# How Shared Screen Affected Team Collaboration Task, A Case Study of Ergonomics Experiment on Team Situation Awareness

Xu Wu[1,2(✉)], Chuanyan Feng[2], Xiaoru Wanyan[2], Shuang Liu[3], Lin Ding[1], Chongchong Miao[1], Yuhui Wang[1], and Xueli He[1]

[1] AVIC China Aero-Polytechnology Establishment, Beijing 100028, China
e126126_19@126.com
[2] Beihang University, Beijing 100191, China
[3] Institute of Marine Technology & Economy, Beijing 100080, China

**Abstract.** Team situation awareness (TSA) had significant influence on collaboration work. As the essential interface of human computer interaction (HCI), visual display terminal was helpful for task performance enhancement. This study developed ergonomics experiment to investigate the impact of shared screen through team work and decision-making task. Three-member team played different roles on experiment task, and caption of the team was required to complete extra task based on others' report. During the experiment, both behavior performance and physiological measurements were recorded was indices of team situation awareness. And each team member was demanded to complete subjective rating scales to evaluate TSA afterwards. The results analysis revealed strong correlation between team situation awareness and collaborate work, while insignificant effect of shared screen usage on individual task.

**Keywords:** Team situation awareness · Collaboration · Shared screen
Human factor · Ergonomics

## 1 Introduction

Situation awareness would occur in process of individual interaction with task situation [1]. As a whole team composed of various operators, continuously observation of inside system, outside environment and team member behavior was necessary to achieve fully comprehension of current task situation, and finally formed TSA of the operator team after analysis and summary [2, 3]. Some of operation tasks could be completed by the individuals such as primary task of visual search, however, facing to rapid changing situation in the battlefield, it was difficult for single operator to understand the whole situation by constantly monitoring all update information.

In consideration of safety and function, observation and comprehension of overall situation was vital for the operator team, especially in complex system and urgent situation, where collaboration teamwork would be expected to perform tasks, including target tracking, distinguish, analysis and decision making [4–6]. According to assigned duty and task, individual operator would observe target information from human computer


D. Harris (Ed.): EPCE 2018, LNAI 10906, pp. 241–249, 2018.
https://doi.org/10.1007/978-3-319-91122-9_21

interface, and achieve decision making and judgment of the operator team through communication and collaboration.

Furthermore, TSA had tremendous influence on effectiveness and efficiency of collaboration work, while both interface design and team collaboration were closely correlated with TSA [7, 8]. Therefore, friendly design of human computer interface and reasonable team collaboration would be more helpful to improve TSA, which led to insurance of efficient interaction and accurate team decision. Recently, TSA has become popular topic of SA research, and many scholars developed their studies on measurement and modeling of TSA [9]. She and Li reviewed and compared various theories of TSA in terms of definitions, conceptual models and theoretical underpinnings, and also provided major controversies on TSA for a dialectical view on the TSA theories [10]. In addition, they developed a new toolkit of digital interface to enhance mutual awareness, and explored knowledge-based tasks of team behavior and performance [11, 12]. The counter-balance could also be found that the increase in mutual awareness led to a reduction of individual situation awareness, possibly due to the limited mental resources.

In this study, to investigate whether HCI with shared screen would affect team work with improved TSA, an ergonomics experiment of typical collaboration task was carried out, and task performance, eye-movement tracking, physiological measurement, and self-rating questionnaire were used to realize multi-dimension ergonomics evaluation.

## 2 Method

### 2.1 Experiment Design

Single channel of visual task was selected in this experiment that simulated operation task of observation and comprehension of current situation. The experiment factor was designed as the usage of shared screen. And the experiment team crew was formed by three members that the captain (role c) was placed in the middle, and the other two (role a and b) were placed either side of the captain. Each member was required to interact with computer screen through normal mouse and keyboard. The experiment interface was

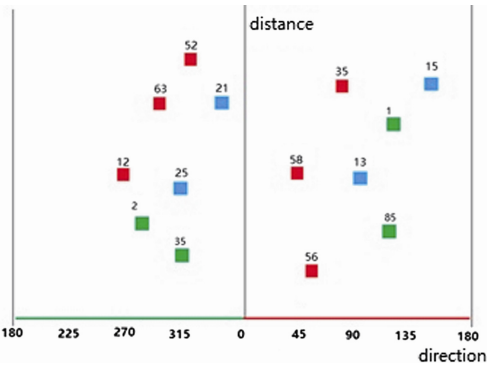


**Fig. 1.** Experiment interface (Color figure online)

displayed in shared (trial A) or single screen (trial B), which showed moving targets with color coding of red, green, blue from different direction and distance, as shown in Fig. 1.

### 2.2 Apparatus

As shown in Fig. 2, SMI Glass was adopted to measure eye-movement indices of fixation, saccade, and pupil diameter, while BioPac MP150 was adopted to measure Heart rate variance (HRV) and respiration in this experiment. And Team-Situation Awareness Rating Technology (T-SART), role conflict and ambiguity scale, and self/partner performance scale were adopted as afterwards evaluation of subjective questionnaire.


**Fig. 2.** SMI glass and BioPac MP150

### 2.3 Participants

Twenty-four graduate students from Beihang University were recruited in this experiment, with age from 22 to 27 years old and normal vision no less than 1.0. They were all informed with the detail of experiment task and procedure, and voluntarily agreed to participate in the experiment. They were divided into eight teams as three members in one team.

### 2.4 Experimental Task

The experiment task was designed accordingly by different roles of team members, and each one of them was required to perform three fundamental tasks, while the captain was required to perform an extra work of decision making. The specific fundamental tasks involved with direction identification task, number counting task, and memory retention task.

**Direction Identification.** Direction identification task required each team member to monitor visual information shown in experiment interface, including its color, direction, distance, number and moving trend. When the question box of this task was activated, the participants were required to track the mentioned target and report its direction.

**Number Counting.** Followed by the first task, number counting task required each team member to collect targets of certain color from all interfaces and input its total number. Meanwhile, the input results of each member were reported and shown in caption's interface, which was necessary to help the caption perform the decision making task.

**Memory Retention.** Memory retention task required each team member to keep real time awareness of task situation shown in the interface, and prepare to response to the randomly occurring questions of target information. The specific questions of memory retention task were involved with both individual and team SA of three levels of perception, cognition and projection.

**Decision Making.** The exclusive task of decision making required the caption to obtain the whole team results of the number counting task, and calculate "threat index" by the given formula, then report the current threat level accordingly.

## 3 Result

### 3.1 Behavior Performance

**Direction Identification Task.** Descriptive statistics analysis showed the team performance of direction identification task in trial A was better than trial B with slightly slower response time (170 ms, 3.4%) and more accurate direction deviation (0.8°, 9.7%). The average correct rate of team task was $0.928 \pm 0.042$ in trial A and $0.928 \pm 0.040$ in trial B, the average response time of team task was $5.069 \pm 0.582$ ms in trial A and $4.899 \pm 0.568$ ms in trial B. And the average direction deviation of team task was $5.642 \pm 0.973°$ in trial A and $6.251 \pm 1.208°$ in trial B. T-test analysis result showed significant difference between each trial in direction deviation ($T = -2.581$, $p = 0.036$) while none was found in correct rate ($T = 0.000$, $p = 1.000$) and response time ($T = 0.871$, $p = 0.412$).

The specific results of each team member were shown in Table 1. Repeated measurement two-way analysis of variance (ANOVA) was used to examine main effect on usage of shared screen (effect 1) and role of team member (effect 2). And the results showed none significant differences in main effect or interaction effect (effect 3) on both correct rate, response time and direction deviation, as shown in Table 2.

**Table 1.** Behavior performance of direction identification task for each team member (M ± SD)

| Team role | Correct rate | | Response time (ms) | | Direction deviation (degree) | |
|---|---|---|---|---|---|---|
| | Trial A | Trial B | Trial A | Trial B | Trial A | Trial B |
| a | 0.913 ± 0.076 | 0.925 ± 0.038 | 5.320 ± 0.796 | 5.051 ± 0.672 | 5.740 ± 1.816 | 7.020 ± 3.539 |
| b | 0.947 ± 0.039 | 0.928 ± 0.036 | 5.009 ± 0.985 | 4.791 ± 0.822 | 5.305 ± 1.044 | 5.762 ± 1.099 |
| c | 0.925 ± 0.057 | 0.931 ± 0.061 | 4.876 ± 0.571 | 4.855 ± 0.865 | 5.881 ± 1.565 | 5.971 ± 1.003 |

**Table 2.** ANOVA results of direction identification task

| Effect | Correct rate | | Response time | | Direction deviation | |
|---|---|---|---|---|---|---|
| | F-test | p | F-test | p | F-test | p |
| 1 | F(1,21) = 0.000 | 1.000 | F(1,21) = 1.559 | 0.226 | F(1,21) = 2.436 | 0.133 |
| 2 | F(2,21) = 0.474 | 0.629 | F(2,21) = 0.472 | 0.630 | F(2,21) = 0.536 | 0.593 |
| 3 | F(2,21) = 0.411 | 0.668 | F(2,21) = 0.308 | 0.738 | F(2,21) = 0.811 | 0.458 |

**Number Counting Task.** Descriptive statistics analysis showed the team performance of number counting task in trial A was much better than trial B with slightly higher correct rate (0.012, 1.4%) and shorter response time (1665 ms, 23.2%). The average correct rate of team task was 0.866 ± 0.067 in trial A and 0.854 ± 0.065 in trial B, the average response time of team task was 5.524 ± 0.597 ms in trial A and 7.189 ± 0.816 ms in trial B. T-test analysis result showed significant difference between each trial in response time ($T = -5.321$, $p = 0.001$) while none was found in correct rate ($T = 0.840$, $p = 0.428$).

The specific results of each team member were shown in Table 3. Repeated measurement two-way analysis of variance was also adopted. And no significant differences of correct rate was found in main effect or interaction effect, while significant differences between response time was found only in main effect on usage of shared screen, as shown in Table 4.

**Table 3.** Behavior performance of number counting task for each team member (M ± SD)

| Team role | Correct rate | | Response time (ms) | |
|---|---|---|---|---|
| | Trial A | Trial B | Trial A | Trial B |
| a | 0.913 ± 0.076 | 0.925 ± 0.038 | 5.320 ± 0.796 | 5.051 ± 0.672 |
| b | 0.947 ± 0.039 | 0.928 ± 0.036 | 5.009 ± 0.985 | 4.791 ± 0.822 |
| c | 0.925 ± 0.057 | 0.931 ± 0.061 | 4.876 ± 0.571 | 4.855 ± 0.865 |

**Table 4.** ANOVA results of number counting task

| Effect | Correct rate | | Response time | |
|---|---|---|---|---|
| | F-test | p | F-test | p |
| 1 | F(1,21) = 0.506 | 0.485 | F(1,21) = 13.779 | 0.001 |
| 2 | F(2,21) = 0.413 | 0.667 | F(2,21) = 1.211 | 0.318 |
| 3 | F(2,21) = 2.136 | 0.143 | F(2,21) = 2.560 | 0.101 |

**Memory Retention Task.** Descriptive statistics analysis showed the team performance of memory retention task in trial A was slightly better than trial B with almost same correct rate (0.012, 2.5%) and shorter response time (557 ms, 9.5%). The average correct rate of team task was 0.384 ± 0.078 in trial A and 0.394 ± 0.053 in trial B, the average response time of team task was 6.390 ± 1.172 ms in trial A and 5.833 ± 1.385 ms in trial B. T-test analysis result showed no significant difference between each trial in response time ($T = -0.277$, $p = 0.790$) or correct rate ($T = 1.812$, $p = 0.113$).

The specific results of each team member were shown in Table 5. Repeated measurement two-way analysis of variance was also adopted. And no significant differences of correct rate was found in main effect or interaction effect, while only critical significant differences between response time was found in main effect on usage of shared screen, as shown in Table 6.

**Table 5.** Behavior performance of memory retention task for each team member (M ± SD)

| Team role | Correct rate | | Response time (ms) | |
|---|---|---|---|---|
| | Trial A | Trial B | Trial A | Trial B |
| a | 0.913 ± 0.076 | 0.925 ± 0.038 | 5.320 ± 0.796 | 5.051 ± 0.672 |
| b | 0.947 ± 0.039 | 0.928 ± 0.036 | 5.009 ± 0.985 | 4.791 ± 0.822 |
| c | 0.925 ± 0.057 | 0.931 ± 0.061 | 4.876 ± 0.571 | 4.855 ± 0.865 |

**Table 6.** ANOVA results of memory retention task

| Effect | Correct rate | | Response time | |
|---|---|---|---|---|
| | F-test | p | F-test | p |
| 1 | $F(1,21) = 0.125$ | 0.727 | $F(1,21) = 3.741$ | 0.067 |
| 2 | $F(2,21) = 1.677$ | 0.211 | $F(2,21) = 0.029$ | 0.971 |
| 3 | $F(2,21) = 1.755$ | 0.197 | $F(2,21) = 1.538$ | 0.238 |

**Decision Making Task.** Descriptive statistics analysis showed the caption performance of decision making task in trial A was better than trial B with higher correct rate (0.075, 9.3%) and shorter response time (2487 ms, 15.0%). The average correct rate of team task was 0.878 ± 0.091 in trial A and 0.803 ± 0.113 in trial B, the average response time of team task was 14.118 ± 0.887 s in trial A and 16.605 ± 1.710 s in trial B. T-test analysis result showed significant difference between each trial in response time ($T = -3.801$, $p = 0.007$) but none was found in correct rate ($T = 1.871$, $p = 0.104$).

### 3.2 Eye Movement Tracking

According to the results of eye movement tracking, measurement indices were selected as fixation, saccade, blink and pupil diameter. The descriptive statistics analysis results of each trial were shown in Table 7. T-test analysis was used to examine main effect on usage of shared screen. The results showed only critical significant difference between each trial in pupil diameter ($T = -2.124$, $p = 0.078$) but none was found in fixation dwell time ($T = -0.512$, $p = 0.627$), fixation frequency ($T = -0.512$, $p = 0.627$), saccade

amplitude ($T = -0.670$, $p = 0.528$), saccade frequency ($T = -0.091$, $p = 0.930$), or blink rate ($T = -0.486$, $p = 0.644$).

**Table 7.** Eye movement tracking results (M ± SD)

| Experiment index | Trial A | Trial B |
|---|---|---|
| Fixation dwell time (ms) | 242 ± 25 | 245 ± 35 |
| Fixation frequency (times per min) | 167 ± 15 | 168 ± 20 |
| Saccade amplitude (degree) | 6.78 ± 1.56 | 7.18 ± 2.70 |
| Saccade frequency (times per min) | 145 ± 10 | 146 ± 21 |
| Blink rate (times per min) | 22 ± 11 | 23 ± 12 |
| Pupil diameter (mm) | 3.37 ± 0.63 | 3.51 ± 0.73 |

### 3.3 Physiological Measurement

According to the results of physiological measurement, experiment indices were selected as HRV and respiration. The descriptive statistics analysis results of each trial were shown in Table 8. T-test analysis was also used, and the results showed no significant difference between each trial in RR interval ($T = 0.702$, $p = 0.506$), heart rate ($T = -0.679$, $p = 0.519$), or respiration rate ($T = -0.099$, $p = 0.924$).

**Table 8.** Physiological measurement results (M ± SD)

| Experiment index | Trial A | Trial B |
|---|---|---|
| RR interval (ms) | 903 ± 131 | 865 ± 127 |
| Heart rate (times per min) | 68 ± 11 | 71 ± 11 |
| Respiration rate (times per min) | 16 ± 2 | 16 ± 2 |

### 3.4 Subjective Rating Scales

Subjective rating scales were selected as T-SART (Team-Situation Awareness Rating Technology), role conflict and ambiguity scale and self/partner performance scale. The T-SART results of each team member were 17.0, 21.9 and 20.3 accordingly in trial A while 16.8, 20.5 and 18.5 in trial B. Repeated measurement two-way analysis of variance showed insignificant effect on usage of shared screen ($p = 0.115$) and role of team member ($p = 0.338$).

And results of role conflict and ambiguity scale of each team member were 13.9, 13.8 and 13.5 accordingly in trial A while 12.3, 12.5 and 11.1 in trial B. Repeated measurement two-way analysis of variance showed significant effect on usage of shared screen ($p = 0.001$) but insignificant effect on role of team member ($p = 0.767$).

Moreover, self-rating results of each team member were 14.4, 12.8 and 12.4 accordingly in trial A while 13.4, 11.4 and 12.8 in trial B. Repeated measurement two-way analysis of variance showed insignificant effect on usage of shared screen ($p = 0.341$) but critical significant effect on role of team member ($p = 0.090$). In addition, partner-rating results of each team member were 14.8, 15.0 and 13.1 accordingly in trial A while 15.4, 13.9 and 14.5 in trial B. Repeated measurement

two-way analysis of variance showed insignificant effect on usage of shared screen ($p = 0.662$) and role of team member ($p = 0.559$).

## 4 Discussion

To examine how shared screen influenced team collaboration, task performance and physiological measurement as well as subjective rating scales were used to evaluate TSA during the experiment task. And the results of descriptive statistics analysis and repeated measured ANOVA revealed significant main effect of shared screen.

The task performance showed equally result between each trial in direction identification task, however, the shared screen could effectively accelerate the response to questions of number counting task. Therefore, shared screen was inclined to help performance enhancement of task where team collaboration was in dominant rather than individual work. In addition, the result of memory retention task was unexpected and lower than 50% in correct rate. It was mainly caused by the tremendous amount of visual information in experiment situation so that the participants were incapable of keeping short-time memory of the whole and chose reckless answers in regardless of time pressure. Moreover, shared screen had a positively effect on reduction of response time but no obviously improvement of correct rate because the time pressure was set as medium level in the experiment. So that the participants could spent more time to complete their tasks as compensation and also achieve high correct rate.

Although the results of eye movement tracking and physiological measurement showed no significant difference between each trial, the effect of shared screen had certain influence on TSA and team workload, which was proved by the critical significant effect only on pupil diameter. Since such measurement in this experiment was failed to reveal considerable interaction between physiological index and TSA, further study should concentrate on the physiological measurement and evaluation indices of TSA to implement analysis of team collaboration work.

Besides, the subjective rating scales were also used to investigate the effect of shared screen. However, T-SART and self/partner rating scales were unable to illustrate significant difference of such effect while role conflict and ambiguity scale was successfully proved to find it. And the overall results of three scales were mainly consistent with task performance. Interestingly, the third scale revealed that the self-rating point seemed to be slightly lower than that of partner-rating. The participants preferred to be strict with themselves and tolerate with others, which was mainly caused by the characteristics of culture custom and education background.

## 5 Conclusion

In conclusion, the experiment results showed that the task performance with shared screen was significantly more outstanding with shorter time of the overall task and higher accuracy, especially for the number counting task where team collaboration was urgent. However, there was no significant difference found in eye-movement tracking and physiological measurement between the usages of shared screen. Moreover, according

to the result of single measured index, the participants with shared screen had lower fixation rate, lower blink rate and lower saccade rate, which seemed to demonstrate the usage of shared screen was helpful to improve TSA and reduce workload to a certain extent.

**Acknowledgements.** The co-authors would like to thank the kindly support by Beihang University and Institute of Marine Technology & Economy.

## References

1. Wei, H.Y., Zhuang, D.M., Wanyan, X.R., et al.: An experimental analysis of situation awareness for cockpit display interface evaluation based on flight simulation. Chin. J. Aeronaut. **26**(4), 884–889 (2013)
2. Liu, S., Wanyan, X.R., Zhuang, D.M., et al.: Situational awareness model based on attention allocation. J. Beijing Univ. Aeronaut. Astronaut. **40**(08), 1066–1072 (2014)
3. Liu, S., Wanyan, X.R., Zhuang, D.M.: Modeling the situation awareness by the analysis of cognitive process. Bio-Med. Mater. Eng. **24**(6), 2311–2318 (2014)
4. Endsley, M.R.: Situation awareness: progress and directions. In: A Cognitive Approach to Situation Awareness: Theory, Measurement and Application, pp. 317–341 (2004)
5. Endsley, M.R., Robertson, M.M.: Situation awareness in aircraft maintenance teams. Int. J. Ind. Ergon. **26**(2), 301–325 (2000)
6. Wickens, C.D.: Situation awareness: review of Mica Endsley's 1995 articles on situation awareness theory and measurement. Hum. Factors **50**(3), 397–403 (2008)
7. Wu, X., Wanyan, X., Zhuang, D., Liu, S.: Pilot situational awareness modeling for cockpit interface evaluation. In: Harris, D. (ed.) EPCE 2016. LNCS (LNAI), vol. 9736, pp. 476–484. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-40030-3_46
8. Wu, X., Feng, C., Wanyan, X., Tian, Yu., Huang, S.: Dynamic measurement of pilot situation awareness. In: Harris, D. (ed.) EPCE 2017. LNCS (LNAI), vol. 10276, pp. 306–316. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-58475-1_23
9. Feng, C.Y., Wanyan, X.R., Chen, H., et al.: Research on situation awareness model and its application based on multiple-resource load theory. J. Beijing Univ. Aeronaut. Astronaut. (2018). https://doi.org/10.13700/j.bh.1001-5965.2017.0532
10. She, M., Li, Z.: Team situation awareness: a review of definitions and conceptual models. In: Harris, D. (ed.) EPCE 2017. LNCS (LNAI), vol. 10275, pp. 406–415. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-58472-0_31
11. She, M., Li, Z.Z.: Design and evaluation of a team mutual awareness toolkit for digital interfaces of nuclear power plant context. Int. J. Hum.-Comput. Interact. **33**(9), 744–755 (2017)
12. Yuan, X.H., She, M.R., Li, Z.Z., et al.: Mutual awareness: enhanced by interface design and improving team performance in incident diagnosis under computerized working environment. Int. J. Ind. Ergon. **54**, 65–72 (2016)