Interacting with Computers Advance Access published February 6, 2013

doi:10.1093/iwc/iws022

Working with an Invisible Active User: Understanding Trust in Technology and Co-User from the Perspective of a Passive User

Jie Xu[1] and Enid Montague[2,*]

[1]*Department of Industrial and Systems Engineering, University of Wisconsin–Madison, Madison, USA*
[2]*Northwestern University, 750 North Lakeshore Drive, Chicago, IL 60611, USA*
**Corresponding author: enid.montague@northwestern.edu*

Distance collaboration technologies affect the way active and passive users interact in technology-mediated systems. Decreases in social and contextual cues in distance collaboration may have a large impact on passive users' perception of active users and the technology. The purpose of this study was to investigate passive users' trust in active users and trust in technology under varied technological conditions and active user performance. A laboratory experiment was conducted using simulated psychomotor tasks distance collaboration scenarios. Participants observed an active user, who performed tasks without being physically present. Their subjective report on trust in the active user, trust in technology and perceived active user's workload, as well as physiological responses, including eye movement, electrodermal activity and cardiovascular activity, were gathered. The results showed that technology conditions affected passive users' subjective reports, specifically; the participants exhibited higher arousal in the affect arousal system during the observation. Furthermore, the passive users seemed to evaluate their trust in the active user according to their trust in technology. This implies that in a distance collaboration context, technology use could affect interpersonal relationships between active and passive users.

RESEARCH HIGHLIGHTS

- Participants observed active user–technology interactions in the study.
- Technological conditions altered passive users' perceptions.
- Technology use may influence interpersonal relationships between users with different roles.

Keywords: passive user; distance collaboration; trust; CSCW

Received 12 August 2012; Revised 12 November 2012; Accepted 20 November 2012

1. INTRODUCTION

1.1. Passive users and distance collaboration

Inbar and Tractinsky (2009, 2010) discussed passive users under the context of face-to-face customer service encounters. A passive user does not have control over the technology being used in a system. For example, in a grocery store setting, the customer is a passive user of the cash register machine with the cashier being the active user during a check out process. Design characteristics of the technology used in customer service, such as how information is shared with the customer and whether the customer has control over certain aspects of the technology, would affect the customer's trust and overall satisfaction (Inbar and Tractinsky, 2012). Montague and Xu (2012) discussed patients as passive users in the health care system. Patients' perceptions of the technologies used by their physicians may affect their perception of the physician and affect the outcomes related to the health care process (Montague, 2010). Overall, the

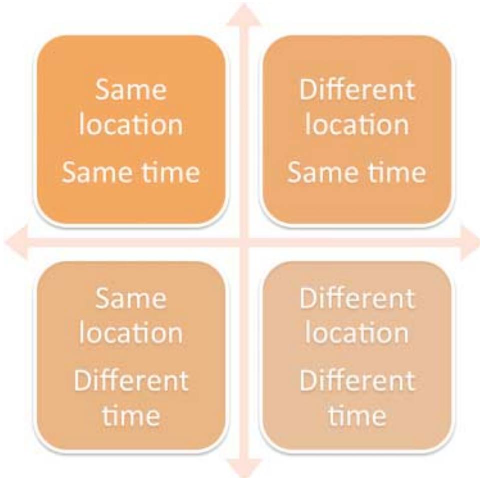

Figure 1. The time/space classification for multi-user system design.

role of passive users in a system remains a topic to be explored in the research community.

According to the time/space classification of collaboration (Bafoutsou and Mentzas, 2002; Desanctis and Gallupe, 1987; Grudin, 1994), the design of the technology for a multi-user system could be classified into four categories: (i) same location and same time, (ii) same location and different time, (iii) different location and same time and (iv) different location and different time (see Fig. 1). Traditionally, passive users may work with active users in same location scenarios. For example, pilot not flying is the passive user of a navigation system and he/she is working with the pilot flying in the same location at the same time. In a work shift, a passive user may receive or utilize the outcome of the interaction between the technology and the active user in the previous shift; thus, it is a passive use of technology in the same location but at a different time.

As information technology advances, distance collaboration is becoming more prevalent. In health care, care providers collaborate remotely through new technologies to provide patient care. For example, telemedicine technology was used for distance medical consultation (Perednia and Allen, 1995); telepresence technology enables the physician to use a robot to 'walk around' intensive care units to monitor and interact with patients (Vespa, 2005a); surgeries can also be performed remotely (Cadiere *et al.* 1999). In 2001, the world's first trans-continental surgery was successfully performed (Marescaux *et al.*, 2002). This laparoscopic cholecystectomy surgery was performed in Strasbourg, France, with the surgeon in New York, USA. Remote-controlled robotic arms and high-speed network technology were used. Shortly after, a telerobotic remote surgery service, which enabled the surgeons to perform surgeries in one hospital from another hospital 400 km (250 miles) away, was established in Canada (Anvari *et al.*, 2005). These new ways of collaboration offered advantages over traditional fact-to-face health care encounters. For example, distance care could be provided to remote areas or war zones (Vespa, 2005b). However, challenges have also emerged. For example, distance surgery systems that afford only a single active user make it difficult for a surgeon to collaborate with other surgeons or teach student surgeons (Hanly *et al.*, 2006). In the different location and same time scenario, local nurses and technicians, and other surgeons who are not in control, become passive users of the system.

Depending on the design of the workflow, passive users also exist in different location and different time scenarios. Workflow may be designed as sequential, where works and activities flow sequentially from one individual to another, or reciprocal, where works and activities flow in a 'back and forth' manner among the individuals (Bell and Kozlowski, 2002; Van De Ven *et al.*, 1976). In both cases, one individual receives and works upon the outcome of the other individuals' work that was done at a different time. What's more, in distance collaboration, it is usual and considered beneficial to have group members with diverse and specialized knowledge, skills and attitudes (Blackburn *et al.*, 2003) and group members may use different technologies in the tasks. Thus, one group member could be the passive user of the technology actively used by another group member at a different time and space.

The implementation of the new distance collaboration technologies may change the way passive users (such as nurses and patients in health care) perceive the system and the interactions. This change of perception may shape the way they interact with each other and lead to unexpected outcomes. For example, a patient's perceived trustworthiness of the physician may be related to the perceived trustworthiness of the technology being used in a distance care context. If the perceived trustworthiness of the technology is low, it will negatively affect the patient's trust in the physician. This can lead to undesired results such as low compliance on treatment plan or change of care provider (Pearson and Raeke, 2000). To minimize negative outcomes, a deeper understanding of the role of passive users in distance collaboration is needed.

1.2. Face-to-face and distance collaboration for passive users

In face-to-face collaboration, the presence of another person would alter an active user's performance in the task or subjective perception of the system, such as trust in technology. For example, the 'mere presence hypothesis' (Zajonc, 1965) states that whenever there is another person present, there will be a un-directional arousal for the task performer. Given that the task performer has learned the task well, this arousal will cause an increase in performance; if the task performer has not learned the task well, a decrease in performance will occur (Larson, 2010). Other authors conjecture this 'presence effect' to the perception of being evaluated (Harkins, 2006). However, there is limited research on people who observe or evaluate the interaction. In active/passive user interactions, an

Table 1. Physiological measurements used in the current study

	Data collection	Definition	Corresponding arousal system
SCL	EDA	The average level of EDA	Affect arousal system
SCR	EDA	Phasic changes of EDA as measured by the number of peaks in the EDA signal	Affect arousal system
HR	Cardiovascular activity	The average number of heart beats per minute	Affect arousal system
HRV in LF band	Cardiovascular activity	The variation of HR in the frequency range of 0.04–0.15 Hz	Effort system
HRV in HF band	Cardiovascular activity	The variation of HR in the frequency range of 0.15–0.4 Hz	Effort system

active user's trust in technology is affected by the presence of a passive user. In Montague and Xu's (2012) experimental study, participants worked in two-person teams consisting of an active user and a passive user. These teams performed tasks with a multi-tasking program with varied task difficulty and technology reliability. In that study, when active users worked with passive users, active users' trust in technology was lower than when they worked alone. In the same study, it was found that active users calibrate their trust in technology according to the technological conditions while passive users calibrate according to technological conditions as well as the observed interaction between the active user and the technology.

In distance collaboration, the conclusion may be different. Previous research has identified considerable differences between face-to-face interaction and distance interaction. In distance collaboration, there is usually a lack of social context cues compared with face-to-face collaboration (Sproull and Kiesler, 1986). These cues include physical appearance, artifacts and non-verbal behaviors, etc. A system with a different degree of nonverbal cues present (e.g. video conference versus teleconference) could lead to different interaction processes and outcomes (Baltes *et al.*, 2002). For example, changing from face-to-face communication to email communication in workplace may lead to more timely and accurately information exchange but also more misunderstanding and weakened relationship (O'Kane and Hargie, 2007). Furthermore, different stakeholders of the system will have different perceptions of the system and of other system users. For example, in telemedicine, the patients were found to prefer a more media-rich system than the physician, since patients perceive conversations about illness more equivocally (Turner *et al.*, 2003). Current research provides little insight into passive user's perspective on distance collaboration.

1.3. The current study

In McGrath's (1984) group task circumplex, there are four quadrants to categorize group tasks: generating task, choosing task, negotiation task and executing task. Studies of computer-mediated collaboration focus on the first three types of tasks but not the executing task, which includes psychomotor performance tasks (Baltes *et al.*, 2002). However, emerging forms of distance collaboration, such as distance surgery, are categorized as executing tasks. These types of tasks are very likely to have passive user involvement.

The current study aimed to explore passive users' perceptions of the active user and the technology in a psychomotor task in a distance collaboration context. To understand the passive user's experience, both subjective self-report metrics and objective physiology metrics were used in this study. Passive users' trust in technology, trust in active user and perceived active user's workload were evaluated through self-report. Physiological measures, including eye movement, electrodermal activity (EDA) and cardiovascular activity, were collected to try to infer the passive user's psychophysiological status during the task process. Eye movement data were used in a bottom-up fashion (Goldberg *et al.*, 2002; Jacob and Karn, 2003) to explore the passive user's attention. Parameters including skin conductance level (SCL) and skin conductance response (SCR) were derived from the raw EDA data as indicators of the level of EDA. Heart rate (HR), heart rate variability (HRV) in low frequency (LF) band and HRV in high-frequency (HF) band were derived from the raw cardiovascular activity data. The use of EDA and cardiovascular activity measurements were guided by Boucsein and Backs (2000)' three-arousal model. SCL, SCR and HR were used for measuring the passive user's arousal of the affect arousal system, which is responsible for focusing attention and generating orienting response. HRV was used for measuring the passive user's arousal of the effort system, which is responsible for inhibiting immediate response behavior to stimuli and allows central processing of information. Table 1 summarizes the physiological measurements used in this study.

The main research questions included: (i) how does the passive user perceive the trustworthiness of the technology and the active user under varied situations? (ii) How does the passive user evaluate the active user's state during the task, in terms of workload? (iii) How do these perceptions relate to each other? (iv) What are the physiology patterns of the passive user while observing an invisible active user performing the task? Specifically, does the passive user have higher arousal in the affect arousal system and the effort system? Does the arousal vary according to varied situations? (v) What are the relationships between the subjective reports and the objective physiology measurements of the passive user? Specifically, could one predict a passive user's subjective experience with arousal levels of the affect arousal system and the effort system?

2. METHOD

2.1. Participants

A total number of 38 participants were recruited from an introduction to human factor course in a large mid-western university. The participants received extra course credits for participating in the study. Data from two participants were excluded from the data set because of instrument malfunctioning. For the 36 participants who were included in the data analysis, the mean age was 21 (SD = 2.26), ranging from 19 to 31. The majority of the participants were in the third (50%) or the fourth (28%) year of college. All the participants were studying engineering with the majority majoring in industrial engineering (75%). Nineteen participants (53%) were females, while the majority of the participants were Caucasians (78%).

2.2. Materials

Six video recordings of an active user performing tasks using multi attribute task battery (MATB) (Comstock and Arnegard, 1992) were used. The active user (i.e. the researcher) performed the tasks for six 6-min trails in MATB. The processes were videotaped and these six videos were used as the main material. The active user in the video performed three tasks in MATB: the monitoring task, the tracking task and the resource management task. In the monitoring task, the active user is supposed to respond to the movements of four dials and the states of two lights by pushing keys on the keyboard as quickly as possible. In the tracking task, the active user controls the movement of a moving target and maintains its position with a joystick. In the resource management task, the active user controls eight pumps to manage the fuel level of the system at optimum. The active user in the videos multitasked on all the three tasks. The videos were screen recordings, so the participants were able to see only what was happening on the screen and were not able to see the user.

2.3. Experimental design

The experiment used a mixed design with one within-subject variable and one between-subject variable. These two independent variables were manipulated according to the content of the six videos. The variable "technological conditions" was the within-subject variable. This variable consisted of three levels, namely normal condition, hard condition and low reliability condition. There were two videos for each of the level. In the normal condition, all the three tasks were in low difficulty level. In the hard condition, the difficulty level of the monitoring task and resource management task was increased. Under this condition, more frequent responses were required in the monitoring task and the target movement in the tracking task became more unstable and unpredictable. The demand in the resource management task remained the same as in the normal condition. In the low reliability condition, the pumps in the resource management task became unstable, such that they were out of the active user's control frequently. The demands in the other two tasks remained the same as in the normal condition.

The between-subject variable was the performance of the active user. There were two levels in this variable: high performance and low performance. This variable was crossed with technological conditions. So there were three videos, corresponding to the three technological conditions, recorded under each performance condition. The performance of the active user in the high-performance condition was higher than that in the low-performance condition across the three tasks and the technological conditions. Specifically, in the low-performance condition, the reaction time in the monitoring task was slower and the miss rate was higher; the root mean square error (which measures the deviation of the target from the desired position) in the tracking task was higher; the deviation of the actual fuel level from the optimal level in the resource management task was higher.

All the participants watched three videos containing the three levels of technological condition. Half of the participants watched the high-performance set of videos and the other half watched the low-performance set of videos. Table 2 summarizes the experimental design.

2.4. Measures

Subjective measurements used in this experiment included trust in technology (Jian *et al.*, 2000), trust in teammate (Mayer and Davis, 1999; Schoorman *et al.*, 1996) and workload (Hart and Staveland, 1988).

Physiological measures included eye movement, EDA and cardiovascular activity (in terms of electrocardiogram (ECG)). Eye movements of the participants were tracked using a Tobii X60 standalone eye tracker and analyzed with the Tobii Studio software (version 3.0). Areas of interest (AOIs) were defined on the screen statically where possible active user or technology error could happen. AOIs included the dials and lights in the monitoring task panel, the tracking task panel and the pumps in the resource management panel (see Fig. 2). AOIs were also defined using time references—from the occurrence of an error to the time the same error was fixed. An error in the monitoring task could be an abnormality in the lights or dials, and is fixed after the active user presses the corresponding key to respond to it. An error in the tracking task occurs when the moving target moves out of the marked rectangle area until the active user moves it back within that area. An error in the resource management task could be a malfunction of any of the pumps. A fixation would be recorded if the gaze orientation of the participant hits the AOI for a minimum of 100 ms. Two parameters were derived from eye tracking: fixation frequency, which is the number of errors fixated by the participant; and fixation period, which is the total amount of time the participant fixated at the errors in a particular task in the video.

Table 2. The experimental design of the current study

		Technological conditions (within subject)		
		Normal	Hard	Low reliability
Active user performance (between-subject)	High ($n = 18$)	Video 1	Video 2	Video 3
	Low ($n = 18$)	Video 4	Video 5	Video 6

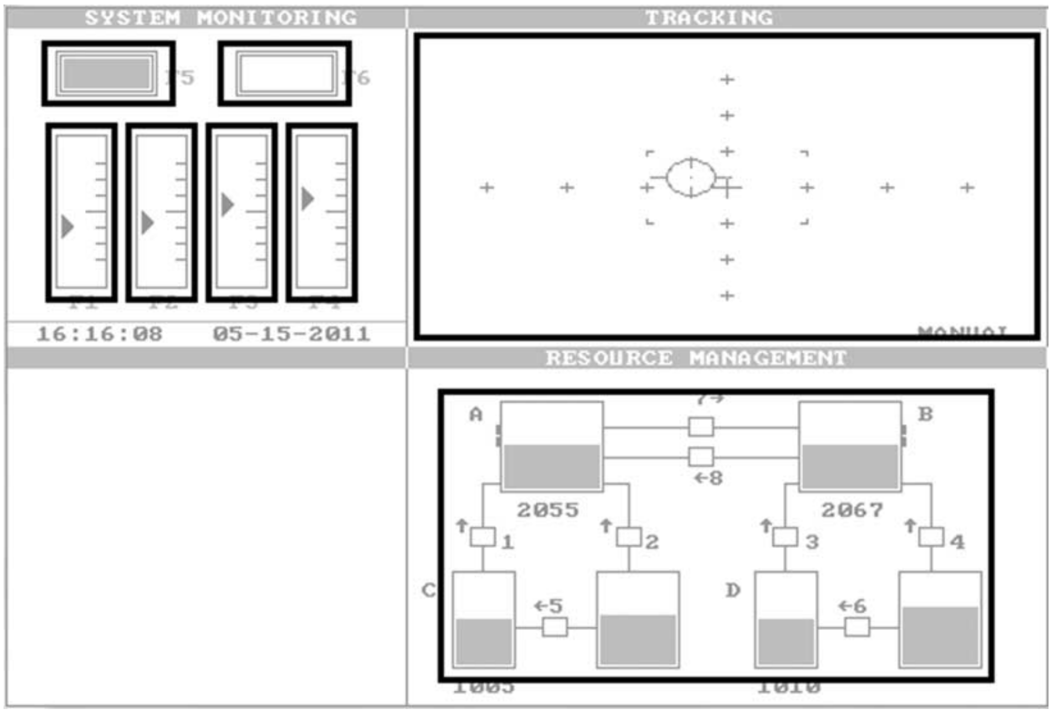

Figure 2. The locations of the AOIs are the areas within the bold box.

EDA and ECG were recorded using a Biopac MP100 Data Acquisition system and the corresponding Acqknowledge software (version 3.7.3). SCL and nonspecific SCRs were derived from the EDA recordings. Average HR, power of LF band of HRV and power of HF band of HRV were calculated from the ECGs. Specifically, LF was defined as the frequency range of 0.04–0.15 Hz and HF was defined as the range of 0.15–0.4 Hz. Program Kubios HRV (Tarvainen *et al.*, 2009) was used for the calculation of HRV with fast fourier transform spectrum analysis.

2.5. Procedure

Upon arrival, the participants were asked to provide informed consent. Next, a 6-min baseline measure for EDA and cardiovascular activity was collected. During the baseline measure, the participants were instructed to relax and sit still with their eyes open. After the baseline physiology measurement, written and oral instructions about MATB were provided to the participants. The participants were informed that they were going to watch three videos about a same trained active user perform tasks with MATB in three different situations, where the task difficulty and technology reliability were varied. Also the participants were asked to imagine that they were teamed up with the active user to perform the task and the job for the participants was to monitoring how the active user and the technology were doing during the task.

Three videos, which contained the three technological conditions, were presented to the participants in three separate sections. At the beginning of each section, the participants completed brief eye tracking calibration procedures to ensure accurate measurement of eye movement. The video was played after the calibration while physiology measurement devices recorded simultaneously. The recordings stopped at the end of the video. A set of surveys were administered to the participants to evaluate their trust in technology, trust in active user and active user's workload. The other two sections would follow the same procedure. The sequence of presenting the three technological conditions was counterbalanced across the participants. At the end of the experiment, all the participants finished a survey

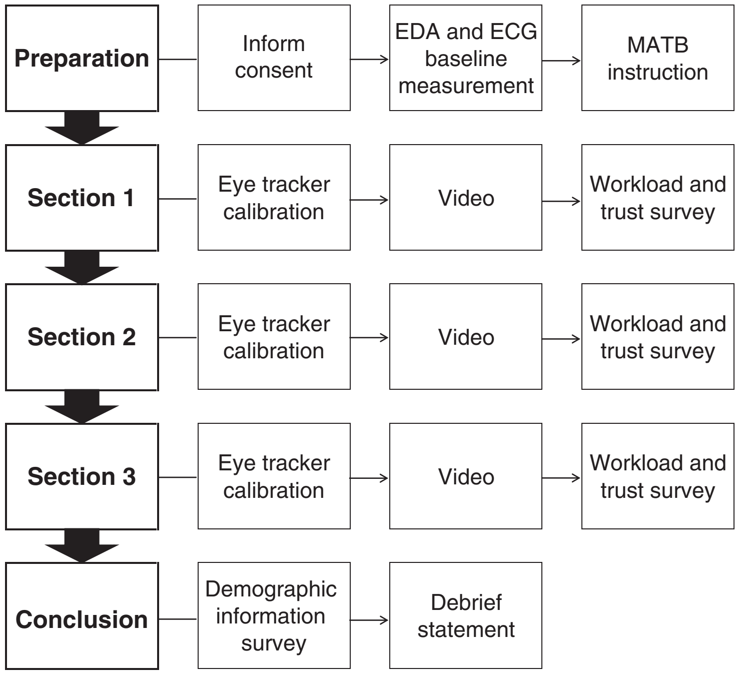

Figure 3. Procedure of the current experiment.

for demographic information. The experimental procedure is summarized in Fig. 3.

3. RESULTS

3.1. Subjective ratings

All the analyses were completed by fitting a linear mixed effects (LME) model to the data using R (R Development Core Team, 2011) with the nlme package (Pinheiro and Bates, 2009). Technological conditions, active user performance and the interaction between these two variables were input as fixed effects in the model. In addition, random intercept of participants was considered.

Significant technological condition effects were found on all the three subjective measures (trust in technology, $F(2.62) = 11.82$, $p < 0.05$; trust in active user, $FF(2.62) = 17.00$, $p < 0.05$; active user's workload, $F(2.62) = 3.26$, $p < 0.05$). *Post hoc* comparison for trust in technology showed that the average rating is lower in the hard condition ($t(62) = 3.37$, $p < 0.0167$) and the low reliability condition ($t(62) = 2.83$, $p < 0.0167$) than in the normal condition. For trust in active user, ratings in normal condition are higher than in the hard condition ($t(62) = 4.03$, $p < 0.0167$). For active user workload, ratings in the hard condition are higher than in the normal condition ($t(62) = 2.52$, $p < 0.0167$). No significant effect for the performance term and the interaction term is found for any of the measures. The results are visualized in Fig. 4.

Table 3. Correlations between subjective ratings

	Trust in technology	Trust in active user	Active user workload
Trust in technology	1	—	—
Trust in active user	0.617[a]	1	—
Active user workload	−0.425[a]	−0.019	1

[a]Indicates that the regression slop is significantly different from zero ($p < 0.05$).

The correlations among the three measures were examined using the method proposed by Bland and Altman (1995). This method evaluates the correlation coefficient using linear regression and controls the effects of participant, so it is capable of investigating correlations with repeated measures. The results are shown in Table 3. Trust in technology is positively correlated with trust in active user and is also negatively correlated with active user workload. The correlation between trust in active user and active user workload is relatively small.

Additional analyses were conducted to explore mediation effects among these measures. A statistical approach proposed by Baron and Kenny (1986) was used. A mediation effect exists, given: (i) the independent variable affects the potential mediator; (ii) the independent variable affects the dependent variable and (iii) the potential mediator affects the independent variable after controlling for the effect of the independent variable. First, the potential mediation effect between trust in technology and trust in active user and the

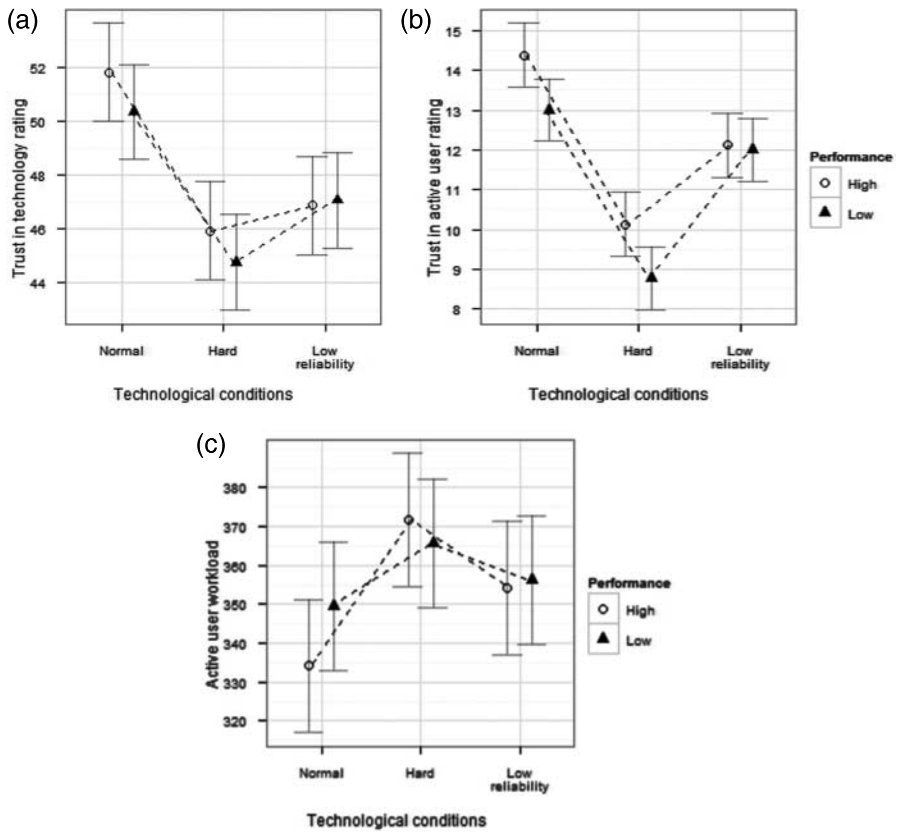

Figure 4. The effect of technological condition and active user performance on the subjective ratings.

independent variables was tested. The result from the LME model suggests that after controlling for the technological conditions, trust in technology still significantly affects trust in active user ($F(1.63) = 11.16$, $p < 0.05$). Second, active user workload was also found to mediate the relationship between trust in technology and the technological condition. The effect of active user workload on trust in technology is significant ($F(1.63) = 4.27$, $p < 0.05$) after controlling technological conditions in the LME model. No mediation effect was found of active user workload on the relationship between trust in active user and the technological conditions ($F(1.63) = 1.00$, $p = 0.32$).

3.2. Eye movement

Significant technological condition effect ($F(2.62) = 162.00$, $p < 0.05$) and performance X technological condition effect ($F(2.62) = 22.36$, $p < 0.05$) are found for fixation frequency in monitoring task (Fig. 5a). Specifically, the most AOI fixations were recorded in the hard condition. In addition, the number of AOI fixations in the hard condition is lower in the high-performance condition than in the low-performance condition ($t(62) = 3.73$, $p < 0.05$). This is because fixations tended to be shorter because of the active user's shorter reaction time in the high-performance condition. A similar pattern is observed in the tracking task (technological condition, $F(2.62) = 556.76$, $p < 0.05$; performance X technological condition, $F(2.62) = 141.92$, $p < 0.05$; see Fig. 5b). In addition, there is a significant performance effect ($F(1.31) = 141.78$, $p < 0.05$). Since there is no AOI defined in the resource management task in the normal and hard conditions, statistical comparison in this task is not available.

For fixation period in the monitoring task, technological conditions and performance effects are significant (technological condition, $F(2.62) = 54.73$, $p < 0.05$; performance, $F(1.31) = 22.07$, $p < 0.05$; see Fig. 5c). The fixation period from the tracking task is similar to that for fixation frequency, all the three fixed effects being significant (technological condition, $F(2.62) = 183.27$, $p < 0.05$; performance, $F(1.31) = 121.85$, $p < 0.05$; performance X technological condition, $F(2.62) = 91.92$, $p < 0.05$); see Fig. 5d).

The eye movement measures were entered into an LME model to predict subject ratings. Trust in technology is positively related to fixation period in the tracking task ($F(1.60) = 4.72$, $p < 0.05$), negatively related to fixation frequency in the tracking task ($F(1.60) = 15.01$, $p < 0.05$) and negatively

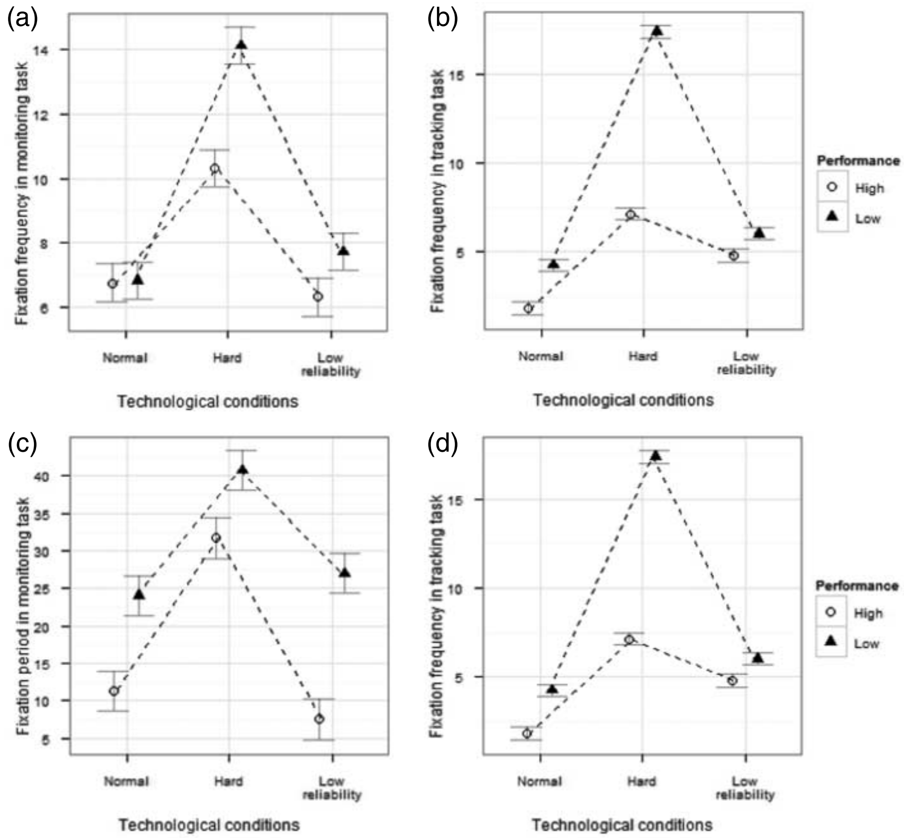

Figure 5. The effect of independent variables on eye movement parameters.

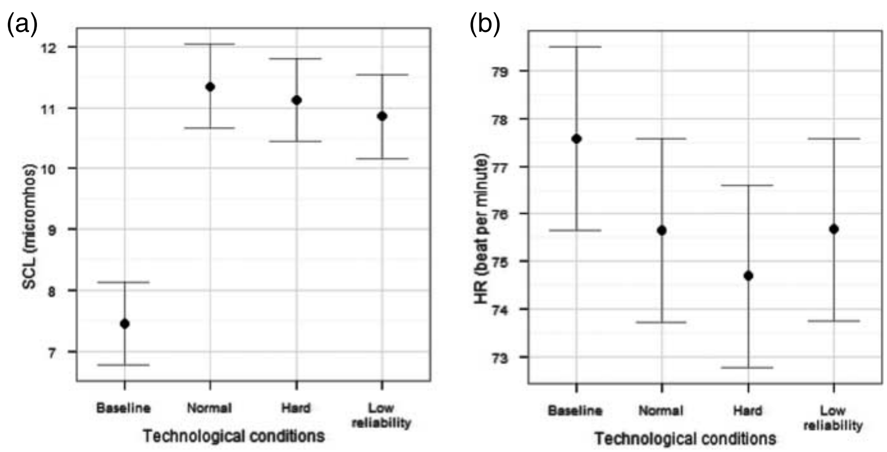

Figure 6. The mean value of SCL and HR in the technological conditions compared with the baseline.

related to fixation period in the resource management task ($F(1.60) = 10.23$, $p < 0.05$). However, if technological condition is also entered into the model as an independent variable, the significance of the eye movement variables disappears. So there is no mediation effect from the eye movement variables on trust in technology.

3.3. EDA and cardiovascular activity

Compared with the baseline, SCL and HR show significant changes during the experimental conditions (SCL, $F(3.96) = 32.31$, $p < 0.05$; HR, $F(3.96) = 3.21$, $p < 0.05$; see Fig. 6). Specifically, SCLs in all the three technological conditions

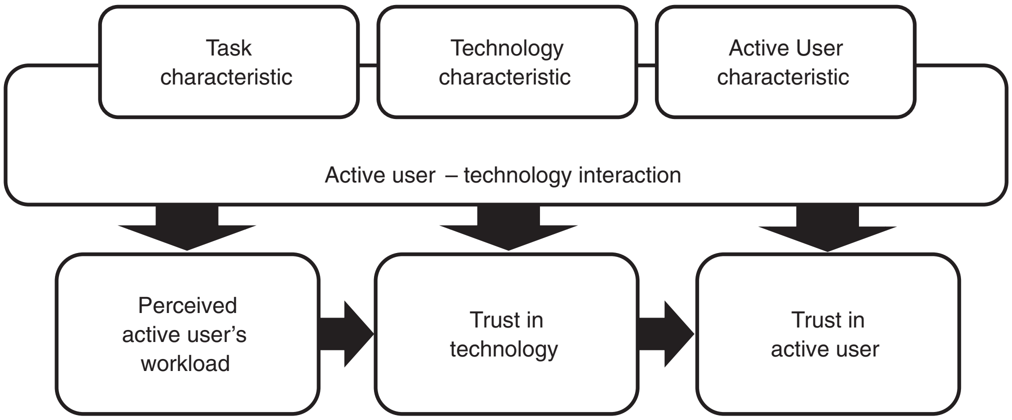

Figure 7. A model proposed on the basis of the results of the experiment.

are higher than the baseline (normal condition, $t(96) = 8.52$, $p < 0.05$; hard condition, $t(96) = 8.03$, $p < 0.05$; low reliability condition, $t(96) = 7.42$, $p < 0.05$). HRs in all the three technological conditions are lower than the baseline (normal condition, $t(96) = 2.02$, $p < 0.05$; hard condition, $t(96) = 3.02$, $p < 0.05$; low reliability condition, $t(96) = 2.00$, $p < 0.05$).

To test whether the arousal levels varied under different technological conditions, EDA and cardiovascular activity variables were analyzed in LME models with technological condition, performance and performance X technological conditions interaction as fixed effects and random intercept for participants. No significant fixed effect was found for any of the parameters (including SCR, SCL, HR, LF of HRV and HF of HRV). So the participants' physiological arousal level did not have significant difference under the three technological conditions.

To answer research question five, the EDA and GSR measures were entered into an LME model to predict the subjective ratings. None of these measures significantly predicted the ratings. Thus, no correlation was found between these measures and the subjective ratings.

4. DISCUSSION

Both trust in technology and trust in active user ratings varied under the technological conditions and were highly correlated. This relationship was not found in previous studies with the active users and passive users who worked face-to-face (Montague and Xu, 2012). In the current study, the remote scenarios created a deficit of social and contextual cues (Sproull and Kiesler, 1986), such as appearance and nonverbal communication from the active user. The passive user evaluates the active user through the interface of the technology as a static social context cue and the interaction between the active user and the technology as a dynamic social context cues. The short interactive may have also contributed to the unstable trust in active user rating, since trust develops slower in distance collaboration than in face-to-face collaboration (Wilson *et al.*, 2006).

In a previous study, Montague *et al.* (2010) found that whether a care provider could use a medical device effectively could influence a patient's trust in the care provider as well as the technology. In this study, the finding about trust in technology's mediation effect on the relationship between trust in active user and the technological conditions further suggests that the passive users' evaluations of the active user may be based on their evaluation of the technology. This could be an issue in distance collaboration. If there is a lack of social context cues for the passive user to evaluate the active user, the passive user's perceptions of the technology may influence their assessment of the active user. So a context that creates a poor relationship might cause user's negative evaluation of the information exchanged (Coughlan *et al.*, 2007); on the other hand, negative evaluation of information could also negatively affect relationship among the users.

A previous study found that the interaction between the active user and the technology is one of the main predictors of passive users' ratings of trust in the technology (Montague and Xu, 2012). In the current study, the passive user's evaluation of the active user's workload could indicate how the passive user perceives the active user's interaction with the technology. High workload for the active user may be perceived by the passive user as the technology's inability to facilitate the active user's work. This perception could lower the passive user's perception of the technology's trust worthiness. So the perceived active user's workload rating should be predictive of the trust in technology rating. The correlations found in the results of this study between active users' workload and trust in technology, and the mediation effect of active users' workload on trust in technology and the technological conditions are consistent with this argument.

Figure 7 illustrates a model to summarize a possible relationship among the variables in this study. The active user–technology interaction process was manipulated by varying task characteristics, technology characteristics and active user characteristics. In this study, these variations were introduced by the two independent variables. In general, the variations in these three aspects represent the results of the design of a system. The arrows in Fig. 7 represent potential causal relationships among the variables. The active user–technology interaction observed by the passive user affects the passive user's evaluation of the active user's workload, trust in technology and trust in the active user. In addition, the trust in technology evaluation is partly based on perceived active user's workload and trust in active user evaluation is partly based on trust in technology. Thus, the active user's positive or negative experience with the technology might not only influence how the passive user perceives the technology being used but also how he/she perceives the active user. In other words, the interpersonal relationship between the active user and the passive user might be influenced by how the active user interacts with the technology. While testing the causality relations in this model is out of the scope of this study, future studies should systematically investigate these relationships.

The eye movement data could serve as a manipulation check. In different conditions, the participants gazed at different errors with different frequencies and lengths of time as expected. During the task period, participants showed physiological arousals in terms of SCL and HR, but not the other measures, including SCR and HRV. According to Boucsein and Backs' three-arousal model (2000), the participants had arousal in the affect arousal system but not the effort system. The affect arousal system is responsible for focusing attention and generating orienting responses (Boucsein and Backs, 2000). So the arousal in this system is an indicator for the participants' attention to the videos. However, this arousal did not differentiate between conditions, and no significant relationship between the physiology measures and the subjective ratings is found.

5. CONCLUSION

This experimental study investigated passive users in distance collaboration in a psychomotor task. Without visual cues of and communication with the active user, the passive user's perceived trustworthiness about the active user and the technology varied under different conditions of technology use, in terms of task difficulty and system reliability. Passive users' trust in the active user is positively correlated with their trust in the technology being used. On the basis of the results of the experiment, a model of passive users' perceptions about the technology and their perception of the active user in distance collaboration was proposed. Future research should further validate this model and test its generalizability.

ACKNOWLEDGEMENTS

This work was supported by the Air Force of Sponsored Research (AFSOR) and the Clinical and Translational Science Award (CTSA) program, previously through the National Center for Research Resources (NCRR) grant 1UL1RR025011 and now by the National Center for Advancing Translational Sciences (NCATS), grant 9U54TR000021. The authors thank research assistants Dhruv Mahtta and Russell Peterson, who assisted with data collection and analysis.

REFERENCES

Anvari, M., McKinley, C. and Stein, H. (2005) Establishment of the world's first telerobotic remote surgical service: for provision of advanced laparoscopic surgery in a rural community. Ann. Surg., 241, 460.

Bafoutsou, G. and Mentzas, G. (2002) Review and functional classification of collaborative systems. Int. J. Inf. Manage., 22, 281–305.

Baltes, B.B., Dickson, M.W., Sherman, M.P., Bauer, C.C. and LaGanke, J.S. (2002) Computer-mediated communication and group decision making: a meta-analysis. Organ. Behav. Hum. Decis. Process., 87, 156–179.

Baron, R.M. and Kenny, D.A. (1986) The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J. Pers. Soc. Psychol., 51, 1173.

Bell, B.S. and Kozlowski, S.W.J. (2002) A typology of virtual teams: implications for effective leadership. Group Organ. Manage., 27, 14–49.

Blackburn, R.S., Furst, S.A. and Rosen, B. (2003) Building a Winning Virtual Team: KSA's, Selections, Training, and Evaluation. In Gibson, C.B., Cohen, S.G. (eds), Virtual Teams that Work: Creating Conditions for Virtualteam Effectiveness. Jossey-Bass, San Francisco.

Bland, J.M. and Altman, D.G. (1995) Statistics notes: calculating correlation coefficients with repeated observations: part 1—correlation within subjects. BMJ, 310, 446.

Boucsein, W. and Backs, R.W. (2000) Engineering Psychophysiology as a Discipline: Historical and Theoretical Aspects. In Backs, R.W., Boucsein, W. (eds), Engineering Psychophysiology. Issues and Applications. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 3–30.

Cadiere, G., Himpens, J., Vertruyen, M. and Favretti, F. (1999) The world's first obesity surgery performed by a surgeon at a distance. Obes. Surg., 9, 206–209.

Comstock, J.R. and Arnegard, R.J. (1992) The multi-attribute task battery for human operator workload and strategic behavior research. National Aeronautics and Space Administration Technical Memorandum No. 104174. NASA, Hampton, VA: National Aeronautics and Space Administration.

Coughlan, J., Macredie, R. and Patel, N. (2007) Editorial: moving face-to-face communication to web-based systems. Interact. Comput., 19, 1–6.

Desanctis, G. and Gallupe, R.B. (1987) A foundation for the study of group decision support systems. Manage. Sci., 33, 589–609.

Goldberg, J.H., Stimson, M.J., Lewenstein, M., Scott, N. and Wichansky, A.M. (2002) Eye Tracking in Web Search Tasks: Design Implications. In Proc. 2002 Symposium on Eye Tracking Research & Applications. ACM, New Orleans, Louisiana, pp. 51–58.

Grudin, J. (1994) Computer-supported cooperative work: history and focus. Computer, 27, 19–26.

Hanly, E.J., Miller, B.E., Kumar, R., Hasser, C.J., Coste-Maniere, E., Talamini, M.A., Aurora, A.A., Schenkman, N.S. and Marohn, M.R. (2006) Mentoring console improves collaboration and teaching in surgical robotics. J. Laparoendosc. Adv. Surg. Tech., 16, 445–451.

Harkins, S.G. (2006) Mere effort as the mediator of the evaluation-performance relationship. J. Pers. Soc. Psychol., 91, 436–455.

Hart, S. and Staveland, L. (1988) Development of NASA-TLX (task load index): results of empirical and theoretical research. Hum. Mental Workload, 1, 139–183.

Inbar, O. and Tractinsky, N. (2009) The incidental user. Interactions, 16, 56–59.

Inbar, O. and Tractinsky, N. (2010) Interface-to-face: Sharing Information with Customers in Service Encounters. In Proc. 28th of the International Conference extended abstracts on Human factors in computing systems. ACM, Atlanta, pp. 3415–3420.

Inbar, O. and Tractinsky, N. (2012) Lowering the line of visibility: incidental users in service encounters. Behav. Inf. Technol., 31, 245–260.

Jacob, R.J.K. and Karn, K.S. (2003) Eye tracking in human–computer interaction and usability research: ready to deliver the promises. Mind, 2, 4.

Jian, J., Bisantz, A. and Drury, C. (2000) Foundations for an empirically determined scale of trust in automated systems. Int. J. Cogn. Ergon., 4, 53–71.

Larson, J.R. (2010) In Search of Synergy in Small Group Performance. Psychology Press, New York.

Marescaux, J., Leroy, J., Rubino, F., Smith, M., Vix, M., Simone, M. and Mutter, D. (2002) Transcontinental robot-assisted remote telesurgery: feasibility and potential applications. Ann. Surg., 235, 487.

Mayer, R.C. and Davis, J.H. (1999) The effect of the performance appraisal system on trust for management: a field quasi-experiment. J. Appl. Psychol., 84, 123.

McGrath, J.E. (1984) Groups: Interaction and Performance. Prentice-Hall, Englewood Cliffs, NJ.

Montague, E. (2010) Validation of a trust in medical technology instrument. Appl. Ergon., 41, 812–821.

Montague, E., Winchester III, W.W. and Kleiner, B.M. (2010) Trust in medical technology by patients and healthcare providers in obstetric work systems. Behav. Inf. Technol., 29, 541–554.

Montague, E. and Xu, J. (2012) Understanding active and passive users: the effects of an active user using normal, hard and unreliable technologies on user assessment of trust in technology and co-user. Appl. Ergon., 43, 702–712.

O'Kane, P. and Hargie, O. (2007) Intentional and unintentional consequences of substituting face-to-face interaction with e-mail: an employee-based perspective. Interact. Comput., 19, 20–31.

Pearson, S.D. and Raeke, L.H. (2000) Patients' trust in physicians: many theories, few measures, and little data. J. Gen. Intern. Med., 15, 509–513.

Perednia, D.A. and Allen, A. (1995) Telemedicine technology and clinical applications. J. Am. Med. Assoc., 273, 483.

Pinheiro, J.C. and Bates, D.M. (2009) Mixed-Effects Models in S and S-PLUS. Springer, New York.

R Development Core Team (2011) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Schoorman, F.D., Mayer, R.C. and Davis, J.H. (1996) Empowerment in Veterinary Clinics: The Role of Trust in Delegation. The 11th Annual Meeting of the Society for Industrial and Organizational Psychology, San Diego, CA.

Sproull, L. and Kiesler, S. (1986) Reducing social context cues: electronic mail in organizational communications. Manage. Sci., 32, 1492–1512.

Tarvainen, M.P., Niskanen, J.P., Lipponen, J., Ranta-aho, P. and Karjalainen, P. (2009) Kubios HRV—A Software for Advanced Heart Rate Variability Analysis, pp. 1022–1025. Springer, Berlin Heidelberg.

Turner, J.W., Robinson, J.D., Alaoui, A., Winchester, J., Neustadtl, A., Levine, B.A., Collmann, J. and Mun, S.K. (2003) Media attitudes vs. use: the contribution of context to the communication environment in telemedicine. Health Care Manage. Rev., 28, 95.

Van De Ven, A.H., Delbecq, A.L. and Koenig, R., Jr. (1976) Determinants of coordination modes within organizations. Am. Soc. Rev., 41, 322–338.

Vespa, P. (2005a) Multimodality monitoring and telemonitoring in neurocritical care: from microdialysis to robotic telepresence. Curr. Opin. Crit. Care, 11, 133.

Vespa, P. (2005b) Robotic telepresence in the intensive care unit. Critic. Care, 9, 319–320.

Wilson, J.M., Straus, S.G. and McEvily, B. (2006) All in due time: the development of trust in computer-mediated and face-to-face teams. Organ. Behav. Hum. Decis. Process., 99, 16–33.

Zajonc, R.B. (1965) Social facilitation. Science, 149, 269–274.