EXPLORING RESUMPTION AIDS FOR TASKS INVOLVING 3D MODELS ON TABLETS

by

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I dedicate this thesis to:

*My parents **Mohamed Almangush** and **Mona Suliman** I for their love, endless support and encouragement.*

*My husband **Ibrahim Aburwais** and my children **Mohamed**, **Fatma**, and **Nader**. I give my deepest expression of love and appreciation for the encouragement that you gave and the sacrifices you made during this graduate program.*

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ABSTRACT

Aircraft mechanics use mobile devices and workstations to view 3D models of parts and assemblies. This offers easy viewing of static perspectives of a 3D model; however, during more complicated tasks when model perspectives need to be rotated, panned, and zoomed, mechanics can experience difficulty resuming the task after interruption, either due to not recalling details of the work, or not recognizing the current perspective in relation to the part or assembly as a whole. In an attempt to reduce the loss of task context after interruption, we developed three resumption aid interfaces. Each provides a different method of capturing work state at key moments for later retrieval. They are: screenshots with audio, video-only, and combined audio/video. We conducted a comparative evaluation (N=32) with four resumption conditions (one for each interface and a control condition with no resumption aid). Participants used the respective aid to record their work while performing tasks. Tasks were interrupted, and resumed in a second session. Our participants used the data recorded in the resumption aids for two purposes: at the beginning of the resumed task, to assist in locating the resumption point, and at the end of the resumed task to assist recalling a task's steps for the purpose of writing a task summary.

Findings show that these tools boost interruption recovery for tasks based on 3D models. Using a resumption aid to record work state in the first session led to faster resumption in the second session if participants did not reference the assigned resumption aid at the point of resumption. If they did use the tool as a reference, resumption time was comparable to the control condition (no resumption aid). When recalling task steps at the end of a task, accuracy was highest when the resumption aid was referenced. Participants preferred combined audio/video and screenshots with audio to the video-only interface. Our results support the memory for goal theory (Altman and Trafton, 2002), which asserts that supporting activation of the interrupted goal and encoding cues before the onset of the interruption will aid later resumption. Our results suggest that audio annotations anchored with screenshots or video help users recall subtasks when working with complex 3D models, and that this is helpful for both task resumption and summarization.

LIST OF ABBREVIATIONS USED

ACT-R	Adaptive Control of Though-Rational
CC	ChittyChatty
DoF	Degree of Freedom
HCI	Human Computer Interaction
LSD	Least Significant Difference
OM	Organic Memory
P	Participants
PP	Pen & Paper
UI	User Interface
VEs	Virtual Environments

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CHAPTER 1 INTRODUCTION

In the field of Human-Computer Interaction (HCI), interruptions are disruptive events, usually constraining performance and causing mistakes. Interruption can critically impact workflow and is therefore an area of focus for many HCI researchers. Interruption often happens in the workplace; it comes from various sources such as other people and devices (email and system notifications). Interrupted people often need to return and resume their original task later, which means they must recall where they were in the task before the onset of the interruption. This depends on the user's ability, which is associated with *prospective memory*. Prospective memory, defined by Meacham & Singer (1977) as remembering to do an intended action after a delay, likely involves some processing phases: intention formation, preserving the intention in memory while conducting a secondary task, performing the intended action at the suitable moment, and assessing the result (Ellis, Brandimonte, Einstein, & McDaniel, 1996). However, people cannot always rely on this aspect of their memory since it sometimes fails and so the goal of the primary task is forgotten. This can be due to several reasons: time passing and memory decay, not committing task details to long term memory in the first place, events between task sessions making it easy to forget prior tasks, other activities making it difficult to context switch. When users resume their task, they usually require time to return to where they had left off, have an increased chance of making mistakes, and may fail to retrieve the last state of the interrupted task. Thus, the ability to resume a task following interruptions depends on the ability of the human brain to manage the disruption of a current process, conduct some secondary activities, then resume the original process with a good level of accuracy and ease, and low resumption lag. Some research in this area aims to clarify the cognitive basis of task suspension and resumption procedures, exclusively focusing on the resumption of the task as a memory-based process (Dismukes & Novinsky, 2007; Monk et al., 2008). According to Altmann &

Trafton (2002), resumption lag changes depending on an interruption's cognitive demand and length. They used resumption lag, defined as the period of time between the completion of the secondary task (i.e., the interrupting task) and resumption of the unfinished primary task (i.e., the interrupted task), as the main measure of the disruptive impacts of interruption. These findings provide support for the model of *memory for goals*, which is a model that predicts that preparation before interruption occurs can assist task resumption; it asserts that supporting activation of the interrupted goal and encoding cues before the onset of the interruption will aid later resumption (Altmann & Trafton, 2002). Hodgetts et al. (2006) report that the longer the interruption, the longer it takes to resume the primary task, and the greater the possibility to make errors at resumption.

1.1 Research Problem

Aircraft and other heavy equipment mechanics work within a number of special conditions such as loud, tight, and restrictive workspaces. They frequently move about within and around the workspace, and need to work with and switch between a variety of tools and materials. 3D models are a critically important information resource for mechanics: they provide detail about the specific parts and assemblies they are working on, providing visual confirmation of work process and desired results. Mechanics can use a range of technologies to access 3D models, including desktop workstations with large displays, rugged laptops, tablets with touchscreens, and paper printouts. In the course of a job, a mechanic might return several times to a 3D model, sometimes moving between stationary workstations away from the worksite and mobile devices at the worksite. In addition, mechanics are often interrupted while viewing a 3D model, as assembly plants for large machinery like aircraft are dynamic environments. These factors require mechanics to expend more energy to remember and then recall what they were doing when they return to a 3D model.

We were inspired by the aircraft mechanics scenario to explore different aids for resuming tasks involving 3D models. The key problem with identifying strategies for task resumption is determining which are most helpful for a certain type of task, and how much variation there is in individual behavior and performance with the different resumption strategies. We were interested in exploring technical aids that would support resuming tasks involving 3D models.

1.2 Research Objective and Research Questions

Our goal in this thesis is to investigate aids for resuming tasks with 3D models. Thus, we designed three techniques intended to help in resuming a suspended task involving 3D models: screenshots combined with audio descriptions, video snippets of interaction, and video snippets combined with audio descriptions. Three resumption aid prototypes were developed (one per technique), each providing the mechanics with the ability to record details of their task and a means to retrieve these later on to support resumption.

We wanted to assess the suitability of each approach for aiding task resumption with 3D models. To do this we conducted a comparative evaluation. In it participants performed a set of tasks involving 3D models, annotating their progress as they saw fit using one of the resumption aids (a no-aid control condition was also administered), and at a specific stage we interrupted them by asking them to move to the next task. In our original study design, interruption and resumption occurred in the same session, but our pilot participants were able to resume easily without the resumption aids. We believed this might have been impacted by environment (e.g., in a noisy work environment resumption may not be as easy), but rather than try to simulate a noisy work environment we decided to examine the effectiveness of the developed resumption aids after longer-term interruptions (lasting a day or longer). This length of interruption is common for workers who return the next day to continue a job, in aerospace and in other industries. We leave a study of shorter-term interruptions in noisy environments for future work.

After completing their task, we asked participants to recall the whole task by writing a summary of each step taken before and after the interruption. Performance was measured primarily in terms of resumption lag and summary correctness.

From this work, we hoped to discern:

RQ1. What is the most helpful aid for task resumption with 3D models (in terms of reducing the resumption lag)?

RQ2. What is the most helpful aid for task recalling with 3D models (in terms of increasing the accuracy of recalling)?

RQ3. What are most appropriate aids for different types of task (specifically *Compare* and *Trace* tasks, defined later)?

In addition to comparing the three approaches, we also wanted to develop a set of criteria that would help identify features for a refined resumption aid interface in such a manner that the strengths of each feature are emphasized and their limitations deemphasized. As such, it may be that a single interface works for a wide range of tasks.

1.3 Contribution

This research makes the following theoretical contributions:

1. It explores how different aid interfaces support resuming and recalling tasks with 3D models when these tasks are suspended.
2. It examines the usability of three resumption aid interfaces for resuming and recalling different kinds of tasks involving 3D models.

The research also makes three practical contributions:

1. The resumption aid interfaces were inspired by visits to aircraft assembly plants and discussions with creators of technical documentation for aircraft mechanics.
2. While a contextual evaluation is beyond the scope of this thesis, we consider the implications of our findings on the design of resumption aids in this domain.
3. We propose features for a task resumption aid for tasks involving 3D models that might be useful in a wider range of contexts.

1.4 STRUCTURE OF THE THESIS

Chapter 2 presents a background of related work. We begin by defining 3D interaction, then we identify interruptions and then outline the factors that make them more disruptive as well as those that can decrease their harmful impacts. We describe some issues that may impact users' performance when they resume their interrupted task and explain how these effects have been measured. We then review the literature on assistive tools and techniques that have been developed to assist people with task resumption and recall to overcome the effects of the interruption.

In Chapter 3, we present the design of the three user interfaces. We illustrate how they work as resumption and recalling aids, explain what are the features that each interface provides.

Chapter 4 begins with an analysis of the pilot study design and its limitations, which lead to the presentation of the final study design; this includes materials, study procedures, data collection, location, participants, recruitment, informed consent, compensation, and analysis.

Chapter 5 discusses the results of the study, including how participants used the interfaces for both resumption and recalling purposes, and the impact of these aids on task resumption and recalling the 3D task.

Chapter 6 discusses our results, presents design recommendations, and identifies areas for future work, and we conclude in Chapter 7.

CHAPTER 2 LITERATURE REVIEW

This chapter covers research literature related to interruptions. We first discuss 3D modeling and interaction with 3D models; present some difficulties with tasks in 3D environments. Then, we discuss the factors that make interruption more disruptive. We then review some methods for managing interruption. Next, we discuss resumption and its associated processes (recovery from interruption). Finally, we present some approaches to assist with task resumption and recall. These reviews serve as the motivating foundation of our preliminary designs and prototype implementations presented in the next chapter.

2.1 Interaction with 3D Models

Recently, the use of high-quality 3D models in workplaces and elsewhere have grown quickly. This direction has led to the establishment of a range of 3D model websites as well as applications and libraries where 3D developers can share models they build (Monk, Boehm-Davis, Mason, & Trafton, 2004). 3D models have been used diversely in many fields such as medicine (N. W. John, 2007; Tendick et al., 2000), manufacturing (Mujber, Szecsi, & Hashmi, 2004), design (Maher, Liew, Gu, & Ding, 2005), and education (Chittaro & Ranon, 2007). Moreover, they play an increasing role in examining spatial abilities (Waller, 2005), and testing directional knowledge (Waller et al., 2004).

Interaction with 3D models is a complex task; it involves three main tasks (navigation, selection and manipulation). When users are performing 3D interaction, a primary goal of the interaction is to manipulate the object in terms of its position and orientation in space.

2.1.1 Navigation

Navigation is a significant aspect of 3D interaction. According to Jul & Furnas (1997), navigation is defined as the process in which people locate where they are, where other things are and how to find and get to specific object or location. Navigation can be difficult: people get lost and their navigation efforts become frustrated (Jul & Furnas, 1997). Similar issues can occur when working with complex 3D models. Users of complex 3D models need to be able to understand what they are viewing or manipulating in relation to the entire model and its subassemblies Without using a good visualization and exploration instruments, it easy for users to get lost while they are navigating through 3D objects, to view these objects from inappropriate angles, to miss key features, and to suffer frustration with the difficulty to navigate as required for a task (Singh & Balakrishnan, 2004).

2.1.2 Selection Task

Before users start interacting with 3D objects, the desired object has to be determined. When interaction is limited to a 3D display, selection tasks can be applied by using image-plane techniques (Bowman, 1999). Selection can be also implemented indirectly by tools of menus and lists.

2.1.3 Manipulation

Another common task performed in 3D environment is selecting a 3D object and then manipulating it directly. Manipulation techniques involve three basic tasks: translation, rotation, and scaling.

2.1.3.1 Translation Task

After a 3D object is selected and a translation task is required, a motion in the level parallel to the surface can be applied to accomplish translation. We used the HOOPS 3D Part Viewer application to preform this type of task.

2.1.3.2 Rotation Task

In 2D, rotation can be performed very easily. For example, one touch point identifies the rotation center, while the size of the rotation is determined by round motion around the rotation center. However, rotation of 3D objects can be more complex than mental rotation of 2D objects (Linn & Petersen, 1985) due to a touch interface limits the user's interaction to 2D rotation in the 3D are hard to understand.

2.1.3.3 Scaling Task

In 3D, scaling tasks can be straightforward if scaling is uniform. If non-uniform scaling is required, specification of the scaling vector to be used to the 3D object is a difficult task. We used the HOOPS 3D Part Viewer application to preform uniform scaling.

2.2 3D INTERACTION ISSUES

Although people live in a 3D world and spend all their lives developing skills to manipulate 3D objects and navigate 3D spaces, it can be difficult to interact with 3D models and within 3D environments. Conventional display devices have only the ability to display two-dimensional (2D) pictures that do not have the depth (3D) information. This significant limitation greatly restricts people's ability to understand and perceive the complexity of 3D objects and their spatial relationships. There is evidence that about 50% of the human brain's capability is assigned to handle visual information (Simpson, 2013); however, flat pictures and 2D displays do not utilize the power of the brain efficiently. Therefore, a lack of true 3D display impacts our ability to accurately visualize high-dimensional data (Geng, 2013).

Multi-touch techniques on 2D screens permit 3D objects to be manipulated using one or more fingers at various pressure levels (Pierce et al., 1997). However, since user interaction is limited to a 2D touch surface, the specification of six degrees of freedom (DoF) becomes non-intuitive, which complicates 3D interaction (Epps, Lichman, & Wu, 2006).

Precise spatial knowledge of complex 3D models can require time, and many users either do not want to or are not able to spend the time required (Ruddle, Payne, & Jones, 1997).

3D interaction issues become more pronounced with the size and complexity of 3D environments (Weatherford, 1985). Since users cannot learn the environment structure from a single point of view they must navigate widely and link information deriving from various points of view.

Other contributing factors to interaction difficulties include unfamiliarity with a specific 3D model, and a lack of experience with 3D model viewer software in general (Ruddle, Payne, & Jones, 1998), a lack of adequate landmarks in the model, and a limited field of view (Sayers, 2004). While navigating complex 3D environments and models is difficult, we expect it becomes more difficult when that main task is interrupted. We survey relevant literature on interruptions next.

2.3 Interruption and Factors That Make It More Disruptive

Several interruption studies focus on identifying the characteristics that make interruptions more or less disruptive (e.g., McFarlane, 2002). Many characteristics have been shown to impact main task performance, including the interrupting task's similarity to the main task, interruption complexity, the relevance of the main task and interruption tasks, and timing of interruption occurrence. Studying these characteristics is important for understanding how people might better handle interruptions to work more effectively. Altmann & Trafton (2002) presented a theoretic model called *memory for goals,* which is especially appropriate for the study of interruption. This model has been examined in several interruption studies (Altmann & Trafton, 2007; Hodgetts & Jones, 2006; Monk, Boehm-Davis, Mason, & Trafton, 2004; Trafton, Altmann, Brock, & Mintz, 2003; Hodgetts & Jones, 2006). The memory for goals model is a formal model of goal encoding and recovery in memory. Understanding the manner in which goals are suspended and resumed is an important element in determining how well a user is able to complete the interrupted task. For example, if the primary task is writing a report, it might be suspended when an instant message is received from an important sender. As with many such conversations, the person might have a chance to go back to his main task while waiting for a reply from the sender. However, with each switch, the person must re-gather his thoughts to resume writing the report.

Since this memory for goals model was built to understand such suspended and resumed goals, it is extremely useful for predicting the effects of interruption on main task resumption. The memory for goals model was built based on the activation model of memory items and is represented by the ACT-R (Adaptive Control of Thought-Rational) cognitive architecture (Anderson et al., 2004; Anderson, Bothell, Lebiere, & Matessa, 1998). In ACT-R, information is preserved in memory in pieces, and each of these pieces has a specific level of activation. The main assumption of this model is that when central cognition uses memory, the memory regains the most active piece at that moment. Going back to the example above, the current goal of the writer has the highest level of activation at that instant. In other words, goals that recently have been encoded or recovered will have a higher activation level (the most recent or frequent goals). The report writer will succeed in resuming a suspended task if it was the center of attention just before onset the interruption or for a long period of time before the interruption.

The impact of interruption on task performance could be tested with the memory for goals theory (Altmann & Trafton, 2002) to provide a theoretical explanation of the decisive factors of goal activation and therefore behavior. For instance, when the main goal is interrupted by a secondary goal, the main goal memory will instantly start to experience activation decay (supposing that the secondary task uses the cognitive resources that should be used to rehearse details for the main task). After the interruption, the required time to resume the suspended goal is mainly associated with its level of activation (Altmann & Trafton, 2002). Primary goals that have been pending for a longer time will require longer to resume supposing no intermediating rehearsal.

2.3.1 Interruption Duration

Studying the duration of interruptions has generated different findings in the literature. Researchers who studied the impact of different interruption durations on interrupted task performance have failed to find any effect (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003). Again, Altmann et al.'s (2002) memory for goals theory, which supposes that each task has a related goal with a specific activation level, is relevant here. When the main task is interrupted, its associated goal is kept in the memory. Altmann et al. (2002) found that during interruption, if the goal is not rehearsed, the activation of this goal decays. After interruption, when the main task is resumed, its goal must be obtained from memory, which requires some time. Similarly, Hodgetts & Jones (2006) have shown an impact of interruption duration on task resumption using the Tower of Hanoi task. Their goal was to test the predictive capability of the memory for goals model. In their work, participants were asked after three moves to perform an interruption by clicking on a "mood" button appearing at the bottom of the computer screen to open the mood checklist task. The interruption continued for either 6 or 18 seconds (s). Resumption time, which is the time to resume a task after the interruption, was longer in the 18 second interruption condition. This was the first practical support of Altmann and Trafton's (2002) model.

Other research could not demonstrate any impact of the duration of an interruption. Gillie & Broadbent (1989) did a set of experiments to investigate why some interruptions are more destructive than others. In the first and second experiments, participants had to play a computer game that required them to navigate through an environment and choose objects from a memorized list. Interruptions occurred after specific objects were chosen. The interruptions were simple mathematical questions. In the first experiment, the interruption length was 30-s, while in the second experiment it was 2.75 min. Neither duration led to post interruption task performance decrements. The researchers stated, "the length of an interruption on its own does not seem to be the critical factor in determining whether it will prove disruptive" (p. 246). Recently, studies in the “prospective memory domain” provided further data concerning the interruption duration issue (Einstein et al., 2003; McDaniel, Einstein, Graham, & Rall, 2004). According to Einstein et al. (2003), people were able to retain goals over short intervals between 5 to 40-s. In a later study, McDaniel et al. (2004) manipulated the interruption length, extending it to examine the impacts of the duration of the interruption. They compared 10-s and 20-s interruption periods. The findings again demonstrated no effect for interruption duration.

A main challenge for the memory for goals model was to illustrate why one of its essential predictions for interrupted task performance had not been supported in the literature. Hodgetts & Jones (2006) revealed several possible reasons for the failure to demonstrate consistent proofs for the effects of interruption duration. One reason was that several interruption studies used global measures, which were not sensitive to the impacts associated with goal resumption. For example, (Gillie & Broadbent, 1989) conducted a study to compare pre- and post-interruption task times and error averages, but did not examine the time participants needed to resume the task after the interruption. Czerwinski, Cutrell, & Horvitz, (2000) measured the total time to perform the interrupted task and the time to respond to the notification of the interruption. Other researchers measured errors rates in the main task performance (Cellier & Eyrolle, 1992; McFarlane, 2002; Oulasvirta & Saariluoma, 2004) and performance of decision- making (Speier, Vessey, & Valacich, 2003). The lack of sensitive measures for how quickly people resume the suspended task after interruption might have been one of the main reasons why past studies failed to find any effects of interruption duration. It was not until Hodgetts and Jones (2006) applied Altmann and Trafton’s (2002) resumption lag measure that proofs for the effects were found. Therefore, the resumption lag measure, which is defined as the required time to resume the suspended goal, is adopted as an important measure in our research.

2.3.2 Timing

Interruption is often disruptive; however, sometimes an individual may feel that there are better and worse moments to be interrupted. Identifying what makes specific moments better or worse has been an interesting area of research. For example, a previous study has found that interruptions occurring at subtask boundaries (the beginning or the end of the subtask) have fewer impacts than those occurring in the middle of a subtask (Czerwinski et al., 2000a; Monk et al., 2004). Iqbal & Bailey (2005) propose that this is due to the subtask boundaries representing moments of low workload, so it is less disruptive to be interrupted at the end of a sequence than in the middle of it. Similary, Botvinick & Bylsma (2005) developed a theory of interruption timing for routine tasks. They tested performance after the interruption. Their work suggested that interruptions have more negative impacts in the middle of the subtask than at subtask boundaries. In their study, the participants were interrupted at different points while they were doing the routine task of making coffee. Results showed that the participants who were interrupted in the middle of a subtask were more prone to commit errors than when they were interrupted at subtask boundaries.

Some systems, such as Oasis built by Iqbal & Bailey (2010), have been created for the purpose of controlling and managing interruption. This system holds notifications until users reach a natural breakpoint in their primary task. The researchers specify three levels for breakpoints: coarse, medium and fine. Fine breakpoints include switching from writing to reviewing a document, while coarse breakpoints happen when users switch to an entirely independent task. Interruption is less disruptive at coarse breakpoints since there is no continuous context that needs to be preserved. The authors ascribed increase in errors during subtasks to "temporal context," which is the required information to make a decision regarding what has been finished and what is left to do. This information was clearest at decision points in which people needed to decide what they should do next. Representation of what has been done and what has not been are important elements for the process of decision-making. Therefore, these components are mostly represented between subtasks. Within a subtask, temporal context is less clear; thus, it is more easily disrupted.

2.3.3 Task Complexity

Gillie and Broadbent (1989), Hodgetts and Jones (2006b), and (Cades, Davis, Trafton, & Monk, 2007) all adopted a processing requirements definition of task complexity. This was consistent with the definition by (Byrne & Bovair, 1997), who indicated that there are a number of features that seem to determine task complexity, including the number of actions to be done, the difficulty of doing these actions, the number of sub-goals to be recalled, and the amount of information to be managed and preserved. Gillie and Broadbent (1989) showed that the complexity of an interruption task reduced the accuracy of the main task. The reason for this decline is that complex interruptions lead to increased processing and memory loads. Hodgetts and Jones (2006) found that the resumption lag was shorter when the interruption task was simpler than when the interruption task was complex. This is due to the intervention between the goal of the primary task and the goal of the complex interruption task. According to Eyrolle & Cellier (2000), the complexity of the interruption can be determined by the amount of information handled over the interruption task. They found a slight effect of complexity on error rate, but there was no effect on the time to complete the main task.

2.3.4 Task Relevance or Similarity

The similarity degree between the content of the main task and the interruption task is a possible predictor of the disturbance of an interruption. However, it does not capture any of the memory impacts that could result from the intervention between the main task and the interruption. For example, if the main task requires memorizing a set of product codes and then an interruption task asks a user to think about a connected set of codes, this may either support recall of the original codes or confuse the user about which codes they were working with earlier (Altmann & Trafton, 2002).

Previous studies about the interruption relevance have considered content similarity and relevance as equivalent. Czerwinski, Cutrell, and Horvitz (2000b) defined relevant interruptions as those that provided participants the answer to a question they were trying to answer in the main task, while irrelevant interruptions provided participants some detail about the environment in which they were working. Iqbal & Bailey (2008) state simply that a relevant interruption is associated with the main task, while an irrelevant interruption is not.

2.4 METHODS OF INTERRUPTION MANAGEMENT

McFarlane (2002) presented a taxonomy of human interruptions in HCI that consisted of four methods of interruption coordination: immediate interruption, negotiated interruption, mediated interruption, and scheduled interruption.

2.4.1 Immediate interruption

In this interruption type, the user is immediately affected by the interruption and has no way to delay interaction with the interrupting task. This likely leads to an issue when users return to the primary task. Regarding resumption, many studies have guided the designers of user interface (UI) on how to make the resumption task easier and more efficient.

2.4.2 Negotiated Interruption

This method is the opposite of immediate interruption. For a negotiated interruption, users can make one of these choices:

- Deal with the interruption immediately
- Postpone, and inform the interrupting person that you will deal with it later
- Explicitly refuse to deal with it (by stating so)
- Implicitly refuse to deal with it by not interacting with the interrupting person

2.4.3 Mediated interruption

This method can be simply explained with an example: in a manager's office, a secretary receives information (interruptions), and they determine how and when to notify the manager that the information has been received. Interruptions to the manager are therefore mediated by the secretary.

2.4.4 Scheduled interruption

The aim of this approach is to inform a user in advance when they will be interrupted. It contributes to making various sorts of interruption less opportunistic so that they will be more like scheduled tasks. However, this approach requires a good understanding the organization of users' time (McFarlane, 2002).

McFarlane implemented four different user interfaces, with each using one of the above interruption methods. The primary task was game-playing and the interrupting task was object-matching. The findings showed that there is no one best method for interrupting users, and depending on the condition and the system, any of the above methods can be utilized. They give specific guidelines based on their results, as follows:

- If *accuracy* is the main objective, then the best method is negotiated and the worst is scheduled interruption.
- If the *number of tasks* is the main objective, then the best method is scheduled and the worst is immediate interruption.
- If *finishing* the intermittent task is the main objective, then the best method is immediate interruption.
- If *speed of response* is the main objective then the best method is immediate interruption (McFarlane, 2002).

As we can see from the previous work outlined above, there are many studies that have considered different kinds of short term interruptions; however, in our study we are not looking at different types of interruption. Instead, we are considering resuming tasks involving 3D models after a longer duration interruption (1 day).

2.5 RESUMPTION (RECOVERY FROM INTERRUPTION)

Interruption often lowers performance, by introducing a time cost for resuming after the interruption and increasing the number of errors during the task (Altmann & Trafton, 2004; Brumby, Cox, Back, & Gould, 2013; Monk et al., 2004). How people resume their task after interruption is an interesting area of research, because it is often the point where errors occur. (Bailey & Konstan, 2006) showed that interruption doubled the occurrence of errors on routine tasks. Also, they found that interruption increased participants' stress. Monk et al. (2004) examined interruption during a driving task and demonstrated that after interruption, participants were slower to resume their task and they even resumed at the wrong point without realizing it. Generally, the literature on resumption shows a picture of slowed progress, with added performance errors as a consequence of interruption.

2.5.1 Resumption Process

Most of the studies on interruption recovery are based on the work of Trafton et al. (2003) who did a task analysis of the interruption process and proposed a model to explain this process. Trafton et al. (2003) expanded McFarlane's negotiation-based method and determined "interruption lag" as the period between when the person receiving the interruption alert and dealing with the interruption task. Then Altman et al. (2003) suggested that interruption lag may be used as a preparatory phase for the interruption and experimentally demonstrated that preparation (e.g., encoding goal) can eliminate the required time to resume the main task. Another important concept in interruption recovery is called the "resumption lag". It is a key measure of the impact of an interruption on resumption (Adamczyk & Bailey, 2004; Altmann & Trafton, 2004, 2007). In exploratory studies, resumption lag is usually measured as the period between a user being asked to resume a task and the initial physical action made like a mouse click. Building on the memory for goal theory (Altman and Trafton, 2002), Altman et al. (2003) proposed a simple cognitive process of interruption. The memory for goal model stated that a goal is preserved in various stages of memory. They assert that the recall of the primary task after the resumption lag is achieved either by encoding the goals prospectively or rehearsal of the last task in the active memory retrospectively. Trafton et al. (2003) indicated that the first stage in task recovery is to recall the last task status before onset of the interruption and the memory for goal theory basically explains how task status is recalled and preserved in working memory to resume the task. Moreover, (Oulasvirta & Saariluoma, 2006) expanded on Altman and Trafton's theoretical model and suggest that in order to reduce the impacts of interruption on memory, task representations have to be maintained in a way so that people can access it reliably and quickly later on. Furthermore, Oulasvirta et al. (2006) expanded on Altman et al.'s concept of encoding the goal. They stated that experts realized hierarchical knowledge representations called "retrieval structures" and use them to encode and recall the task after an interruption.

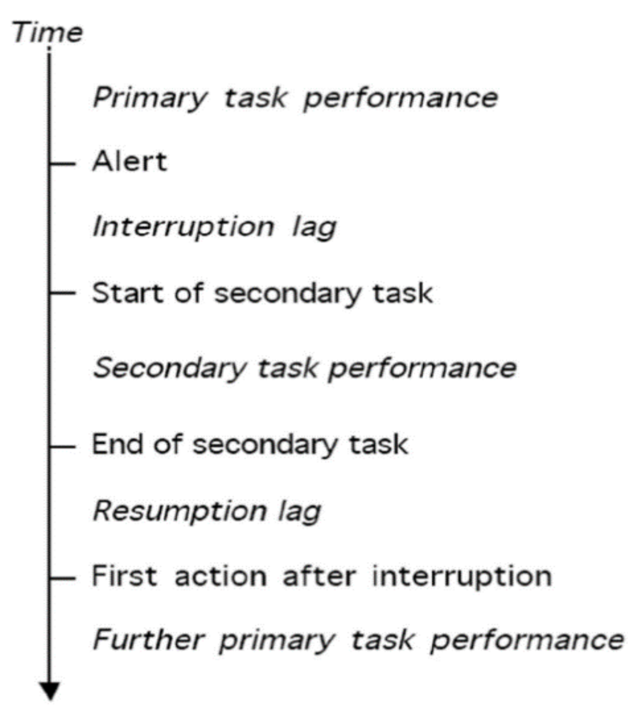


Figure 1 Interruption recovery process (Trafton et al., 2003).

2.5.2 Tools to Help in Interruption Recovery

Several methods to facilitate interruption recovery have focused on aiding users to recall what they were doing before the onset the interruption (e.g., (Altmann & Trafton, 2004). This research indicates that the undesirable impacts of interruption can be mitigated if users are provided with a chance for preparation prior to the interruption.

2.5.2.1 Replay Interruption Recovery Approaches

Some studies have focused on developing recovery tools in an attempt to mitigate the loss of context after interruption. (Safer & Murphy, 2007) developed the Animated Snapshots Tool, which quietly captures snapshots of a programmers' screen as they work and then offers a means of replaying the captured snapshots to determine task boundaries to assist programmers in multi-tasking.

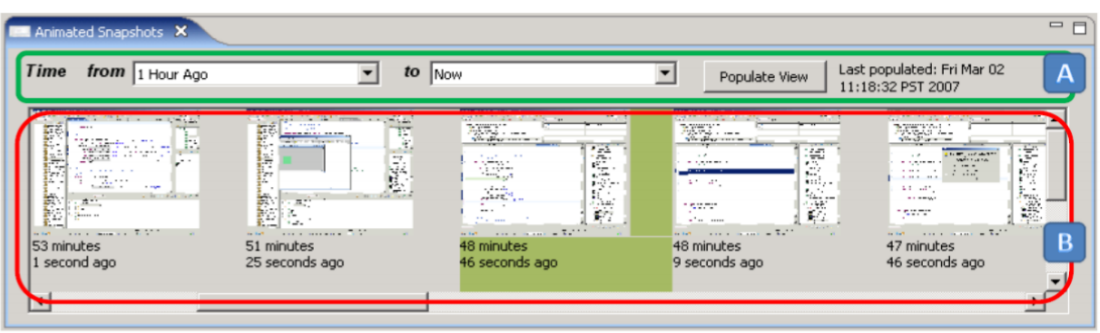


Figure 2 Animated Snapshots Tool. Part A provides controls to specify the time and duration of interaction considered. Part B show thumbnails of the snapshots representing a programmers' working environment (Safer & Murphy, 2007).

Similarly (Joyita & Rozenberg, n.d.) designed a snapshot tool that records the screen of a programmer. Snapshots are captured every 2 seconds. This tool was developed to assist the programmer with visual details about the task context. It may be used by the programmers to retrieve task context after the end of the interruption. This tool, called Replay, provides developers with a video stream of snapshots of their work up to the onset of the interruption. The researchers conducted a study to evaluate this tool and see how this tool assists developers to overcome the destructive impacts of interruptions. They wanted to investigate if usage of the visual presentation of the previous working status of the participants helps them get back to the main task easily and reduces the time to resume coding. Participants were asked to do a simple coding task and they were interrupted in the middle of that task. When participants use this tool for interruption recovery, they have two options; they either scroll between the snapshots or play a video of the snapshots of their screen before the interruption. The results showed that visual recollection is a helpful tool that assists developers to recall their task context and probably improve their performance. Participants who used Replay expressed satisfaction with the tool.

Many studies have focused on assisting people to resume and recall what they were doing before the interruption. Other research has studied interruption recovery in a supervisory control task such as military command and control, air traffic control and emergency response. These tasks depend on realizing what changes have happened in the controlled system, which may or may not be associated with the user's previous activities. Instant replay allows users to review a high-speed video of the period where they were interrupted and mitigates the impacts of interruption on task resumption. (M. John, Smallman, & Manes, 2005) have examined instant replay as a resumption aid in "dynamic monitoring activities", which are considered a vital factor for conducting several supervisory activities. Their study demonstrated that video replay as a recovery aid is less effective than providing a history list of textual action descriptions in assisting people with task resumption. Moreover, findings showed that video replay usually led to increased resumption lag (slower resumption). However, (Scott, Mercier, Cummings, & Wang, 2006) suggested that these results may have been affected by limitations in the design of the capture tool itself: for example, their tool design did not highlight any specific events; also, it did not allow users to control which events were played. All these factors led to wasting too much time watching the video replay to recall their past actions. On the other hand, the textual history list gave a summary of critical events, but it required time and cognitive effort to link the contextual text to the graphical component on the screen. Scott et al. (2006) developed an interruption recovery tool called the Interruption Assistance Interface. The main components of this tool are an interactive event timeline that summarizes past events visually with iconic bookmarks and a replay window that displays past events in their proper context. To investigate approaches of discovering past events, two methods of interaction for viewing events were developed: the animated replay and bookmarked replay. In animated replay, a specific series of events could be viewed in the replay window. In bookmarked replay, when an event bookmark is selected, the replay window shows the system status at that time. The result showed that both assistance interfaces are effective interruption recovery tools since they provide bookmarks of highlighting system events.

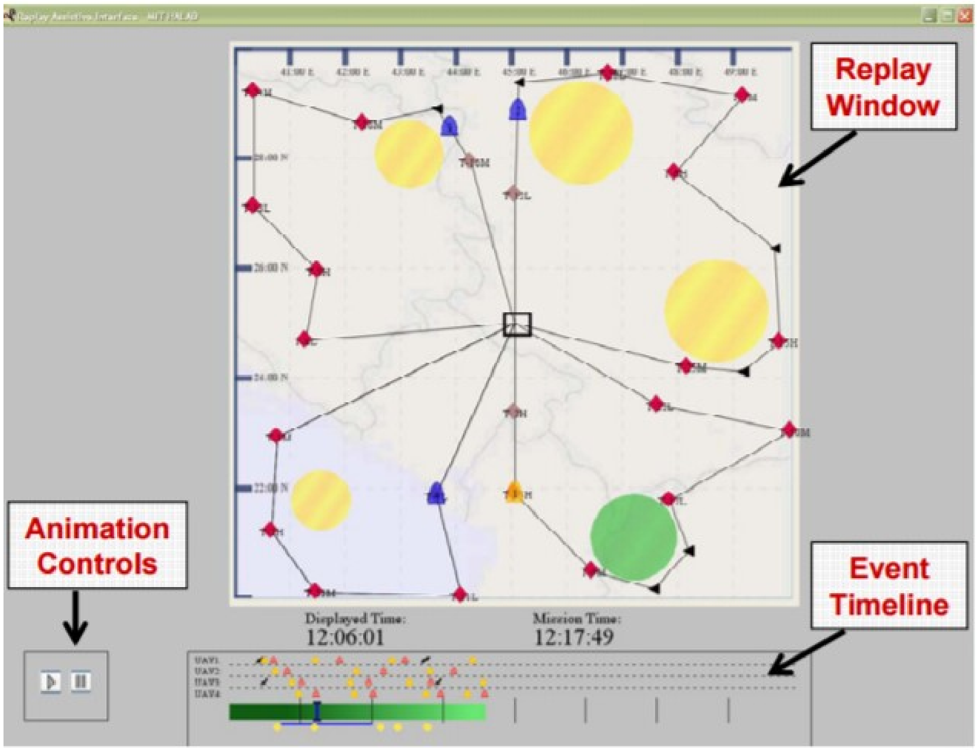


Figure 3 Interruption Assistance Interface (Scott et al., 2006).

2.5.2.2 Contextual Cues

Some investigators have illustrated that an external cue such as red dot can work as a cue to take a specific action (McDaniel et al., 2004). Moreover, Trafton et al. (2005) tested various environmental cues, and then measured their impacts on resumption after interruption. They conducted an experimental study in which participants were interrupted, and at resumption they were provided with one of two kinds of cues or no cue. The first kind of cue was a red arrow which provided a blatant environmental cue of their prior action, while the second one was a mouse cursor left on the same place before the onset of the interruption, considered as a subtle environmental cue of the users' prior actions. Results indicated that the arrow cue allowed users to resume their tasks faster than users than users who had the cursor cue or no cue. Moreover, there was no difference between the subtle environmental cue condition and no cue condition.

(Jones, Gould, & Cox, 2012) have looked for a method to alleviate the impacts of interruption on performance of "computer-based routine procedural tasks". To do so, they explored the effectiveness of various kinds of cues. They compared three cue conditions: the control condition with no cues, previous-action cueing, and next-action cueing. According to their findings both previous and next action cueing mitigated the average error level to below 5%. Other investigators have focused on other tools for assisting suspended goals. Altmann and Trafton (2004), Hodgetts and Jones (2006), and Trafton et al. (2005) have shown a strong positive relationship between the availability of contextual cues and decreased resumption costs. In contrast, Cutrell et al. (2000, 2001) did not find a pronounced benefit of marker-based cues on resumption, stating "we confirmed our earlier assessment that there is little to no benefit of having a marker present after a notification was received" (2001, p. 268).

2.5.2.3 Rehearsal

The theory of Trafton et al. (2005) made three basic predictions about task resumption after an interruption. First, the goals of the main task decay relatively steadily. They assert that the main aim of designing a helpful interruption tool is to reduce or slowdown that decay in some way. Their theory supposes that there are two fundamental methods to reduce goals decay: using environmental cues (discussed above), or rehearsal. Rehearsal can be either retrospective (What was I doing?) or prospective ("What was I about to do?"). Both of these kinds of rehearsals are significant in the models proposed by Altmann & Trafton (2002) and Trafton et al., (2003). However, the empirical data (Trafton et al., 2003) suggests that people do more prospective rehearsal when given the opportunity.

Trafton et al. (2003) did an observation study of people who used prospective rehearsal of their tasks. Results showed that taking prospective rehearsal at the interruption time has both positive and negative impacts. (Clifford & Altmann, 2004) examine the effectiveness of mental and physical notes that people take before the onset of the interruption, to see whether they mitigate time cost at resumption. While participants performed the primary task a visual notification was randomly presented to inform the participant that the peripheral task was about to launch. There were about six seconds as interruption lag, and during that time the participant was not able to perform any action on the primary task interface. After that, the primary task was replaced by the peripheral task (interruption), which continued for about 30 to 45 seconds, then the primary task was presented again, to be instantly resumed. The study had three conditions, as follows:

- *The No Cue Condition* the display of the primary task is cleared in the beginning of the interruption lag.
- *The Cue Condition* the display of the primary task is kept during the interruption lag.
- *The Record Condition*, participants are guided to use the interruption lag to record some details on a prepared sheet about the primary task.

The results showed that in the *No Cue Condition,* there was a notable increase in resumption lag, while in the *Cue Condition,* the resumption lag was clearly lower than in the *Record Condition*. These results indicate that visual cues reduce the resumption lag of the primary task. However, recording contextual details on a sheet of paper slowed down the resumption of the primary task.

Taking notes as retrospective rehearsal was examined by (Kalnikaito & Whittaker, 2007) who conducted an experiment exploring the relationship between note-taking methods (digital or paper based) and the later recovery. Participants were given two systems: a note-taking device called ChittyChatty (CC) that integrate digital notes with an audio record and traditional Pen & Paper (PP). The researchers wanted to examine whether the quality and quantity of those notes associated with subsequent organic memory (OM) (e.g., human memory without any external aids), they also investigated people's understanding of the accuracy of their OM in terms of the quality and quantity of their PP and CC notes, examine whether people who thought they had faulty memories took more notes or not. The results showed that taking high-quality notes boosted OM; however, taking large numbers of notes did not. This result seemingly runs counter to the distraction hypothesis which would suggest that taking notes may cause people to remember less using OM at recall; however, it is likely that taking good notes constitutes a form of rehearsal that commits task sequences to memory, rather than a distraction to the main task, thereby facilitating recall. Moreover, there was a close equivalence between digital and pen and paper notes. Furthermore, people who have less confidence about their OM tend to take many notes. This indicates that those people have an awareness of the poor quality of their OM that is why they are trying to overcompensate by taking more notes.

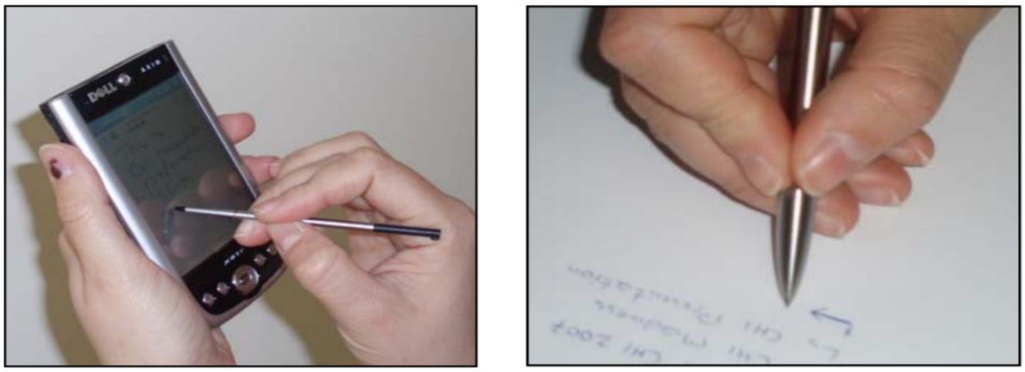


Figure 4 ChittyChatty (CC) Interface – temporal coindexing of notes and audio and Pen & Paper (PP) (Kalnikaito & Whittaker, 2007).

We applied some of the practices from the literature to our study design. Firstly, we built our resumption aid interfaces based on memory for goals theory because we believe that during interruption, if the goal of the task is not rehearsed, the activation of this goal decays. Therefore, we developed these aids to help people preserve some important details about their task status that might help them later for faster resumption. Secondly, some results from previous studies of the impacts of duration, complexity, timing, and relevance of the interruption showed that interrupting people in the middle of their task with a longer, more complex and irrelevant interruption have more disruptive effects on the resumption. We wanted to evaluate our resumption aids in a kind of challenging situation where people might need aids to resume tasks. Thus, we interrupted the participants in the middle of their main task and exposed them to a long duration of interruption, during which they may perform many irrelevant tasks of different complexities. The interruption was an immediate so they had no chance to delay the interaction with the interrupting task (McFarlane, 2002).

In the design of our resumption aids we adopted the idea of the Replay tool proposed by Joyita and Rozenberg (n.d.): we employ a visual presentation of the previous working status of the past task status as a key component of the three proposed interfaces. Based on results from Kalnikaito and Whittaker (2007), who demonstrated that taking high-quality notes boosted memory, we wanted to examine the effectiveness of taking of audio notes while performing tasks based on 3D models, so we utilized audio annotation as another main component of two of our developed resumption aids.

By looking to the previous interruption recovery approaches, we can see that there are many approaches and techniques used as resumption aids for different task types. They used different tools (e.g., visual presentations and audio annotations) to help users recall the previous state of their work; however, none of them has focused on work involving 3D models. We identified a gap in helpful aids for 3D task resumption, and investigated how well these aids assist with resuming 3D tasks to reduce the impact of the interruption.

CHAPTER 3 USER INTERFACES

In this chapter, we present the applications we use in our study: the HOOPS 3D Part Viewer and the three resumption aid interfaces. For the resumption aid prototypes, we will present their design, features, and explain how they can be used for task resumption.

3.1 HOOPS 3D Part Viewer

We used this application as the tool to view 3-D models. HOOPS is commercial software targeting users in aerospace and other manufacturing industries. Through consultation with the developers, a custom version was built in the lab to permit interaction on touchscreens. Three basic interactions were implemented: zoom, pan, and rotate. Zooming is achieved using the standard pinch interaction, panning by dragging two fingers in the desired direction of movement, and rotating by dragging one finger in the desired direction of rotation. The application was also designed to log all user interactions for analysis purposes.

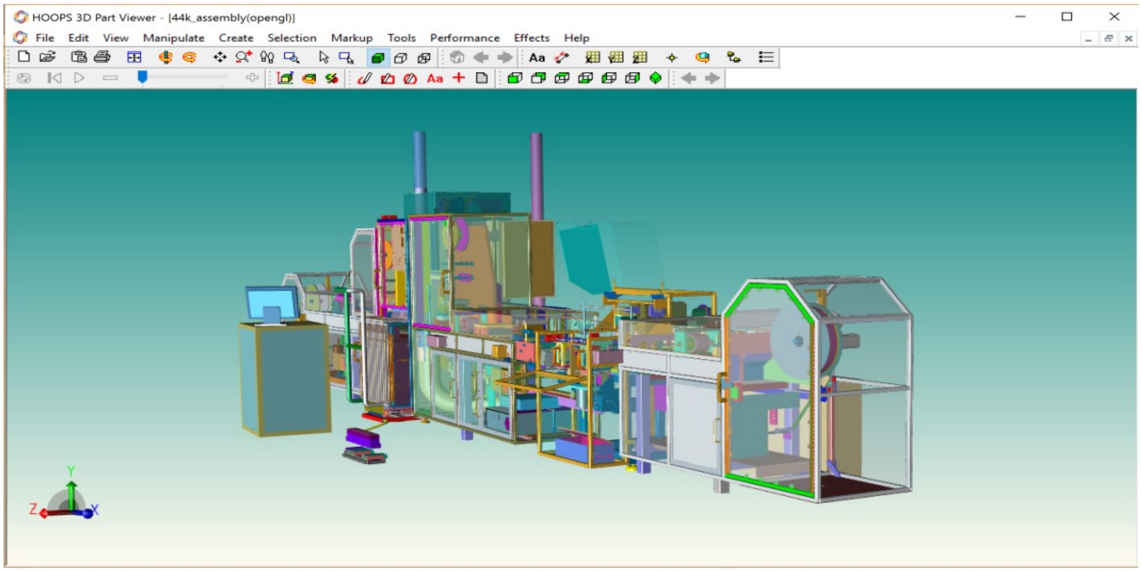


Figure 5 HOOPS 3D Part Viewer.

3.2 The New Prototypes

We used Microsoft Visual Studio 2013 to build the three-resumption aid prototypes. These prototypes were designed to aid resumption of tasks involving 3D models. The design of each resumption aid provides users with a visual presentation of their previous work states. This is done in different ways in each prototype: using screenshots combined with an audio description, providing a video record of user-selected interaction segments, and providing a video record alongside audio description.

3.2.1 Audio Notes Prototype

This prototype was designed so that users can record audio notes during their interaction with the 3D model. When users start their task, they log in to retrieve data about their past sessions.

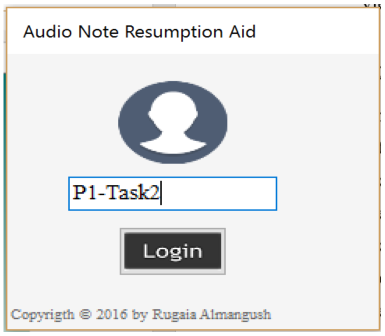


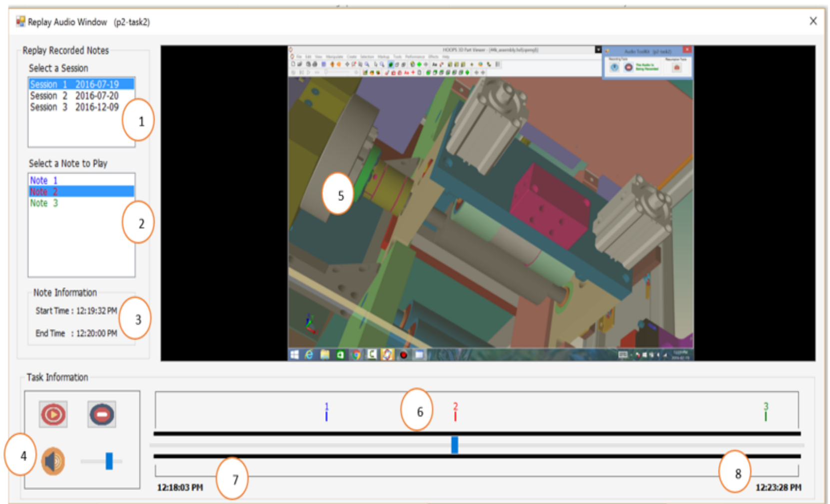
Figure 6 Audio Notes Resumption Aid login window.

Once users are logged in, they will see the *Audio Toolkit* on the top right corner of the screen. They can use this toolkit to record audio notes when interacting with the 3D model.

To begin recording, users need to press the "start recording" button and press the "stop recording" button to stop recording. Each recording is accompanied by a screenshot that captures the 3D model view when the user stops recording; this is similar to the Replay tool developed by (Joyita & Rozenberg, n.d.) and the Animated Snapshots Tool designed by (Safer & Murphy, 2007). These tools quietly capture snapshots of a programmers' screen as they work and then offer a means of replaying the captured snapshots. When users are interacting with the 3D model, they may record as many notes as they want.

Figure 7 The Components of the Audio Toolkit.

When users want to resume their task, they need to press the "resumption" button (see Figure 7). Then they will see a *replay* audio notes window that has the audio notes that they recorded in the current session and any previous sessions. Sessions are defined as instances that the HOOPS viewer is opened, and the audio notes tool is initialized, used at least once (which starts the session), and then explicitly closed (which saves the session). The current application session is also presented (on the bottom of the list). They are numbered sequentially and the date of each session is provided in the list box to facilitate disambiguation.



1. List of the sessions
2. List of audio notes for the selected session
3. Information time about the selected audio note
4. Audio control box
5. Audio note's associated screenshot
6. Audio note bookmarks
7. Task start time
8. Task end time

Figure 8 The Components of the Replay Audio Notes window.

Each session has numbered audio notes, which appear in a second list box when a session is selected (Figure 8). When users press on the "resumption" button, they will see a screenshot that shows the 3D model view when they stopped recording the selected audio note, presented on the right panel of the window (Figure 8). They also see a timeline at the bottom of this window that shows the time in the session that each audio note was recorded. The audio description plays when the user selects a note, which can be done either from the list or on the timeline. The note's duration is also presented in the window. Users can enlarge the screenshot by double tapping on the screenshot being displayed, and then double tapping again to revert back to the original size. Also, they may open the replay audio notes window from the audio notes toolkit as many times as they want when they continue the task. When they complete the task, they press the "Close" button in the *Audio Toolkit* to save the interaction as a new session and close the window.

3.2.2 Video Replay Prototype

This prototype was designed so that users can record a video of the screen during their interaction with the 3D model. When users start their task, they log in to retrieve data about their past sessions.

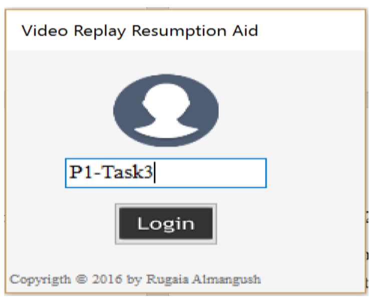


Figure 9 Video Replay Resumption Aid login window.

Once users are logged in, they will see the *Video Toolkit* on the top right corner of the screen. They can use this toolkit to record a screen capture video of their interactions with the 3D model.

To begin recording, users need to press the "Start recording" button in the video recording tools and press the "stop recording" button to stop recording. This tool captures all the interactions users perform with the 3D model. This prototype does not support audio recording, but video recording only. As users interact with the interface, the locations where they touch the screen with their fingers will be recorded as interaction points. Users may use this to indicate unlimited points of interest in their interactions. For example, interactions such as long press, double tap, etc. can be used to mean different things during the interaction. We called this feature the "*Finger Taps"* feature (see Figure 11).

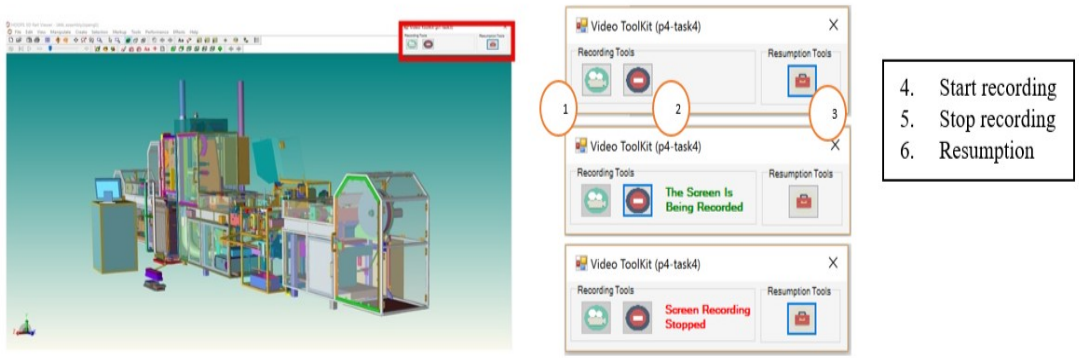


Figure 10 The Components of the Video Toolkit.

When users want to resume their task, they can click on the "resumption" button (see Figure 10). Then they will see a *Replay video* window that has the video recording that has been recorded in the current session and any previous sessions.

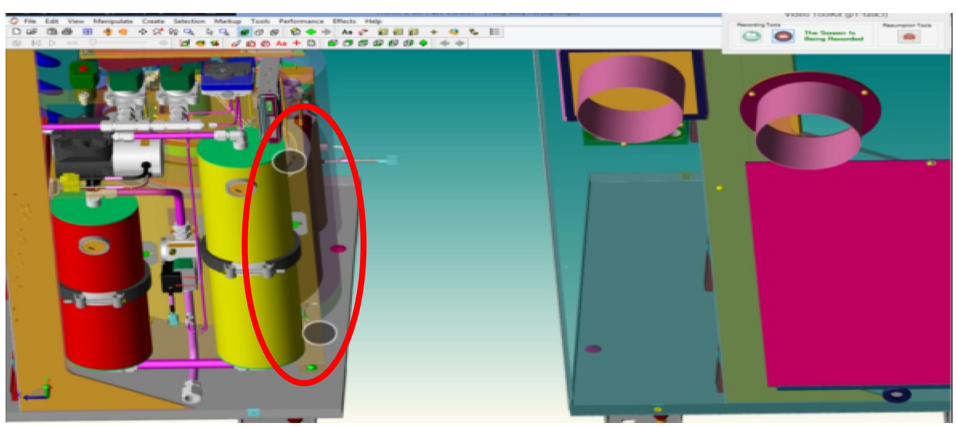
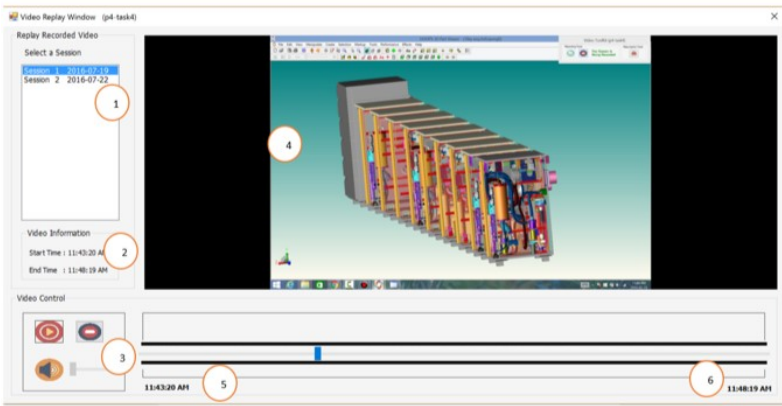


Figure 11 Location of user figures as interesting interaction points.



1. List of the sessions (videos)
2. Information time about the selected session
3. Video control box
4. Video interaction associated with the selected session
5. Session start time
6. Session end time

Figure 12 The Components of the Video Replay window.

Sessions are defined as times that the HOOPS viewer is opened, and the *Video Replay* tool is initialized, used at least once (which starts the session), and then explicitly closed (which saves the session). The current application session is also presented (at the bottom of the list). They are numbered sequentially and the date of each session is provided in the list box to facilitate disambiguation. Once users click on a session, it will be played, although users can also press the “play” button to see the interaction video. They may also “pause” the video at any time by pressing the “play” button again. To stop video replay, users need press the “stop” button to the right of the “play” button. Users can also enlarge the video by double tapping on the video being displayed, and double tapping again to revert back to the original size. Users can open this replay video window from the video toolkit as many times as users want as they continue with the task. When they complete the task, they press the “Close” button in the *Video Toolkit* to save the interaction as a new session and close the window.

3.2.3 Combined Audio Video Prototype

This prototype was designed so that users can record a video of the screen and record audio notes during their interaction with the 3D model. When users start their task, they log in to retrieve data about their past sessions.

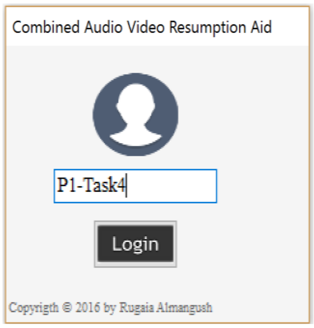


Figure 13 Combined Audio Video Resumption Aid.

Once users are logged in, they will see the *Audio Video Toolkit* on the top right corner of the screen. They can use it to record a screen capture video of their interaction with the 3D model and can also record audio notes. This prototype supports audio and video recording, combining the features of the previous prototypes. As users interact with the 3D model, a video of the screen will be recorded. Users can record as many audio notes as they want. Moreover, the locations where users touch the screen with their fingers will be recorded as interaction points.

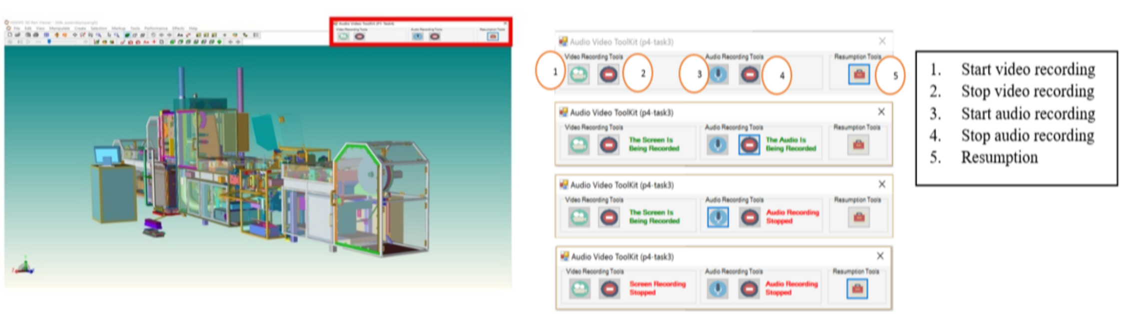
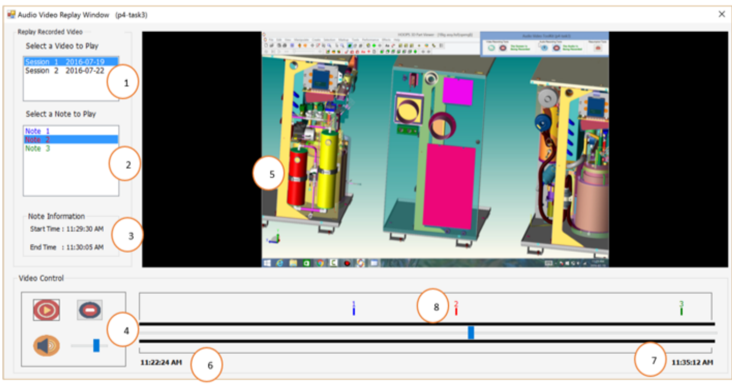


Figure 14 The Components of the Combined Audio Video Toolkit.

When users want to resume their task, they can click on the "resumption" button (see Figure 15). Then they will see a *Replay video* window that has the audio notes that they recorded in the current session and any previous sessions.



1. List of the sessions
2. List of audio notes for the selected session
3. Information time about the selected audio note
4. Video control box
5. Video interaction associated with the selected session
6. Task start time
7. Task end time
8. Audio notes bookmark

Figure 15 The Components of the Combined Audio Video Window.

Similar to the previous resumption aid interfaces, sessions are defined as times that the HOOPS viewer is opened, and the *Combined Audio Video* tool is initialized. Like the *Audio Notes* resumption aid, each session has numbered audio notes. When users click on a session, the whole video interaction will be played; however, users can also click on individual audio notes to play the associated video interaction. The "play" button can be pressed to see the interaction video. Also, the video can be paused at any time by pressing the "play" button again. To stop video replay, users need to press the "stop" button to the right of the "play" button. Users will see a timeline at the bottom of the screen showing at what point time in the interaction they recorded the audio notes when a note is selected. This is similar to the Interruption Assistance Interface (Scott et al, 2006) that provides bookmarks of highlighted system events. Users can also enlarge the video by double tapping on the video being displayed, and double tap again to revert back to the original size. Users can open this replay video window from the *Audio Video toolkit* as many times as they want as they continue with the task. When they have completed the task, they press the "Close" button in the *Audio Video Toolkit* to save the interaction as a new session and close the window.

CHAPTER 4 USER STUDY

To compare the three developed resumption aid interfaces and their suitability as resumption aids for tasks involving 3D models, we conducted a laboratory study. This chapter first describes the pilot study then details the formal study design, including tasks, data collection, location, participants, recruitment, informed consent, compensation, and analysis.

4.1 PILOT STUDY

After we finished designing the three resumption aids, we designed our study with four independent variables: (1) Resumption Aids which had four levels, *No Aid*, *Audio Notes*, *Video Replay*, and *Combined Audio Video*; (2) Model, which also had two levels, Model 1 and Model 2; (3) Main Task, which had eight levels, Task 1-Model 1, Task 2-Model 1, Task 3-Model 1, Task 4-Model 2, Task 5-Model 2, Task 6-Model 2, Task 7-Model 4, Task 8-Model 2; and, (4) Interruption Task which had four levels, Simple-Related, Simple-Unrelated, Complex-Related and Complex-Unrelated. The study was conducted in one session and each participant performed 4 main tasks with each model and one type of interruption in the middle of the task. The length of each interruption was between 10-15 minutes. When we piloted this design with 3 participants, we encountered a number of issues:

1. The study took too much time, almost 3 hours for each participant to perform all tasks (8 main tasks+ 8 interruption tasks).
2. The interruptions did not distract participants sufficiently so that they had difficulty recalling the context of their main tasks. We posited that the resumption aids were too coarse-grained to support most short term interruptions.
3. While unrelated tasks introduced a slight disruption (however not pronounced), we found that related tasks (whether simple or complex) were not at all disruptive for our participants. This is consistent with the findings of Iqbal & Bailey (2008), who indicated that relevant interruptions are less disturbing than irrelevant ones.

To better compare the utility of the three resumption aids, we made the following modifications to the study design:

1. Extended the interruption period to one day. During this period the participant was free to do many unrelated tasks of varying complexity. The study then required two sessions (before and after interruption).
2. Removed the four levels of interruption task. We don't consider the type of interruption (indeed we do not control for this in our study, rather just allow the participants to leave, and return the next day)—we are reliant on the passage of time suffiently long to expect that some task details would be forgotten. We acknowledge that this loss of control means that some participants may have experiences in the intervening time that make it more difficult to resume tasks, but mitigate this by conducting interface conditions within-subjects. This also reduced the number of main tasks required. Therefore, our study designed was modified to include four main tasks (two tasks with each model).
3. Interrupted the participant in the middle of each task rather than at task boundaries because, according to Botvinick et al. (2005), interrupting people in the middle of their task has more negative impacts on performance.

4.2 STUDY DESIGN

In this study, our goal is to compare the different resumption aids in a number of realistic cases. To be able to generalize it to the real world, we need at least two different type of tasks (e.g., Compare and Trace) and two different 3-D models (1: Easy, 2: Hard). Therefore, the basic design would need 16 conditions (2 Tasks by 2 Models by 4 Resumption Strategies).

The simplest design for this study would be a simple between-subject approach. In this design, each participant would only be exposed to one combination of Resumption aid (*No Aid*, *Audio Notes, Video Replay*, and *Combined Audio Video*), Task (e.g., Compare or Trace) and Model (1: Easy, 2: Hard). However, this design is ineffective since it would need a large number of participants, likely 10 to 20 participants per condition (or 160 to 320 in total). Also, each participant is measured once for a short time, which is why this design is weak compared with other approaches.

The main alternative design would be the within-subjects design. In the fully within-subjects design, each participant is measured in all conditions. Thus, we would have 16 conditions. For our study design, this within-subjects design is not practical. There are two main problems. The first problem is it would create issues for recruitment of participants since it would require many sessions for each participant, which would be difficult for participants and they may not be able to finish all the sessions. Then we would need to drop each participant who did not finish the study from the analysis. The second problem with this design is we would suffer from a serious issue which is practice effects. Since the various task may require similar skills, the tasks that come first would provide some practice for the tasks that come later leading to learning and familiarity. Therefore, higher performance on the later tasks might be affected by the practice. Moreover, since these tasks may require similar skills, the tasks that come later may also suffer from fatigue effects (e.g., motor fatigue, cognitive fatigue, boredom, frustration), which are likely to lead to lower the performance of later tasks.

Since the previous study designs present several challenges, we elected to try the mixed design. This design combines the elements of both the between-subjects design and the within-subjects design. It is more complicated to analyze, but it is simplest to manage. We had to make many changes to finally come up with the final study design shown in Table 1. This design is considered as mixed. Each participant performs four conditions, but the conditions are mixed to avoid the carry-over effects. We used counterbalancing (Latin squares) to overcome these effects. Each participant performs two tasks with both Models 1 and 2, but the models are combined with different tasks and different resumption aid conditions.

Table 1 The final study design for the current study.

Group	Model	Task	Resumption Aid	Task	Resumption Aid
1	1: Easy	1: Trace	A	2: Compare	B
	2: Hard	1: Trace	C	2: Compare	D
2	1: Easy	1: Trace	B	2: Compare	A
	2: Hard	1: Trace	D	2: Compare	C
3	1: Easy	1: Trace	C	2: Compare	D
	2: Hard	1: Trace	A	2: Compare	B
4	1: Easy	1: Trace	D	2: Compare	C
	2: Hard	1: Trace	B	2: Compare	A
5	1: Easy	2: Compare	A	1: Trace	B
	2: Hard	2: Compare	C	1: Trace	D
6	1: Easy	2: Compare	B	1: Trace	A
	2: Hard	2: Compare	D	1: Trace	C
7	1: Easy	2: Compare	C	1: Trace	D
	2: Hard	2: Compare	A	1: Trace	B
8	1: Easy	2: Compare	D	1: Trace	C
	2: Hard	2: Compare	B	1: Trace	A
9	2: Hard	1: Trace	A	2: Compare	B
	1: Easy	1: Trace	C	2: Compare	D
10	2: Hard	1: Trace	B	2: Compare	A
	1: Easy	1: Trace	D	2: Compare	C
11	2: Hard	1: Trace	C	2: Compare	D
	1: Easy	1: Trace	A	2: Compare	B
12	2: Hard	1: Trace	D	2: Compare	C
	1: Easy	1: Trace	B	2: Compare	A
13	2: Hard	2: Compare	A	1: Trace	B
	1: Easy	2: Compare	C	1: Trace	D
14	2: Hard	2: Compare	B	1: Trace	A
	1: Easy	2: Compare	D	1: Trace	C
15	2: Hard	2: Compare	C	1: Trace	D
	1: Easy	2: Compare	A	1: Trace	B
16	2: Hard	2: Compare	D	1: Trace	C
	1: Easy	2: Compare	B	1: Trace	A

Where: A= No Aid, B= Audio Notes, C= Video Replay, D= Combined Video Audio

4.3 MATERIALS

4.3.1 Training Tasks

Since participants were recruited from the general Dalhousie University community, we could not expect that they would have the know-how of interacting with 3D models. Therefore, we included a training task for each participant to use the Hoops 3D Part Viewer application. Therefore, in the beginning of the first session, we used a third 3D model exclusively for training. This was a simpler model and we did not use it for the actual study tasks (see figure 16).

In the first session, we trained our participants on how to use both applications, so in the beginning of the first session we used a third simple 3D model, which we did not use to perform the actual study tasks. Using this model, we showed the participant how to use the first application which is the 3D viewer application; we explained how to rotate, zoom in, zoom out, and move the model. Also, we trained the participants on how to use the resumption aid prototypes. Therefore, before the participant performed the actual task with the assigned resumption aid interface, we showed the participant a (5-minute) video that explained how to use the assigned resumption aid interface with an example. We then gave the participant a simple 3D task to perform and during that time we asked them to use the assigned resumption interface to record some details about the task. We believe that the training and practice helped participants to understand how our application works and how to use the 3D model. See Appendix A.

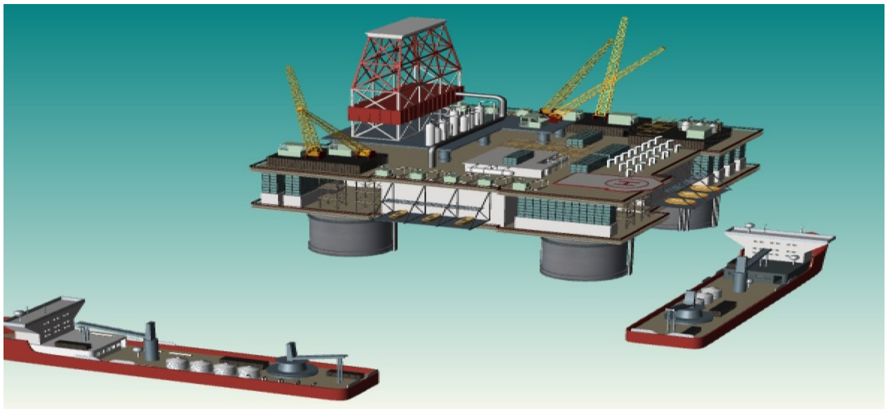


Figure 16 3D Model used in the study to perform training tasks.

4.3.2 Main Tasks

Each participant will perform four main tasks for the entire study using two different 3D models (our tasks per model). Figure 17 show the two 3-D models. The complete set of study tasks is available in Appendix A.

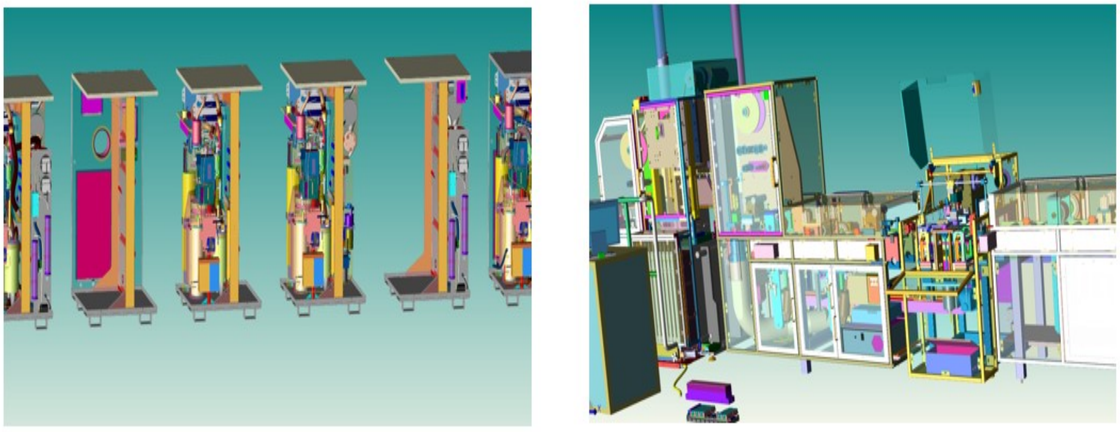


Figure 17 Two 3D Models used in the study to perform main tasks.

The main tasks are divided into two type of tasks: compare tasks and trace tasks.

4.3.2.1 Compare Task

In the first session, this type of task required the participants to explore specific components on the 3D model. Participants needed to distinguish colors and numbers or locations of each component they were asked to locate, and store some details about the component using the assigned resumption aid interface. In the second session, participants could review their stored details from the first session to find where they stopped during last session (resumption point). At this point they were provided with a small picture of the resumption point and they needed to explore the model (rotate, zoom in and zoom out) until they located the resumption point, then they needed to go to different areas of the model to explore some components similar to the ones they discovered in the first session. Also in this session, the participants were required to store some details like colors and numbers or locations of each component that they discovered. At the end of the task, we asked the participant to compare each similar component in terms of color and number. At this stage the participant could use the stored details from the first and second session to help them write the comparison. See Appendix A.

4.3.2.2 Trace Task

In the first session, this task type required the participants to find a specific component (a starting point), and then trace the models from a starting point to an endpoint, which is another component on the model. While tracing, the participants need to distinguish colors and numbers or locations of each component they were asked to trace and store some details about the component using the assigned resumption aid interface. In the second session, the participants could review the stored details from the first session to find where they stopped during last session (resumption point). At this point they were provided with a small picture of the resumption point and they needed to explore the model (rotate, zoom in and zoom out) until they found the resumption point, which would be considered as a new starting point for this session. From there, they had to trace until they reached the endpoint of the second session. Also in this session, the task required participants to store some details like colors and numbers or locations of each components that they traced. At the end of the task, we asked the participant to write a summary of each session, i.e. to briefly describe the steps that they took during the two sessions. At this stage, the participant was allowed to use any stored details from the first session and the second session to help them write accurate summaries. See Appendix A.

4.3.3 Interruption Task

The interruption task involved a long-term interruption (leaving the task for one day over which period they do many unrelated tasks). While no explicit interruption tasks were assigned to the participant, it was expected that the participants would perform several unrelated tasks during that interval, which would count as interruption tasks. We did not record any details of the type of tasks that participants performed during this interval.

4.3.4 Writing Summaries Task

In the second session, each participant had to summarize the two sessions. The summaries are different for each type of task. For the Trace task, participants had to briefly summarize the steps of the tasks that they performed in each session. While for the compare task, participants were required to write summaries comparing the two tasks they performed in each session.

4.4 STUDY PROCESS

The study required two hours divided into two sessions (an hour for each session). In the first session, participants performed four tasks and for each task, participants were given an instruction paper of the first part of the task; it included pictures of the components that they needed to search for in this session. In the middle of each task, they were interrupted (at approximately the middle of the task), i.e. they were instructed to stop the current task and to begin the next task. Then, in the second session (one day later), we gave them another instruction paper for the second part of the task; this paper included a small picture of the resumption point that they needed to locate to resume the task as well as pictures of the components they needed to search for in this session. Participants were asked to use the assigned resumption aid that they had used on the previous day to help them resume their task. After participants resumed each main task, they were required to write the summaries. Then they answered a questionnaire asking them how easy it was to resume their work after the interruption based on the resumption aid they used to resume the task. After they finished the study, they completed a post-study questionnaire that asked them to rate the resumption strategies and answer the spatial ability test. Finally, they took part in a short semi-structured interview where we collected their feedback on all tasks and resumption strategies they used.

4.4.1 Study Procedures

The study took two hours and was divided into two sessions (an hour for each session) as shown in Figure 18.

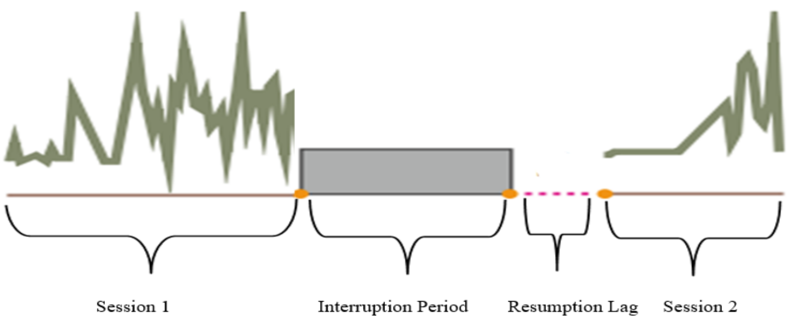


Figure 18 Study Procedures (Session1, Session 2, Interruption Period, and Resumption lag).

4.4.1.1 Task Breakdown During First Session:

- Initial meeting and consent: 5 minutes
- Pre-study questionnaires: 10-15 minutes
- Perform study tasks before the interruption: ~10 minutes per task * 4 (~40 minutes)

4.4.1.2 Task Breakdown During Second Session:

- Resume study tasks after the interruption: ~10 minutes per task * 4 (~40 minutes)
- Complete summaries task ~ 5 minutes.
- Post-study questionnaires, interview and payment: 10-15 minutes.

For each task, the participant used the assigned interface and resumption aid for two purposes:

- As a resumption aid: at the beginning of the second session, participant mays use the aid to help them locate the resumption point.
- As a memory (recalling) aid: at the end of each task participants may need to use the assigned aid to help them write a summary for each session.

4.5 PARTICIPANT ORDER

We counterbalanced the tasks and the strategies for resumption between all the participants (See Table 1).

4.6 DATA COLLECTION

We used seven main data collection methods during this study: device logs, a demographic questionnaire, spatial ability test, a post-task questionnaire, post-study questionnaire, a semi-structured interview, and video recording.

4.6.1 Browser Logs

Each time participants performed tasks on the device, the device logged the interactions with model (e.g., rotations and zooming). Also, the device logged their interaction with the resumption aid tools (such as button clicks and opening and closing windows). This logged data allowed us to capture how participants interacted with both applications (the 3D viewer and the resumption aid interfaces) as they performed and resumed tasks. This allowed us to see if there are differences in how users performed these tasks for the different resumption strategies. The logs captured the time of the tasks on the device. With the logs, we can see how efficient and effective participants were with resuming tasks after the interruption. All logged data were transferred from the device after each participant completed the study and stored on a secure server accessible only by the researchers.

4.6.2 Demographic Questionnaire and The Spatial Ability Test

The demographic questionnaire (Appendix D) asked general demographic questions, such as age, department, general web use, mobile use, and the type of tasks they do on the devices. The spatial ability (Appendix E) test helped us score the participant on how spatial they were to see if this influenced their study performance. The spatial mental test questionnaire is comprised of the questions chosen from (Neuburger, Jansen, Heil, & Quaiser-Pohl, 2011; Vandenberg & Kuse, 1978). This test measures mental rotation abilities. Each stimulus was a 2D image of a 3D object drawn by a computer. Each image was then shown at various directions rotated around the vertical axis. We used this test to see if participants with high mental rotation scores have better performance at resumption. We considered that high mental rotation ability may allow a person to more quickly correlate the model orientations shown in video or snapshots with the 3D model's current orientation.

4.6.3 Post-task Questionnaires

The questions (Appendix F) asked the participants how easy it was to resume their tasks using *No Aid*.

The questions (Appendix G) asked the participants how easy it was to resume their tasks using *Audio Notes* resumption aid interface.

The questions (Appendix H) asked the participants how easy it was to resume their tasks using *Video Replay* resumption aid interface.

The questions (Appendix I) asked the participants how easy it was to resume their tasks using *Combined Audio Video* resumption aid interface.

4.6.4 Post-study Questionnaire

The questions (Appendix J) asked the participants about how they like and feel about resuming different tasks with 3D models using different resumption strategies.

4.6.5 Post-study Interview

In a semi-structured interview (Appendix K), participants were asked about their experiences using the different resumption strategies to resume tasks and get feedback on improvements or other strategies they might find helpful.

4.6.6 Video Recordings

We videotaped all tasks, which conducted using a think-aloud protocol (we asked our participants to talk through each task, and prompted participants to do so if they did not). At the end of the study, the video data were transcribed by the investigators and grouped according to resumption strategies used, and assessed in terms of expressed confusion, hesitation, or frustration, envisioned sequence of steps, fluency and dexterity when using the technique, unexpected uses/interpretations of the strategy.

4.7 Location of the study

The study took place in the Graphics and Experiential Media (GEM) lab, fourth floor, Mona Campbell building.

4.8 Study Participants

We recruited a total of 32 participants (21 male, 11 female) from the Dalhousie University community, they were between 20- 43 years old.

4.9 Recruitment

All participants were recruited by email announcements through Notice Digest (notice.digest@dal.ca) and through the Computer Science mailing list (csall@dal.ca), which is also a monitored mailing list. In the recruitment notice, participants were asked to email their interest to participant to the listed researcher. The participant and researcher then communicated to find an appropriate time for the participant to do the study. The email recruitment script is shown in Appendix B.

Participants were Dalhousie University students who currently own and use a touchscreen device.

4.10 Informed consent

All participants involved in the study signed a consent form (see Appendix C). This was administered by me, the lead researcher, at the initial meeting of the study. I distributed it to all participants, asking for their written consent. The consent form outlines the purpose of my research, the risks and benefits associated with participation, and the conditions involved. These included what they would be required to do and, the fact that they were able to withdraw from the study at any time, should they want to. As well, the consent form made it clear to participants that they could withdraw from the study without loss of compensation.

4.11 Compensation

Participants were compensated $20 for participating in the study (whether they are able to finish or not). This was clearly outlined in the consent form.

Participants signed the Participant Payment Receipt (Appendix L) upon receipt of their payment. Participants did not incur any expenses during the study.

4.12 Analysis

After finishing the study, we started our analysis phase by transcribing all participants' interviews. Transcribing included timestamps for each participant along with what they said. Then we coded the data we got from the interviews using thematic coding. We coded the browser logs, spatial ability test, and resumption aid questionnaires to explore patterns of performance and satisfaction of each strategy type. We used a questionnaire to examine user preference of the different resumption aids. Also, we used logs (time) to calculate the resumption lag, which is defines the time it takes for users to locate the resumption point when resuming a task, and the summary time, which is defined as the time that participants took to complete writing the summary of each task. We used these calculations as key measures of the efficacy of the proposed resumption aid interfaces. We collected a measure of mental rotation ability for the participants, then we correlated this against the task completion time and the resumption lag as an indication of whether mental rotation ability influences performance.

Also, we recorded user interaction with the 3D model using the Bandicam Screen Recorder. This allowed us to match the interaction data captured in logs with the video of interaction on the screen. We used this to observe participant behaviors when we found any interesting indicators in the log data. All video screen capture data was transferred off the device after each participant completed the study, and this was stored on a secure server only accessible by the researchers. We asked for consent to record video from the participants on the consent form.

CHAPTER 5 RESULTS

In this chapter, the results of the study are discussed. First, we looked at the impact of the spatial ability on the participants' performance. Second, we looked at how many participants used the resumption aid for resuming and recalling tasks separately to explore the importance of the resumption aids in both cases. Third, we discuss how annotations were used while performing 3D tasks and whether they assist later resumption. Fourth, we illustrate how using the resumption aids facilitates recalling tasks using 3D models. Fifth, we consider how audio annotation is effective for resuming and recalling tasks involving 3D models.

5.1 Spatial Ability

A measure of spatial ability (mental rotation ability) was collected to see whether the spatial ability of participants affects task performance efficiency as well as performance at resumption. Therefore, spatial ability first was correlated against the task resumption time. However, there were no significant correlations for resumption time: the largest was only $r = .163$ ($r^2 = .026$). Moreover, the correlations between mental rotation ability and resumption lag time just for those cases where the aid was used during resumption (Used Aid) was not significant r=. 0.27 ($r^2 = .073$). We therefore do not consider spatial ability as a factor in our analysis.

5.2 Using Task Annotations For Recalling 3D Tasks vs. Resuming Them

In the second session of the study, participants had the option of using the assigned resumption aid or not to assist them in resuming their task. We found that after completing tasks with the three different interfaces, of the 32 participants, 11 used the resumption aid for all three tasks, 9 used the resumption aid for 2 of 3 tasks, 6 used the resumption aid for 1 of 3 tasks, and 6 never used the resumption aid at all. Table 2 breaks down the number of participants who used/did not use the tool for resumption, by Task Type, Model, and Resumption Aid.

Table 2 Numbers of participants using the resumption aid for resumption purposes.

Task	**Model**	**Use Aid**	**Resumption Aid**		
			Audio Notes	**Video Replay**	**Combined Audio Video**
Trace	1	Yes	2	6	4
		No	6	2	4
	2	Yes	4	5	6
		No	4	3	2
Compare	1	Yes	4	2	5
		No	4	6	3
	2	Yes	7	6	6
		No	1	2	2

From Table 2, we can see that within each task, there was some use and some non-use. Resumption aids were used most often for the Compare tasks with Model 2.

When completing the summary (i.e. recalling their tasks) for session 1 and 2, of the 32 participants, 25 used the resumption aid for all three tasks, 5 used the resumption aid for 2 of 3 tasks, 1 used the resumption aid for 1 of 3 tasks, and 1 never used the resumption aid. Table 3 presents a more detailed breakdown of the numbers for each task (Task Type by Model by Resumption Aid). Generally, there is higher use across the board for all Resumption Aids, Task Types, and Models.

Table 3 Numbers of participants using the resumption aid for recalling purposes.

Task	Model	Use Aid	ResumptionAid		
			Audio Notes	Video Replay	Combined Audio Video
Trace	1	Yes	7	6	8
		No	1	2	0
	2	Yes	8	7	8
		No	0	1	0
Compare	1	Yes	6	8	7
		No	2	0	1
	2	Yes	6	7	8
		No	2	1	0

5.3 USING ANNOTATION DURING TASKS FACILITATES LATER RESUMPTION

We used the resumption lag, which is defined as the required time to resume the suspended task, as a key measure for the efficiency of our three resumption aid interfaces. The mean Resumption Lag in seconds is presented in Table 4 as a function of Task, Model and Resumption Aid.

Table 4 The means and standard deviations for Resumption Lag by Task, Model and Resumption Aid.

Means		Resumption Aid			
Task	Model	No Aid	Audio Notes	Video Replay	Combined Audio Video
Trace	1	382.88,127.46	200.25,46.88	265.25,20.19	150.38,25.74
	2	405.00,179.80	184.38,29.57	276.13,39.09	264.75,55.18
Compare	1	143.25,16.92	221.38,50.24	166.88,23.81	200.00,44.10
	2	280.88, 44.38	253.88,31.19	299.63,64.16	272.63,34.11
Mean for Aid		303.00	214.97	251.97	221.94

From Table 4, we can see that the *No Aid* interface condition yielded longer resumption lags for Trace tasks than the three Resumption Aid conditions. The standard deviations show that Trace Models 1 and 2 with *No Aid* have the most variability between participants. We also note that resumption lag is comparable across interface conditions (including No Aid) for Compare tasks, with a higher average time for Model 2. The data is presented graphically in Figure 19.

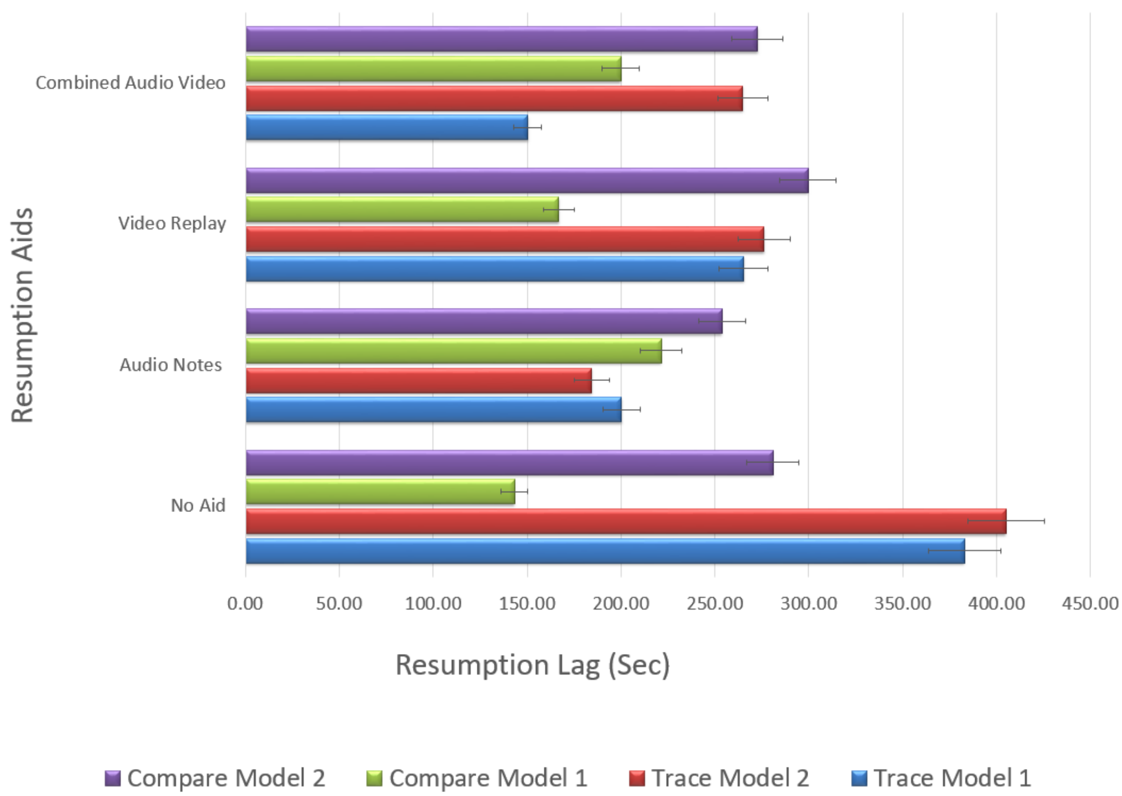


Figure 19 The change in performance for Resumption Lag across Resumption Aid, Tasks and Models.

For the analysis, there were three independent variables: Resumption Aid (*Audio Notes* vs *Video Replay* vs *Combined Audio Video*), Task (Trace vs Compare), Model (Model 1 vs Model 2). Table 5 summarizes the analysis.

Table 5 The Analysis of Resumption Lag as a function of Task, Model and Resumption Aid.

	F	**df**	**p(F)**
All Effects	1.21	15,81	.272
Task	1.13	1,81	.291
Model	3.44	1,81	.067
Resumption Aid	1.37	3,81	.256
Task * Model	0.80	1,81	.375
Task * Resumption Aid	0.75	3,81	.523
Model * Resumption Aid	0.20	3,81	.896
Task * Model * Resumption Aid	0.27	3,81	.848

As we can see from Table 5, there was no effect of Resumption Aid, no effect of Task, and there was a marginal effect of the Model. The lack of significance for Resumption aid may be due to the fact that the Resumption aid is divided over four levels, while the Model effect is divided over only two levels.

In the second session of the study, participants had the option of using the assigned resumption aid or not to assist them in resuming their task. Therefore, it was interesting to see that participants referred to their annotations from the previous session to assist them resuming their task performed differently from who did not use them. Thus, the previous analysis was repeated to include the coding of the variable of use vs non-use (Use Aid with yes/no). The *No Aid* condition was not included in the analysis since it did not offer a resumption aid. The means for *No Aid* are included for comparison (they are replicated from Table 4).

Table 6 The means and number of participants for Resumption Lag (in sec) as a function of Task, Model, Use Aid, and Resumption Aid.

Task	**Model**	**Use Aid**	**Any Aid**	**No Aid**	**Audio Notes**	**Video Replay**	**Combined Audio Video**
Trace	1	Yes	250.25 (12)	382.88 (8)	310.00 (2)	274.17 (6)	184.50 (4)
		No	160.33 (12)		163.67 (6)	238.50 (2)	116.25 (4)
	2	Yes	280.73 (15)	405.00 (8)	223.75 (4)	292.20 (5)	309.17 (6)
		No	176.78 (13)		145.00 (8)	249.33 (3)	131.50 (2)
Compare	1	Yes	239.18 (11)	143.25 (8)	235.50 (4)	210.50 (2)	253.60 (5)
		No	159.62 (13)		207.25 (4)	152.33 (6)	110.67 (3)
	2	Yes	296.32 (19)	280.88 (8)	268.57 (7)	337.17 (6)	287.83 (6)
		No	195.8 (5)		151.00 (1)	187.00 (2)	227.00 (2)
Means for Resumption Aid		Yes	271.49 (57)	303.00 (32)	255.12 (17)	292.11 (19)	266.10 (21)
		No	168.44 (39)		169.47 (15)	193.31 (13)	137.64 (11)

Table 6 shows that those who used the resumption aids took longer than those who did not.

For the analysis, there were four independent variables: Resumption Aid (*Audio Notes* vs *Video Replay* vs *Combined Audio Video*), Task (Trace vs Compare), Model (Model 1 vs Model 2), and Use Aid (Yes vs No). The main effects and the two-way interactions were included in the model. The effects are summarized in Table 7.

Table 7 The analysis of Task, Model, Resumption Aid, and Use Aid.

	F	**Df**	**p(F)**
All Effects	0.90	14,50	.566
Task	0.04	1,50	.840
Model	1.60	1,50	.212
Resumption aid	0.45	2,50	.639
Use Aid	4.00	1,50	.051
Task by Model	0.14	1,50	.715
Task by Resumption Aid	1.08	2,50	.348
Task by Use Aid	0.07	1,50	.792
Model by Resumption Aid	0.07	2,50	.932
Model by Use Aid	0.02	1,50	.897
Resumption Aid by Use Aid	0.92	2,50	.406

From Table 7, we can see that only the main effect of Use Aid is (marginally) significant. The lack of significance for Resumption Aid is consistent with the previous analysis which showed that these three resumption aids were not different. The lack of a main effect of Task is also consistent. The lack of an effect of Model is not significant (it approached significance in the prior analysis), and this appears due to the removal of the *No Aid* which had a large difference in lag duration between models in the Compare tasks, and potentially to the loss of statistical strength due to the reduced sample size. Overall, the mean time for Used was 271.49 (n = 86) while the mean time for Not Used was 168.44 (n = 10).

To explore the importance of having any of the developed resumption aids at resumption, we recoded all the Resumption Aids within a single combination of Model and Task were collapsed (*Audio Notes*, *Video Replay* and *Combined Audio Video* within Model, Task). These were then labeled as Any Aid which had two level (use and did not use the aid). Performance for Any Aid was compared with performance for *No Aid*. The analysis is summarized in Table 8.

Table 8 The analysis of Task, Model, and Use Aid.

	F	Df	p(F)
All Effects	1.922	11,116	0.817
Task	4.018	1,116	0.168
Model	3.508	1,116	0.047
Use Aid	1.400	2,116	0.033
Task by Model	1.154	1,116	0.239
Task by Use Aid	0.374	2,116	0.319
Model by Use Aid	0.480	2,116	0.688
Task by Model by Use Aid	1.922	2,116	0.620

For this analysis, there was no main effect of Task, but there was a main effect of Model and a main effect of Use Aid. Overall, the Did Not Use Aid was fastest while *No Aid* was slowest. Follow up tests using Post hoc test using Fisher's LSD showed that *No Aid* was significantly different from Did Not Use Aid ($p < .009$), but *No Aid* was not different from Use Aid ($p < .170$), and Use Aid was not different from Did Not Use Aid ($p < .118$). In addition, none of the interactions were significant.

5.4 Using Resumption Aids Facilitates Reviewing and Summarizing Tasks

Each task required participants to write a summary of what they did in each session (i.e., pre and post-resumption), and each summary required four steps (one point was assigned for correctly completing each step). Summaries for both sessions were written at the end of each task (i.e., once the task was completed after resumption). We calculated the score of each summary depending on how many accurate steps were recorded in the summary.

5.4.1 Summarizing the First Session

For most participants, writing a summary for the first session was a bit challenging since they had to recall the whole first session to write a more accurate summary, so it is interesting to see how they completed their first summary for each task. Table 9 presents the means for the scores of the first summary by Task, Model and Resumption Aid.

Table 9 The means and standard deviation for the score of the first summary by Task, Model and Resumption Aid.

Means		**Resumption Aid**			
Task	**Model**	**No Aid**	**Audio Notes**	**Video Replay**	**Combined Audio Video**
Trace	1	0.25 ,0.16	3.88 ,0.12	2.50 ,0.38	3.88 ,0.12
	2	0.63 ,0.18	3.50 ,0.19	2.63 ,0.37	3.88 ,0.12
Compare	1	0.50 ,0.19	3.00 ,0.57	3.00 ,0.00	3.25 ,0.49
	2	0.50 ,0.19	3.00 ,0.46	2.38 ,0.42	3.50 ,0.19
Mean for Resumption Aid		0.47	3.34	2.63	3.63

The mean scores in Table 9 show some variation. The lowest condition is *No Aid* and the highest is *Combined Audio Video* resumption aid. The data is presented graphically in Figure 20.

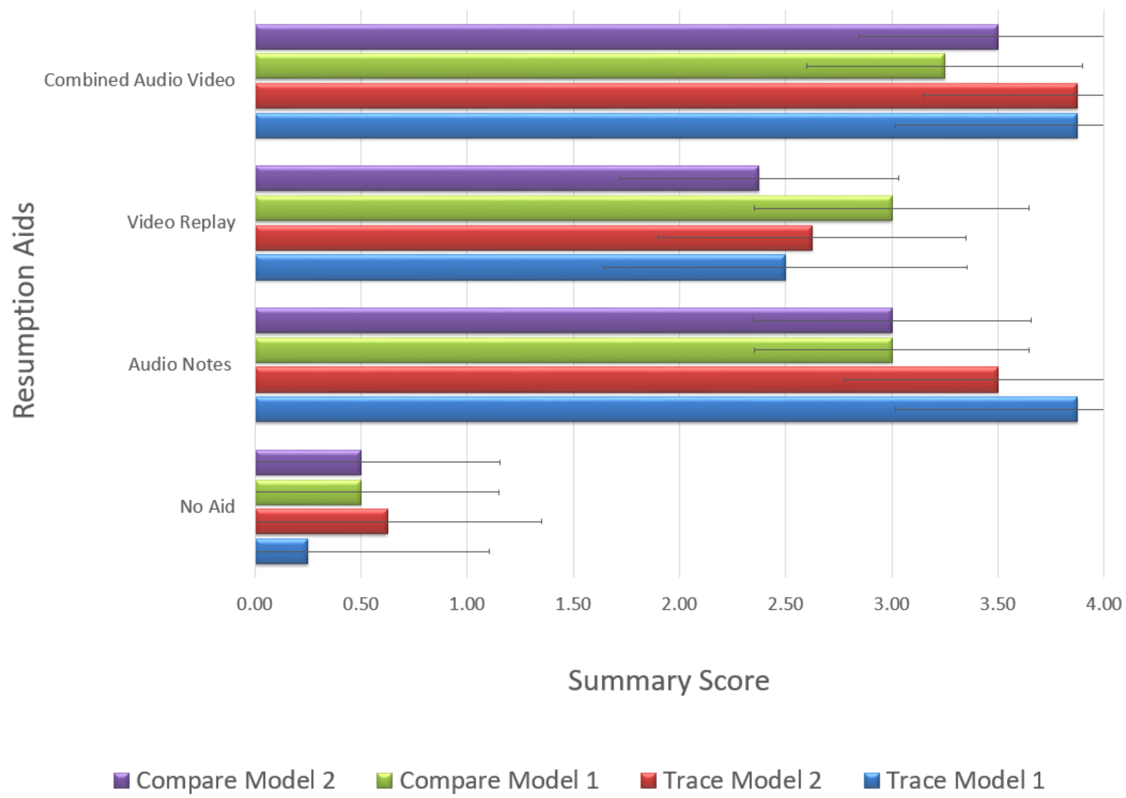


Figure 20 The change in score for the first summary across Resumption Aid, Tasks and Models.

For the analysis of the accuracy of the first summary the independent variables were Task, Model and Resumption Aid. The analysis is summarized in Table 10.

Table 10 The analysis of the score of the first summary as a Function of Task, Model, and ResumptionAid.

	F	**df**	**P(F)**
All Effects	28.6	15,8	0.00
Task	2.46	1,81	0.12
Model	0.20	1,81	0.66
Resumption Aid	101	3,81	0.00
Task * Model	0.45	1,81	0.50
Task * Resumption Aid	0.08	3,81	0.97
Model * Resumption Aid	0.46	3,81	0.73
Task * Model * Resumption Aid	1.09	3,81	0.36

As we can see from Table 10, There is a significant effect of Resumption Aid. There was no significant main effect of Task or of Model, and no interaction effects.

Since using resumption aids was optional, it was interesting to see that participants who used the assigned resumption aid to help them summarize the first session of their task performed differently from who did not use it. Therefore, the previous analysis was repeated to include the coding of the variable of use vs non-use (Use was indicated with yes/no). Because the *No aid* condition did not offer a resumption aid, it was not included in this analysis. The means are presented in Table 11.

Table 11 The means for of the score of the first summary as a function of Task, Model, Use Aid, and Resumption Aid.

Task	**Model**	**Use Aid**	**No Aid**	**Any Aid**	**Audio Notes**	**Video Replay**	**Combined Audio Video**
Trace	1	Yes	0.25 (8)	3.57	3.86 (7)	2.83 (6)	3.88 (8)
		No		2.33	4.00 (1)	1.50 (2)	
	2	Yes	0.62 (8)	3.48	3.50 (8)	3.00 (7)	3.88 (8)
		No		0.00		0.00 (1)	
Compare	1	Yes	0.75 (8)	3.43	3.83 (6)	3.00 (8)	3.57 (7)
		No		0.667	0.50 (2)		1.00 (1)
	2	Yes	0.50 (8)	3.29	3.67 (6)	2.71 (7)	3.50 (8)
		No		0.67	1.00 (2)	0.00 (1)	
Means for Resumption Aid		Yes	0.53 (32)	3.44	3.7 (27)	2.89 (28)	3.71 (31)
		No		1.10	1.40 (5)	0.75 (4)	1.00 (1)

From Table 11, we can see that those who used the resumption aids for recalling the first session had more accurate summaries than who did not use an aid except for Trace, Model 1, Not Used with *Audio Notes* condition. Overall, the mean score for Used was 3.44 (n = 86) and the mean score for Not Used was 1.10 (n = 10), with a difference of 2.34 points.

Moreover, it was interesting to see how well the participants did with each step of the first summary when categorized in this way (*No Aid*, Did Not Use Aid, Use Aid). For each task, the participant had the choice to use the designated resumption aid or not. To assess the effectiveness of the aid on the summary, we coded each step of the summary as correct, incorrect or did not attempt. The important comparison revolves around the decision to use or not use the resumption aid that was provided. For each condition, we considered the number of correct steps, the number of incorrect steps, and the number of steps not attempted. Figure 21, shows the Box Plot for No Aid, Do not Use Resumption Aid, and Used Resumption Aid Conditions.

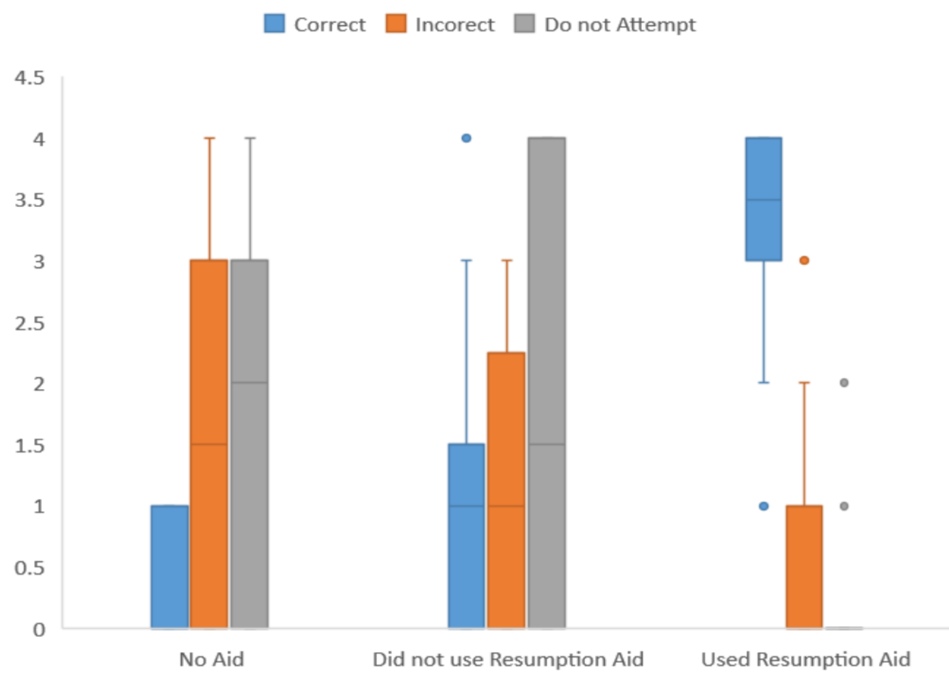


Figure 21 The Box Plot for No Aid, Do not Use Resumption Aid, and Used Resumption Aid Conditions.

5.4.2 Summarizing the Second Session

For most participants summarizing the steps of the second session was less challenging than summarizing the steps of the first session, since they had to recall what they had done in the same session; however, participants who used the assigned resumption aid to recall the first session also used it to recall the second session. Table 14 presents the means and the standard deviation for the score of the second summary by Task, Model and Resumption Aid.

Table 12 The means and the standard deviation for the score of the second summary by Task, Model and Resumption Aid.

Means		**Resumption Aid**			
Task	**Model**	**No Aid**	**Audio Notes**	**Video Replay**	**Combined Audio Video**
Trace	1	2.63 ,0.26	4.00 ,0.00	2.88 ,0.12	3.88 ,0.12
	2	2.38 ,0.32	3.88 ,0.12	2.75 ,0.25	3.63 ,0.18
Compare	1	2.63 ,0.26	3.38 ,0.42	3.00 ,0.00	3.38 ,0.26
	2	2.38 ,0.42	3.38 ,0.26	2.75 ,0.25	3.50 ,0.19
Mean for Aid		2.50	3.66	2.84	3.59

The means from Table 14 show not much variation between conditions. However, the *No Aid* condition still the lowest and the highest is Audio condition. The data is presented graphically in Figure 22.

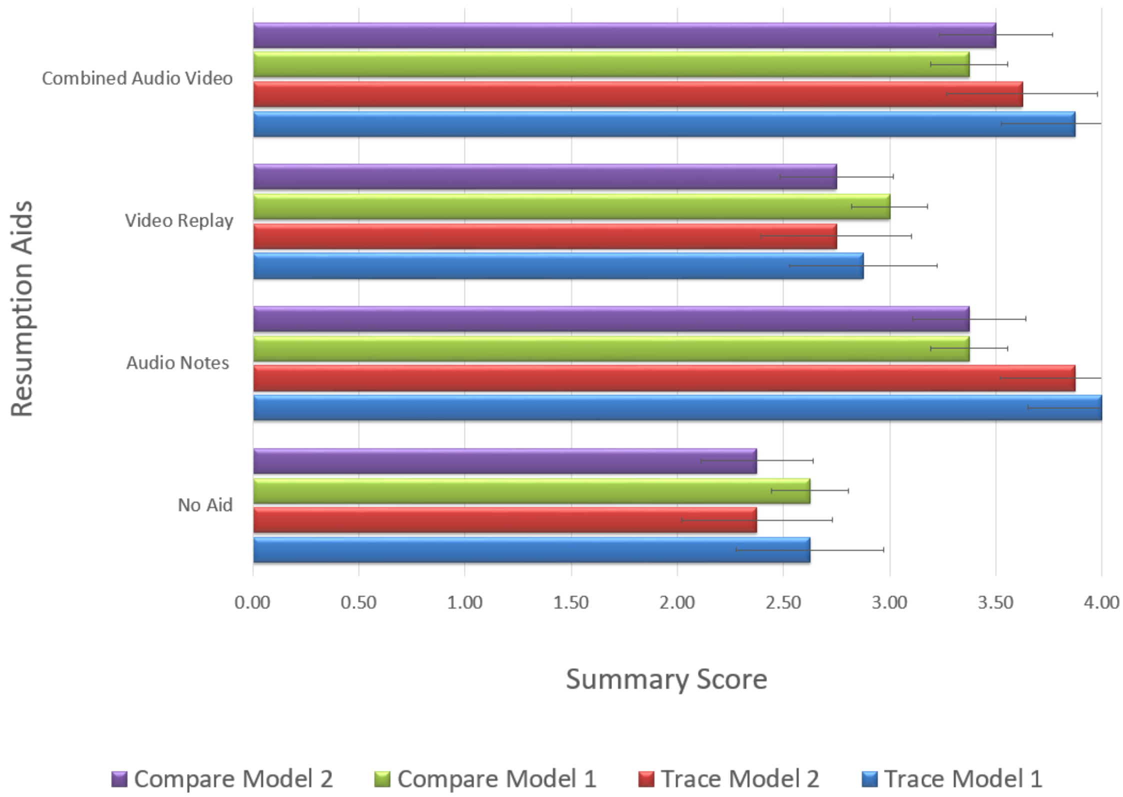


Figure 22 The change in score for the second summary across Resumption Aid, Tasks and Models.

The analysis is summarized in Table 15.

Table 13 The Analysis of the score of the second summary as a Function of Task, Model, and ResumptionAid.

	F	**df**	**p(F)**
All Effects	6.37	15,81	0.00
Task	2.70	1,81	0.10
Model	1.29	1,81	0.26
Resumption Aid	21.2	3,81	0.00
Task * Model	0.14	1,81	0.71
Task * Resumption Aid	0.18	3,81	0.91
Model * Resumption Aid	0.14	3,81	0.94
Task * Model * Resumption Aid	0.14	3,81	0.94

As we can see from Table 15, There is a significant effect of Resumption Aid. There was no main effect of Task, and no effect of Resumption Aid. The *No Aid* and *Video Replay* conditions aids show lower scores than the two audio notes conditions. For the *No Aid* condition, this difference was simply due to the fact that participants were unable to complete the summary in this condition as well as those who used a resumption aid since it was hard for them to recall steps' details about specific 3D objects especially those from the first session. For *Video Replay*, the difference may be because participants did not use one of the main features of the interface (*Fingers Taps*) to highlight salient details on the model, making it difficult to recall task details from the video. Also, video information alone might not be helpful, but the video plus audio combination allows one to focus on the audio stream, and then to consider the video information as needed.

Since using resumption aids was optional, it was interesting to see how participants who used the assigned resumption aid to assist them summarize the second session of their task performed differently from who did not use the aid. Therefore, the previous analysis was repeated to include the coding of the variable of use vs non-use

(Use Aid was indicated with yes/no). Because the *No Aid* condition did not offer a resumption aid, it was not included in this analysis. The means is presented in Table 16.

Table 14 The means for of the score of the second summary as a function of Task, Model, Resumption Aid, and Use Aid.

Task	Model	Use Aid	No Aid	Audio Notes	Video Replay	Combined Audio Video
Trace	1	Yes	2.625 (8)	4.000 (7)	2.833 (6)	3.875 (8)
		No		4.000 (1)	3.000 (2)	
	2	Yes	2.375 (8)	3.875 (8)	3.000 (7)	3.625 (8)
		No			1.000 (1)	
Compare	1	Yes	2.625 (8)	4.000 (6)	3.000 (8)	3.428 (7)
		No		1.500 (2)		3.000 (1)
	2	Yes	2.375 (8)	3.667 (6)	2.714 (7)	3.500 (8)
		No		2.500 (2)	3.000 (1)	
Means for Resumption Aid		Yes	2.500 (32)	2.889 (27)	2.893 (28)	3.613 (31)
		No		2.400 (5)	2.500 (4)	3.000 (1)

From Table 16, we can see that the difference in scores was not as wide when summarizing the second session than when summarizing the first session, as expected.

5.5 Audio Annotations Are More Effective Than Video Only

We compared Resumption Aids using Fisher's LSD based on resumption lag, and we found that there was a significant difference between *No Aid* and *Audio Notes* (p = .034), a marginally significant difference between *No Aid* and *Combined Audio Video* (p = .051), but no difference between *No Aid* and *Video Replay* (p = .217),

Also, we compared Resumption Aids using Fisher's LSD based on score of the first summary, and we found there was a significant difference between *No Aid* and both

Audio Notes and Combined *Audio Video* at the $p < .001$ level. We also found a significant difference between *Video Replay* and both *Combined Audio Video*, and *Audio Notes* at the $p<.001$ level. There was no difference between *No Aid* and *Video Replay,* both yielding lower average scores than the audio annotation techniques. Finally, we found no difference between *Audio Notes* and *Combined Audio Video* ($p = .096$).

Despite average scores being closer across annotation conditions for the second summary, we find similar differences here also. Again using Fisher's LSD we found there was a significant difference between *No Aid* and the audio annotation conditions at the $p<.001$ level, and between *Video Replay* and the audio annotation conditions at the $p<.001$ level. There was no difference between *No Aid* and *Video Replay,* both yielding lower average scores than the audio annotation techniques. There was no difference between *Audio Notes* and *Combined Audio Video* ($p = 0.67$).

5.6 Ease of Use and Effectiveness

During the study, participants answered questionnaires for each resumption aid. While some questions were specific to the resumption aid they had just used, we consider three comparative questions in this section.

One comparative question was "**overall, this resumption aid interface was useful**". Results from a Friedman test analysis indicated that there was a statistically significant difference across conditions $\chi^2(3) = 12.567$, $p < .002$. Further follow-up planned tests using Post-hoc analysis with Wilcoxon signed-rank test were conducted, indicating that *Combined Audio Video* was different to both *Audio* ($p =.046$) and *Video Replay* ($p < .001$), and that *Audio Notes* differed from *Video Replay* ($p = .043$). The means were 4.469, 4.219, and 3.688 for *Combined Audio Video, Audio Notes*, and *Video Replay*, respectively. Figure 23 visually presents the responses of this question for *Audio Notes, Video Replay*, and *Combined Audio Video* resumption aid questionnaires.

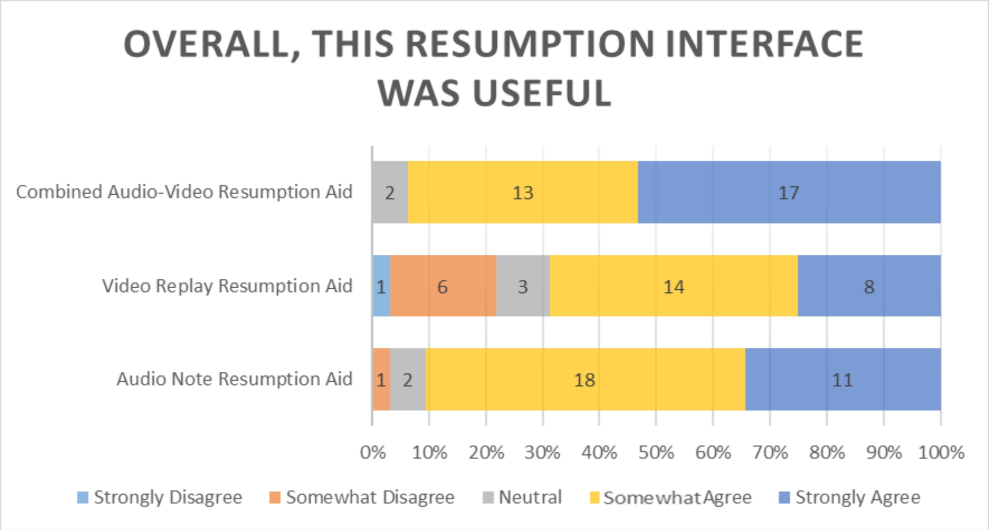


Figure 23 Responses for Audio Notes, Video Replay, and Combined Audio Video Resumption Aid questionnaires.

The second similar question was **"Overall, this resumption interface was easy to use"**. Results from a Friedman test analysis indicated that there was a statistically significant difference across conditions χ^2 (3) = 6.603, p < .037. Further follow-up planned tests using Post-hoc analysis with Wilcoxon signed-rank test were conducted, indicating that *Video Repay* Resumption Aid differed from *Combined Audio Video* (p < .010). Again, *Video Replay* Resumption Aid was lower than the rest. The means were 4.438, 4.250 and 3.875 and 4.438 for *Combined Audio Video, Audio Notes*, and *Video Replay*, respectively. Figure 24 visually presents the responses of this question for *Audio Notes, Video Replay*, and *Combined Audio Video* resumption aid questionnaires.

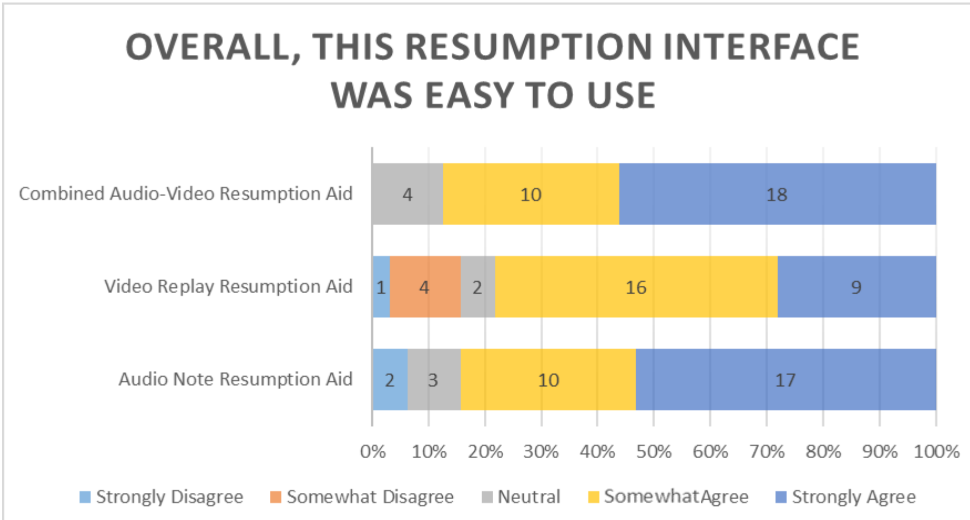


Figure 24 Responses for Audio Notes, Video Replay, and Combined Audio Video Resumption Aid questionnaires.

The third similar question was **"Overall, it was efficient to use this resumption aid interface"**. Results from A Friedman test analysis indicated that there was a statistically significant difference across conditions χ^2 (3) = 8.771, p < .012. Further follow-up planned tests using Post-hoc analysis with Wilcoxon signed-rank test was conducted, indicating that the *Audio Notes* Resumption Aid was different from the *Video Replay* Resumption Aid (p < .033) and the *Video Replay* Resumption Aid differed from *Combined Audio Video* (p < .004). Again, *Video Replay* Resumption Aid was lower than the rest. The means were 4.438, 4.188 and 3.719 for *Combined Audio Video, Audio Notes*, and *Video Replay*, respectively. Figure 25 visually presents the responses of this question for *Audio Notes, Video Replay*, and *Combined Audio Video* resumption aid questionnaires.

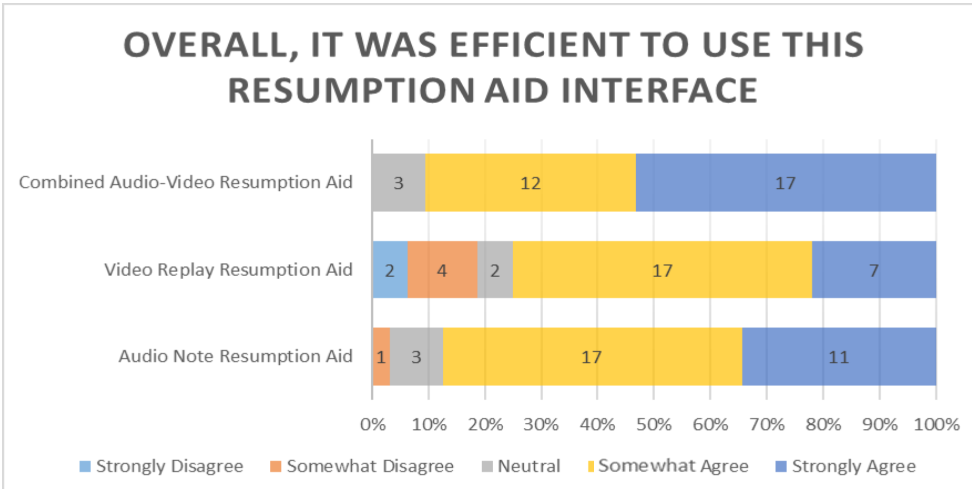


Figure 25 Responses for Audio Notes, Video Replay, and Combined Audio Video Resumption Aid questionnaires.

Generally, the participants liked the *Audio Notes* Resumption Aid and the *Combined Audio Video* Resumption Aid, but they had less favorable impressions of the *Video Replay* Resumption Aid. Participants preferred *Combined Audio Video* over *Audio Notes* for usefulness, but ranked both similarly for ease of use and efficiency.

In the end of the second session, participants answered eight questions in a post study questionnaire (see appendix J).

One set of Likert scale questions asked for agreement on the statement "**The resumption aid provided enough details to recall where I was in the model before the interruption**" for each resumption interface condition. Results from a Friedman test analysis indicated that there was a statistically significant difference across conditions χ^2 (3) = 38.138, p < .001. Further follow-on planned tests using Post-hoc analysis with Wilcoxon signed-rank test was conducted, indicating that *No Aid* differed from *Audio Notes* (p < .0005), and *No Aid* differed from *Combined Audio Video* (p < .0005). *Audio Notes* differed from *Combined Audio Video* (p <. 012). *Video Replay* differed from *Combined Audio Video* (p <. 004). The means were 4.56, 4.00, 3.97 and 2.63 for *No*

Combined Audio Video, *Audio Notes*, *Video Replay* and *No Aid* respectively. Figure 26 visually presents the data. *Combined Audio Video* was preferred over the other interfaces for recalling the resumption point on the 3D model.

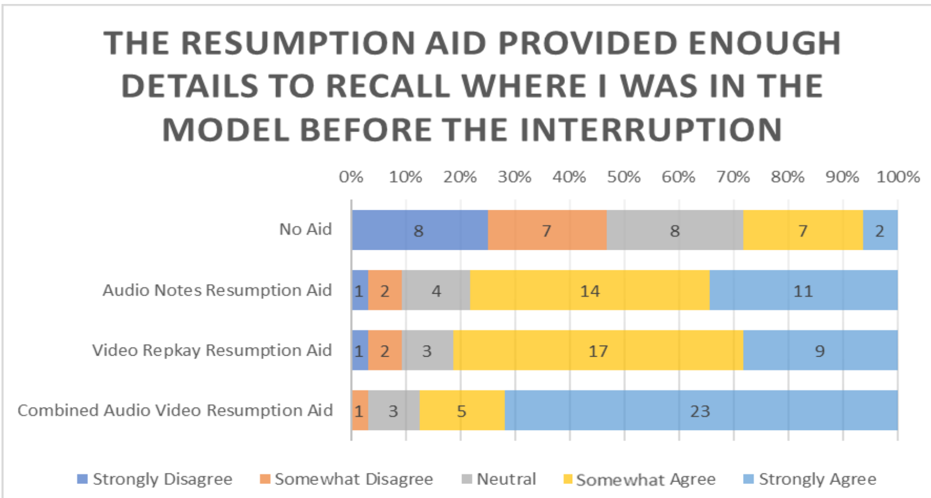


Figure 26 Responses for No Aid, Audio Notes, Video Replay, and Combined Audio Video Resumption Aid Questionnaires.

another set of Likert-scale questions asked for agreement on the statement **"I was satisfied with the amount of time I took to complete the primary task when I used the resumption aid"** for each resumption interface condition. Result from a Friedman test analysis indicated that there was a statistically significant χ^2 (3) = 27.368, p < .00005. Further follow-on planned tests using Post-hoc analysis with Wilcoxon signed-rank test was conducted, indicating *No Aid* differed from *Audio Notes* (p < .001), and *No Aid* differed from *Combined Audio Video* (p < .0005). The *Video Replay* Resumption Aid differed from *Combined Audio Video* Resumption Aid (p <. 001). The means were 4.75, 4.03, 3.72 and 2.87 for *No Combined Audio Video*, *Audio Notes*, *Video Replay* and *No Aid* respectively. Figure 27 visually presents the data. Here again we see that *Combined*

Audio Video was preferred in terms of task duration, although not significantly more so than *Audio Notes*.

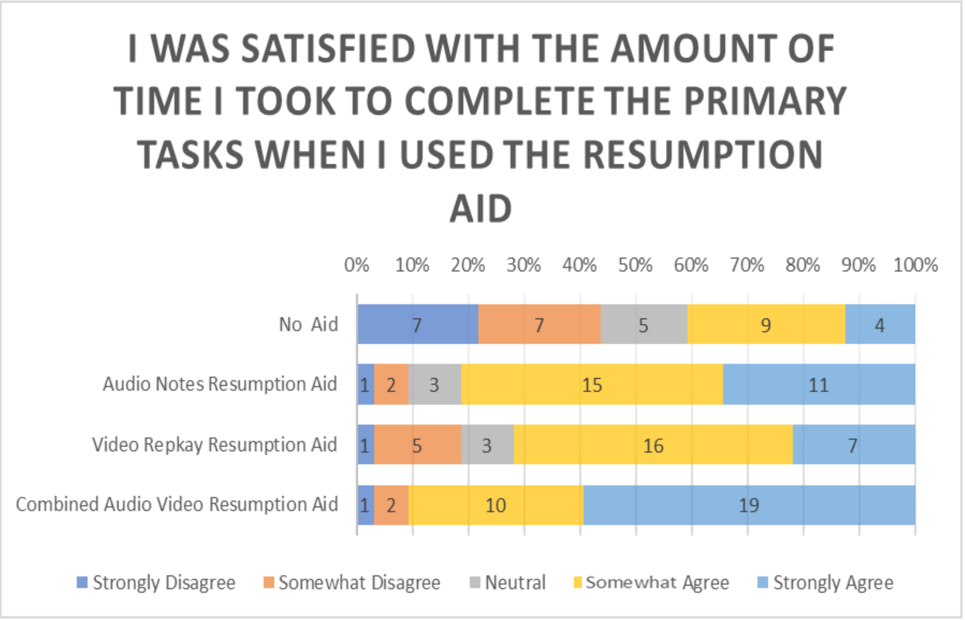


Figure 27 Responses for No Aid, Audio Notes, Video Replay, and Combined Audio Video Resumption Aid.

Generally, participants had a positive impression of the three resumption aids; however, they liked the *Audio Notes* Resumption Aid and the *Combined Audio Video* Resumption Aid more than the *Video Replay* Resumption Aid.

CHAPTER 6 DISCUSSION

Our study investigated resumption aids for assisting in task resumption with 3D models. We developed three kinds of aid interfaces for boosting effective task resumption and recall based on 3D models after a long term of interruption. Safer & Murphy (2007) and Joyita & Rozenberg (n.d.) found that visual recollection is a helpful tool that assists developers to recall their task context and probably improves their performance. Similarly, we found that providing users with resumption aids which visually present the past task events promotes recall of 3D tasks, leading to lower resumption time and better recall for past activities, however this visual presentation needed to be combined with a useful audio annotation. Using the resumption aid at the time of resumption appears less necessary than having used the aid prior to resumption. Using the aid was more useful for recalling of tasks conducted in earlier sessions.

The most important result is that these three developed resumption aids are more helpful for recalling important details about specific tasks than resuming interrupted tasks based on 3D models. Results indicate that the number of participants who used the aids for recalling purposes was greater than those who used it for resumption purposes, since recalling details about specific 3D objects from either the current or previous session was more challenging for the participants than finding the resumption point for that task. That is, they were not able to recall all the steps for the two sessions, especially the first session since it was from the previous day and they may have forgotten some details about the task. Therefore, participants had to use the resumption aid to recall details about the task to write accurate task summaries.

It was optional to use the aids during resumption, and there are a number of possible reasons why participants chose not to use them. First, like aircraft mechanics who typically view 3D models on desktops or laptops alongside textual instructions (either on screen or on paper), we provided participants with written instructions alongside pictures of the relevant components. For some participants, this was sufficient to resume the task. 20 participants indicated that the provided instructions and picture were helpful for resumption. For example, P11 said "*I very much relied on the guidelines given to complete the task because the last point from last session was given, then I resumed my task from there*". Second, by observing the videos of the participants' interactions, we noticed that although each participant had a training session which provided them with an understanding of how each resumption aid works as a resumption tool, some of them did not realize the features that each resumption interface offered. However, as each task required writing two summaries and to complete these summaries correctly, most participants had to use the assigned resumption aid to help them write those summaries correctly. At this point, some of them started to realize the importance of using the resumption aid, and then used them in resuming the next tasks—this lack of awareness regarding the aids' utility may be a factor in their lack of use. Finally, the duration of the interruption (one day), while sufficiently long to require some effort in recall, likely had varying impact on recall across participants. P5 stated that "*If I have to resume that task after one week I may find it difficult to first find the component and I'd definitely need a resumption aid."*

Generally, participants liked the resumption aids. Results from the secondary analysis indicate that participants had a positive impression of the resumption aids even if they did not use them during resumption.

Trafton et al., (2003) did an experiment investigating the efficiency of using some rehearsal tools in assisting task resumption. They found that resumption lag was longer in the *No Cue* condition. Similarly, when we consider the distribution of resumption lag durations for each resumption aid condition, we found that the resumption lag in the *No Aid* condition was the longest of the three conditions. For the other conditions, we found that *Audio Notes* had the shortest resumption lag (though not much shorter than *Video Replay* or *Combined Audio Video*).

No Aid was the longest resumption lag because participants tended to take a long time to find their stop point from the prior session without a resumption aid. All participants indicated that resuming 3D tasks without any cue is challenging since it takes time and effort to locate the resumption point.

Our results show that the task where the participants needed the aids most is the Compare task performed with Model 2. With the *Audio Notes* resumption aid, 7 participants used the aid while just 1 did not. For both the *Video Replay* and *Combined Audio Video* Resumption Aids, 6 participants used the aid while 2 did not. This was due two reasons. First, the model has many similar and complex compartments with similar components inside them; therefore, most participants could not find the resumption point easily. Second, the resumption point was a component which was in inside a compartment, making it hard to find without knowing the compartment number. P5 said "*If the components you had given were located somewhere outside of the model it would be much easier to identify them. However, if the components are complicated and are located somewhere inside some others compartments, it would be hard to identify them to resume the task.*". Moreover, for all three resumption aid conditions, the Compare task with Model 2 has the longer mean resumption lag compared to other tasks. The Compare task with Model 1 had a shorter resumption lag, which may be because the resumption point of this task is on the surface of the model so it was easy to find. Four participants who resumed this task with *No Aid* declared that this task was simple and finding the resumption point was not too complicated so it was easy to locate it and then resume the task.

We found that there was a big difference in resumption lag for *Combined Audio Video* trace model 1 vs. trace model 2; this can be attributed to both the complexity of the model and the location of resumption point.

In our findings, the standard deviations for Trace task with *No Aid* are very large, that is, there were three participants that had a long resumption lag: (P2, 1140 sec, trace, model 1, task 2), (P21, 710, trace, model 1, task 3), (P6, 1620 sec, trace, model 2, task 3). In contrast, there were another three who had a short resumption lag: (P32, 111 secs, trace, model 1, task 4), (P17, 80 secs, trace, model 2, task 1), (P18, 116 secs, trace, model 2, task 1). From interviews with the participants who had longer resumption lags, it was very hard for them to resume the task with any aid. Also, for the recorded video interaction, we noticed that these participants had a very hard time rotating, moving, zooming in, and zooming out the models until they found the resumption point for their tasks. For the three who had shorter resumption lags, they stated that the task was very easy to resume. P18 said that "*I just depend on my memory and maybe because it was the first task I did yesterday maybe the memory was rather clear for that component*". P32 said that "*I remembered that the component was on the bottom of the model, so I think the placement of the component I was looking for was very helpful. So, once I looked to the provided picture I remembered the location of the component. Also, the shape was simple since it was not really connected to any other component."*

Therefore, we can say that resuming tasks with complex 3D models is a complicated process that might require additional tools to facilitate resumption. Also, the location and the physical characteristics of the resumption point play an important role in task resumption involving 3D models. Weatherford (1985) indicated that navigation through 3D objects becomes harder with the size and complexity of those objects. In accordance with this we believe that if the task being interrupted involves complex, detailed, and large-scale models, resumption will require more time and cognitive effort to recall the resumption point. As a result, resumption aids would be useful in such a case. More research is required to better understand the characteristics of 3D models that make resumption more difficult.

The *Audio Notes* resumption aid has the shortest average resumption lag. 29 participants indicated that they like this aid since it offers good features: it is helpful, precise, and importantly, quick to use, saving time when they used it during resumption. Moreover, it allows the user to record many important points separately so that when they resume they do not have to go through all notes; they can just pick whatever notes they think are helpful for them. According to P11, "*I like it was split up to notes so I do not have to listen to whole notes, so I just need to select which note would be helpful for* *me*.” Also, P30 stated that “*I liked the notes. They gave me the main point, in easy, quick, and faster way*”. However, 7 participants pointed that to have a strong advantage from using this aid, users must properly use it to get a clear audio description with a specific screenshot of the component they are describing. P20 stated “*I think this one of the best if not the best. It is very useful to have the entire timeline and then just the check points for you to add stuff, it is kind of chronological way of thinking. If you know that what you need to find is in the end to just jump and try to find it. And if the screen shot was taken probably in good angle it helps to find where I was that in the model when I took the screen shots*”.

Previous work indicated that visual recollection is a helpful tool that assists developers to recall their task context and perhaps improve their performance (Joyita & Rozenberg, n.d.). In the context of 3D interaction, however, just replaying a visual presention (*Video Replay*) did not seem to be helpful for locating resumption points. With the *Video Replay* resumption aid, participants could just review the last section of their video interaction. However, reviewing video sections of 3D objects without audio descriptions was not helpful especially if these objects were zoomed in while capturing the video. These objects were likely somewhere inside the model where participants could not locate them without knowing some information about the part of the model where these objects were. Thus, our participants often had to review larger sections of video to get a sense of what was going on and how they reached the resumption point, which required more time to resume the task. If the video replay were integrated with the model viewer software itself, indicators of model position could be provided alongside the video to ameliorate this issue.

Interestingly, the results indicated that those who used the resumption aids during resumption took longer to resume the task than who did not use them at resumption. This may be because the resumption lag includes the time that participants took to open the replay window of the assigned resumption aid and review their stored details. During resumption, they sometimes moved back and forth between the resumption aid tool and the 3D viewer application to find their resumption point. Moreover, as unfamiliarity with a specific model and a lack of experience with 3D model viewer software in general are contributing factors to navigation difficulties (Ruddle, Payne, & Jones (1998), we believe that unfamiliarity with both resumption aid interfaces and the 3D viewer application may have slowed participant performance. However, those who used the resumption aid in the first session during their task resumed the task the fastest (for all resumption aid conditions), which indicates that the act of annotating key moments in their task was helpful for resumption even if the annotations were not referenced during resumption. In the context of interacting with 3D models as Jul and Furnas (1997) stated, navigating 3D objects can be difficult; people get lost during their navigation and sometimes they do not even know what the objects are, but they can still use the annotation to help them get back to where they left off.

Although participants who used the aids for resumption purposes took longer to resume tasks than those who did not use them, this does not mean that the aids are not effective resumption tools. As the results for the aids questionnaires indicate, the participants tended to have a positive impression of the aids even if they did not use them during resumption. Performance with the resumption aids may also improve over time.

Results for evaluating the aid as “recalling” aids while writing summaries indicate that the number of participants who used the resumption aid for recalling was greater than those who used them for resumption. That is, they were not able to recall all the steps for the two sessions, particularly the first session because it was from the last day, so for them to write accurate summaries they had to use the resumption aid to reveal more details about the task.

Participants who used the resumption aids as a memory aid to help them write the summary for each task took a long time in all conditions; however, their summaries were more accurate than who did not use the resumption aids. They took longer to write the summaries because they kept the replay window of the assigned resumption aid open for the duration and they went through their stored details from the beginning to the end. For example, if the resumption aid was *Audio Notes*, they had to review the notes from the first until the last. If the assigned resumption aid was the *Video Replay*, they had to watch the whole video to recall what they were doing with the task. For the *No Aid* cases, participants took a short time to write the summaries because they were unable to complete the task summaries as well as those with a resumption aid.

Kalnikait et al. (2007) found that taking high-quality notes boosted human memory. Similarly, our results indicate that the *Audio Notes* and the *Combined Audio Video* aid were more effective tools for recalling tasks than *Video Replay*. These results are consistent with the questionnaire results which show that participants liked the *Audio Notes* resumption aid and the *Combined Audio Video* resumption aids, but they had less favorable impressions of the *Video Replay* resumption aid. This was due to the limitation of the *Video Replay* resumption aid we mentioned before in the result section. Moreover, having an interactive timeline with bookmarks of audio notes may help participants to realize the chronology of the task steps then recall them properly. These results are supported by Scott et al. (2006) who stated that having a timeline with bookmarks of system events is an effective tool to help people recall the past events of their task.

Results show that the most helpful aid interface for resuming the Trace tasks is the *Combined Audio Video* aid, for which it has the lower mean resumption lag in most cases. For Compare tasks, *Combined Audio Video* still has the lower mean but this is due to 3 participants not using it for resumption. This is definitely consistent with participants' opinions when we asked them "Is *Combined Audio Video* resumption aid interface more helpful for tracing or comparing tasks? 29 participants indicated that this interface was helpful for both tasks (comparing and tracing). Since this interface has the video divided into notes, participants could either review specific notes or watch the whole video if they needed to.

For Compare tasks with Model 1, *Video Replay* seems to be the most helpful resumption aid. This is because the resumption point of this task was located on the surface of the model. That is why just reviewing the video was enough for the participants to find the resumption point and then resume the task. However, for Compare task with model 2 the *Audio Notes* Aid seems to be more helpful. This task required more details to resume and *Audio Notes* allowed participants to capture precise details about components.

Therefore, we can say that for both Compare and Trace tasks with a difficult-to-locate resumption point, participants more often used the resumption aid to access detailed information in order to help them find the resumption point. Depending on annotation behavior, such details were more readily available in the *Combined Audio Video* and *Audio* aids. However, for tasks with a resumption point that is easier to locate, reviewing the video stream alone could be sufficient to find the resumption point. Indeed, results from secondary analysis showed that *Video Replay* and *Audio Notes* resumption aids were about equal in terms of provide enough details to recall the resumption point.

Finally, we measured the mental rotation ability of our participants because we thought that mental rotation ability may make it easier to compare the current model orientation with the orientation shown in screenshots or video. However, we did not find any correlation between the spatial ability and the performance of the participants at resumption to complete the task, implying that mental rotation ability had very little to do with performance.

6.1 Limitations

This study had some limitations. First, the duration of interruption was not extended enough for most participants to completely forget the task in the first session including where they stopped in the last session. Having a longer interruption time might provide more interesting results for using the resumption aid interfaces for resumption purposes.

The design of the three resumption aid interfaces does not allow participants to cancel recordings of specific details (e.g., undesired video or audio note that includes unclear or unspecific details). Also, it does not offer a feature to remove data about the past sessions that are no longer needed.

We did not consider the case where a 3D model viewer allows the user to save the state of the model between sessions. In such cases, there is little to no effort required to locate the resumption point (it is visible by default); we imagine this would lead to less frequent use of resumption aid interfaces during resumption, but that annotating task steps would still be helpful in "picking up where one left off", and for summarizing work done.

The *Video Replay* resumption aid recorded silent video annotations, but included a feature that showed all touch interactions overlaid on the screen capture. It was intended that participants use this to focus visual attention by "double tapping" items of relevance to the task on the 3D model. There were several issues with this design. First, participants did not consistently use this feature, and in fact it was generally underutilized in the study despite being part of the interface training. It may be that participants viewed doing this as tedious or simply not beneficial. Second, the screen capture video did not visually distinguish touch interaction for 3D object manipulation and double taps, perhaps making it difficult to notice when items were being called out as relevant. Finally, due to issues with the frame rate of the captured video, some double tap interactions were not evident on the video when replayed, either showing up as a single tap or not at all. We believe all of these factors affected how the resumption aid was used and how it was assessed by participants. We still feel that using visual cues to call out relevant details on a 3D model would be beneficial for resumption, especially when the cues are visually conspicuous and used in combination with audio description.

6.2 Future Work

Based on our experience of implementing the three resumption aid interfaces and evaluating them in a laboratory study, we identified a number of potential enhancements to these resumption aid interfaces. We identify two key enhancements here. First, the ability to cancel recordings, delete selected annotations, and organize kept annotations would offer users more control in how they create and use annotations. Second, the resumption aid could be integrated into the 3D viewer to facilitate resumption and recalling task with 3D models; for example, when the users click on a specific note to review this might reorient the 3D model or highlight the object(s) related to that note.

To further explore resumption aids for tasks involving 3D models, we recommend varying the duration of the interruption and the complexity and nature of the tasks. Finally, a contextual evaluation of the resumption aids with aircraft mechanics (or in another suitable domain) would generate important insights as to how our findings translate into practice in the workplace.

CHAPER 7 CONCLUSION

Interruptions are an unavoidable part of every user's work. Maintaining high productivity depends on timely task resumption after interruptions. However, people's task resumption ability is compromised by disturbing environments and human cognitive limitations. This thesis presented three resumption aid interfaces (*Audio Notes, Video Replay, Combined Audio Video*) that help users recover the context of their pre-interruption work by displaying different data concerning the task up until the point of interruption. Each of these resumption aids provides various features of capturing the state of the work at certain time for later recall. They are: screenshot with audio, video-only, and audio-video. We conducted a user study to evaluate the four resumption conditions (one for each interface and a control condition with no resumption aid). Our participants used the assigned resumption aid to record the state of their work as they performed each task. We interrupted their work and then asked them to resume it in the second session. In the second session, the resumption aids were used for two purposes: at the beginning to help find the resumption point, and in the end to help recall a task's steps for writing a task summary.

Our results show that these resumption aids promote recovery from interruption for task based on 3D models. Providing a resumption aid to record the progress or state of the work in the first session reduced the resumption lag if the participants did not use the assigned resumption aid. If they did use the resumption aid, the resumption lag was comparable to the control condition (*No Aid*) due to the time participants spent interacting with both (the assigned resumption aid and the 3D viewer application). During resumption, they sometimes moved back and forth between the resumption aid tool and the 3D viewer application to find their resumption point. For recalling task steps at the end of the second session, performance in terms of both time and accuracy was highest when the resumption aid was used. Participants preferred *Combined Audio Video* and *Audio Notes* resumption aids to the *Video Replay* resumption aid. The time was highest for the same reason we stated for resumption (interaction time with the applications). For the two task types (Compare and Trace), the results showed that when the resumption point was hard to find the participants tended to use the resumption aid to recall detailed information to assist them to locate the resumption point. *Combined Audio Video* and *Audio Notes* resumption aids were more helpful than *Video Replay*; however, when the resumption point was easy to find, replaying the video alone may be enough to locate the resumption point.

Our findings are consistent with the memory for goal theory (Altman and Trafton, 2002), which emphasizes that supporting activation of the interrupted goal and encoding cues before the onset of the interruption will assist later resumption. Moreover, our findings suggest that with tasks involving complex 3D models, using audio annotations to describe 3D objects during the task and before the interruption encourages faster resumption. Referring to those audio annotations along with their associated visual presentation improved recall of specific details about those 3D objects that are relevant to the task.

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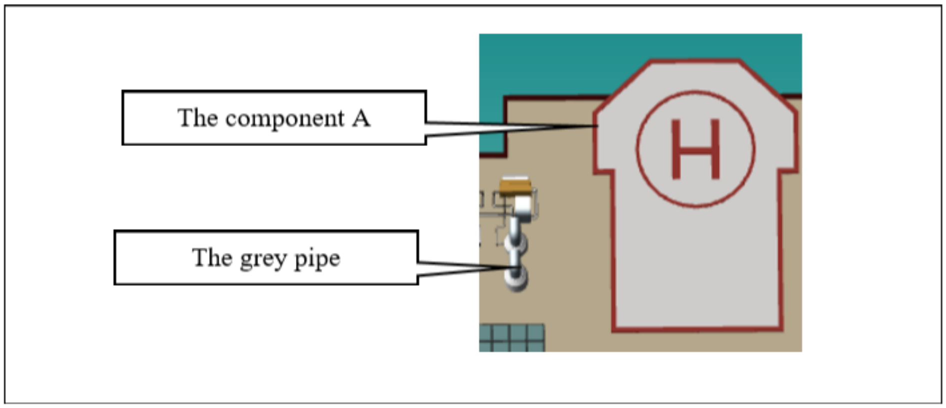
APPENDIX A STUDY TASKS

TRANINING TASKS

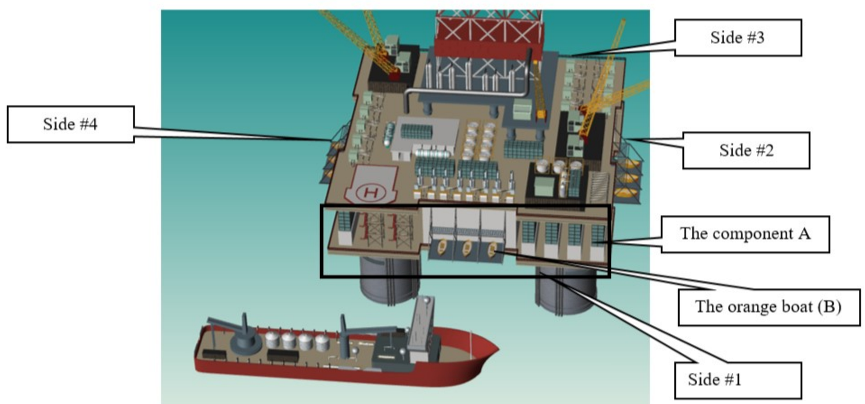
First Training Task (Audio Notes resumption aid)

1. Find the component (A) shown in the figure below.
2. On the left of (A) there is a group of grey pipe count how many grey pipe in this group. When you at last grey pipe describe it and its connected components.



Second Training Task (Video Replay resumption aid)

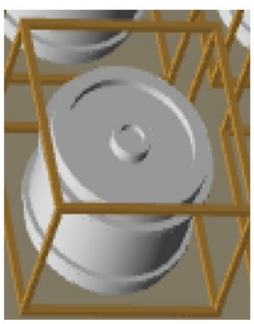
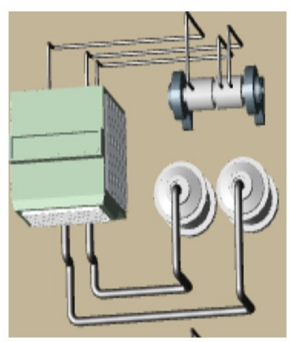
For side #1 and side #3 of the model, find the component (A) and the orange boat (B) shown in the figure below, and count each of them.



Third Training Task (Combined Audio Video Resumption Aid)

Go on the surface of the model and find and count each of the following components (see the figure below):

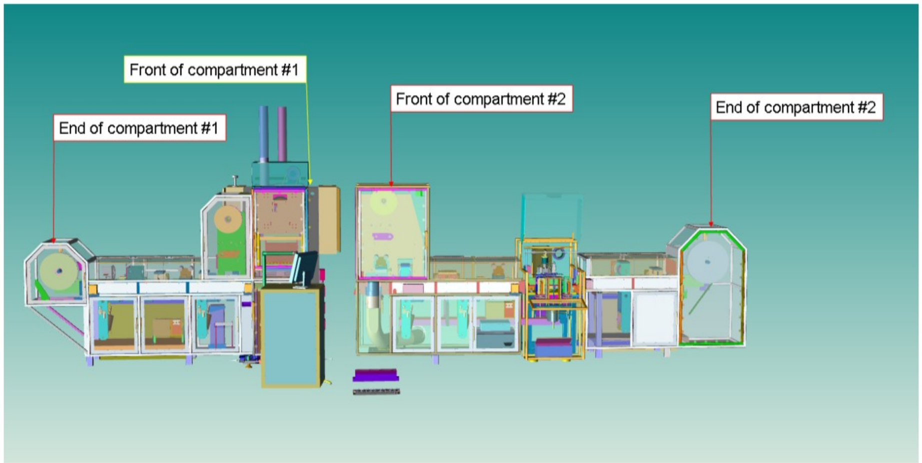
1. The grey cylinder (A).
2. Component (B).
3. Component (C).

		
The grey cylinder (A)	Component (B).	Component (C)

MAIN TASKS

Compare Task (First Session)- Model 1

The Compartments of the Model



1. Go near the end of compartment #2, and find the small square purple box (A) (see Figure 1), then do the following:
2. Find each component behind the olive panel (B) shown in figure 2.
3. Follow the connected components until you reach the brown panel (C) shown in figure 3; verbally describe it and to describe how it is connected to the following component (from all angles of the diagram). Take an audio note when you reach to each component to record you finding.

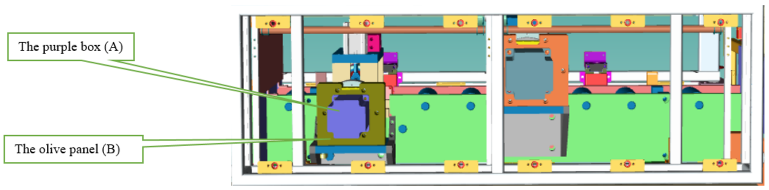


Figure 1

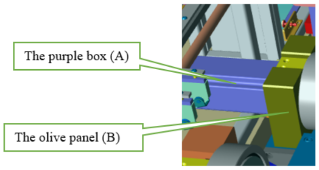


Figure 2

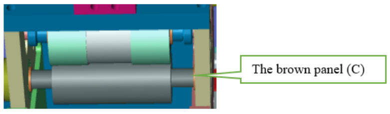


Figure 3

4. Find and count all the blue rods (D) that are found between the long green panel (F) and the long pink panel (E) (see figure 4), record an audio note to record your finding.

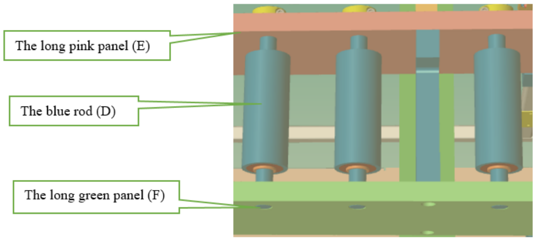


Figure 4

Compare Task (Second Session) - Model 1

1. Go near the end of compartment #2, and find the components shown in Figure 5 (where you stopped during the last session).
2. Go near the end of compartment #1, and find the small square purple box (G) shown in figure 6, then do the following:
3. Find each component behind the olive panel (H) shown in Figure 7 and follow the connected components until you reach the brown panel (I) shown in figure 8; verbally describe it and to describe how it is connected to the following component (from all angles of the diagram). Take an audio note when you reach to each component to record you finding.

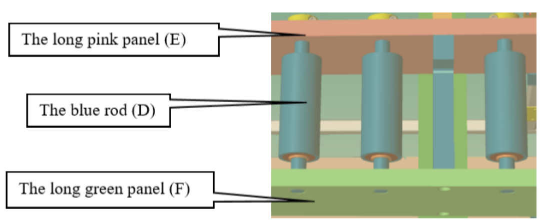


Figure 5

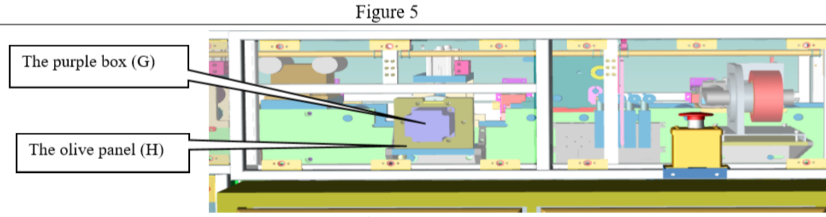


Figure 6

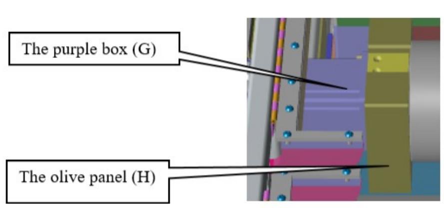


Figure 7

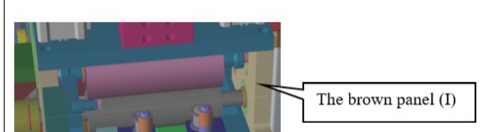


Figure 8

4. Find and count all the blue rods (J) that are found between the long blue panel (L) and the long green panel (K) (see figure 9). record an audio note to record your

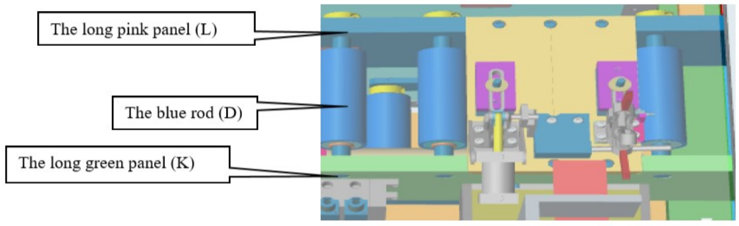


Figure 9

finding.

5. Fill the following table for each component you found in Session #1 and Session #2 to see if there any difference between the components in both sesssions.

Session 1			Session 2		
The Name	The Color	The Number	The Name	The Color	The Number

Trace Task (First Session)- Model 1

Go the end of compartment #1, and find the light green panel(A) that is attached to the large yellow wheel (B) (see figure 1). Then do the following:

1. Trace along the light green panel (A) until you get to its end (see figure 2). Take an audio note when you reach to each component.
2. Find the grey rod (C), and trace the dark grey panel (D) attached to the grey rod (C) (see figure 2) until you get to the lighter grey panel (E) (see figure 3). Take an audio note when you reach to these components.
3. In the center of the grey panel (E) there is a red component (F) (see figure 3). Take an audio note when you reach to this component.

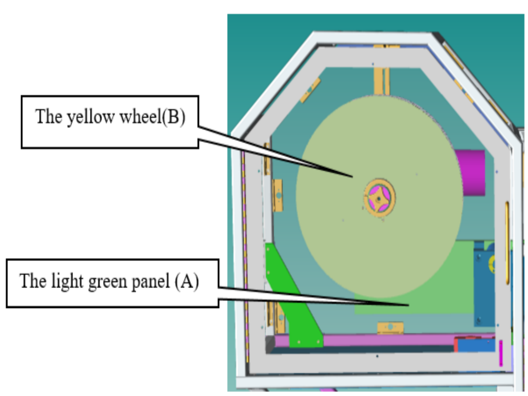


Figure 1

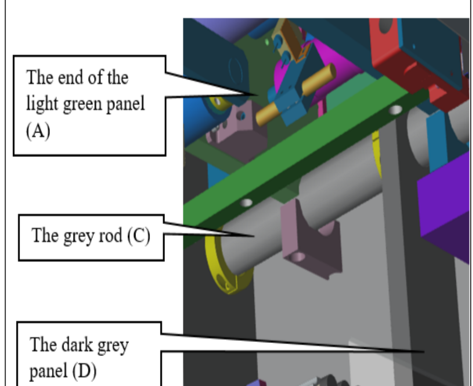


Figure 2

4. Find the yellow wire (G) connected to the red component (F) (see figure 3). Take an audio note when you reach to these components.

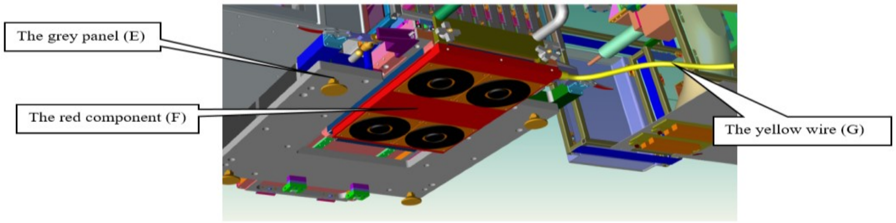


Figure 3

Trace Task (Second Session)- Model 1

1. Re-find the yellow wire (G) shown in figure 4 (where you stopped during the last session).

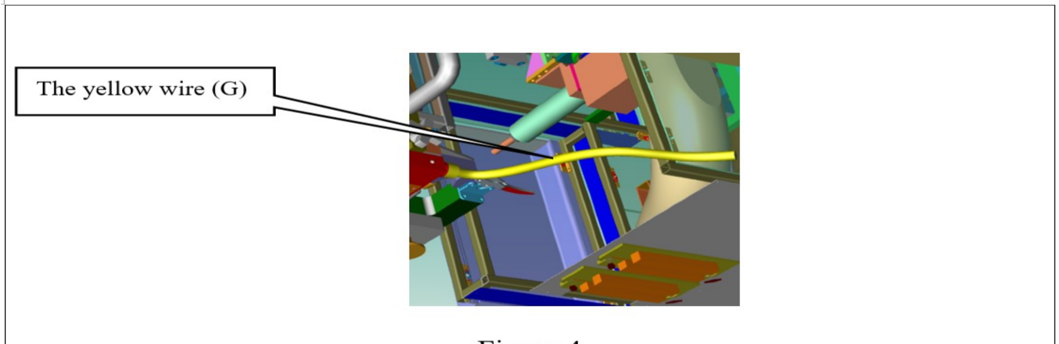


Figure 4

2. Assume that it is connected to the small yellow cylinder (H) on the compartment #2 (see figure 5). Take an audio note when you reach to this component.
3. Trace the pink panel (I) until you get to its end (see figure 6). Take an audio note when you reach to this component. Then find the light brown box (J) that is located near the end of pink panel (I) (see figure 6). Take an audio note when you reach to these components.

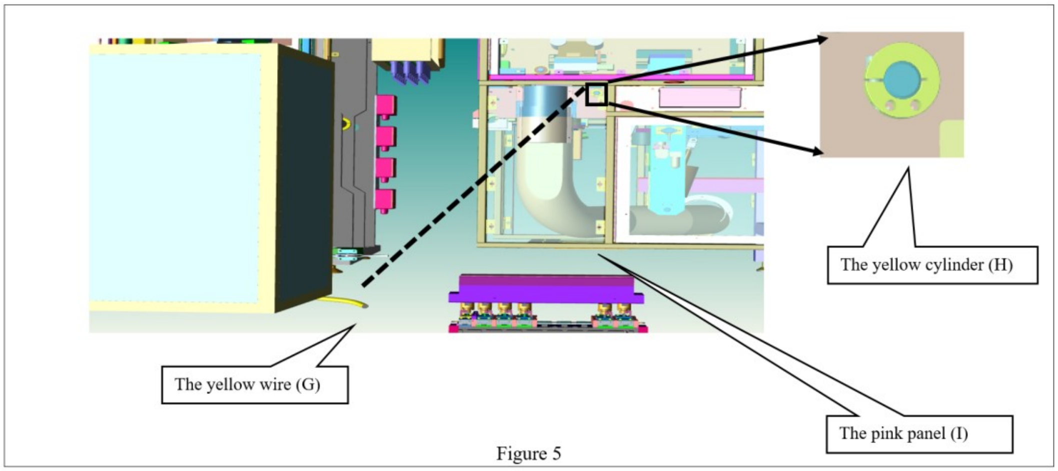


Figure 5

4. Trace all components that start from the brown box(K) (see figure 6) and continue until the grey cylinder (L), then find the end of the blue component (M) attached to the grey cylinder (L) (see figure 7). Take an audio note when you reach to these components.

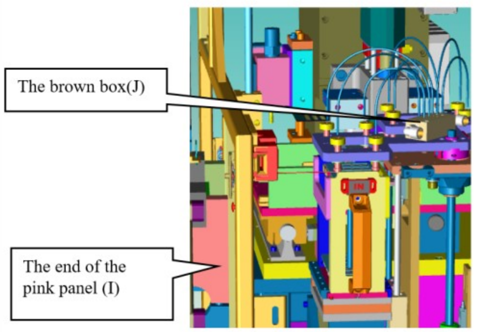


Figure 6

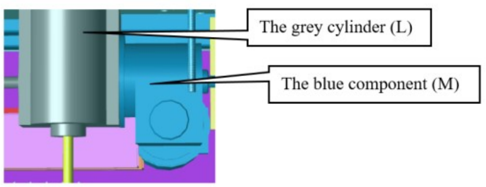


Figure 7

5. Summarize the steps of the task you performed in the first session.

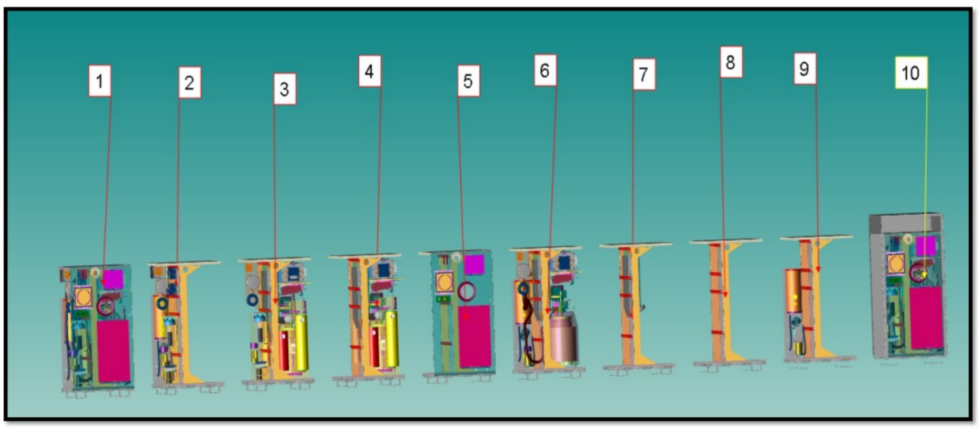
1.	
2.	
3.	
4.	

6. Summarize the steps of the task you performed in the second session.

1.	
2.	
3.	
4.	

Compare Task (First Session)- Model 2

The Compartments of the Model



1. Go to compartment #1, and find the grey box with its components (see figure 1). Then do the following:
2. Verbally describe how these components connect to the grey box, and how they are connected to each other as well. When you reach to each component take an audio note for your finding.
3. Find and count the number of the green screws attach the grey box. Take an audio note for your finding.
4. Find the endpoints of the blue cables that are attached to the two fasteners on the right side of the grey box. Take an audio note for your finding at each point.

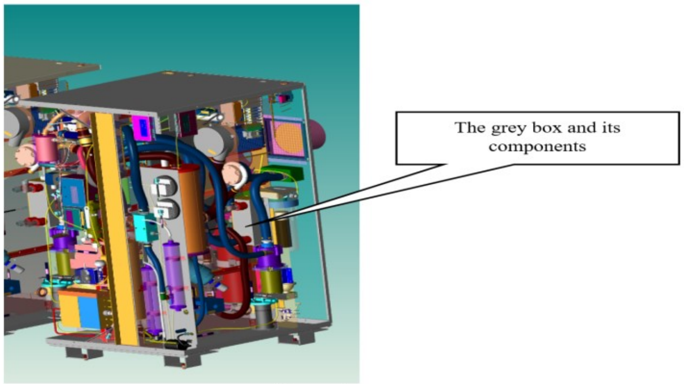


Figure 1

Compare Task (Second Session)- Model 2

1. Re-find the endpoints of the cables that are attached to the two fasteners on the right side of the grey box (where you stopped during the last session). See figure 2.

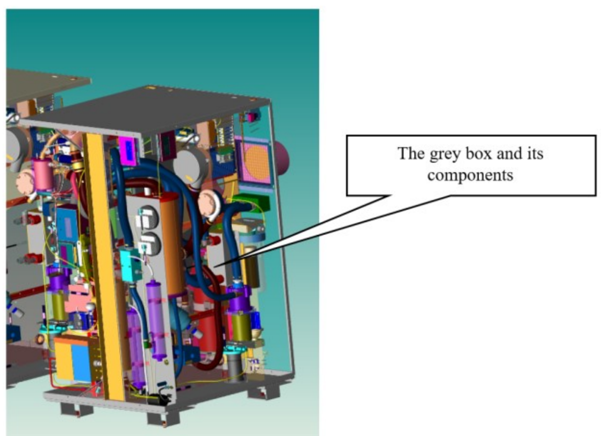


Figure 2

2. Go to compartment #3 and find the grey box with its components shown in figure 3.
3. Verbally describe these components connect to the grey box, and how they are connected to each other as well. When you reach to each component take an audio note for your finding.
4. Find and count the number of screws that attach the grey box to its glass pane. Take an audio note for your finding.

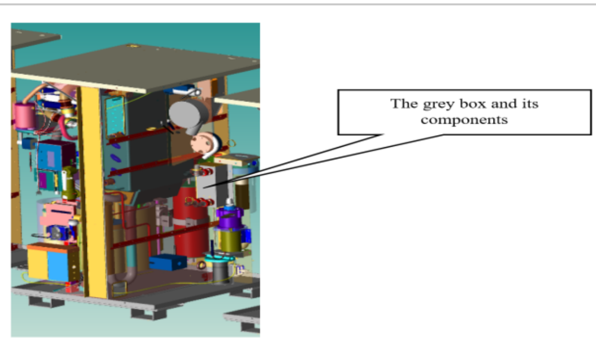


Figure 3

5. Fill the following table for each component you found in Session #1 and Session #2 to see if there any difference between the components in both locations.

Session 1			Session 2		
The Name	The Color	The Number	The Name	The Color	The Number

Trace Task (First Session)- Model 2

1. Go to compartment #3, and find the grey fastener (A) that is connected to the pink pipe (B), then trace the pink pipe (B) until you get to the yellow cylinder (C). See figure 1. Take an audio note for your finding when you reach each component.

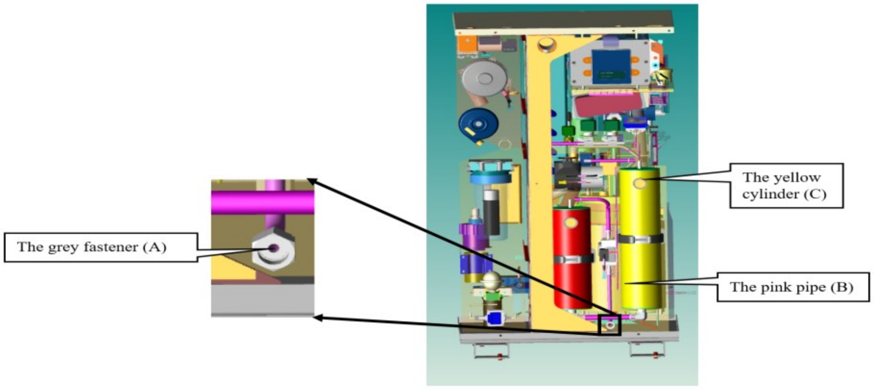


Figure 1

2. Jump to the compartment #4, and find the yellow cylinder (D) which same the cylinder (C) and assume that the yellow cylinder (D) is connected to the compartment #6 through the blue component (E). See figure 2. Take an audio note for your finding when you reach each component.

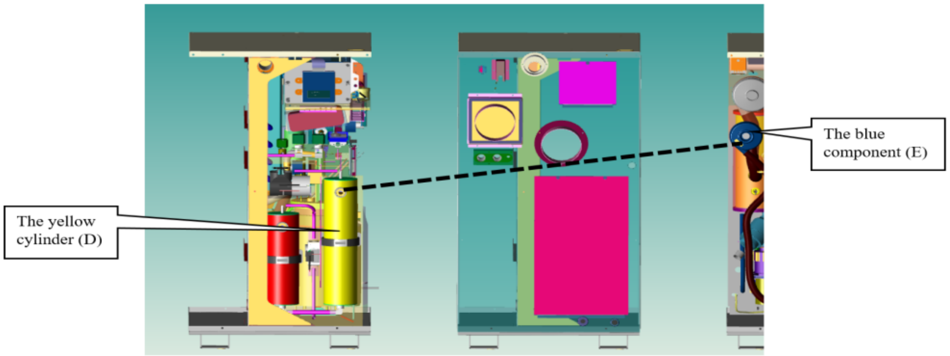


Figure 2

3. Trace the burgundy cable (F) that is connected to the blue component (E) (see figure 3) until you get to its endpoint (G) that is connected to the yellow cylinder (H) in figure 4.
4. Trace the grey tube (I) on top of (H) and find its endpoints (J) (see figure 5). Take an audio note for your finding when you reach each component.

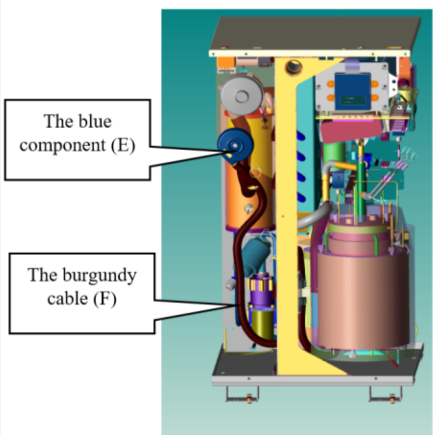


Figure 3

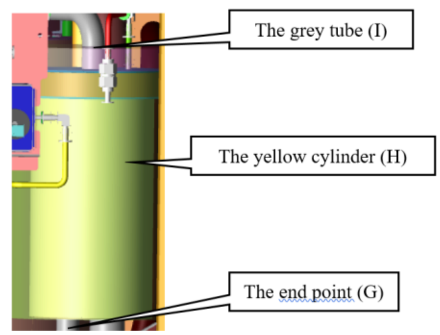


Figure 4

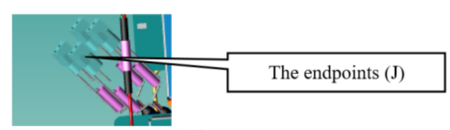


Figure 5

Trace Task (Second Session)- Model 2

1. Re-find the endpoints shown in figure 6 (where you stopped during the last session).
2. Assume that the endpoints (J) are connected to the orange cylinder(K) on the comportment #9 through the point (L) (figure 6).

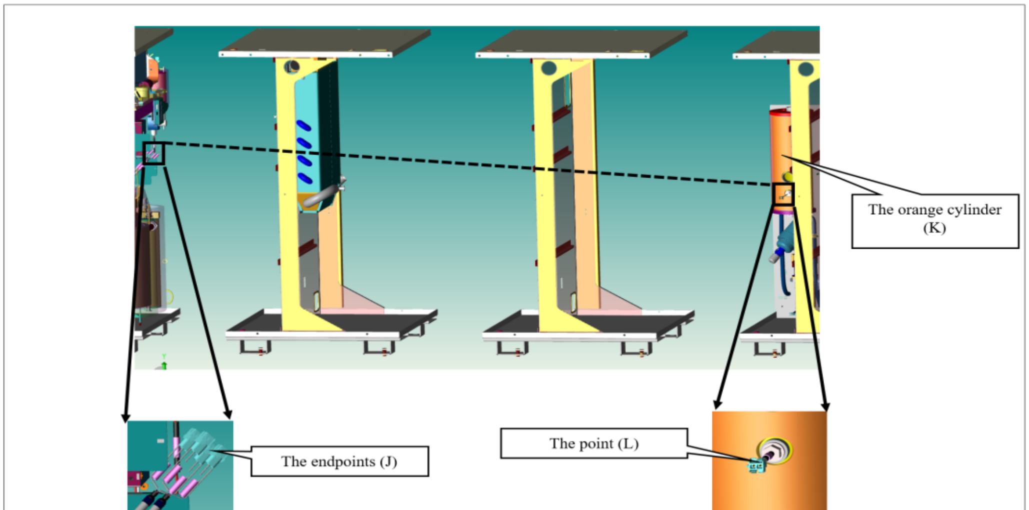
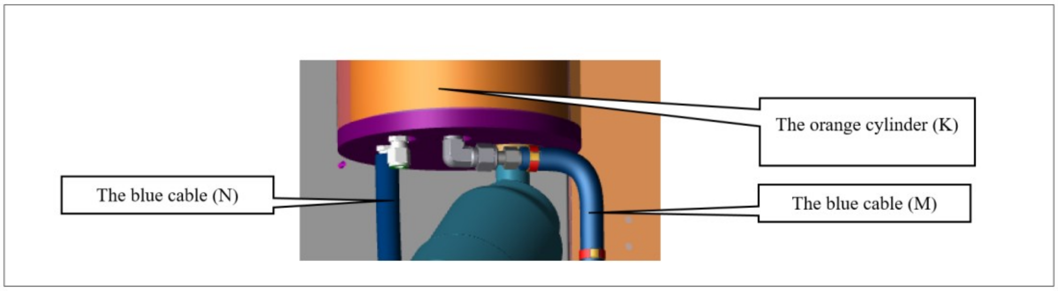


Figure 6

3. find the two blue cables (M, N) down to the orange cylinder (J) (See figure 7).

4. Trace each of them to find its endpoint. Take an audio note for your finding when you reach each component.



5. Summarize the steps of the task you performed in the first session.

1.	
2.	
3.	
4.	

6. Summarize the steps of the task you performed in the second session.

5.	
6.	
7.	
8.	

APPENDIX B RECURUMENT NOTICE

We are recruiting participants to take part in a research study examining what would be helpful in task resumption with 3D interface, so we want to test different type of strategies for aiding task resumption based on 3D models. We are looking for users who are Dalhousie University students, currently own and use any touch screen device. The study will be conducted in the Mona Campbell building and it will be over two sessions (about a day apart) and that each session will take about an hour. In the first session, you will first meet with a researcher to go over the study details, give consent to do the study, fill in a background questionnaire and a questionnaire to score your spatial ability. You will then be video recorded while you perform set of tasks with 3D models using an iPad tablet that will provided. In the middle of each task you will be interrupted by being asked to stop the current task and to start the next task. Then in the second session, you will be required to resume these tasks where you left off in the first session using one of the four resumption aids. You will fill in questionnaires after resuming each task and at the end of the study that will ask about your experience with performing and resuming the tasks in a questionnaire and short interview. Compensation is $20 for completion of the study. If you are interested in participating, please contact Rugaia Almangush (rg734888 @dal.ca).

APPENDIX C INFORMED CONSENT

DALHOUSIE UNIVERSITY *Inspiring Minds*

Exploring Strategies to Aid Task Resumption with 3D Models on Mobile Devices.

Principal Investigators: Rugaia Almangush, Faculty of Computer Science
Derek Reilly, Faculty of Computer Science
Bonnie MacKay, Faculty of Computer Science
Raghav Sampangi, Faculty of Computer Science

Contact Person: Rugaia Almangush, Faculty of Computer Science, rg734888@dal.ca

We invite you to take part in a research study being conducted by Rugaia Almangush at Dalhousie University. Your participation in this study is voluntary and you may withdraw from the study at any time. Your academic (or employment) performance evaluation will not be affected by whether or not you participate. To be eligible to participate in the study, you must be a Dalhousie University student, currently own and use any touch screen device. The study is described below. This description tells you about the risks, inconvenience, or discomfort which you might experience. Participating in the study might not benefit you, but we might learn things that will benefit others. You should discuss any questions you have about this study with Rugaia Almangush.

The purpose of the study is to investigate what would be helpful in task resumption with 3D models; we want to test different types of strategies(tools) for aiding task resumption based on 3D models. You will be asked to participate in two hours-long study; it will be over two sessions (about a day apart) and that each session will take about an hour. In the first session, you will perform four tasks. In the middle of each task you will be interrupted by being asked to stop the current task and to start the next task. Then in the second session, you will be required to resume these tasks where you left off in the first session using one of the four resumption aids. The device will log the time to do tasks, and your navigation and interactions with the 3D models (such as, rotation and zooming). Also, the device will log your interaction with the resumption aid tools (such as, button clicks and opening and closing windows). The device will also use video screen capture software that will record your interactions with the 3D models on the screen. You will also be video recorded to capture how you interact with the device while performing and resuming tasks.

You will be compensated $20 for participating in the study; you can withdraw during the study itself, and up to 2 months after the study without any consequence, and you can have your data removed from analysis by contacting Rugaia Almangush up to 2 months after the experiment. A researcher is always available over the study period by email or to meet in person to answer any questions you may have or address any problems that you may experience with the tasks.

All personal and identifying data will be kept confidential. Anonymity of textual data will be preserved by using pseudonyms. All data collected in the logs, questionnaires, video, and interviews will use pseudonyms (e.g., an ID number) to ensure your confidentiality. The informed consent form and all research data will be kept in a secure location under confidentiality in for 5 years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

"*I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I hereby consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time.*"

Participant		Researcher	
Name:	______________________	Name:	______________________
Signature:	______________________	Signature:	______________________
Date:	______________________	Date:	______________________

"*I understand and consent that my participation in the experiments will be video recorded for the purpose of analysis. I understand that this is a condition of participation in the study, and I understand that this video record will not be used in publication or presentation of results.*"

Participant		Researcher	
Name:	______________________	Name:	______________________
Signature:	______________________	Signature:	______________________
Date:	______________________	Date:	______________________

Please select one of the options below:

☐ "*I agree to let you directly quote any comments or statements made in any written* *reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using pseudonyms.*"

Participant		Researcher	
Name:	________________________	Name:	________________________
Signature:	________________________	Signature:	________________________
Date:	______________________	Date:	______________________

Or

☐ *"I want to read direct quotes prior to their use in reports and I understand that the anonymity of textual data will be preserved by using pseudonyms."*
[if this option is chosen, please include a contact email address: ______________________________]

Participant		Researcher	
Name:	______________________	Name:	______________________
Signature:	______________________	Signature:	______________________
Date:	____________________	Date:	____________________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results.

APPENDIX D BACKGROUND QUESTINNAIRE

PART I - PLEASE FILL IN THE FOLLOWING INFORMATION:

1. Age: ________
2. Sex: ☐ Male ☐ Female
3. Faculty: ________________________________
4. Level/Year: (if you are student)
   - ☐ 1st Year Undergraduate ☐ 2nd Year Undergraduate
   - ☐ 3rd Year Undergraduate ☐ 4th Year Undergraduate
   - ☐ Graduate – Masters ☐ Graduate – PhD
   - ☐ Other ______________
5. How many times per week do you use a touch device (e.g. tablet or smartphone)?
   - ☐ Once a week or less
   - ☐ (2-4) times a week
   - ☐ (5-7) times a week
   - ☐ More than 7 times a week
6. How often are you interrupted while working? (e.g. a roommate enters your room to ask you a question while you are doing an assignment)
   - ☐ Once a day or less
   - ☐ (2-4) times a day
   - ☐ (5-7) times a day
   - ☐ More than 7 times a day
7. How often do you need to resume tasks after one or more days?
   - ☐ Never
   - ☐ Rarely

☐ Occasionally

☐ Frequently

☐ All the time

8. How often do you have difficulty to resuming your work after interruption?
(For example: locating where you left off on a document, being able to complete an unfinished paragraph)

☐ Never

☐ Rarely

☐ Occasionally

☐ Frequently

☐ All the time

9. How difficult would you say it is to resume a task for you (on average)?

☐ Very difficult

☐ Difficult

☐ Neutral

☐ Easy

☐ Very easy

10. How do you resume your work after an interruption? (check all that apply)

☐ Rely on your own memory

☐ Using a memory aid

Explain what do you use?

___

___

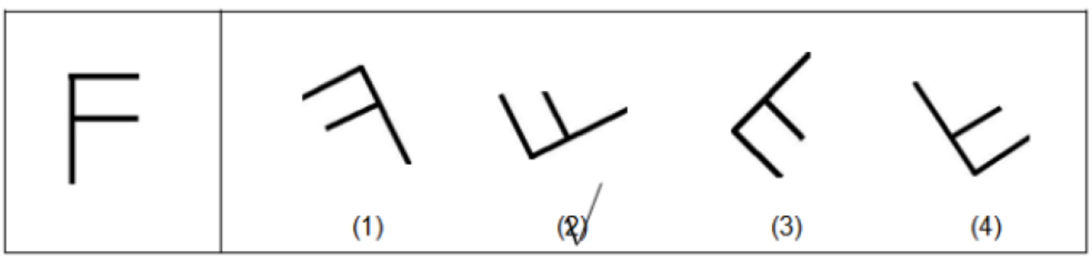
___

APPENDIX E SPATIAL ABILITY TEST

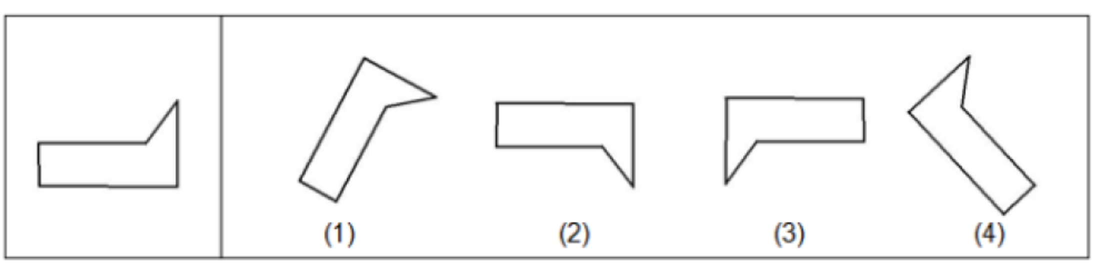
Spatial Ability Test: Mental Rotation

Instruction: In the right side, which one is the same with the left target after rotating? Please circle or tick the right answer. Do not rotate the page.

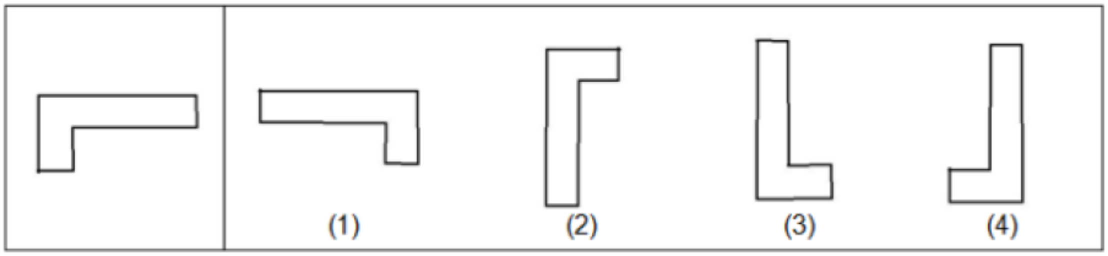
Sample:



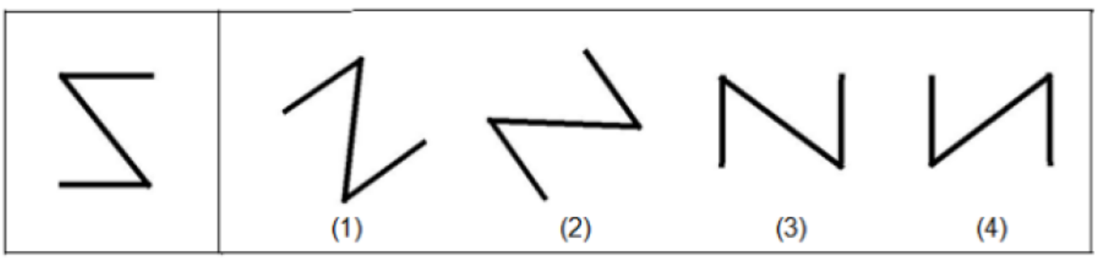
Practice:



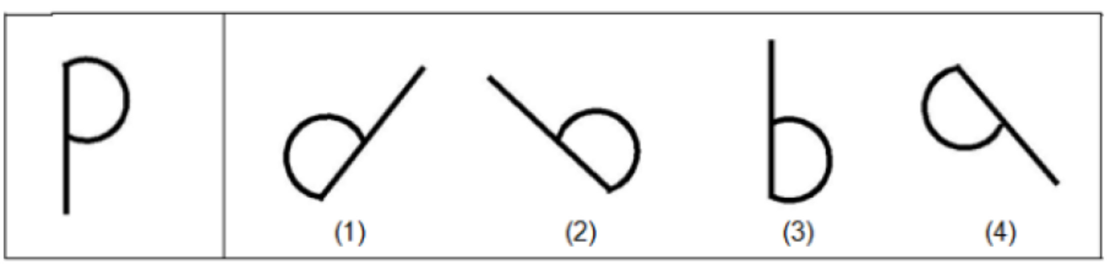
Question1:



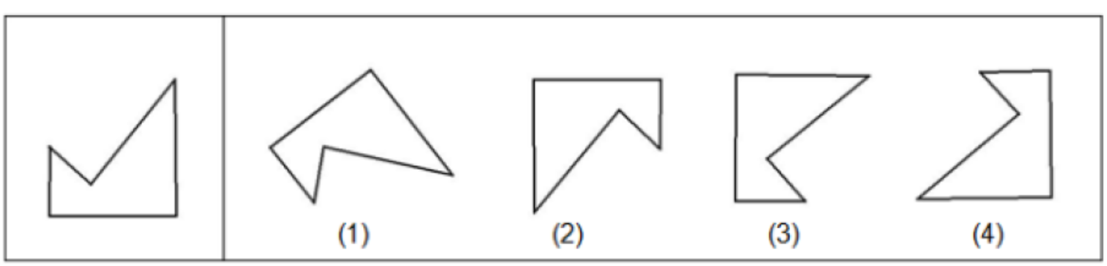
Question 2:



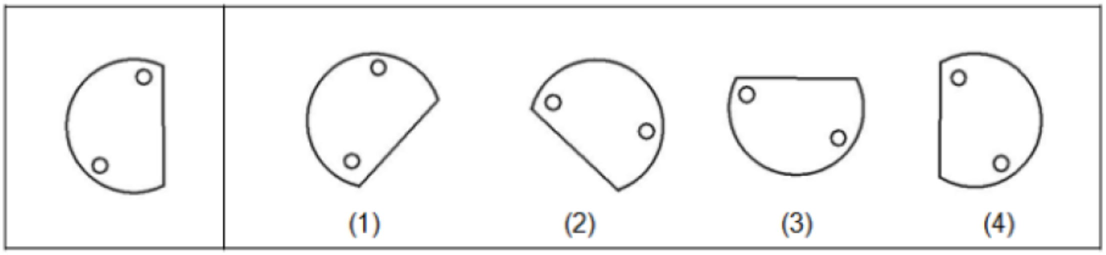
Question 3:



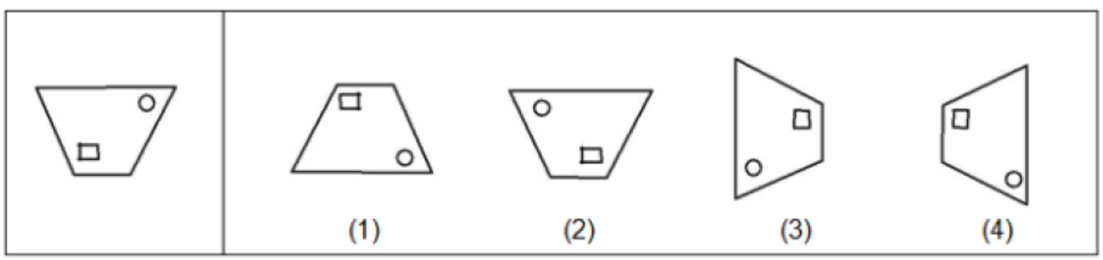
Question 4:



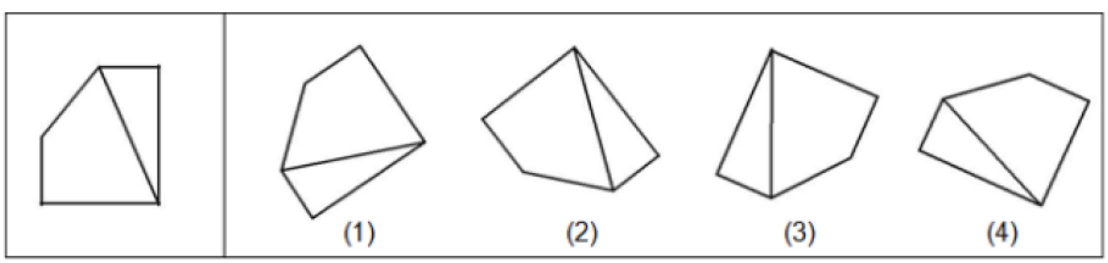
Question5:



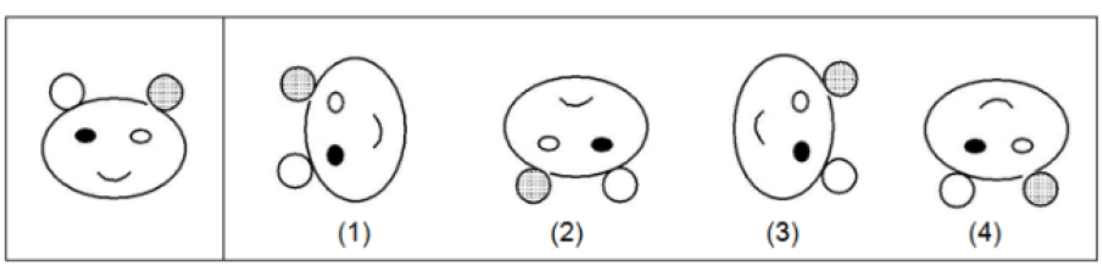
Question 6:



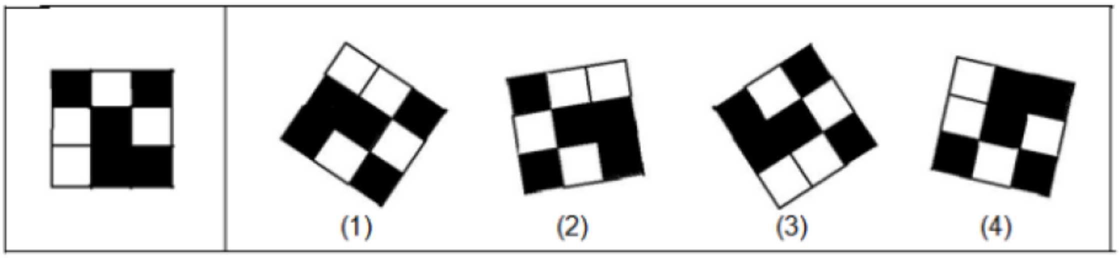
Question 7:



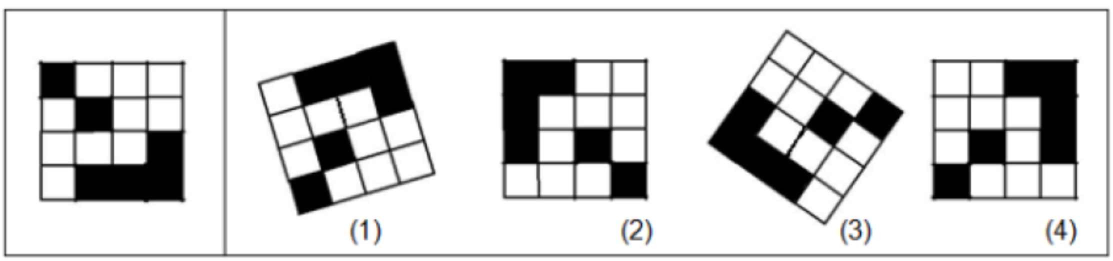
Question 8:



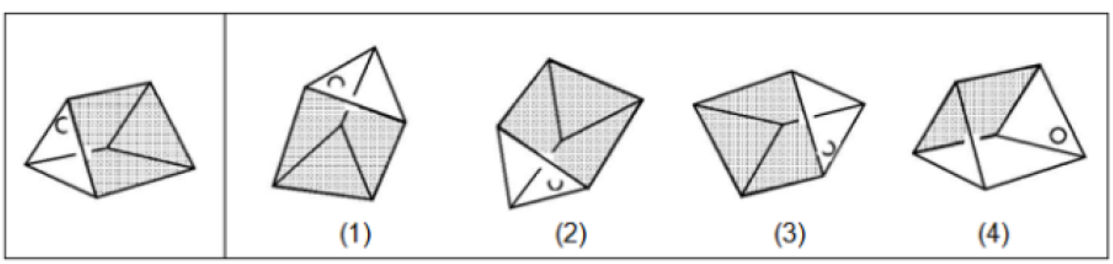
Question 9:



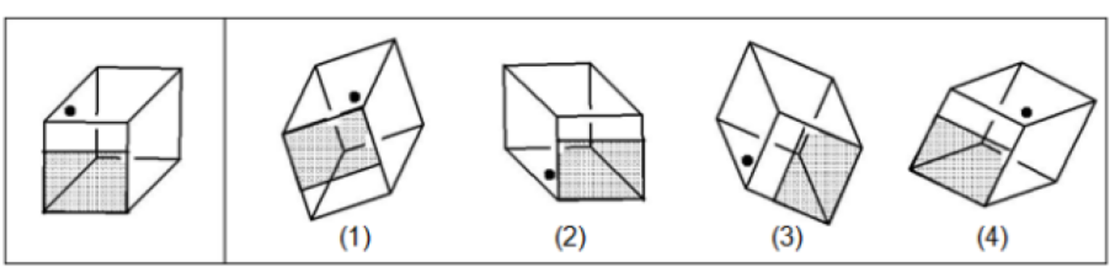
Question 10:



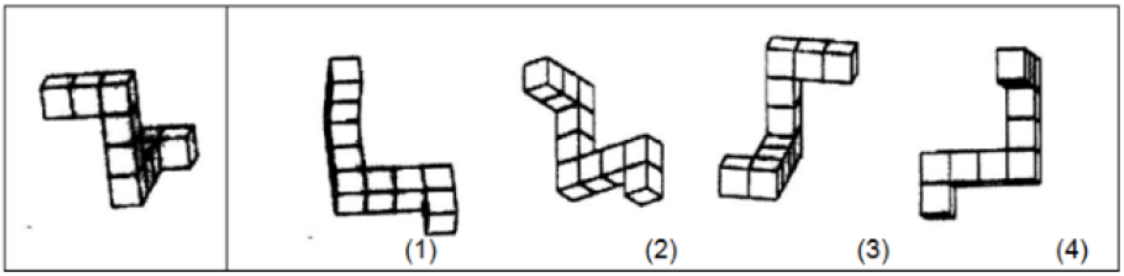
Question 11:



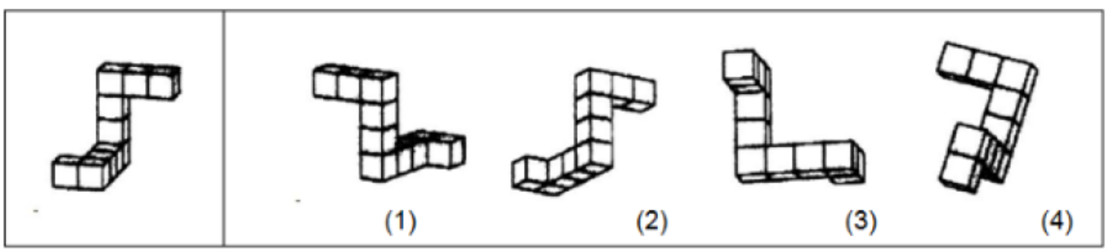
Question 12:



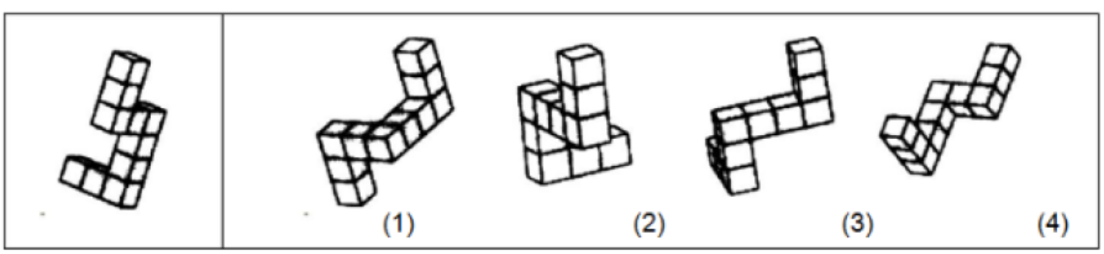
Question 13:



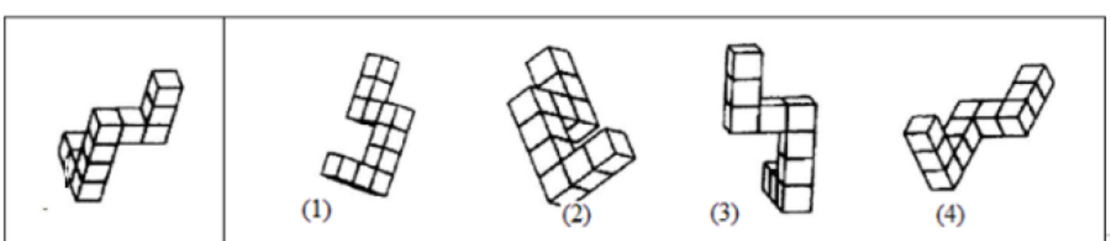
Question 14:



Question 15:



Question 16:



APPENDIX F POST TASK QUESTIONNIRE (NO AID)

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

QUESTIONS						
1.	It was easy to tell where I was in my task after the interruption.	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
2.	It was easy to continue with my task after the interruption	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
3.	I found this task is ease to complete	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
4.	I completed this task in a reasonable amount of time	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

APPENDIX G POST TASK QUESTIONNIRE (AUDIO NOTES RESUMPTION AID)

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

QUESTIONS						
1.	It was simple to start and to stop recording an audio note.	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
2.	It was easy to play, stop and pause the audio note	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
3.	It was easy to move from one note to another to play	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
4.	Having an audio description was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
5.	Having corresponding screen shot to each audio note was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
6.	It was easy to expand and shrink the audio note's corresponding picture	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
7.	Having the feature of expanding and shrinking the picture was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
8.	Having a note information below the note list was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

9.	Having a task timeline was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
10.	Overall, this resumption aid interface was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
11.	Overall, this resumption aid interface was easy to use	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
12.	Overall, it was efficient to use this resumption aid interface	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

APPENDIX H POST TASK QUESTIONNIRE (VIDEO REPLAY RESUMPTION AID)

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

QUESTIONS						
1.	It was simple to start and to stop recording a video of the screen.	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
2.	It was easy to play, stop and pause the video	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
4.	Having a video interaction without audio was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
6.	Playing the whole video was helpful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
8.	I preferred playing last section of the video rather than playing the whole video	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
5.	It was easy to expand and shrink the video	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
6.	Having the feature of expanding and shrinking the video was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

7.	Having a video information below the video list was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
8.	Having a task timeline was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
10.	Overall, this resumption aid interface was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
11.	Overall, this resumption interface was easy to use	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
12.	Overall, it was efficient to use this resumption aid interface	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

APPENDIX I POST TASK QUESTIONNIRE (COMBINED AUDIO VIDEO RESUMPTION AID)

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

QUESTIONS							
1.	It was simple to start and to stop recording an audio note.	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
2.	It was simple to start and to stop recording a video of the screen.	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
3.	It was easy to play, stop and pause the video in the replay window	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
4.	It was easy to move from one note to another to play	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
5.	Having video interaction with audio was helpful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
6.	Playing the whole video was helpful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
7.	Having the video divided into audio video notes was helpful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

8.	I preferred playing the notes rather than playing the whole video	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
9.	It was easy to expand and shrink video	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
10.	Having the feature of expanding and shrinking video was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
11.	Having a task timeline was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
12.	Having a note information below the note list useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
13.	Overall, this resumption aid interface was useful	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
14.	Overall, this resumption aid interface was easy to use	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
15.	Overall, it was efficient to use this resumption aid interface	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

APPENDIX J POST STUDY QUESIONNIRE

Please respond to the following statements using the given scale (circle response):

1	*2*	*3*	*4*	*5*
Strongly Disagree	*Somewhat Disagree*	*Neutral*	*Somewhat Agree*	*Strongly Agree*

QUESTIONS						
1.	Resuming task without any aid provided enough details to recall where I was in the model before the interruption	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
2.	I was satisfied with the amount of time I took to complete the primary tasks when I did not use any aid	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
3.	The *Audio Notes* resumption aid provided enough details to recall where I was in the model before the interruption	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
4.	I was satisfied with the amount of time I took to complete the primary tasks when I used the *Audio Notes* resumption aid	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

5.	The *Video Repay* resumption aid provided enough details to recall where I was in the model before the interruption	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
6.	I was satisfied with the amount of time I took to complete the primary tasks when I used the *Video Repay* resumption aid	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
7.	The *Combined A*udio *Video* resumption aid strategy provided enough details to recall where I was in the model before the interruption	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree
8.	I was satisfied with the amount of time I took to complete the primary tasks when I used the *Combined A*udio *Video* resumption aid	**1** Strongly Disagree	**2** Somewhat Disagree	**3** Neutral	**4** Somewhat Agree	**5** Strongly Agree

APPENDIX K POST STUDY SEMI-STRUCTURE INTERVIEW

1. In general, what did you like about resuming task with the 3D models without using any resumption aid?

2. In general, what did you find challenging with resuming task with the 3D models without using any resumption aid?

3. Describe the approach that you took to help you resume a task, when you had to resume without using any resumption aid?

4. In general, what did you like about resuming task with the 3D models using the *Video Replay* resumption aid interface?

5. In general, what did you find challenging with resuming task with the 3D model using the *Video Replay* resumption aid interface?

6. Describe the approach that you took to help you resume a task, when you had to resume using the *Video Replay* resumption aid interface.

7. In general, what did you like about resuming task with the 3D models using the *Audio Notes* resumption aid interface?

8. In general, what did you find challenging with resuming task with the 3D models using *Audio Notes* resumption aid interface?

9. Describe the approach that you took to help you resume a task, when you had to resume using the *Audio Notes* resumption aid interface.

10. In general, what did you like about resuming task with the 3D models using the *Combined Audio Video* resumption aid interface?

11. In general, what did you find challenging with resuming task with the 3D models using the *Combined Audio Video* resumption aid interface?

12. Describe the approach that you took to help you resume a task, when you had to resume with using the *Combined Audio Video* resumption aid interface.

13. What was your favorite resumption aid interface? Why?

14. What was your less favorite resumption aid interface? Why?

APPENDIX L PARTCIPANT PYMENT RECIEPIT

My signature below confirms that I received a sum of $20 (CDN) cash from Rugaia Almangush as an honorarium payment for participating in the "Exploring Strategies to Aid Task Resumption with 3D Models Mobile Devices.

" research project.

I understand this honorarium is taxable income and it is my responsibility to claim it on my income tax as Dalhousie University will not be issuing a T4A for this payment.

Name (please print): ___________________________________

Signature: ___________________________________

Date: ___________________________________

APPENDIX M RESEARCH ETHICS BOARD APPROVAL LETTER

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board Letter of Approval

February 23, 2016

Rugaia Almangush
Computer Science\Computer Science

Dear Rugaia,

REB #: 2016-3767
Project Title: Exploring strategies to aid task resumption with 3D models on mobile devices

Effective Date: February 22, 2016
Expiry Date: February 22, 2017

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans.* This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.