated as less comfortable.

Surprisingly, in the failure-upright case, comfort levels were also as low as in the slumped conditions. A possible explanation is that the natural tendency to slump following failure was in conflict with the monitor positions influence on them to sit more upright. This might have made an otherwise comfortable upright position uncomfortable.

7. DISCUSSION

We adapted a number of factors from Riskind's original study to work with RoCo. These changes have a number of implications that may explain why some of our results differ.

First, there is always the danger of an experimenter bias effect when interacting with human subjects. Using RoCo as a substitute for the experimenter in the study itself reduces the danger of the experimenter inadvertantly introducing affective bias. The RoCo experiment system can guide the user with instruction screens through each step of the experiment giving the user both privacy and avoiding experimenter contamination. A disadvantage of this approach is that RoCo cannot detect if the user does not understand the task and it cannot answer questions.

Second, because RoCo can effectively be made "blind" to the user's posture and affective state, the dependent measure tasks can be performed while the subject is in the assigned posture. Recall in Riskind's study, subjects were taken to a separate room and told to hold the assigned posture for approximately eight minutes under the pretense of a biofeedback experiment. They then performed the second set of tasks without controlling for posture. In our experiment, the expectation was that the mitigating or reinforcing effects of posture would be more pronounced due to the near zero latency between posture manipulation and measured performance.

Third, given that RoCo is responsible for posture manipulation instead of a human experimenter, this change makes the manipulation more subtle and more unobtrusive in our experiment – especially with respect to not having to pause work flow in order to do the posture manipulation. Recall that Riskind's subjects were forced to hold the manipulated posture for 8 minutes, without moving. In contrast, our expectation was that the screen readability constraint would be enough to manipulate the user to the desired posture (see Figure 5). However, this subtlety comes at the cost of control. The user is free to adopt any posture he or she wishes as long as they can still read the screen.

Analysis of the video footage shows that users did in fact adjust their posture as they performed the tasks. It appears that this is done for reasons pertaining to comfort. Subjects tended to adjust their posture the most while thinking about possible solutions (especially in the RAT). And while thinking, the primary posture manipulation technique (screen viewability) is relaxed.

Video footage shows that subjects who encountered the slumped RoCo did not hold their corresponding posture as consistently as in the neutral or upright cases. In fact, subjects in the slumped condition adjusted their posture more frequently and with a larger range of movement than in the other two conditions — although they did tend to hold their head lower and dip their chin more. For instance, they might adopt a slumped posture to read the screen, and then lean back to think in an upright posture. In contrast, video footage indicates that subjects in the upright condition held this posture reasonably consistently throughout the experiment. Further, they held their chin higher than in the case of RoCo's neutral posture.

Outcome	Slumped	Neutral	Upright
$n =$	*10*	*11*	*9*
Success	8.15	8.32	11.97
$n =$	*12*	*10*	*11*
Failure	8.33	8.75	8.41

Table 2: Average number of tracing attempts

Outcome	Slumped	Neutral	Upright
$n =$	*12*	*11*	*11*
Success	3.08	4.18	4.18
$n =$	*12*	*10*	*12*
Failure	3.08	4.10	3.25

Table 3: Average self-reported comfort levels

From the comfort hypothesis posulated above, it is possible that using RoCo in the upright state led to a more comfortable upright posture that the user was willing to sustain. The slumped state, in contrast, kept subjects in a slumped posture only as long as they needed to be on account of the discomfort.

Thus, in the success-upright condition, comfort and natural tendancy aligned to produce the anticipated effect. In fact, our success-upright effect appears to be even stronger than what Riskind found ($p < .01$ in our study as opposed to $p < .03$ in Riskind's study).

In the slumped condition, on the other hand, discomfort caused people to adopt other or more varied postures. Hence, one possible explanation for not seeing the "negative-stooped" interaction in our study may be that subjects did not sustain the stooped posture for a sufficiently long period of time. This suggests perhaps a different task, such as reading instructions written in small font on the LCD monitor to encourage people to hold the target posture longer.

Another question to consider is whether the persistence effect that we found is independent of the hypothesized interaction between affect and posture, and instead is simply due to making people comfortable or not. One might think that the more comfortable you are, the more likely you are to persist. While this explanation can fit some of the data we found, the tables also contain evidence that this explanation does not hold in general. For example, in some cases where persistence is the same (e.g., success-neutral and failure-slumped) the reported comfort is quite different. The failure-slumped group reported being more uncomfortable, but they persevered as well as the success-neutral group. Furthermore, Riskind also carefully controlled for postural comfort in his studies and found that comfort did not account for his findings.

8. FUTURE WORK

The study presented in this paper is the first to show that a computer's "pose" can not only influence ergonomic factors such as comfort, but perhaps more surprisingly, influence cognitive factors such as task persistence. As immediate next steps, we are conducting a new experiment with a different task designed to encourage the subject to remain in the target posture for a longer period of time. Hopefully, this will allow us to achieve the full "stoop to conquer" effect.

Below we outline the major research questions we wish to explore as next steps with this novel robotic computer. Each requires that RoCo dynamically change its posture over time in relation to the user's cognitive, postural, and emotional state in order to foster their back health, improved cognitive performance, and increased learning outcomes. These are areas for future consideration.

8.1 Movement and Ergonomics in Computer Use

An ever increasing number of Americans, approximately 75%, spend the bulk of their work day in static sitting postures, often in front of computers. Correspondingly, an increasing number of Americans also suffer from musculoskeletal problems. In particular, reports of lower back pain and discomfort have risen [8]. The correlation between these two trends is not coincidental. Consequently, the term ergonomic has become a major selling point for chairs, tables, and the like. Studies have shown, however, that physical movement is one of the simplest and most effective preventive measures for back pain [17]. Individuals who change their posture throughout the day can better sit for prolonged periods. Furthermore, continuous movement is not only therapeutic for joints and ligaments, but the associated muscle movement also improves circulation. In current workplaces the burden is on the individual to change his posture throughout the day.

One solution to this problem would be to have a computer program remind the user to take a break. Indeed such programs already exist to help prevent RSI and other typing related injuries. But, the burden still rests on the user's shoulders to heed the program's advice. With social robotics and a slight but important paradigm shift, we might be able to do better.

We would like to use our robot computer to explore a different alternative. Consider that when people collaborate, they tend to move in a variety of reciprocal ways. Research has shown that people will also frequently mirror the posture of a robot when engaged in a social interaction, much as they do with other people [3]. As a social robot, RoCo could encourage this mirroring behavior as a method to adjust the user's posture. RoCo could also use the tactic of moving to a position such that the user has to adjust to better view the screen. With these behaviors, RoCo could take a more active role to subtly and unobtrusively induce ergonomic movement.

In sum, the potential benefit of introducing healthy movement into daily computer use is an important reason to fundamentally rethink current desktop computer design, transforming its static nature to one that moves and invites movement.

8.2 Movement and Social Rapport

The benefits of RoCo's movement extend beyond the realm of movement ergonomics. Another motivation for building a physically animated system is the development of applications that benefit from establishing a kind of social rapport with the system.

As discussed previously, when people collaborate, they engage in a variety of reciprocal movements. These movements not only serve as vital nonverbal cues, but they also act to build social rapport. So called "immediacy behaviors" (also called affiliative or liking behaviors) such as forward leaning, nodding, frequent gesturing, and postural openess all project liking and engagement [1], [18]. Christensen & Menzel [5] also showed that "immediacy behaviors" in teachers also increase learning outcomes. And in general, collaborations between friends is a more effective learning expeirence than collaborating with acquaintences [10]. Finally, even in the abscence of social interaction, posture combined with affective state can also affect such things as persistence and feelings of control.

By inducing the appropriate posture dynamically following a success or failure, RoCo could potentially help maximize or minimize the effects of success or failure respectively [19]. Hence, RoCo can alter not only the user's physical posture, but the user's cognitive and affective state as well.

8.3 Movement and Eliciting Human Emotion

Many people have had the experience of "picking up" the mood of another person. Some individuals describe attending a class where the teacher was so excited about a topic that they became excited too. We may also feel depressed talking to somebody who is depressed. Emotion contagion effects are well-known, yet little is known about exactly how they work. While mimicry and reading of posture, facial expressions, and vocal cues are believed to be involved [11], most studies have taken place through people observing people, making it very hard to control for all the possible influential elements. We also do not know of any efforts that look at whether emotion contagion effects exist between people and machines, and especially when the machine does not look like another person. The smooth expressive movement capabilities of the new RoCo platform can enable new, precisely controlled, explorations of the influence of machine movement on emotion contagion. Understanding such effects may enable not only new theories of emotion contagion, but also new applications of technology that can contagiously help people adjust their moods, for better or worse.

8.4 Appropriate Movement

It is certainly possible that the robotic computer, if not equipped with appropriate knowledge and sensory information about people, might move in ways that distract or annoy the user. For example, if it moves while you are in the middle of concentrating to edit a paper, this would probably be annoying. We are planning to develop the ability for the technology to sense information related both to task and to the user's state of concentration, the latter by extending the work of el Kaliouby [7]), equipping RoCo with computer vision techniques for recognizing complex cognitive-affective states from facial and head movements. We are also planning to extend earlier work by Mota and Picard that recognizes not only posture but also user level of interest from dynamic shifts in posture [15]. The idea is that RoCo can hold still when you are concentrating or very interested in something, so that it does not distract you. At the same time, it can watch for when you naturally move or could move without distraction (perhaps between tasks, or when your interest fades). Equipped with knowledge of how you naturally move in the chair, and when you are concentrating, interested, or other important states, it could choose a strategy that minimizes distraction and maximizes healthy and effective movement.

9. CONCLUSION

RoCo is a novel robotic platform designed to explore how the physical embodiment and relational movement of a machine to its user can improve task performance measures and ergonomic factors in unprecedented ways. This research is motivated and inspired by well established empirical work in psychology that identifies the interplay of body, affect, and cognition on human performance. We are also inspired by related work in ergonomics that identifies the importance of movement for back health. Our initial study with 71 subjects offers promising results in support of our hypothesis that RoCo's posture not only manipulates the user's posture, but also elicits posture-affect interactions in its user as well. Specifically, we found effects on increased persistence on a subsequent cognitive task, and effects on perceived level of comfort. This work is the first step in a new research agenda to explore how the physical embodiment and animated movement of a machine in relation to its user's body and affective states can bring cognitive and health-related benefits to them.

10. ACKNOWLEDGMENTS

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