Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 22 (2013) 113 – 122

Procedia Computer Science

17th International Conference in Knowledge Based and Intelligent Information and Engineering Systems - KES2013

Discusys: Multiple User Real-time Digital Sticky-Note Affinity-Diagram Brainstorming System

William Widjaja[a,*], Keito Yoshii[a], Kiyokazu Haga[a], Makoto Takahashi[a]

[a]*Tohoku University, Aobayama Campus 6-6-10 Aramaki Aza Aoba, Sendai, 980-8579,, Japan*

Abstract

Traditional-based brainstorming using sticky notes has been an integral part in many collaborative group discussion environment.Yet, despite the advancement in technology and the increased research effort to use technology to support group brainstorming, many groups still continues to relies on conventional paper-based discussion methods to generate, structure and communicate their ideas with each other. Discusys is a discussion support system that aims to augment the participants capabilities in group brainstorming by implementing 1. separation of private and public area during initial idea generation to allow ideas to mature without judgment of others 2. quick input and navigational design to help users to create, edit, view and manipulate the group generated ideas. 3. multi-platform synchronization technology to create a real-time visual information of the current status of the discussions which can be accessed by multiple users. Discusys utilized a dual-monitors PC client that separates the private and public dashboard, real-time network socket infrastructure to allow multiple users from different clients to interact with each other under one discussion ecosystem and multi-touch capabilities to create a natural, deep and structured collaborative discussion for multiple-users.

Selection and peer-review under responsibility of KES International

Keywords: Human Factors; Design; Measurement; CSCW; Brainstorming; Affinity-Diagram; Idea-generation; Collaboration

1. Introduction

Brainstorming is one of the most effective technique for a group to enhance creativity and generate ideas[1]. Affinity-diagram activities also helps teams to group and link their collective thoughts into a clear and understandable structure[2]. Beyer et al.[3] claim that affinity-diagramming is well suited for team-based data analysis. Most brainstorming sessions are conducted in a single located group situation[4] and Diehl et al.[5] claimed that the numbers of ideas generated is significantly higher and wider when working in group rather than individuals. It is reported that the key contributing factors in reducing the effectiveness of brainstorming is 1) Fear of negative evaluation which results the participants to withhold their ideas to themselves [6] . 2) Production blocking where users do not write down their ideas fast enough during discussion as a result ideas are not longer relevant and original [7]. 3) Weak idea output where ideas generated are shallow and unsupported by sources which resulted in difficulties for others to understands and accept the authors' ideas [8] .

*Corresponding author. Tel.: +81-90-2988-0647; fax: +81-22-795-3865.
E-mail address: william.widjaja@most.tohoku.ac.jp.

Selection and peer-review under responsibility of KES International
doi:10.1016/j.procs.2013.09.087

Traditional brainstorming activities are usually conducted using pens, sticky notes and whiteboard. However, in recent years, many research institution have conducted research to development and build solutions to improve the effectiveness group brainstorming using electronic system. Though, computer assisted brainstorm offer many advantages. Yet despite these benefits, computer-assisted brainstorming system also face many challenges yet to be solved. These activities typically include the following work flow 1) searching and gathering of information 2) Idea generation by converting thoughts to recorded text 3) refining of ideas where ideas are improved after group interaction. In this paper, we aim to introduce a prototype system to effectively support this brainstorming work flow. Discusys is a multi-users multi-platform discussion support system. It aims to leverage the technologies of current generation of consumer devices, multi-touch display technology and proprietary network socket server technology to create a real time multi-platform synchronized discussion support system. Discusys system aims to solve some of the problem faced by traditional brainstorming by employing these design goal. Firstly, to reduce negative idea evaluation anxiety a separate private and common information dashboard is divided to give users privacy to explore their ideas first before sharing with others[9]. Secondly, reducing production blocking by designing a quick input user interface system to empower users to quickly creates and edit their ideas to the system database. Finally, a common interactive public space to allow multiple users to naturally manipulate their ideas and create meaningful affinity-diagram to group and link similar and connected ideas together.

1.1. Other related works

In recent years, there are various researches that aims to solve some of the issues hindering the productivity of digital brainstorming. Four research papers have influenced the design of Discusys . They are 1. Hilliges et al.[10] which developed a digital brainstorm system where users are able to cluster and link generated idea collaboratively, giving group participants ability to create a clear structure visual graphic of their collective ideas. 2. Drew Harry[11] designed a tablet application to allow users a private dashboard interface to input thoughts and ideas at the back end while discussion is on-going thus thus allowing users to record their opinion and thoughts without interrupting the flow of discussion. 3. AffinityTable by Geyer et al. [12] which proposed using a private working space for input and editing while maintaining a public visual space for an overview status of the affinity diagram. 4. Proxemic Brainstorm which proposed a cross-platform synchronized system of personal hand-held devices and public digital board to enable multiple users to create, edit and manipulate ideas collaboratively [13]. The above research papers play a strong a strong influences in the creation and development of discusys.

2. System development background

Discusys is a multi-users real-time digital sticky note brainstorming system that aims to give users a personal space to create and curate their ideas while allowing them to also have intuitive control of their ideas in public common spaces during collaboration. In addition, Discusys also utilizes commonly available off-the shelf available consumer technology, multi-touch gestured-based monitor and standard database server and wireless technology to create this digital discussion solution. The development of Discusys has been created in Tohoku University Human Factor Lab, utilizing the latest agile methods in software development engineering and strict usability testing methodology to achieve a consistent development pace. The team focuses only on using easily available technology on the available market and leverages with highly designed software development capabilities to create a high-quality product with superior user experience for supporting group discussion.

2.1. Tohoku university discusys system overview

Discusys utilizes multiple client synchronization technology to separate both private spaces while maintain interactivity with public spaces. Each client consists of a 13.3-inch Windows 7 powered Laptop with a standard laser mouse and is connected with Wi-Fi Internet network connection for accessing Internet and the server database. In addition , the client monitor is extended to a secondary 22-inch secondary monitor installed with Infra-Red light emitter at the top corner of the monitor which acts as a touch sensor to create multi-touch capabilities for users. In addition, Pixel Sense SDK is used to allow monitor sensor to be read by the Windows 7 HID touch framework for multi-touch capabilities. The server system also acts a moderator clients which is equipped with a 32 inch

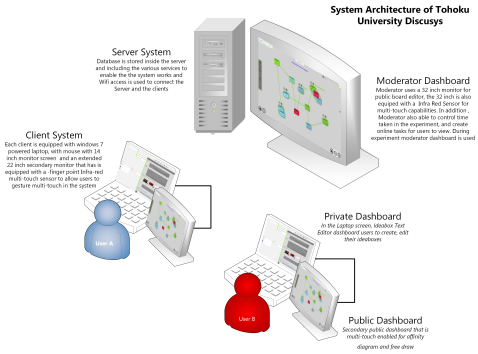

Fig. 1. Overall system architecture for Discusys with overall experience

monitor for the moderator to presents the experiment subjects important information during the experiments. It is also being equipped by Windows 2008-based server equipped with 2012 Microsoft SQL, ASP.Net ,MVC for database. architecture, Photon Engine for real-time synchronization and a dual band 2.4 Ghz wireless access point for multiple clients networking system.

2.1.1. Backend infrastructure overview

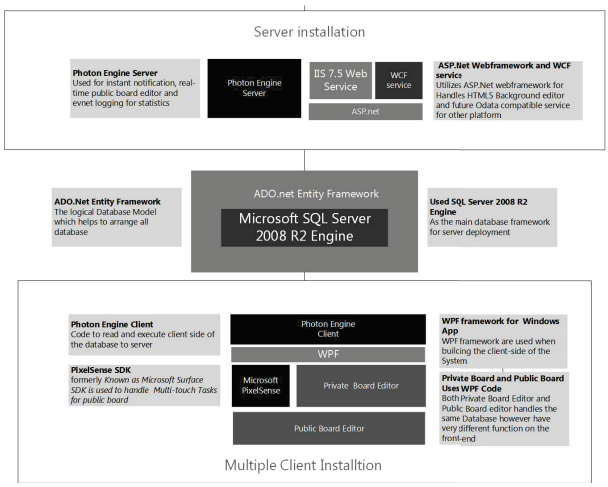

Fig. 2. Architecture Model of the Discusys System technology-stack

Software is mainly developed under the Microsoft .Net 4.5 Framework and C# language is the main language for the development of the solutions. The technology stacks include Microsoft SQL 2008 R2, Photon Networking Engine, ASP.Net , IIS 7.5 WPF, WCF, ADO.Net Entity framework and Pixel Sense SDK previously known as Surface 2.0 SDK. All data are a single database utilizing Microsoft SQL Server 2008 R2 Engine for all experimental sessions throughout system installation's lifetime and Clients utilizes WPF framework to access the database directly via the ADO.Net Driver and Entity Framework. In addition, the Database also utilizes WCF data services for accessing some web services provided by the moderator system. Asp.net web application and is hosted within IIS 7 web server. Besides hosting data service, it also hosts a couple of web handlers. One handler serves content of HTML5 version of discussion background created by moderator. In addition , Pixel Sense SDK

previously known as Microsoft Surface 2.0 SDK are stacked on top of the WPF-framework client to handles all multi-touch tasks. These component are deployed under a single physical server system.

2.1.2. Real-time synchronization Technology

To synchronize events and operations between severs and multiple clients, Discusys relies on using network socket infrastructure called Photon Engine created by Exit Games. It's typically designed for MMOG and provides reliable low-latency data transport services on top of user datagram protocol (UDP). Photon can also be considered as Remote Procedure Call (RPC) system and server-side runtime for Application logic.The basic concept behind Photon Engine is it acts as a delivery medium of code execution and callback between multiple clients and servers. Example if client calls some code on server side, the server side code executes and (perhaps) returns some arguments back to the client. The benefit of Photon is that it serialize the code logic by packeting it to small size byte of integers and create continuous call for event update (approximately 10 times per second) to simulate a real-time synchronization behavior. Without photon, we would have to use with network packets directly (either using TCP/IP or UDP sockets). This cause of inefficiency of code execution stream which will increase high latency in the system. Photon handles all instant notification needs including 1) All updates created both by moderator and multiple users 2) All operations of public board editor (interactive user cursors, moving and editing any shapes) are based on Photon notification logic 3) Logging statistics of operations for further analysis.Thus, in summary server application will process all Discusys main functions and automatically update any changes made to the SQL server database in real-time.

2.2. Front-end software explanation

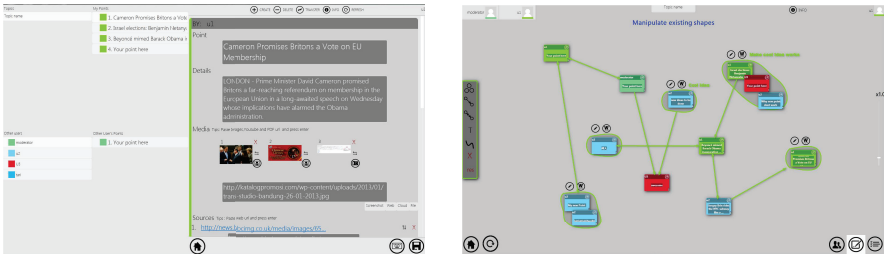

Fig. 3. (A) Three column user interface design for the private dashboard and (B) user Interface design for the public dashboard with ideaboxes, cluster and link.

The front-end of the system is developed under the Windows Presentation Foundation (WPF) and Blended for UI framework. When users participate in the experiment, they will see 2 monitor client at the left side of the monitor will display the (A) Private Dashboard which focuses on user personal space which allows users to create, edit of points privately which also have the ability to view other person points and at the right side of the monitor (B) Public Dashboard allows users to arrange and zoom the user point arrange, cluster link and free draw.

2.2.1. Moderator and private editing dashboard

Before starting any discussion, moderator would need to create a discussion session room and the discussion information background, the background is created using rich HTML5 coding which allow users to attach images and URL sources for more in-depth understanding, Moderator will also need to create color choice ID (which color is available to the users) and assign users which topic that they should be assign in. Users first need to enter their username and select a color that will symbolize their visual identity that will differentiate the user identity with other participants. In private editing dashboard, the user interface has three column layout to help users control the information in their own private dashboard. First column is the discussion topic name and other user list, second column is the user point list and third column is the in depth information of the users' point. Basic button such as create, delete, refresh and save are displayed at the top UI. Users are able to create point and write an in-depth description of the point at the third column of the UI. In addition to the descriptive input capabilities, function of adding sources and media attachment which include, images, screen shot, PDF and office documents

are is also provided thought this functionality is not heavily experimented in this paper. When users create points in private dashboard, the point will be automatically displayed as boxes with the users color id at the at the public dashboard. This is to simulate a Sticky-Note look on the public dashboard and for simplicity sake , we decided to call this icons as ideaboxes.

2.2.2. Public multi-touch digital board

Public Dashboard system screen is located at the secondary extended monitor which act as a second screen and is multi-touch capable allowing users to manipulate public board using multi-touch gesture. Whenever new ideaboxes is change or edited , photon will update the changes automatically without saving. Public board is fixed at 1080 resolution and used the cartesian system coordinate to measure the position of the ideaboxes. Using Photon network engine technology, it broadcast the position of the ideaboxes publicly to all clients, When changes of position is initiated by users, the new movement is send to server where server will broadcast the changes to other clients to update the position changes, this logic helps to create the real-time synchronization across all board.

Affinity diagramming which is also known as the KJ Method [2] is commonly used as brainstorming tools for groups to organize and helps users to structure and create a meaningful groups and link between their collective ideas. There are few functions in the public board to augment users ability in creating affinity-diagram.

1. **Free Draw** - Users are able to create free draw using the WPF ink canvas technology and using synchronization technology, it also broadcasts the free draw vector and coordinates to other clients resulting in a synchronized drawing board across all platform.
2. **Clustering** - Clustering is the ability to intelligently group ideaboxes using a bezier spline curves gesture. Users are able to group the ideaboxes together by performing a circular gesture. Once the ideaboxes is clustered, the ideaboxes are bounded by the groups and when user move the clustered groups, all the ideaboxes in the cluster simultaneous moved together. In addition, when single ideaboxes is remove or added from the cluster, the cluster reformed its shapes to the remaining ideaboxes
3. **Linking** -Linking system will link and bound multiple ideaboxes or cluster with an arrow links. To create links users need to enable the link button and by touching/clicking the first ideaboxes and the second ideaboxes, an automated arrow link will bound the two ideaboxes. When users move the ideaboxes, link automatically follows the ideaboxes so not to break between the two ideaboxes

This public board functionality helps users to create affinity-diagram easily and effectively and to prove the advantages of the discusys system, formal usability experiment was conducted fusing traditional white-board as a comparison to prove the system capabilities

3. Experimental condition

We hypothesize that discusys will enable groups to more effective and produce a higher quality discussions for problem-solving brainstorming activities and to prove our hypothesis, we set up two discussion conditions and invite subjects to participate in a typical problem solving sessions. One condition of brainstorming will be called the digital conditions where brainstorming takes place by utilizing the full discusys system and and another condition which will act as as comparison and control experiment will be called analog condition where mainstream tool are utilized to aid discussion such as sticky-note and whiteboard.

3.1. Analog condition and digital condition

In order to promote fairness between the two conditions, experiment are designed to give experiment subjects similar capabilities in both conditions. In this section, we will explain in details the difference between the two conditions. In analog condition, subjects are provided with a specific colored sticky-note that defined their color identity , a similar color marker pen is also provided and subjects are given Internet access for helping the subject to research online sources to support their ideas and a common white board are provided for the group to create their affinity diagram collaboratively. In digital condition, subjects are given a dual display-monitor computer system where at the left- side of the display show their private editing dashboard, while at the right-side show

their public discussion dashboard, the computer system is also connected to the Internet for subjects to research for online sources. At the left-side of the experiment, users are able to create and edit their points and description and at the right side of the experiment, users are able to use the synchronized public dashboard, they are able to arrange the positions of the ideaboxes, view other users ideaboxes and create groups and links to create a collaborated affinity-diagram of the collective ideas.

3.2. Experiment methodology

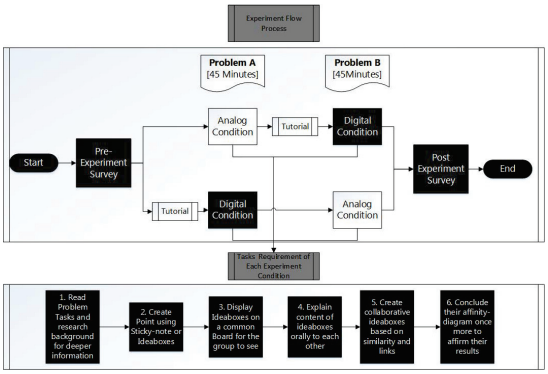

Fig. 4. Experiment design flow and Tasks

The experiment is designed to compare group discussion under two different conditions, experiment subjects are given tasks to solve two similar problem scenario to solve (Problem A and Problem B) . They are asked to gather intelligence, present ideas to others and conduct a collaborative affinity diagram to find the common group and link of their ideas between themselves within a space of 45 minutes. In this experiment, two recent controversial local news about lack of public trust towards the government are used for the problem case in our experiment . In problem A, subjects asked tasked to brainstorm ideas on how to increase public trust in the government regarding recent demonstration about policies to reduce subsidies for national oil. While in problem B, subjects are similarly asked to brainstorm ideas on how to increase public trust in government after recent news reported that some government official brought their families on holiday while on official business, at the tax payers expenses.

Before the experiment started, subjects participated in pre-experiment survey where subjects' previous experiences in group discussion are quantify in a self-reporting survey. Once subjects completed the survey, the groups are randomly drawn to start either with Problem set A or B. This is to prevent biasness and to promote fairness throughout the experiment. When subjects starts from the analog conditions, subjects are explained about their tools and the structure of the discussions flow. However if they start with digital conditions, a full tutorial about all the function of the system are explained and demonstrated. Subjects are also given a mock run to ensure that they do know the functions of the systems and were only allowed to proceed when they gained enough confidence . Once they are ready, subjects were asked to read the problem tasks and the requirement of the experiment. Upon understanding both system functions and tasks required, subjects are then given 45 minutes to do a non-moderated, non-structured discussion. In the 45 minutes discussion, subjects are required to write down all their points and thoughts in a sticky-note or ideaboxes, . Once subjects completed their written points, they need to put their points on a common board. Under analog condition, subjects have to stick their sticky-note on a white-board, while in digital condition, the system secondary screen automatically display the ideaboxes. Then subjects are asked to present their ideaboxes to each other to ensure that the other parties understood the points and ideas inside the ideaboxes. After understanding both parties points, subjects are then asked to do a collaborative affinity-diagram of the points by grouping and linking similar points they might have. Finally, once they completed both of their experiment tasks, they will be ask to complete the 5-point rating scale self-reporting survey to quantify their positive or negative experience during the experiment. In the next section, we will further discuss about the methodology and observation.

3.3. Measurement methodology

The goal of the experiment is to validate that by using discusys, discussion will be more effective and productive and will lead to a higher satisfaction in the quality and the result of the discussion. To prove the hypothesis, Experiment subject must rate and compare their experience a number of usability and satisfaction metrics. The Survey questionnaire are based on a 5-point likert-scale measurement where subject are asked to rate their perception on a specific metrics ranging from 1-point being the most negative to the 5-point being the most positive. We assumed that the survey are normally distributed and use variable mean and standard deviation to compare the two conditions. We also calculated the confidence interval up to 95% to find its Lower and Upper margin CI. We also calculate the probability of standard error using the inverse distribution methods and finally to compared the two conditions using paired t-test analysis . We also calculated the P-value to determine whether there is any statistically difference between the two groups.Observation reporting are divided into 2 groups. The first group called usability control measurement focuses on the ease of use in completing the basic tasks and the second group called satisfaction rating measurement focuses on the subjective perception on the user satisfaction of the discussion.

1. **Usability control** - We asked we asked subjects to rate and compare between the usability of basic functions of create, edit and manipulate between two conditions on which of the two conditions is the easier to use.
2. **Satisfaction rating** - We asked subjects to judge and rate their personal perception on the difference quality between the two conditions. We also ask about how much subjects understand other parties point of view , their perceived the satisfaction towards the the results generated by the two conditions and to conclude we ask the subjects to rate their explicitly overall experience thoughts when participating discussion on both the discussions conditions.

4. Observation

There are a total of [N=18] experiment 11 men and 7 woman that participated in this experiment. The experiment subjects are recruited through a mailing list in the university club and comprises mainly a mix of undergraduate and graduate students from the faculty of engineering and liberal arts. These experiment participants are divide into groups comprising of 2 person per session with each session running up to 4 hours each. During the experiment, subjects are usually paired randomly and experiment design and task are not provided in advance so that all subjects will have equal time to learn and complete the experiment tasks. Subjects are asked basic questions including their previous experience group discussion, the frequency they participate in the formal group discussion, their basic behavior and perception about their past experience during group discussions. Here are some basic overview on the subjects prior experience.

- **Previous training**-In the survey, we asked subjects whether they previously had formal training in leading group discussion. 61.1% (N=11) claimed that they somehow have formal training on leading group discussion while the rest 38.9% (N=7) claimed no such training.
- **Frequency of Discussion**-Pre-survey asks about the frequency of subject participation in formal group discussion subjects participates per month. 66.6% claims they participate approximately 1-4 discussion per month, while the remaining 27.8% claim they participate 5 or more times of discussion per month, one subject claimed that they participate less than 1 discussion per month.
- **Supporting Tool for discussion**- In this measurement, we asked subjects what is their normal technique when they do group brainstorm 61.1% (N=11) claimed that they usually use white-board and marker during discussion , while 16.7% (N=3) of the subject use paper and pen, while another 16.7% (N=3) utilizes sticky-note and white-board during discussion. 1 subjects claimed to use computer-assisted software when doing group discussion.

The pre-experiment survey shows that more than half of the experiment subjects encompasses some formal training to participate and lead in group discussion and have on average participates more than two formal group discussions per month. During discussions, the majority of the group rely on low fidelity traditional analog tools

such as sticky-note white-board and paper for supporting group discussion. Thus, it is fair to say that the experiment group on average is capable of conducting formal group discussion and have no prior experience in using technology to support their discussion effort.

4.1. Measuring perception on system usability

In this measurement, the test aims to find the user perception on their ability to create, edit and manipulate the discussion points between the two conditions. In order to find out the difference, self-reporting survey question asked subjects to rate their perception on ease of creating point, flexibility to change and manipulate point and affinity-diagram and finally a psychological judgment on their own ability to control the discussion point between the two conditions. In analyzing the result from the survey, assuming the data is normally distributed, paired t-test

Table 1. Descriptive statistics and paired t-test self-reporting survey results for usability control

Measuring Usability Control										
	Descriptive Statistics					Paired T-test Statistics				
Create Point	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.33	0.84	2.92	3.75	12.53%	0.56	0.07	1.04	2.3965	0.02833
Digital	3.89	0.68	3.55	4.23	8.65%					
Arranging Point	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.11	1.02	2.6	3.62	16.35%	1.67	1.22	2.12	-4.2764	0.00051
Digital	4.50	0.71	4.15	4.85	7.81%					
Create Draw	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.94	0.64	3.63	4.26	8.06%	-0.44	0.018972	0.86991	2.203893	0.04160
Digital	3.50	0.68	3.04	3.96	13.12%					
Editing Draw	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	2.89	1.18	2.30	3.47	20.36%	1.11	-1.83253	-0.38969	-3.24946	0.00471
Digital	4.00	0.58	3.82	4.4	7.05%					
Manipulation	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	2.89	1.08	2.35	3.43	18.57%	1.22	0.67	1.78	-4.6532	0.00022
Digital	4.11	0.58	3.82	4.4	7.05%					

was conducted over these few metrics to determine the users perceived usability and control of the discussion. In creating discussion ideaboxes ,there is a significant difference in the mean for analog (M=3.33, SD=0.84) and Digital (M=3.89, SD=0.68) conditions; t(17)=2.3965, p = 0.002. These results suggest that it subjects felt easier to create discussion point in digital condition compared to analog condition. When asked about their perceived ease of arranging the points, there was also a significant difference in mean score for analog condition (=3.11,SD=1.02) compared with digital condition (M=4.50, SD=0.71) ;t(17)=-4.2764, p = 0.0005. This concludes that it is easier for subjects to arrange their point in the digital multi-touch board compared to the traditional White board. When measuring the ease of draw during discussion, the results shows there subjects find drawing in analog white-board (M=3.94,SD) condition is easier compared to to digital board (M=3.50,SD=0.68) condition ; t(17) =2.203893, p= 0.04. However when asked about the ease of editing their drawing, results suggest otherwise, stating that redrawing is harder in analog (M=2.89,SD=1.18) condition compared to digital (M=4.00, SD=0.58) ; t(17) =-3.24946, p=0.004. In addition, while creating affinity-diagram, paired t-test also shows there was a huge significant difference between using analog condition (M=2.89,SD=1.08) and digital condition (M=4.11, SD=0.58) ;t(17)=-4.6532, p = 0.0002. These difference suggests that creating affinity-diagram in digital condition is significantly easier compared to the traditional analog condition. These results suggest that digital condition benefits, while it has not achieve the similar natural feel of free drawing in traditional white-board, it provides a superior editing and manipulating capabilities for subjects to manipulate and control their discussion points.

4.2. Measuring satisfaction on discussion quality

In this section, the survey are design to question the subjects perception on the quality of the discussions during the experiment. The survey measure three self-reporting questionnaire including, their ability to understand the discussion contents, their perceived quality of the discussion and their satisfaction of the final results of the

discussions. Subjects are asked also to rate their subjective overall discussion experience. After completing their 5-point rating scale survey, paired-samples t-test is performed to find the significant difference between the two conditions.

Table 2. Descriptive statistics and paired T-test self-reporting survey results for quality satisfaction

Measuring Satisfaction of Quality										
	Descriptive Statistics					Paired T-test Statistics				
Mutual Understand	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.39	0.85	2.97	3.81	12.41%	0.50	-1.231	0.23	-1.4477	0.1658867
Digital	3.89	1.02	3.38	4.40	13.08%					
Productivity	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.17	0.99	2.68	3.66	15..47%	0.94	-1.59	0.3	-3.0708	0.006924
Digital	4.11	0.58	3.82	4.40	7.05%					
Perceived Quality	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.33	0.59	3.04	3.63	8.86%	0.67	0.25	1.08	-3.365	0.003664
Digital	4.00	0.59	3.7	4.3	7.81%					
Satisfaction Result	Mean	StDev	Lower	Upper	Std Error	Mean. Diff	Lower	Upper	t	P-value
Analog	3.22	0.65	2.9	3.54	9.98%	0.78	0.31	1.25	-3.5	0.002744
Digital	4.00	0.59	3.7	4.3	7.39%					

We assumed that the resulted are normally distributed and after testing for its confidence interval and determining its Lower and upper CI and p value, we conducted paired t-test based on mean of the variable. During post experiment survey, we asked subjects about their ability to understand the content of the discussion, there is a ,mean difference between the analog condition (M=3.39, SD=0.85) and digital condition (M=3.89, SD=1.02) ; t(17)=-1.4477, p = 0.1658867. However, we fail to reject the null hypothesis because of P-value is more than 0.05, thus we are unable to statically conclude that there is a difference on user ability to mutually understand the content of discussion between the two conditions .When asked about their perceived opinion on the productivity level between the two conditions, there is a significant difference between Analog condition (M=3.17,SD=0.99) and Digital condition (M=4.11, SD=0.58) ; t(17)=-3.0708, p = 0.006924 and this results suggests that experiment participant felt more productive while performing their task on digital condition compared to analog condition. However, when measuring the subjects' perceived quality on the quality of discussion, there is a statistically difference between analog condition (M=3.33,SD=0.59) and digital condition (M=4.00,SD=0.59) ;t(17)= -3.367, p =0.0036639 . The results suggest that subjects perceived that Discussion on digital condition provides a higher quality discussion compared to analog conditions. Finally when asked about the satisfaction about the results they generated after the discussion, there is a significant difference between the analog condition (M=3.22, SD=0.65) and digital condition (M=4.00, SD=0.59) ;t(17)= -3.5, p =0.002744. This results suggests that subjects felt more satisfied with the final results while performing their task on the digital condition compared to the analog condition.

4.3. Discussion

Based on the paired-samples t-test results, it is concluded that with the assistance of Discusys, results shows that subjects have benefited from discusys functions in having a better controls of creating, editing, arranging and manipulating of their idea points compared to traditional tools. The result also suggests that subjects felt that free drawing in traditional white board is easier than discusys system. However Discusys functions of Editing free draw provides better capabilities for subjects to edit and manipulate free draw. Arranging functions in discusys which is used during affinity-diagram activities, gives subjects significantly more control compared to analog method that resulted in user perceiving to have higher productivity. In addition combining all the discusys features functions that gives users superior speed and control of their discussion points leads to an increase satisfaction in the overall experience and results of the discussions. Finally, to firmly affirm our results , we asked subjects to explicitly select the better experiment conditions that helps them to complete their tasks more effectively. Our results shows that out of the N=18 subjects, 88.9% [N=16] has a preference on selecting Digital condition with Discusys as the center of the discussion as the main discussion support system citing that computer-assisted technology helps

them to quickly create, manipulate and manage their discussion point more effectively than traditional methods of discussion ,while 11.1% [N=2] prefers the traditional discussion condition citing that it is the first time that they used a computer-assisted discussion system and feels more comfortable using traditional methods of discussion using paper and pen.

5. Conclusion and future research direction

This paper is part of an ongoing research that aims to validate discusys as a potential technological innovation to augment user capabilities in conducting a more higher quality and productive group discussion, while conducting previous experiment we discovered many functions that discusys could be developed to further improve the user capabilities in conducting discussion. There are functions that discusys is currently on development, this include the ability to attach on line sources in ideaboxes to further increase the depth of the discussions and comment system to increase the number of recorded communication discussion to promote collaboration. The next plan experiment will also include further test on performance metrics such as time-taken to complete the tasks and task success rate to further prove the validity of the system benefits for supporting group discussion in problem solving and affinity-diagram. While, there are many other researches and solutions out there that has made progress in supporting productivity and quality of group discussions by leveraging advanced interaction technology and new techniques. Discusys direction of research is focused on leveraging current track-proven matured technology such as multi-touch and network socket engine while building the system. Discusys continuous iteration design is based on the result of observation of users behavior when interacting with currently available technology and build a well design user interface flow to create the best supporting technology for users to augment their capabilities in group discussion. Discusys hopes that by offering alternative design direction, backed by strong usability-test, new meaningful innovation could be born in the system that could potentially provide an essential technical assistance in supporting group discussion.

Acknowledgments

We would like to extend our gratitude to Tohoku University for providing laboratory facilities, Japanese MEXT for government funding and scholarship, the team from Elsevier who provided the latex format and for KES organizing International committee for organizing the conference.

References

[1] A. F. Osborn, Applied Imagination; Principles and Procedures of Creative Problem-solving: Principles and Procedures of Creative Problem-solving, Scribner, 1963.
[2] J. Kawakita, The original kj method, Tokyo: Kawakita Research Institute.
[3] H. Beyer, K. Holtzblatt, Contextual design: defining customer-centered systems, Morgan Kaufmann, 1997.
[4] R. Sutton, A. Hargadon, Brainstorming groups in context: Effectiveness in a product design firm, Administrative Science Quarterly (1996) 685–718.
[5] M. Diehl, W. Stroebe, Productivity loss in brainstorming groups: Toward the solution of a riddle, Journal of Personality and Social Psychology; Journal of Personality and Social Psychology 53 (3) (1987) 497.
[6] B. Mullen, C. Johnson, E. Salas, Productivity loss in brainstorming groups: A meta-analytic integration, Basic and applied social psychology 12 (1) (1991) 3–23.
[7] T. Herrmann, A. Nolte, The Integration of Collaborative Process Modeling and Electronic Brainstorming in Co-located Meetings Collaboration and Technology, Vol. 6257 of Lecture Notes in Computer Science, Springer Berlin / Heidelberg, 2010, pp. 145–160.
[8] K. Nishimoto, K. Mase, R. Nakatsu, How an autonomous information retrieval agent affects divergent thinking by a group, JOURNAL-JAPANESE SOCIETY FOR ARTIFICIAL INTELLIGENCE 14 (1999) 58–70.
[9] H.-C. Jetter, J. Gerken, M. Zöllner, H. Reiterer, Model-based design and implementation of interactive spaces for information interaction, Springer, 2010.
[10] O. Hilliges, L. Terrenghi, S. Boring, D. Kim, H. Richter, A. Butz, Designing for collaborative creative problem solving, in: Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition, ACM, 2007, pp. 137–146.
[11] D. Harry, E. Gordon, C. Schmandt, Setting the stage for interaction: a tablet application to augment group discussion in a seminar class, in: Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work, ACM, 2012, pp. 1071–1080.
[12] F. Geyer, U. Pfeil, J. Budzinski, A. Höchtl, H. Reiterer, Affinitytable-a hybrid surface for supporting affinity diagramming, Springer, 2011.
[13] T. Ballendat, N. Marquardt, S. Greenberg, Proxemic interaction: designing for a proximity and orientation-aware environment, in: ACM International Conference on Interactive Tabletops and Surfaces, ACM, 2010, pp. 121–130.