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Exploring the Effects of Users' Location on HCI Factors Using Multi-touch Tabletops

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***Abstract*— With the intention to study the role of new interfaces in multi-user applications, multi-touch tabletops are investigated to examine if they effectively aid their users in working together synchronously. Multi-player games are selected as a case of collaborative work. Early studies of distributed multi-touch tabletops did not cover the HCI related aspects associated with multi-player games, especially in distributed configuration. A simple multi-player maze game has been designed and implemented over two connected and physically separated multi-touch tabletops. This configuration is used to test two conditions: co-located users and distributed users. Thirty two volunteers have been assigned randomly to the conditions such that each one is exposed to both, then a comparative analysis is conducted between the findings in both conditions. The aim of this work is to investigate the effects of distribution on users' performance, collaboration, and usability of multi-user interfaces using multi-touch tables. The results indicate that, in general, the differences of HCI factors for distributed users versus co-located users are not significant for such type of applications if a simple and efficient communication mechanism is provided for the users in the distributed condition. Users expressed almost the same level of usability, engagement, and enjoyment for the two conditions. This may have a strong impact on the HCI aspects when designing similar applications in the future.**

Keywords- Human-Computer Interaction; Collaboration; Usability, User performance; Distribution; Co-location; Multi-touch tabletops

I. INTRODUCTION

The topic of distribution of computer system's users has been widely studied by researchers in a variety of academic disciplines such as learning, information management, human-computer interaction, and computer supported collaborative work. Distribution of users means that a system's users are not in the same physical place, as opposed to being co-located, though they are using the same system at the same time. There are many software environments that support multi-users to work collaboratively together in co-located and distributed conditions. The majority of these software require the users to use the traditional interaction techniques of mouse-keyboard-monitor to perform tasks [1]. The co-located condition of users sitting around a single desktop computer to work collaboratively came across well documented problems such as inadequate space for collaborators to perform their task in various parts of the workspace [2]. These problems get more complicated when adding the distribution factor of users being physically separated and using more than one connected computer to work remotely and collaboratively [3]. Efforts to maintain remote collaboration tended to exploit conventional interaction of the traditional mouse-keyboard-monitor to facilitate common workspaces. However, these projects revealed the same problems as in the co-located condition in addition to the problem of users losing awareness of each other's activities [2], [4].

Multi-touch tabletops are investigated for they effectively aid their users in working collaboratively as they intuitively provide a natural multi-user interface [5]. The user interface of conventional software applications is designed traditionally as a single user system that presents other users and their activities in an unclear manner [1], [6]. Performing a certain task collaboratively needs a clear computerized support with a good user-centered interface that should allow and assist the collaborative interactions among users [7], [8]. Multi-touch interfaces can accommodate more than one user concurrently, which is particularly useful for collaborative work.

Adding the distribution factor has its implications on any software regardless of the platform [3]. Maintaining awareness and facilitating communication among collaborating users are two of the most significant obstacles that face remote collaborative software designers. Several studies have shown how multi-touch tables can be used in distributed configuration, and have reported the discovered problems and some proposed solutions for them (e.g. VideoArms [9]).

The objective of this research is to find out whether there is a significant difference in HCI aspects between the co-located and the distributed conditions. In both conditions, users are supposed to collaboratively work together, however, they use the same table in the **co-located** condition, and they use two different tables in two different locations in the **distributed** condition. Previous researchers have studied such differences [10], [11], however, the objective of this research is different in that it focuses on the HCI aspects within the context of multi-player game-like applications. Differences in *performance*, *collaboration*, and *usability* between the co-located and distributed conditions are thoroughly analyzed in addition to the differences in the relationships among the aforementioned areas. Studying these HCI aspects revealed interesting findings about how users interact with such applications in co-located and distributed scenarios. That can help in suggesting recommendations and guidelines for multi-user applications designers for multi-touch surfaces.

II. BACKGROUND

Usability engineering is becoming a recognized discipline with established practices and standards (Shneiderman [12]). As software becomes more and more interactive, attention to the needs and preferences of the end user intensifies (Te'eni et al. [13]). Usability studies the factors that make a software system effectively, efficiently, and satisfactorily usable when users use it to perform the tasks that that system was designed for, taking into consideration that users became more diverse and less technical [13], [14].

Multi-touch interfaces have some intuitive features that indicate good usability such as zooming, scrolling, and bi-manual operations. For manipulating virtual objects over a *multi-user* table surface, multi-touch seems to be an ideal approach from a usability point of view. The real challenge will lie in attempts to integrate multi- touch into a wider range of applications. Usability will make or break any such attempts. It seems likely that multi-touch interfaces will succeed in efficiency and satisfaction areas of usability (Ha et al. [15] and Morris [16]). But when it comes to complex tasks, multi-touch interfaces do not seem to provide enough flexibility to be truly easy to learn and work efficiently. There should be implemented mechanisms in the interface to help users to avoid making a frustrating actions, such as reaching to each other's personal workspace or loosing awareness of each other's activity [15]. Simply touching the screen rather than pointing with a mouse will not automatically remove these challenges. Therefore, the designers of multi-touch groupware should be keen to examine the usability implications of these challenges.

Olson and Olson [3], [17], [18] have studied the effects of users distribution on the collaborative work and groupware. Their findings fall into two categories: behavior that will change for the better when the technology achieves certain qualities, and behavior that will never change which confirms that distance will continue to matter even with significant technological advances [3].

Computer Supported Collaborative Work, or simply, CSCW, is a much related area of research to group work. It is a research field that involves factors from different disciplines and focuses on tools and techniques to support group working using computer systems (groupware). CSCW provides its users with the ability to collaborate and work together in co-located or distributed settings to accomplish shared goals (Eseryel et al. [19]). Collaboration is considered successful when the goal is achieved by the group not an individual. Within CSCW, activities require three elements to be shared effectively: *mutual responsiveness*, *commitment to the shared task*, and *commitment to mutual support* (Bratman [20]). As the aim of CSCW is to support group work effectiveness, it is concerned with the group working process and the technology that might be used to support it (Olson and Olson [21]). CSCW has proven to be beneficial in many situations, however, it introduced some practical challenges. For example, users may simultaneously access shared areas of the screen and change some settings there. Also, the ease of reaching digital artefacts on multi-touch surfaces may affect the efficiency and collaboration level of users (Morris et al. [22]).

Earlier research in the area of collaborative work focused on adjusting conventional applications interfaces to add collaboration support. Another approach was also proposed that make use of the multi-touch tabletop interfaces powerful collaborative features (Tuddenham et al. [23]). The design challenges that are involved in using tabletops include the legibility of the presented information, utilizing an efficient navigation mechanism between the different parts of the table surface [24], and supporting awareness among collaborators [23]. The benefit of collaborating around a mutual display is the combined context it gives (Amershi and Morris [1]).

An interesting point to consider when studying group work with multi-touch tabletops is the amount of parallel participation that users engage in during their work. Multi-touch tabletops naturally support concurrent interactions by more than one user, which, generally, should enhance productivity (Basheri et al. [25], [26]).

As people work together in a group work task, they adopt different collaboration styles. Sometimes, they work on the same problem; at other times, they may separate to work on different problems. These different styles allow them to investigate solutions, test ideas, and plan their work. Isenberg et al. [27] identified eight styles of collaboration that users around tabletops may follow during their group work. They also categorized those styles into two categories: close collaboration and loose collaboration. Generally, it is found that participants spend almost half of their time in close collaboration during the given task. Close collaboration is usually encouraged, hence systems should facilitate its styles as much as possible [28].

When used in a co-located configuration, tabletop interfaces are a form of single display groupware that use a large display together with multi-user direct input mechanisms such as styluses or a multi-touch surface [11]. Supporting remote collaboration had tended to use conventional monitor/mouse interaction to present shared workspaces. However, problems have been encountered with such experiments. For instance, on a conventional monitor there is often insufficient space for collaborators to work in different parts of the workspace without losing the awareness of each other's actions (Dourish et al. [29] and Gutwin et al. [30]). Another problem of these solutions is the lack of awareness among collaborators about each other's actions in the workspace, with collaboration suffering as a result. The problem is particularly acute in systems in which each collaborator can manipulate their view of the workspace independently of others, for example to scroll to a different region of the workspace (Tuddenham et al. [11] and Gutwin et al. [31]).

The possibility of linking two or more geographically-separated tabletops has been investigated to provide a shared workspace for remote distributed collaborators. Each of those distributed collaborators sits at their own tabletop display. The displays are then linked so that the remote collaborators all see the same artefacts and can then interact simultaneously and see each other's actions, as if they are around a co-located tabletop (Tuddenham et al. [11]); this has a great impact on awareness.

III. STUDY DESIGN

This research considered some HCI (human-computer interaction) aspects that are inherent in remote collaboration when using multi-touch tabletops. These aspects fall in three main areas of study: performance, collaboration, and usability. These areas were the major criteria of comparison between the co-located and distributed conditions (or scenarios). A multi-player game is designed and implemented to work in both configurations: co-located and distributed. Users participated in a two parts experiment to analyses the differences between the two conditions.

A. *Methodology*

Repeated-Measures (within-subject) experimental design has been used in this research. This design is more economic and helps in minimizing the sources of random variations [32], [33]. Thirty two (32) participants were used for the experimental sessions. Each participant is exposed to both experiment conditions: co-located (same table) and distributed (two different tables). The order of conditions in which a group is playing is randomized among the groups to counterbalance the effect of conditions order. The task (game) that is given in both condition is similar in complexity, details, and time allowance. Data has been collected in each session from both conditions to be analyzed and compared for similarities and differences.

Randomization of participants to experiment conditions is used; that is, the list of participants' names is randomly assigned to the conditions and the participants know in which condition they will begin only when they start the experimental session. By this, it is ensured that any differences within the groups are not systematic and that any differences are due to chance.

In co-located condition, the two players use the same table to play the game. They work together towards the same target and they are allowed to verbally communicate and discuss their plan and ask each other for help and offer help to each other. On the other hand, in the distributed condition, the two players use physically separated tables connected together via the software application. However, they are not allowed to verbally talk to each other nor to directly look to each other's table. The application provides messaging mechanism for the players to communicate with each other by asking for or offering help and by accepting or rejecting help.

The experimental sessions are video recorded in each condition, and the participants are asked to fill in a questionnaire after they finish each part of the experiment. Another invaluable source of data is the system logs that capture all internal interactions with different parts of the application interface and the usage of the messaging communication system.

Dependent variables used in this study are categorized into three groups that are mapped to the three areas of the research: Performance, Collaboration, and Usability. Table 1 summarizes these variables.

All investigations include statistical comparisons between the means of variables in the two conditions. In addition to comparisons, correlation analysis among the variables in each condition is also carried out to find out whether the variables have any noticeable effect on each other.

B. *Participants*

There were, originally, 32 participants in this study. However, after analyzing for outliers, we decided to remove two participants[1] making them 30 (15 females and 15 males), with their ages between 21 and 43 years.

19 of the participants were familiar with multi-player computer games, 27 were familiar with computer games in general. With the exception of 3 participants, they were also familiar with using multi-touch interfaces (mainly smart phones). Participants were randomly grouped into 15 pairs as each session needed two participants to work together.

C. *Experimental Procedure*

All participants have been given a short training session in each experimental condition before they start the actual experiment. As most game-like applications, there was a time limit for each group to finish the game (10 minutes), otherwise the game is over and the participants cannot interact with the interface any more. The experiment activity is video recorded in each condition (with one camera for each table), and the participants are asked to fill in a

[1] The removed participants were not taking the experiments seriously and performed extremely bad.

questionnaire after they finish each condition of the experiment. Another source of data was the system logs that capture all internal interactions with different parts of the game interface and the usage of the messaging communication system.

IV. FINDINGS AND DISCUSSION

The objective of this study is to examine the differences and similarities between the co-located and distributed conditions within the context of multi-player activity over multi-touch tabletops. As mentioned before, three HCI factors were considered: Performance, Collaboration, and Usability. The following subsections summarize the findings in each.

Area	Factor	Sub-factor	Description
Performance	Efficiency	Duration	Total time that a group spent on the task (from start to finish/game over)
		Effort	Total number of questions a group has solved during the game (including correct and wrong answers)
		Speed	Number of correctly answered questions per minute (the answers that cause progress)
	Accuracy	Incorrectness ratio	Ratio of incorrect answers to the total answers a group has given, per minute
		Added difficulty ratio	Ratio of the added parts to the game solution to the most efficient solution, per minute
		Unnecessary work ratio	Ratio of the time spent on working on irrelevant parts of the game solution to the total time spent on the game, per minute
Collaboration	Styles	CH	Communicating for Help; when the participants are communicating to assist each other
		VE	View Engaged; when one of the participants is not actively working on the task but he/she is engaged in watching what the other participant is doing
		SSP	Same Single Problem; when both participants are working at the same time on the same part of the problem
		SGP	Same General Problem; when both participants are working at the same time on the task but on different parts of the problem
	Communication	Frequency	Number of total communication attempts (initiation, responding, and others) per minute
		Start	Time of the first communication attempt as a ratio of the total game duration
		Interval	Time span from first communication attempt to the last one as a ratio to total game duration
		Help initiation	Number of communication attempts for help (ask and offer) per minute during communication interval
		Help response	Number of responses received for help initiation (affirmative and negative) per minute during communication interval
		Response time	Average response time (in seconds) between the participants when they communicate for help
	Balance	Work	Total number of solved questions (correct and incorrect) per minute
		Communication	Total number of communication attempts per minute
Usability	Satisfaction		User subjective satisfaction with the interaction experience
	Ease of learn and use		How easily the user can learn to interact with the new system and to complete the given task
	Physical and cognitive demand		The level of physical or cognitive requirements that the system exerts on users

A. Performance

The differences were only in the *Efficiency* factor, in particular, in the effort and speed sub-factors. The differences for the other factors were statistically insignificant, and hence, can be neglected. In addition, the differences in the correlation coefficients among those factors between both conditions were also statistically insignificant. This is discussed in more details in the following subsections.

a) Efficiency

In the area of efficiency, we considered three sub-factors that affect the overall efficiency of work for the players groups. Those sub-factors are: duration, *effort*, and *speed*. When those sub-factors were compared in both conditions, we found that there was not a significant difference in the scores of duration, however, there was a significant difference in the scores for effort, as well as speed.

To get a deeper understanding of these sub-factors, we conducted a correlation test between them to see how they interact and affect each other. We noticed that, in both conditions, there is a strong relationship between duration and effort and a strong negative relationship between duration and speed. However, in the distributed scenario, the relationship between duration and effort is slightly stronger, and the relationship between duration and speed is slightly weaker.

b) Accuracy

Accuracy was also studied by taking three sub-factors into consideration: *incorrectness ratio*, *extra difficulty ratio*, and *unneeded work ratio*. For all these sub-factors, the more the ratio the less the accuracy. Test for differences between both conditions for the mentioned accuracy sub-factors revealed that there is a significant difference in the scores of incorrectness ratio (for the advantage of the co-located scenario), but the differences are insignificant in the scores of extra difficulty and unneeded work ratios respectively. The lower incorrectness ratio in the co-located scenario can be explained by the high speed and less effort in that condition. However, there was not a strong evidence that distribution affected the players' decision to avoid extra difficulty or unneeded work.

A similar correlation test has also been carried out on the sub-factors of accuracy. The results were insignificant and the relationships among the sub-factors were weak.

B. Collaboration

Differences were found in the Styles, Communication, and Balance factors. For the Styles part, there were significant differences in VE and SGP styles. In Communication part, the differences were found in frequency, start time, interval, and response time. The difference for the third factor, Contribution Balance, was found in equity of work participation. Differences in other sub-factors were statistically insignificant, and differences in sub-factors correlation were also insignificant.

a) Collaboration Styles

Participants spent, in total, 45.3% and 36.4% of their time in close collaboration in the co-located and distributed scenarios, respectively. However, the differences in two of the close collaboration styles are statistically insignificant (CH and SSP), so the significant source of difference should be the VE and SGP styles.

b) Communication

It was noticed that the differences are on the time related aspects of communication (frequency, start time, interval, and response time), while the differences in the other aspects (help initiation and help response) are statistically insignificant. Participants have communicated 2.78 and 1.64 times per minute in the co-located and distributed scenarios, respectively. Higher frequency is not always an advantage especially in the co-located condition as it could be a source of distraction.

c) Balance

For work balance, Gini coefficient technique was applied in order to measure the relative contribution of the individuals within each group in each condition. The results indicated that the equity of work participation in the co-located condition was greater than that of the distributed condition, and the difference between the conditions was statistically significant. In most cases, the equity of participation is more obvious in the co-located scenario than that in the distributed scenario.

A similar analysis has also been carried out to study the equity of communication participation. The results indicated that the equity of communication participation in the co-located condition was less than that of the distributed condition. However, the difference between the conditions was statistically insignificant.

C. Usability

Differences were found only in the satisfaction factor. The differences in the other factors were statistically insignificant. Moreover, the differences in the correlation coefficients among those factors between both conditions were also statistically insignificant.

a) Satisfaction

The satisfaction score in co-located scenario is higher than that in the distributed scenario, and the difference was statistically significant. The major source of difference was that users were disappointed with the communication part in the distributed scenario, and they were not fully aware of each other's progress. The messaging communication mechanism, though very simple and efficient, lacks the ability to discuss strategy and plan as in verbal communication in co-located condition.

D. Overall Relationships

A correlation test has been carried out to find out whether there are differences between co-located and distributed scenarios in the *relationships* among the three areas of the research, performance, collaboration, and usability. The correlation analysis between performance and collaboration sub-factors showed that there was a significant difference between the two conditions in the relationship between Accuracy (added difficulty) and Collaboration Styles (SSP), with no significant differences found between other sub-factors. The differences for the other areas: performance and usability, and collaboration and usability, were statistically insignificant.

V. Conclusions

A. Performance

Results showed that users (players), generally, have the same level of performance in both scenarios. Users could perform the given task with less time and effort in the co-located scenario, although they were working at a higher speed in the distributed scenario. This gives an indication that, in such type of collaborative applications, the measurement of efficiency is more reliable when total time and total work are taken into consideration rather than depending only on the speed of the users' actions. The accuracy of task results were comparable in both scenarios. Accuracy has a strong correlation with communication, which can lead to the conclusion that the distributed scenario configuration was successful in providing a collaborative environment that helped the users in achieving accurate results as in the co-located scenario.

B. Collaboration

This research identified clear differences in the three sub-areas of collaboration. Firstly, for the collaboration styles, results showed that users spent more time in close collaborative styles in the co-located scenario than that in the distributed one. On the other hand, they spent more time in loose collaborative styles in the distributed scenario. A more engaging communication and awareness mechanism, such as audio/video chatting, in the distributed condition will have great advantage on the whole experience. Secondly, for the communication part of collaboration; the implemented system should provide an effective communication mechanism for the users in the distributed scenario [34]. Based on the results of the experiment, the users should be able to convey their messages in the shortest time with the least effort. They should, also, start to communicate as soon as possible once they start the task, and they should stay in contact for the longest time during the work session. And, finally, for the contribution balance side of collaboration; this research found that users work contribution is more balanced in the co-located scenario. Being co-located make it easier and more natural for users to coordinate the work balance which is a desired objective in collaborative work in general [25].

C. Usability

Users showed a higher satisfaction level in the co-located scenario than that in the distributed scenario. As the usability analysis showed, the major concern of the users was their inability to effectively communicate and coordinate work in the distributed condition. Although, this concern did not severely affect their total performance or collaboration level, it negatively affected their satisfaction with the user experience in the distributed scenario. Implementing a more sophisticated communication and coordination system for users in the distributed condition may help them in achieving higher engagement which will lead to a higher satisfaction level. However, and as previously mentioned, these additional options must be designed carefully to ensure that they will not obstruct the users' main focus nor add more complexity to the given task, which may have a negative impact on the users' performance.

References

[1] S. Amershi and M. R. Morris, 'Co-located collaborative web search: understanding status quo practices', in *CHI '09 Extended Abstracts on Human Factors in Computing Systems*, New York, NY, USA, 2009, pp. 3637–3642.

[2] M. Morris, 'A survey of collaborative web search practices', in *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, Florence, Italy, 2008, pp. 1657–1660.

[3] G. M. Olson and J. S. Olson, 'Distance matters', *Hum-Comput Interact*, vol. 15, no. 2, pp. 139–178, 2000.

[4] M. R. Morris and E. Horvitz, 'SearchTogether: an interface for collaborative web search', in *Proceedings of the 20th annual ACM symposium on User interface software and technology*, New York, NY, USA, 2007, pp. 3–12.

[5] W. Westerman, J. G. Elias, and A. Hedge, 'Multi-Touch: A New Tactile 2-D Gesture Interface for Human-Computer Interaction', *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 45, no. 6, pp. 632–636, 2001.

[6] D. Wigdor, J. Fletcher, and G. Morrison, 'Designing user interfaces for multi-touch and gesture devices', in *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems*, 2009, pp. 2755–2758.

[7] M. B. Twidale, D. M. Nichols, and C. D. Paice, 'Browsing is a collaborative process', *Inf Process Manage*, vol. 33, no. 6, pp. 761–783, 1997.

[8] A. Tang, M. Tory, B. Po, P. Neumann, and S. Carpendale, 'Collaborative coupling over tabletop displays', in *Proceedings of the SIGCHI conference on Human Factors in computing systems*, New York, NY, USA, 2006, pp. 1181–1190.

[9] A. Tang, C. Neustaedter, and S. Greenberg, 'VideoArms: Embodiments for Mixed Presence Groupware', in *People and Computers XX — Engage*, N. Bryan-Kinns, A. Blanford, P. Curzon, and L. Nigay, Eds. London: Springer London, 2007, pp. 85–102.

[10] S. Brave, H. Ishii, and A. Dahley, ‘Tangible interfaces for remote collaboration and communication’, in *Proceedings of the 1998 ACM conference on Computer supported cooperative work - CSCW ’98*, 1998, pp. 169–178.

[11] P. Tuddenham and P. Robinson, ‘Distributed Tabletops: Supporting Remote and Mixed-Presence Tabletop Collaboration’, in *Second Annual IEEE International Workshop on Horizontal Interactive Human-Computer Systems, 2007. TABLETOP ’07*, 2007, pp. 19 –26.

[12] B. Shneiderman, *Designing the User Interface, 3rd Ed.*, 3rd ed. Addison Wesley, 1997.

[13] D. Te’eni, J. M. Carey, and P. Zhang, *Human-Computer Interaction: Developing Effective Organizational Information Systems*. John Wiley & Sons, 2006.

[14] ‘ISO 9241: Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems.’ [Online]. Available: http://www.iso.org/iso/iso_catalogue/52075. [Accessed: 21-Jan-2013].

[15] V. Ha, K. M. Inkpen, T. Whalen, and R. L. Mandryk, ‘Direct Intentions: The Effects of Input Devices on Collaboration around a Tabletop Display’, in *Proceedings of the First IEEE International Workshop on Horizontal Interactive Human-Computer Systems*, Washington, DC, USA, 2006, pp. 177–184.

[16] M. Morris, ‘Supporting Effective Interaction with Tabletop Groupware’, Stanford University, 2006.

[17] J. S. Olson, L. Covi, E. Rocco, W. J. Miller, and P. Allie, ‘A room of your own: what would it take to help remote groups work as well as collocated groups?’, in *CHI 98 Cconference Summary on Human Factors in Computing Systems*, New York, NY, USA, 1998, pp. 279–280.

[18] J. S. Olson and S. Teasley, ‘Groupware in the wild: lessons learned from a year of virtual collocation’, in *Proceedings of the 1996 ACM conference on Computer supported cooperative work*, New York, NY, USA, 1996, pp. 419–427.

[19] D. Eseryel, R. Ganesan, and G. S. Edmonds, ‘Review of computer-supported collaborative work systems’, *Educ. Technol. Soc.*, vol. 5, no. 2, p. 2002, 2002.

[20] M. E. Bratman, ‘Shared Cooperative Activity’, *Philos. Rev.*, vol. 101, no. 2, p. 327, 1992.

[21] G. M. Olson and J. S. Olson, ‘Groupware and computer-supported cooperative work’, in *The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications*, L. Erlbaum Associates Inc., 2003, pp. 583–595.

[22] M. R. Morris and F. Vernier, ‘Beyond “Social Protocols”: Multi-User Coordination Policies for Co-located Groupware’, *ACM*, vol. 6, no. 3, pp. 262–265, 2004.

[23] P. Tuddenham, I. Davies, and P. Robinson, ‘WebSurface: an interface for co-located collaborative information gathering’, in *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, New York, NY, USA, 2009, pp. 181–188.

[24] E. Beheshti, A. Van Devender, and M. Horn, ‘Touch, click, navigate: comparing tabletop and desktop interaction for map navigation tasks’, in *Proceedings of the 2012 ACM international conference on Interactive tabletops and surfaces*, New York, NY, USA, 2012, pp. 205–214.

[25] M. Basheri, L. Burd, and N. Baghaei, ‘A multi-touch interface for enhancing collaborative UML diagramming’, in *Proceedings of the 24th Australian Computer-Human Interaction Conference*, 2012, pp. 30–33.

[26] M. Basheri and M. Munro, ‘Enhancing the quality of software design through multi-touch interfaces’, presented at the Frontiers in Education Conference (FIE), IEEE, Madrid, 2014, pp. 1–7.

[27] P. Isenberg, D. Fisher, S. A. Paul, M. Ringel Morris, K. Inkpen, and M. Czerwinski, ‘An Exploratory Study of Co-Located Collaborative Visual Analytics around a Tabletop Display’, *IEEE Trans. Vis. Comput. Graph.*, vol. 18, no. 5, pp. 689–702, 2012.

[28] M. Basheri and L. Burd, ‘Exploring the significance of multi-touch tables in enhancing collaborative software design using UML’, in *In proceeding of: 42nd ASEE/IEEE Frontiers in Education Conference*, Seattle, Washington, USA, 2012, pp. 735 –739.

[29] P. Dourish and V. Bellotti, ‘Awareness and coordination in shared workspaces’, in *Proceedings of the 1992 ACM conference on Computer-supported cooperative work*, New York, NY, USA, 1992, pp. 107–114.

[30] C. Gutwin and S. Greenberg, ‘Design for individuals, design for groups: tradeoffs between power and workspace awareness’, in *Proceedings of the 1998 ACM conference on Computer supported cooperative work*, New York, NY, USA, 1998, pp. 207–216.

[31] C. Gutwin and S. Greenberg, ‘A Descriptive Framework of Workspace Awareness for Real-Time Groupware’, *Comput Support. Coop Work*, vol. 11, no. 3, pp. 411–446, 2002.

[32] A. Field and D. G. J. Hole, *How to Design and Report Experiments*. Sage Publications Ltd, 2003.

[33] J. Lazar, J. H. Feng, and H. Hochheiser, *Research Methods in Human-computer Interaction*. John Wiley & Sons, 2009.

[34] T. Manninen, ‘Towards Communicative, Collaborative and Constructive Multi-player Games’, in *Computer Games and Digital Cultures Conference*, Tampere, Finland, 2002, pp. 155–169.