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PARTICIPANTS' ATTENTION LEVEL IN REMOTE COLLABORATION TASKS

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ABSTRACT

Farhan Hossain: Participants' Attention Level in Remote Collaboration Tasks.
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This thesis aims at studying participants' attention level in remote collaboration tasks. The study focused on gaining insights on certain Remote Collaboration challenges that are commonly faced nowadays due to lack of communication cues. A research experiment study was conducted to address the focus area of the thesis. Two sessions of same experiment were conducted each comprising of 3 participants from Tampere University. At the beginning of the experiment, a lecture on *Social Entrepreneurship* was played among Participants, after which they were asked to perform a collaboration task on shared virtual environment called Mural board based on the topics from video lecture. ETU driver was used to collect Mouse Tracking data of each participant to plot their mouse movements against certain working areas at specific timestamps.

The study found that in most of the cases, participants' mouse movements were in alignment with the working areas of a task in the Workspace. However, certain differences were also observed due to different mouse movement behaviour of participants such as the one where a particular participant would try to comprehend all the information that are present in the screen using the mouse instead of performing an action. Hence it is not conclusive to the idea of measuring Participant's Attention level solely based on Mouse movements due to different mouse movement behaviours.

This thesis focused to understand if participant's can put their attention to the relevant areas where other collaborators are working. The results from this study may help to pave the way for further development of Remote Collaboration tools for better results. In summary, this study aimed to address the dawning concept of Remote Collaboration to provide insights on Participants attention level during the collaboration work.

Keywords: Remote Collaboration, Attention, Eye-Mind Assumption

PREFACE

I am immensely grateful to my thesis supervisor Päivi Majaranta for her constant support and guidance throughout the whole thesis work period. The idea of the thesis topic came while I was attending one of the courses of Päivi. Hence, when I proposed the topic, she was very supportive of it and encouraged me to pursue the thesis work. I can still recall, when I was struggling to come up with the design of the research study, it was Päivi who with great ideas and suggestions came to the rescue. Again, my sincere gratitude for her constant support and guidance.

I am also forever indebted to Oleg Špakov, without whom the research study would not have been possible the way it is. ETU Driver developed by Oleg was the fundamental element in measuring the experiment data. His constant support and guidance even with analysis of the data collected from ETU Driver was something that I would be forever grateful to.

It was particularly challenging to recruit participants for the experiment in due time. Hence, I express my warm gratitude towards all participants for investing their valuable time for this research experiment in short notice.

Last but not the least I am forever grateful to my family and friends, who constantly supported me throughout the whole Thesis Journey. Their constant love and prayers helped me to push forward and complete the Thesis work efficiently.

Tampere, 2 May 2024

Farhan Hossain

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1. INTRODUCTION

During recent years, method of learning among students have taken different approach. Factors such as social distancing due to Covid-19 also demanded more flexibility which has encouraged application of technological solutions for remote collaboration in learning methods. According to Douligeris et al. (2017), the focus has changed towards group work instead of individual efforts in recent years, which also demands smooth interaction among members and adaptation of technological solutions.

However, online group collaboration comes with its own share of challenges as well. During Covid-19, lack of interaction with fellow students and inefficient learning methods in online platforms were mentioned by students (Soria et al., 2020). Moreover, Visualization tools were not initially developed for collaboration purposes, rather they meant to provide viewing accessibility to larger audience (Douligeris et al., 2017).

When multiple participants work in conjunction to put cognitive efforts, then the method itself can be described as Collaboration (Green et al., 2008). It was also observed that Human mostly use certain modes of communication such as Speech, Gesture, Gaze for communicating with each other (Green et al., 2008). According to Kendon (1967) and Argyle (1967), Gaze influences in-person collaboration to great extent through specified visual cues, which in return helps to maintain concentration level. Hence, it is possible to understand the potential challenges that remote collaboration may encounter in the absence of certain in-person modality advantages.

It was observed that gaze fixation is very high when people work in pairs in remote collaboration compared to single person completing the same task due to constant following of peer members gaze cue (Wisiecka et al., 2023). According to D'Angelo et al. (2016) participants in remote collaboration work efficiently if the gaze cursor for other participants is displayed. However, smaller misalignment in eye tracking may cause confusion among participants while collaborating in a remote setting (D'Angelo et al., 2016). It was observed that people in remote collaboration felt there was less control over the task and more cognitively demanding than in person collaboration (Wisiecka et al., 2023).

It is evident from aforementioned studies that displaying gaze cursor of other participants often enhances the remote collaboration experiences. However, there still remains challenges where people may struggle when there are more than two collaborators. More

than two gaze cursors would potentially increase the overall inefficiency of the remote collaboration due to complexity of following specific gaze cues among several. For that reason, gaze or mouse movement tracking may reveal relevant insights on participant's visual attention level by highlighting their current focus area. Although Attention is a broader concept, this method is expected to provide at least some measurement of Attention level which can be analysed for collaboration efficiencies.

This thesis proceeded further with the presumption that participants in a remote collaboration are likely to struggle when there are multiple cursor cues to follow. A hypothesis was observed that participants would find it difficult to follow the stimuli locations without hints provided by other participants or the system. This study focuses on contributing to the broader future aspect of remote collaboration by addressing these research questions. Understanding participant's experience during remote collaboration and their attention level during the task would help develop the design of future remote collaboration tools.

This thesis focuses on scope of work for students, where they collaborate on specific task remotely using online tools. An experiment was conducted in two sessions, where each session consisted of three participants. The experiment was divided into two parts. In the first part, all participants watched a video lecture on *Social Entrepreneurship* together. In the next part, participants collaborated in Mural board, to sort some of the concepts based on the video lecture. Participants communicated over Zoom, a video communication platform for the whole experiment. During the collaboration part of the experiment, each participant's mouse movements were tracked using a Mouse Tracking Software. Several questionnaires were provided to participants to collect their feedback and experience after the study. The questionnaires focused on determining participants subjective attention and particular challenges if any during the experiment.

This thesis is constructed by multiple Chapters. The first chapter introduces the idea of the Thesis. Chapter 2 to 4 consists of literature review that are relevant to the thesis. Chapter 5 discusses more in detail about Motivation and Research Questions. After the research questions, methodology that is being used for the study is presented. Chapter 7 includes the research findings based on the data analysis followed by discussion and conclusion sections of the Thesis.

2. REMOTE COLLABORATION

Collaboration refers to the linked and affiliated activities among multiple participants who want to achieve a shared goal (Haubar, 2008). According to Schmidt (2002), Collaboration focuses on placing and merging participants activities in a coherent approach without affecting everyone's contribution. Educational Science refers to collaboration as an organized and integrated activity which accompanies individuals to achieve a shared goal and understand subject matters (Roschelle & Teasely,1995). Collaboration makes knowledge accessible to students through situated learning where they are expected to utilize their analytical and tactile capabilities (Stein,1998).

According to Marques et al. (2022) concept of collaboration has recently progressed from simple in person interaction to more multiplexed remote collaboration, enclosing multiple team members situated in different locations with different background and expertise. Remote collaboration is a dawning concept which needs to be spread among communities due to its technological advances and cost efficiency (Druta et al., 2021). According to Marques et al. (2022) Computer-Supported Co-operative Work (CSCW) has emphasized technological development for remote collaboration by the means of outlining and prototyping methods for communication, cooperation and learning between geographically different collaborators.

2.1 Awareness in Remote Collaboration

Based on the nature of collaboration work, it is important to be aware of activities performed by other collaborators in the work environment. Dourish and Belotti (1992) classifies this phenomenon as *awareness*, whereas other researchers have used different approaches to classify their focus (Schmidt,2002). According to Kim et al. (2018) some of the specific classification examples could be where Lauwers and Lantz (1990) defined *collaboration awareness,* Gaver (1991) referred to *general awareness* and Gutwin and Greenberg (1996) introduced *work-space awareness.*

Since this study focuses on remote collaboration with digital tools, *work-space awareness* definition introduced by Gutwin and Greenberg (1996), seems to be more prudent to the situation. According to Snowdon et al. (2000), workspace is the breeding ground for activities carried out during a collaboration. The phenomenon of awareness was further classified into three categories: *who* (e.g. existence and identity of other participants), *where* (e.g. activity area, gaze cue of participants), *what* (e.g. actual activities,

communication methods) (Gutwin & Greenberg,2002). Antunes and Ferreira (2011) and Ferriera (2011) further highlighted on *how* collaborators interact within the given work-space.

Moreover, remote collaboration requires a source of medium which would carry out communication proceedings and ensure awareness among participants (Olson & Olson,2000). According to Kim et al. (2008) and Olson and Olson (2000), medium for remote collaboration would highly correlate with the task. Schmidt (2002) suggests that video conferencing could be an effective source of medium with audio and video options. However, ensuring same level of awareness as in person collaboration would be difficult in video conference (Gutwin & Greenberg,1999).

According to Kim et al. (2008), awareness in remote collaboration can be enhanced by developing interfaces for conveying information. A collaboration workspace solution called Clearboard was invented by Ishii et al., (1992,1994), focusing on the purpose of sharing *gaze awareness* in workspaces. On another note, Kim et al., (2013) and Sakata et al., (2003) introduced *Pointers* to user interfaces as a communication cue, to indicate specific information for better workspace awareness. These research studies emphasise on the great influence of *awareness* in remote collaboration. In following Chapters, we would be further reviewing more specific topics such as Eye-mind assumption with relation to technologies such as gaze detection and mouse tracking.

2.2 Importance of Collaboration

According to Singh-Gupta and Troutt-Ervin (1996), effective collaboration prowess is recognized as a vital measure of success in education and professional environment. Zhang (1998) and Webb et al., (1998) suggests that collaboration impacts the cognitive growth among students. Based on Soller (2001) and Baghaei et al., (2007) observation, Collaboration has proven to be fostering student's responsibility, adaptation in addressing challenges and knack for inquiry and rationale. According to King et al., (1997), students absorb information in a different manner when working in collaboration environment in comparison to when they are working by themselves.

Van Boxtel et al., (2000) suggests, participation in collaboration allows students to improve their understanding through conversation and achieve mutual understanding through collaborative negotiation. Existing literature also implies that collaboration is important for developing *problem solving* and cognitive skills (Wittrock,1989). Collaborative effort in a convoluted chore can initiate supplementary ideas and mutual understanding

that would be difficult otherwise to attain without social interaction (OECD, 2013). According to Glaser (1992), encouraging students in collaborative work environment enhances advanced cognitive abilities such as *problem solving*. Darling-Hammond et al., (2003) suggests, participation in collaboration for addressing problems enables students to indulge in more in-depth thought processes about solutions throughout the interaction with peers. This in return enriches their conceptual understanding and effective task management skills.

2.3 Challenges in Remote Collaboration

According to Kuruppuarachchi (2009), Hertel et al., (2005) and Martins et al., (2004), Remote work that is convoluted in nature faces communicative difficulties in addition to leadership and trust issues. This phenomenon in return adversely affects the output of the work (Cramton & Webber, 2005). Richter et al., (2006) and Nurmi (2011) suggests that Remote work even incorporates feeling of extended cognitive load and sense of seclusion. According to Gibson and Cohen (2003), Lipnack and Stamps (2000), dispersedly located teams with limited in-person collaboration opportunities suffers from poor performance and process losses. According to Driskell et al., (2003), dispersedly located teams' retentiveness and task involvement gets affected in the form of technological arbitration.

Koehne et al., (2012) suggests, that remote collaborators often struggle to maintain their visibility with other team members. This requires additional effort in the form of communication to ensure their presence is visible, which in return may affect the overall work performance (Koehne et al., 2012). Raghuram et al., (2001) indicates, that clarity of work criteria is important in remote work environment and lack of clarity may constitute ambivalence which would influence the collaborator to chase misinterpreted goals. According to Azoulay et al., (2011), during initial stage of a project, when knowledge remains implicit and expressing ideas is strenuous, remote collaboration appears to be more challenging.

3. ATTENTION

Attention is the concept that helps human beings to allocate cognitive resources among interesting aspects of the world, hence perception of world relies heavily on attention (Anderson,2000). Welsh (2020) suggests that, although in essence *attention* may appear as a single resource, studies however indicate that it comprises a blend of capabilities. For instance, research with Traumatic patients implies that the capacity to allocate assets related to attention may get affected while the basic functions of attention may remain unaffected (Whyte et al., 2003). According to Welsh (2020), comprehending differences in attention among individuals can provide insight into the divergences observed in the decision taking skills.

Sohlberg and Mateer (1989) outlined a cognitive-based model of attention, which is categorized into five sections. Namely they are, *Alternating Attention*, *Sustained Attention*, *Divided Attention*, *Focused Attention* and *Selective Attention*. *Focused Attention* is the fundamental individual reaction to stimuli that is generated either from external or internal environment with inputs such as tactile, cognitive, visual or auditory. Sohlberg and Mateer (1989) indicates that, *Sustained Attention* is the persistent response to stimulus that is continuous in nature, which is mainly developed with certain elements namely 'Vigilance' and 'Working Memory'. 'Working Memory' indicates the cognitive capacity required to retain and manipulate information whereas 'Vigilance' entails maintaining a consistent response over a duration (Sohlberg & Mateer,1989). *Selective Attention* indicates the capacity to choose and concentrate on a certain stimulus while ignoring other internal or external stimuli. *Alternating Attention* indicates the capability to manage attentional resources for transitioning between cognitive tasks (Sohlberg & Mateer, 1989). Whereas *Divided Attention* is the capacity to parallelly address several cognitive inputs.

In this research study, we would be focusing on analysing participant's *Divided/Alternating Attention,* where they need to simultaneously communicate and perform certain tasks. Reason for focusing on these two attention levels is because, *Divided Attention* can be also considered as frequently alternating attention.

3.1 Joint Attention with Complexities

According to Tomasello (1999) and Trevarthen (1979), Joint Attention is the idea that allows us to collectively participate in shared experiences, harmonize our thoughts and actions which as a result helps to efficiently collaborate with others. Pöysä-Tarhonen et

al., (2021) suggests that Joint Attention Behaviour assists in effectively comprehending collaborative problem-solving (CPS), specifically its social dimensions from the perspective of remote one-on-one interactions. Graesser et al., (2018) and Funke et al., (2018), indicates that CPS is considered to exist in a dual framework enclosing both cognitive and social dimensions, which amalgamate through the problem-solving processes. Hence according to Roschelle and Teasley (1995) and Alterman and Harsch (2017), CPS encompasses both the cognitive tasks and social framework through which participants ideate and exchange knowledge, track their progress and rectify issues by the means of communication.

Barron and Roschelle (2009) found cooperation and negotiation of meanings both necessary in order to formulate 'if-then' problem solving guidelines while collaboratively resolving issues and building a mutual comprehension of a common subject. Schneider and Pea (2013) suggest that positive accomplishment of Joint Problem Solving is closely dependant on Joint Attention. Hence if Joint Attention cannot be achieved then it affects the build-up of common ground among participants (Baker, 2015) also affects consideration of other participants opinion (Moll & Meltzoff, 2011) and mutual ideation for proposing solution towards problems (Pöysä-Tarhonen et al., 2021). Hence, Joint Attention Behaviour is considered as a vital element in social interaction, evaluating efficient collaboration (Barron & Roschelle, 2009), as a result better interpreting CPS and its social dimensions (Pöysä-Tarhonen et al., 2021).

Eilan (2005) identifies Joint Attention as the capability to collectively direct attention with other participants in the direction of an external stimulus or object that persists within the environment. The focal point of Joint Attention includes versatile sensory inputs including auditory or visual cues, as well as tangible objects and past, present or future events (Siposova & Carpenter, 2019). Seemann (2012) recognises gaze tracking as an important part of Join Attention Behaviour Study. Roschelle and Teasley (1995) finds gaze tracking critical in collaborative tasks, where participants need to create a common understanding of the specific task. In essence, O'Madagain and Tomasello (2019) suggests that every participant should realize that they are focusing on the common element in the collaboration task to achieve Joint Attention.

Siposova and Carpenter (2019) has classified the social dimension of Joint Attention Behaviour into four levels. Namely they are *Shared, Mutual, Common and Monitoring*. In the *Monitoring* level, a particular participant takes the role of a spectator while another participant exists and thus both addresses the common element in the environment (Siposova & Carpenter, 2019). According to Pöysä-Tarhonen et al., (2021), each partic-

ipant at this level holds own perception about the situation and their attention is not influenced by each other's activities. In *Common* level, all the participants act as spectator while simultaneously following what other participants are focusing on (Siposova & Carpenter, 2019). Pöysä-Tarhonen et al., (2021) suggests that specific element of attention should be clearly identified in this level, so that all the participants are aware of addressing the same element. To achieve the ultimate common goal of the collaborative task, being aware of other participants attention level is relevant to participants (Pöysä-Tarhonen et al., 2021). The last two levels of Joint Attention in terms of social attention are bidirectional in nature withholding the spectator role from previous levels. In *Mutual* level, all the participants are addressing the same task or element but communication among themselves is not compulsory (Siposova & Carpenter, 2019). According to Pöysä-Tarhonen et al., (2021), in this level participants are collaboratively generating an experience with their shared knowledge base. *Shared*, the fourth level is identical to *Mutual* level except the fact that participants need to intentionally convey the element to which they are focusing their attention to (Siposova & Carpenter, 2019). Pöysä-Tarhonen et al., (2021) suggests, that behaviours indicating everyone's focus of attention does not have to be particularly verbal. According to Siposova and Carpenter, 2019, the behaviours can also be gestures for example showing and pointing, where the knowledge type is mutual. We will be focusing on *Shared* Joint Attention level of participants in our study.

Siposova and Carpenter (2019) further identifies certain complexities with Joint Attention. It is observed that social attention levels are more convoluted and stretched over time in real life. For example, while a particular person may be observed for their level of attention, they may co-exist in a shared or common level with other participants for an indefinite period. This makes the identification and analysis process particularly more complicated. The next complexity noticed by Siposova and Carpenter (2019) is that a person can transfer between different levels of attention very promptly. It is also possible that one certain level may instigate the next level of attention, resulting in hierarchically submerged levels. They further observed that the attention occurs simultaneously and in real-time. Hence, instantaneous effect of social attention carries certain distinctive qualities compared to experiences that are separated by space or time (Siposova & Carpenter,2019).

To address the focus of our study, a combination of remote collaboration tool and movement tracking technology can measure certain social attention levels of participants, since the collaboration usually takes place in real time. However, certain complexities may persist regarding submerged hierarchy of attention and duration of the collaboration to properly measure social attention levels.

4. EYE MIND ASSUMPTION: GAZE AND MOUSE TRACKING

According to Orquin and Loose (2013), the eye-mind assumption implies a robust contributory relation between attention and working memory. Just and Carpenter (1980) suggests eye-mind assumption is the concept where position of retina keeps static on a word for the period that word goes through processing. Eye-mind assumption further implies that there is minimal delay between what is being looked at and what is being processed (Just & Carpenter,1980). These literatures highlight the relation between Eye position and cognitive thought process of a person at a certain time, which encourages to further explore and analyse analyse Focus of Attention (FOA), where FOA refers to the ability to put attention to specific source of stimuluses.

Orquin and Loose (2013) further indicates that the process of transferring information from attention to working memory is very specific and influenced by explicit requirements of the task. As a result, decision-makers have the capability to keep certain number of features in their working memory during their focus. Nevertheless, the features that are kept should be pertinent to the actual task (Orquin & Loose, 2013). Egner et al., (2018) suggests that assessing attention provides valuable information for examining advance cognitive functions like literacy, engagement and comprehension. Traditionally attention measurement has been closely associated with eye tracking (Groner & Groner,2000). In this thesis, we have used the terms eye tracking and gaze tracking as synonymous for each other.

4.1 Eye Tracking

According to Ou et al., (2008), Gaze tracking techniques offer detailed insight into how individuals utilize visual data. Eye tracking has been utilized to examine the connections between where individuals look and the actions they perform during physical tasks (Keysar et al, 2000). It is also found beneficial to utilize Eye tracking for comprehending interpersonal communication (Eberhard et al., 1995), improvising a denotive communication practise where certain individuals describe a collection of objects to another individual who in turn must find the specific target among several options (Ou et al., 2008). Further research studies suggest that eye-tracking indicates individual's focus of attention during conversation (Ou et al., 2008). Vertegaal et al., (2001) studied gaze pattern in a conversation that consisted of four participants and results implied that gaze pattern strongly correlates with participants FOA.

Eye tracking comes with certain advantages and challenges as an evaluation method. Goldberg and Helfman (2011) indicates that eye tracking includes observing pre-attentive behaviours of individuals, which in return can provide valuable insights for strategic decisions. Moreover, Patterns of fixated regions can contribute to understanding the approach adopted from the starting to ending of a certain task (Goldberg & Helfman, 2010). However, certain challenges such as defining Areas of Interest (AOI), where AOI refers to the specific subsections of the presented stimuli for measurement purposes may persist while performing Eye tracking. The measurements of eye tracking may also get affected due to retinal position measurement inaccuracy (Goldberg & Helfman, 2011).

4.2 Gaze and Cursor Position Relation

Versatile research findings indicate that gaze and mouse cursor position of individuals are closely correlated. Gaze and mouse cursor position were found in close proximity in AOI for certain webpages in a research study (Chen et al., 2001). A stronger connection between gaze and cursor positions was identified by Hauger et al., (2011), when the mouse cursor was moving specifically in sessions with big number of mouse movements. Buscher et al., (2009) identifies that scrolling behaviour combined with data from browser's viewpoint are very much relatable to gaze tracking data of same situation. Egner et al., (2000) developed "mouse-click Attention Tracking (mcAT)" procedure for detecting attention based on mouse clicks. The idea is that the mouse clicks can be calculated and stretched together into a chronological sequence similar to that of eye movement which as a result showcases measurement of attention (Egner et al., 2018). Mouse like gaze position responds to two important characteristics of page elements, their significance to user's task and their placement (Navalpakkam et al., 2013). They further developed certain models based on strong correlation between eye and mouse movements to detect attention level. Kim et al., (2018) conducted an analysis from data visualization perspective by comparing mouse click with gaze detection experiment and found significant similarity between the resultant heatmaps.

Huang et al., (2012) classified mouse cursor behaviour of individuals into four categories. Cursors that are stationary and disregarded by the user for a certain period of time is called *Inactive cursors*. Cursors that are used when user intends to execute a task (e.g. drag, click) is referred to as *Active* Cursor (Huang et al., 2012). *Reading* cursors are the ones being utilized to track the text while the user reads a page. During Page examination, users move around *Examining* cursors which excludes 'action' or 'reading' cursor activities (Huang et al., 2012). They further derived rules for identifying these categories in following manner. If a cursor position is static for at least one second, then it is labelled

as *Inactive. Action* behaviour of cursor is the one occurring within the one second timeframe before a click. The cursor which does not travel vertically beyond 50 pixels, moves horizontally by at least 150 pixels and returns to the left by at least 50 pixels are called *Reading* Cursors. For the rest of all interactions, where the cursor did not engage in any action, reading or inactive state are classified as *Examining* cursor (Huang et al., 2012). In our research study, we would be analysing mouse movement data of the participants to identify these behaviours mostly *Action* behaviour. As the collaboration task would require certain actions for specific AOI against time.

5. MOTIVATION AND RESEARCH QUESTION

In the post Covid-19 era, remote collaboration has become a dawning concept that has been integrated into most of our daily work routine. Academia, Corporate, Social Networking are some of the mentionable areas where remote collaboration is gaining more popularity. Since, Covid restrictions has already made some impact on our lifestyle decisions, remote collaboration helps to carry those practices in an optimistic manner. It gives more flexibility in terms of maintaining schedules while focusing on work-life balance as well.

However, technologies carry certain challenges as well with the actual innovation. In remote collaboration it is observed that lack of in person collaboration benefits such as gaze cue or certain body gestures makes it challenging to follow other participants observation. Eventually this affects the result of different collaboration work and creates confusion and misinterpretation among participants. Studies also suggest that participants feel more cognitive load and secluded from their group while working in a remote collaboration setup.

So, despite all the collaboration platforms with different features such as sharing cursor position, communication channels etc., a practical question remains that whether participants are focusing on AOI in a remote collaboration task. In author's opinion, this question would help to develop more user-oriented Computer-Supported Co-operative Work (CSCW) platforms. In this research study, we are hoping to gain some insights on this question from mouse tracking data based on AOI for different parts of the workspace in the screen. Hence, we address the Research Question of the study as follows:

Research Question: Are the participants focusing on Area of Interest (AOI) of a task during remote collaboration?

Research Sub-Question: If not, then what are the challenges faced by the participants?

6. RESEARCH METHODOLOGY

In this chapter, we focus on describing the methodologies that were used for conducting the research study. Details of participants, experiment design, setup and execution procedure with data collection and analysis methods are presented. A feasibility study was conducted to validate the practicalities of the experiment design. It was found that the equipment's available at Block 1, Ludus Lab at Tampere University, City Center Campus were compatible with the research study requirements. This feasibility study helped to ensure readiness for the actual research study by installing and testing relevant software packages beforehand.

6.1 Research Participants

The research study consisted of three participants in each session. As a result, total 6 participants participated among which 5 participants were Master's Students at Tampere University under different faculties and one participant was a researcher from Tampere University. Three of the participants were male and another three were female. Mean age of all the participants was calculated to be 30 years. The participants had a versatile background (Appendix 2) from Native Languages perspective. This information helped to understand whether there is any difficulty comprehending each other's messages, while the communication language for the experiment was English. Two of the participants did not have prior experience working with Collaboration tool for example 'Mural', whereas 50% of the participants had prior knowledge on *Social Entrepreneurship* (topic for the collaboration during the study).

The participants were carefully chosen, so that they get to collaborate with other participants that they probably haven't worked with before. The reason behind this was, in most coursework requirements, collaboration work requires students to be in random breakout rooms in Zoom or just be part of a group that they are not familiar with. This research study focused on analysing participant's attention in a relatively new environment out of their comfort zone, as working with known faces would not help to reveal the challenges in remote collaboration easily.

	P1	P2	P3	P4	P5	P6
Gender	Male	Female	Female	Male	Male	Female
Age	25	40	23	34	38	25
Native Language	Indonesian	Oron	Urdu	Bengali	Bengali	Chinese
Occupation	Researcher	Master's Student	Master's Student	Master's Student	Master's Student	Master's Student
Experience with Mural	Yes	Yes	No	No	Yes	Yes
Knowledge on Social Entrepreneurship	No	Yes	No	Yes	Yes	No

Table 1: Participant background details

Table 1 showcases the background of the participants which are versatile in nature. The common ground however is that most of the participants are Master's students in Tampere University, which is the focus group for this research study.

6.2 Research Study Setup and Procedure

The Study was conducted at Ludus Lab, Tampere University City Center Campus. Block 1 of Ludus Lab with four cubicles out of which three for participants and one for the author as moderator of the study was used for the study purpose. Each cubicle was equipped with Alienware Compact PC with table and chair for each participant separating them from each other by the soundproofed cubicles. Zoom Application (https://zoom.us/) was installed on each computer for communication purposes among participants. For tracking mouse movement, ETU Driver developed by Oleg Špakov at Tampere University was installed. The driver was capable of tracking mouse movements every 20ms, which

helped to monitor inactive periods if any among participants mouse movements. External Logitech Web Camera was used on the PCs to view participant's face. Participants were asked for their consent (Appendix 1) to allow access to their video and audio, including screen recording of the whole remote session. Based on the response from each participant, the camera and other outputs were managed accordingly, and the session was recorded through Zoom application. The screen resolution of the participants monitors was set at 1920X1080 where the Monitor was 27 inches in size. The setup of the study is illustrated in Figure 1 below.

Figure 1: An example of the cubicle

Two experiment sessions were conducted, each consisting of 3 participants. (P1-P3 for first experiment and P4-P6 for second experiment) After arrival, participants were greeted and appreciated for their time and effort regarding the experiment after which they were guided to the cubicles. A concise overview of the experiment including purpose of the experiment, the process to be followed and the data privacy steps taken were

clearly communicated to the participants. Following the overview, the consent form (Appendix 1) which also included the details of the overview was asked to be filled out.

The study was distributed into two parts. In the first part, a TEDx Talks lecture by Andy Stoll on *Social Entrepreneurship* was played by the author for all participants on Zoom application by screen sharing. After the video ended, participants were given clear instructions on how to perform the task. Specific instructions and task details are explained elaborately in the next section. After giving instructions, the ETU Driver at each participant's PC was calibrated and started by the author. After that, the actual task began which will be explained elaborately in the next section. After completion of the task, three questionnaires (Appendix 2, Appendix 3, Appendix 4) were asked to be filled out. After which the study was announced finished by the author and participants were again thanked for their time and effort.

6.3 Task

The study consisted of a task, where participants had to perform card sorting in Mural Board based on the Video topic *Social Entrepreneurship*. The Mural board was divided into four quadrants or sections based on Important topics from the Video Lecture. Each of these four sections had 3 relevant answers given into the Mural Board in the form of cards. However, the cards were scattered in different positions from which the participants had to identify the correct card and drag them to the section that it belongs among four quadrants. They were asked to collaboratively decide and work on a specific section together.

The Mural Board also included one blank card for each quadrant or section. Participants had to discuss among themselves, to come up with an example for the relevant section and fill up a blank card for that section. Each participant was required to pick at least one written card for each section and at least one blank card for a section. After completing each section with four cards, participants mentioned the next section name and started to work on it accordingly. Participants were encouraged to discuss among themselves the topics and card answers.

Participants were asked specifically to refrain from zooming in and out of the screen and keep mouse movements limited to the task only, as this would affect the result of the study since the mouse movements won't be mapped against a static screen anymore. Moreover, they were discouraged to give clues on exact position of cards to other participants, as per author it would also affect the results of the study, since individual participants attention level would be influenced by other participants.

The idea behind the task design implies to observe *work-space awareness* and s*hared joint attention* of participants as discussed in Chapter 2 and 3 respectively. Hence, the focus of the study was to observe participants collaborative efforts rather than correctness of answers. If the participants had picked a wrong answer that would have made little impact on our study compared to focusing on a different section than the other participants.

In general scenarios, students are expected to ideate and share opinions to achieve a collective goal in collaborative tasks such as organizing data in related groups. It was hypothesized that while working in a remote collaboration environment, heatmaps of Participants mouse movements for each specific task would appear to be in the same region. The deviations from the expected outcome could be further analyzed for attention tracking.

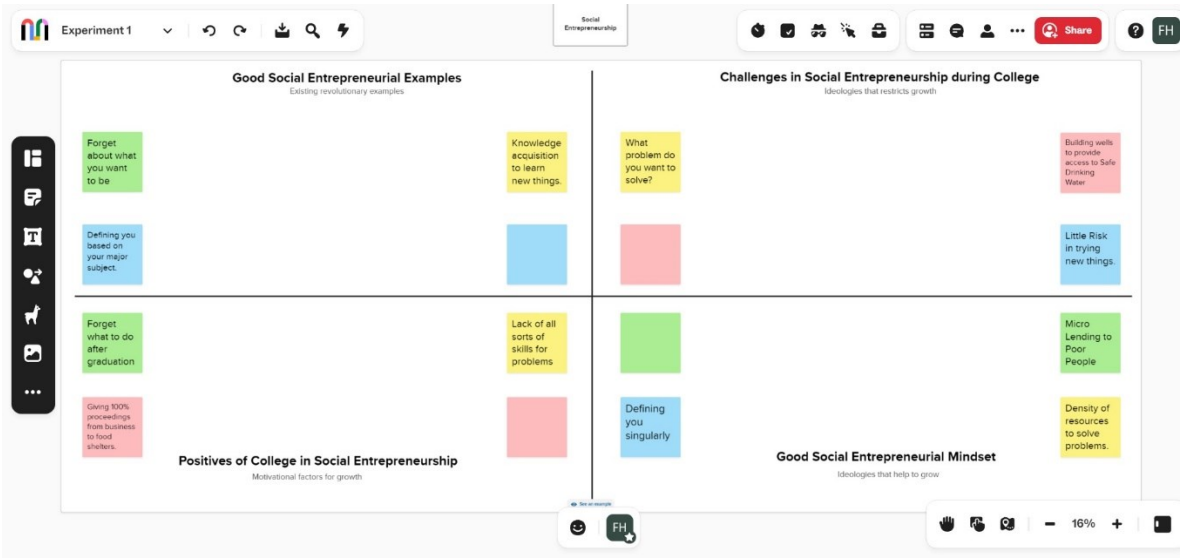

Figure 2: Mural board workspace

6.4 Data Collection and Analysis Process

Mouse Tracking data for the research study was collected using ETU Driver, which was able to log data every 20ms. To analyze Participant's focus of Attention in AOI in Mural board, we divided the Mural board workspace screen into four quadrants. The Quadrants are numbered 0,1,2,3 clockwise and each quadrant represents one AOI. Each of these four quadrants represent one specific topic, which participants collaborated on a specific time together. Mouse tracking data log was collected using ETU Driver for each participant. Based on the timestamp recorded for each task, tracking data was calculated and

visualized per quadrant for each participant in Microsoft Excel. Then a comparison between the expected heatmap for each task and participant's mouse movement was conducted which can be seen in the Results section.

A background questionnaire (Appendix 2) was used after the collaboration ended, to gather some demographic information about participants to correlate any issues faced during collaboration. The questionnaire collected information about Participant's age, gender, mother tongue, experience working with collaboration tools, knowledge about *Social Entrepreneurship* and any challenges they faced during the task. Nasa Task Load Index (Nasa TLX) developed by Human Performance Group at NASA (Appendix 3) and Subjective Attention Scale (SAS) developed by Welsh, M., (2020) (Appendix 4) were used to consecutively identify Workload level of the collaboration task and participant's own evaluation about their level of Subjective Attention. For ease of calculation, Nasa TLX questionnaire data was collected on a 7-point scale for 6 questions, which was then rescaled to 0 to 100 range using the formula developed by Preston and Colman, (2000) as follows:

Rescale formula: (Value - lower endpoint)/ (Max endpoint – lower endpoint) X 100. Preston and Colman, (2000)

According to Welsh, M., (2020), the Subjective Attention Scale comprised of 15 statements each 3 of which were based on five attention types outlined by Sohlberg & Mateer, (1989). The 3 statements from each attention type included a reverse-scored statement as well. The statements were presented on a Likert scale manner to the participants to answer between Strongly Disagree to Strongly Agree which were scaled between 1 to 5. Scores from all statements were summed together to produce a score ranging from 15 to 75, where higher scores indicate a positive subjective evaluation of attention (Welsh, M., 2020).

7. RESULTS

Results of the research study and analysis of three questionnaires are presented in this Chapter. There were two sessions with three participants in each of them. Hence the results are presented for Session 1 and Session 2 accordingly. To interpret the results correctly, a comparison between the expected heatmap of cursor movements and participants' cursor movements is presented for both sessions. Results of the questionnaires are evaluated subjectively to understand any effect on participants attention level.

7.1 Experiment Results

Since there were four quadrants that participants worked on in the Mural Board, we marked these quadrants as 0,1,2,3 clockwise for ease of data interpretation. The expected heatmap of mouse movements for each quadrant is compared below with participants mouse movements based on the task order that they decided as a group.

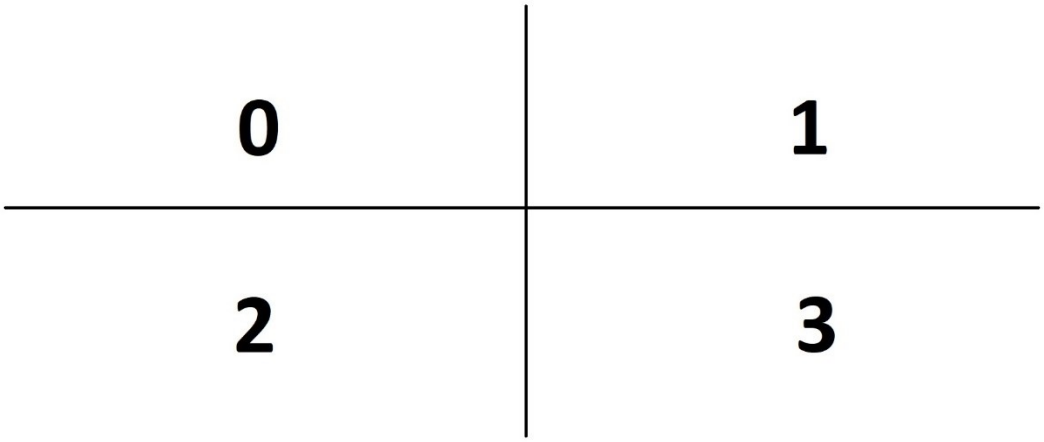

Figure 3: Quadrant numbering for data interpretation

For Session 1, all the participants gave consent to recording audio, video and tracking data. The participants decided to work on the collaboration task in a counterclockwise manner. Based on the collected data, the following are the interpretation of Session 1.

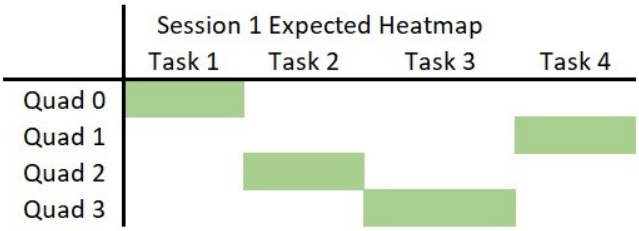

Figure 4: Expected heatmap for Session 1

	Participant 1			
	Task 1	Task 2	Task 3	Task 4
Quad 0	14%	7%	6%	6%
Quad 1	1%	5%	5%	42%
Quad 2	82%	65%	77%	28%
Quad 3	3%	23%	12%	24%

Figure 5: Participant 1 heatmap in Session 1

	Participant 2			
	Task 1	Task 2	Task 3	Task 4
Quad 0	62%	0.5%	6%	0
Quad 1	4%	5%	8%	92%
Quad 2	21%	83%	8%	0
Quad 3	13%	11.5%	78%	8%

Figure 6: Participant 2 heatmap in Session 1

	Participant 3			
	Task 1	Task 2	Task 3	Task 4
Quad 0	27%	0	0	1%
Quad 1	4%	0.5%	22%	25%
Quad 2	66%	27%	24%	1%
Quad 3	3%	72.5%	54%	73%

Figure 7: Participant 3 heatmap in Session 1

In reference to the above illustrations, we classified the mouse movements of participants for each task based on percentile against the timestamp of each task. As we can see, the heatmap of Participant 2 aligns with the expected heatmap of the Session 1,

where major percentages of mouse movements fall under the expected quadrants. However, for Participant 1 and 3 we can see certain deviations from the expected heatmap. Based on our analysis the deviations are the result of Mouse Cursor Behavior defined by Huang et al., (2012). It was observed that Participant 1 and 3 depicted majorly an *examining cursor behavior* over the *action cursor behavior* which was mostly required for the research study as instructed during the study. The minimal mouse movements that we observe in the expected quadrants marked in red are due to *active cursor behavior* that was compulsory to finish the task.

For Session 2, all participants except Participant 4 gave consent for video recording. Hence, we continued the experiment with recording audio and mouse movements for all participants and video only for Participant 5 and 6. In Session 2, the participants decided to work on the collaboration task in the order of the Quadrant number, that is 0,1,2 then 3. Based on the collected data, the following are the interpretation of Session 2.

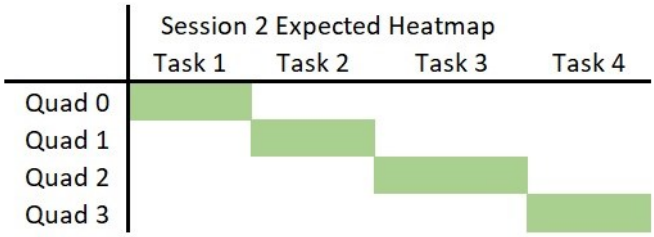

Figure 8: Expected heatmap for Session 2

	Participant 4			
	Task 1	Task 2	Task 3	Task 4
Quad 0	79%	2%	0	0
Quad 1	11%	67%	17%	53%
Quad 2	8.50%	14%	66%	5%
Quad 3	1.50%	17%	17%	42%

Figure 9: Participant 4 heatmap in Session 2

	Participant 5			
	Task 1	Task 2	Task 3	Task 4
Quad 0	54%	11%	40%	98%
Quad 1	32%	35%	1%	0.0
Quad 2	0	19%	50%	2.0%
Quad 3	14%	35%	9%	0

Figure 10: Participant 5 heatmap in Session 2

	Participant 6			
	Task 1	Task 2	Task 3	Task 4
Quad 0	74%	0	0	3%
Quad 1	23%	54%	0	0
Quad 2	3%	38%	52%	3%
Quad 3	0%	8%	48%	94%

Figure 11: Participant 6 heatmap in Session 2

Again, as per the above illustrations, mouse movements of Session 2 participants were classified for each task based on percentile against the timestamp of each task. The illustrations show that for all the participants, most of the mouse movements are in alignment with the expected heatmap for Session 2. We have marked some of the quadrant percentile as green although the percentage is a bit lower because the difference among the percentage is very low or even equal. Our observation is that participants were aware of the workspace but due to their *examining cursor behavior* these specific quadrants are almost equal or low by small margins in percentile. However, we are inconclusive of the interpretation for Task 4 of Participant 5 which shows a reverse result compared to the expected heatmap of Session 2. Possible reasons could be data logging issues of ETU Driver for mouse tracking or different timestamp that Participant 5 used for Task 4.

To put things into perspective, here are two visualization examples of *examining* and *action* specific cursor movements, where *examining* cursor movements are all over the workspace outside the relevant AOI and *action* specific movements are mostly centered around the relevant AOI.

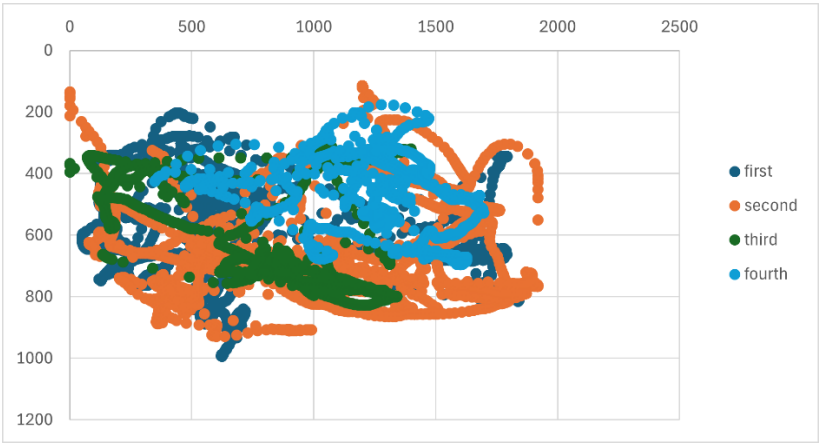

Figure 12: Examining mouse movement of participant 1

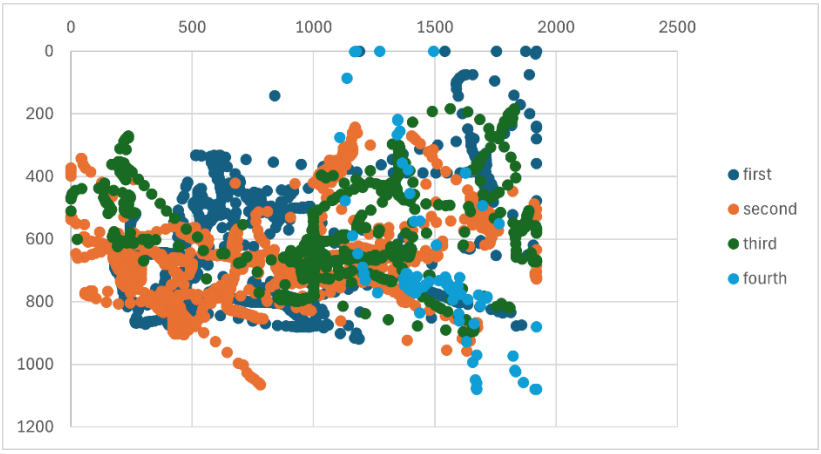

Figure 13: Action specific mouse movement of participant 2

7.2 Questionnaire Results

A background questionnaire, Nasa Load Index and Subjective Attention Scale were used to correlate research study results with Participants own interpretation about their attention level. Background questionnaire showed insights about Participants Native Language, Experience using Collaboration Tools such as Mural board and prior knowledge on *Social Entrepreneurship*.

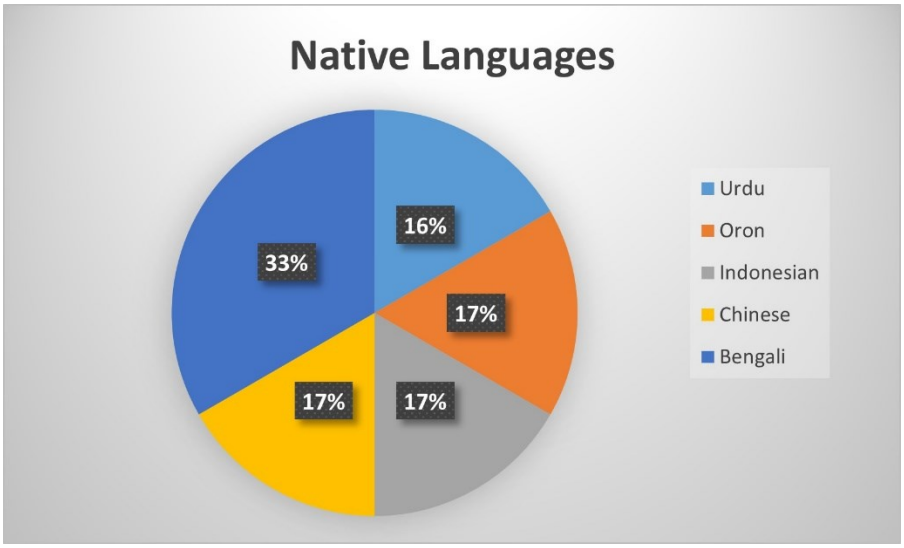

Figure 14: Native languages of participants

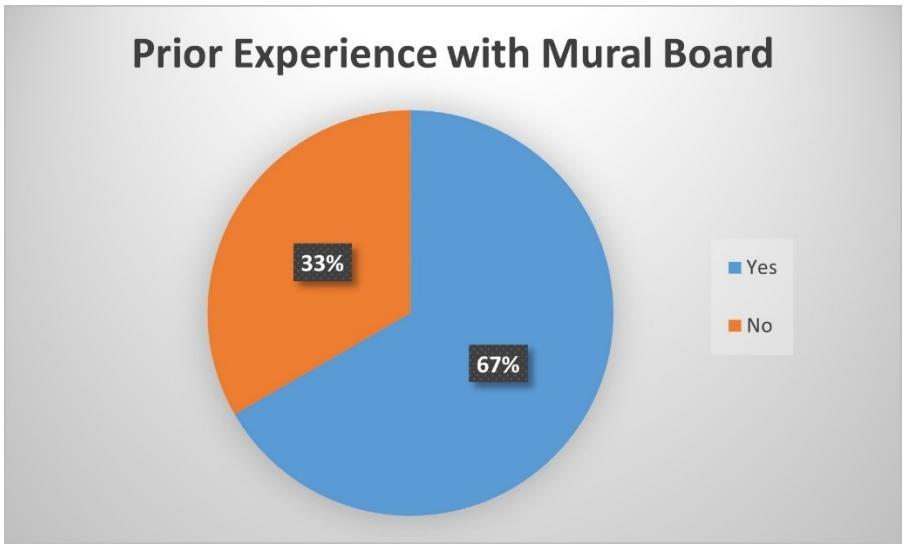

Figure 15: Prior experience with collaboration tools

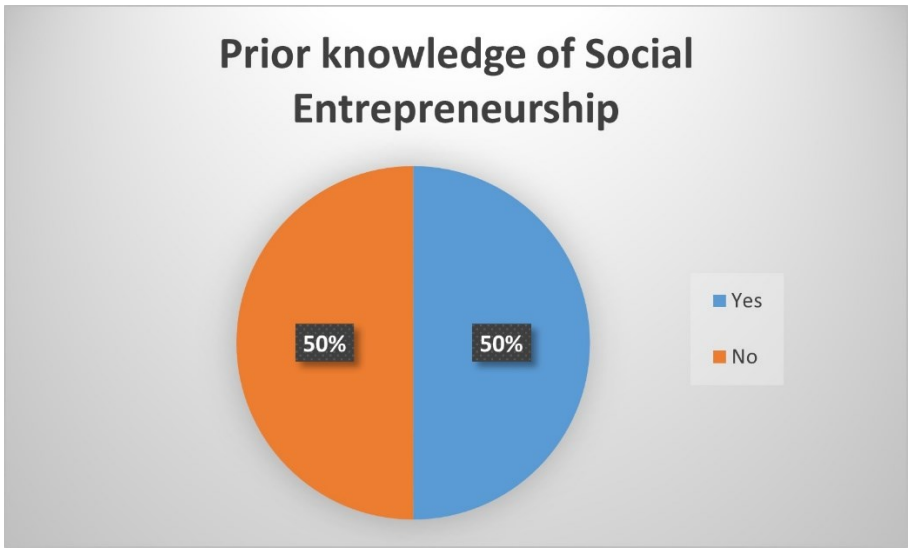

Figure 16: Prior knowledge of Social Entrepreneurship

As we can see from the above illustrations, there were versatile native language backgrounds of participants. We tried to analyze if there were certain difficulties in communication based on language which might have affected participants attention level during collaboration. We observe from video and audio analysis that, although there were some confusions among participants about others opinion, they were necessarily not due to different native language backgrounds, since the common language used was English. Our interpretation is that the confusion or repetition of opinions could have been due to accent that different Participants carried in the conversation.

The Background Questionnaire has provided insights about Participants prior experience and knowledge on Remote Collaboration Tools and *Social Entrepreneurship*. Participant 3 and 4 indicated that they do not have prior experience working with Mural board. However, it is inconclusive on the idea that lack of prior working experience with collaboration tools may affect Participants attention level because among these two Participants, mouse movement heatmap of Participant 4 aligns with the expected heatmap. Moreover, further insights from the background questionnaire shows that 3 participants, namely Participant 1,3 and 6 mentioned that they were not familiar with the concept of *Social Entrepreneurship*. Again, this is inconclusive to the idea that lack of prior knowledge on *Social Entrepreneurship* may influence Participants attention level since heatmap of Participant 6 clearly aligns with expected heatmap of Session 2. The Background Questionnaire also asked if the participants faced any difficulties while participating in the collaboration work. Most of the participants did not face any difficulties except Participant 5, according to whom, the initial instructions were a bit confusing.

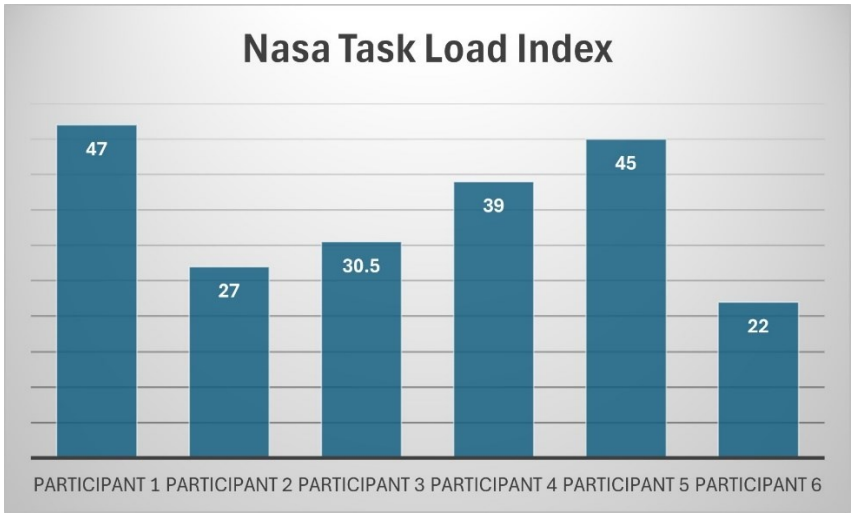

Figure 17: Nasa Task Load Index Survey Results

The above figure showcases the Participants perception about the intensity of the collaboration task of the research study. It was observed that most of the participants rated the task low on a 0-100 scale, where the mean value was 35 in terms of load that they faced. Which addresses the participants observation of facing little difficulties throughout the collaboration task.

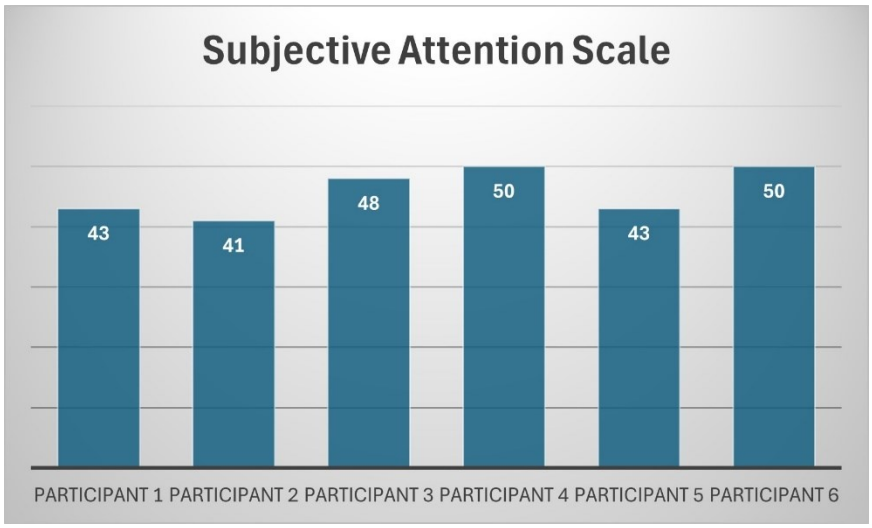

Figure 18: Subjective Attention Scale (SAS) Survey Results

The Subjective Attention Scale (SAS) developed by Welsh, M., (2020) showcases the Participants own perception about their general subjective attention level. It was observed that most of the participants evaluated themselves above average on a 15-75 scale. Which reflects on the study results, as most of the Participants mouse movement heatmaps were in alignment with the expected heatmap.

8. DISCUSSION

The main idea behind this research study was to figure out if individuals can put their attention in the areas where most of the collaborators are working in a remote collaboration setup. The result from the study shows that in most cases, participants' attention was focused on the current quadrant that all the participants were working on at the same time, which was shown in the analysis of AOI. However, certain different results were also observed due to the mouse movement behavior of participants. These results are due to several limitations that this research study is acquainted with.

To start with, the workspace area for the collaboration task was not complex enough for the Participants. It is reflected from the feedback of Nasa Task Load Index Survey. The limitation for workspace area complexity was due to static screen requirement. If the workspace was bigger with more content, then the Participants would have to zoom in/out of the screen which would affect the mouse tracking data analysis based on quadrants, as the contents would become dynamic hence less accurate results. As a result, number of Participants were also required to be kept low so that it fits with the demand of the task. Ideally a group of at least 5-6 Participants with more complex workspace for collaboration would depict more insightful results.

The research study was designed and planned around mouse movement tracking for measuring attention levels. The idea was to design the study from a realistic point of view, as in most real-life cases, students decide to keep their Camera's off during remote collaboration. Hence absence of gaze in most real-life cases inspired to utilize mouse movements for attention tracking. However, the results were affected by different mouse movement behavior of Participants. Hence, a combination of both gaze and mouse tracking would provide more insights into the research question that is being addressed.

Based on the literature study, we indicated to focus on *workspace awareness* and d*ivided/alternating attention* of the participants. The research study indicates that in most of the cases, participants were able to focus on common areas that other participants were also working on, which resembles workspace awareness. However, it is inconclusive to say that there was lack of d*ivided/alternating Attention* from participants part due to several misalignments in mouse movement heatmaps. As we have already discussed, this was due to *examining mouse movement behavior* of some Participants. Neverthe-

less, mouse movement tracking remains relevant to the topic of Attention, as they provide valuable insights and certain levels of measurement data which can be used to interpret Attention behavior of participants.

9. CONCLUSION

To conclude, this research study aimed to provide insights on Participants level of attention in a remote collaboration setup. Despite certain limitations mentioned in previous Chapter, findings from this research study are as follows:

- Most of the participants were able to focus on the areas where other participants were also working at the same time in the remote collaboration.
- Mouse movement behavior can affect the interpretation of Participants Attention Level.
- No major difficulties were faced by the Participants in the Remote Collaboration work.

Based on the results and limitations of this research study, the scope of future work could be to utilize both gaze and mouse detection to get more insights on Attention level. This would help to develop more user-friendly remote collaboration tools which in return would ensure better collaboration outcomes.

In this Post Covid-19 era, remote work has become the new normal in most of our regular routines including corporate and educational spectrum. It provides greater work life balance and flexibility due to which it is increasingly becoming more popular. However, certain challenges are incorporated with benefits as well, such as lack of communication cues which may affect the result of the remote work. Hence, understanding the challenges and designing a better remote collaboration working technology would help to ensure better user experience and in return more productivity.

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APPENDICES

Appendix 1

Consent Form

Consent Form for Participation in 'Attention Detection in Remote Collaboration' Experiment

I welcome you to participate in the research experiment for my Thesis Work aiming to measure Attention level in Remote Collaboration. By participating in this research experiment, you help us to evaluate the collaboration phenomenon, which would enrich future work on developing certain efficient collaboration tools.

In this research experiment, you will watch a Video Lecture on 'Social Entrepreneurship' with your fellow collaborators. After that, you will be asked to perform a card sorting collaborative task in 'Mural Board' and to think out loud while doing the task. After the collaboration task, we will ask you to fill in three questionnaires: 1. Background, 2. NASA TLX and 3. SAS to understand your participation level in the experiment.

Please be informed that the whole experiment session will be recorded. During the test, we will record the computer screen with audio and video images of your face and, we will track your mouse pointer activities during collaboration task. The materials recorded during the test will be used for analysis of the experiment. In addition to myself, my thesis supervisor will have access to the recordings and other materials from the test.

All identifiable data will be saved securely, protected by password. The data recordings will be removed after my thesis work is completed.

The results of the experiment will be reported anonymously. A report of the results will be published in my thesis submission. Video, audio recordings or any other personal data will not be revealed.

At any point of time, you can stop participating in the research experiment at your own will. We are happy to answer if you have any questions.

* Required

1. I give consent to record *

- My Mouse Tracking Movements during Collaboration
- The screen (of the device where the task is being conducted)
- Audio (My voice and potential sounds in the background)
- Video (My face and background)

2. I have received information about the research experiment, and I had opportunity to ask questions.

I am participating in this test voluntarily.

To consent to the above terms, please enter your name (First name and Surname) *

Appendix 2

Background Questionnaire

We are collecting Background Information to find relevancy with the Research Experiment Topic and Environment.

* Required

1. Participant Number *

2. Age *

3. Gender *

   - Woman
   - Man
   - Non-binary
   - Prefer not to say

4. Native language(s) *

5. Occupation *

   - Bachelor's Student
   - Master's Student
   - Doctoral Student
   - Researcher
   - Professor/Lecturer/Teacher Other

6. If you answered "Other" in question 5, please explain

7. Do you have prior experience working with Digital Collaboration Tools such as Mural, Miro Board? *

   - Yes
   - No

8. Were you familiar with the concept of 'Social Entrepreneurship' before this Experiment? *

- Yes
- No

9. Did you face any difficulty while participating in the collaboration task? *

- Yes
- No
- Maybe

10. If you answered 'Yes' or 'Maybe' in Question 9, please mention in one sentence your observation.

Appendix 3

Nasa Task Load Index Survey

Subjective assessment tool for rating workload to assess a task.

* Indicates required question

1. Participant Number *

2. Mental Demand. (How mentally demanding was the task?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

3. Physical Demand. (How physically demanding was the task?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

4. Temporal Demand. (How hurried or rushed was the task?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

5. Performance. (How successful were you in doing what you were asked to do?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

6. Effort (How hard did you have to work to accomplish the task performance?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

7. Frustration (How insecured,discouraged,stressed or annoyed were you during the task?) *

Mark only one oval.

1 2 3 4 5 6 7

Very Low Very High

Appendix 4

Subjective Attention Scale (SAS) Survey

Subjective assessment of attention

* Indicates required question

1. Participant Number *

2. I am better than most people I know at searching for objects or information. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

3. I have a longer attention span than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

4. I am more easily distracted than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

5. I can switch back and forth between different tasks more quickly than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

6. I lose concentration more easily than other people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

7. When focusing on a task, I can ignore distractions more easily than most people I know. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree Strongly Agree

8. I am better at multi-tasking than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

9. I notice details that most people I know would miss. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

10. I find it harder to switch between tasks than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

11. I have better attention to detail than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

12. When reading, I do not notice distractions like music or others talking as much as most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

13. I am less aware of my surroundings than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

14. When switching between tasks my performance suffers less than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

15. Focusing on multiple tasks at once is more difficult for me than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree

16. I can continue working while carrying on a conversation more easily than most people I know. *

Mark only one oval.

1 2 3 4 5

Strongly Disagree Strongly Agree